Top Sector Logistics

Charging infrastructure for electric vehicles in city logistics

Buck Consultants International
CE Delft
Connekt
DISTRICON
Hogeschool van Amsterdam
Panteia Research to Progress
TNO innovation for life

CONTENTS

MANAGEMENT SUMMARY

ZE city logistics

In the Climate Agreement presented on 28 June 2019, there is a major role for electric transport, including in city logistics (www.klimaatakkoord.nl/mobiliteit). Almost 12 percent of CO_2 emissions are produced by road transport, and 30 to 35 percent of the CO_2 emissions in road transport are related to city logistics. The Climate Agreement states that road transport must have reduced CO_2 emissions in city logistics by 1 Mt by 2050.

Zero-emission zones will be created in 30 to 40 cities, including the Municipality of Amsterdam. Amsterdam is already working on a 'Clean Air' action plan and a programme to restrict traffic in the city (city logistics is part of this). Further specification of these ambitions should ensure that traffic and the public space in the city are more suitable for future needs, with a high level of traffic safety, more room for pedestrians and cyclists plus clean air and lower CO_2 emissions.

Over the next 10 years, an increasing number of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) will appear on the roads in order to comply with the zero-emission requirements.
For businesses that have to deliver goods in the city or collect them, the challenge is not only making the step to zero-emission vehicles but also minimising the number of delivery vans and trucks that enter the zero-emission zone. Walking, cycling and public transport will be given priority within the growing need for urban mobility.
City logistics is not only about supplying shops, offices and building sites, delivering parcels to consumers and companies, delivery vans of service companies, removal companies, but it is also about local shops, caterers and florists who deliver to their customers.

What kind of charging infrastructure will be required if BEVs are used to make ZE zones possible for city logistics?

Electric vehicles require charging stations for recharging batteries in the right locations and with the right capacity to suit the daily way of working in city logistics. Goods transport, where predictability of supply and low costs have the highest priority, has very different requirements for the charging infrastructure than passenger mobility.

The large-scale use of BEVs and PHEVs gives rise to many questions, such as: Does the grid have enough capacity? How and where will companies be charging their vehicles in the future? Are there enough charging points in the right locations? What investments are required? Will the power grid have to be modified, either in the run-up to 2025 or thereafter? Will the demand be covered by the public charging infrastructure, or will companies be installing private charging stations?

The Topsector Logistics has asked six experts and knowledge institutes to investigate these questions and to present a concrete approach to how sensible and well-substantiated answers can be provided. To make things highly tangible, the Amsterdam region was investigated; the approach could however be applied anywhere.

Calculation of local solutions for charging infrastructure

In this study, a calculation module was developed and applied, which indicates the consequences for the desired charging infrastructure if electric goods vehicles are used on a large scale within a specific region, in this case the Amsterdam Metropolitan Area (AMA). The tangibility and level of detail were chosen to ensure that the assumptions and results can be recognised and translated by not only businesses (including transport), local governments, grid operators but also their financiers. The calculation module can be used for regions other than the AMA by modifying the underlying data and for specifying the consequences of policy scenarios. The analysis of the charging infrastructure was made by analysing the journeys of various companies in the region, of delivery vans and trucks in different sectors. The study is based on the assumption that the availability of enough electric vehicles will not be an issue from 2022 as a 'stress test' for the charging infrastructure.

Related questions and answers

When asking about the charging infrastructure required for the use of BEV goods vehicles, it turns out that related questions apply in various sectors:

- **Charging stations**
  - Which location is ideal for businesses?
  - What kind of charging stations are required and what capacity should they have?
  - What effect does the charging speed have on operational use (delivery on time) and the energy and personnel costs (waiting times while charging)?
  - What is the availability of the charging stations (queues or predictable access)?
  - Are the vehicles charged at public or private charging stations?
  - Who decides to invest in the charging stations and who funds them?
  - How easy it is to modify the infrastructure?
- **Journey profiles**
  - What are the operational requirements for each logistical segment (e.g. e-commerce, fresh produce, food and construction) regarding the capacity of the vehicle, journey length and the number of stops?
  - What are the starting points and destinations for each segment? The journeys pass through the city, but where do they come from and where do they go?
- **Charging strategy versus batteries**
  - For the time being, batteries are both costly and low-capacity. What is the best charging strategy for each segment and type of vehicle to be able to work operationally and to deliver predictably in practice?
- **Lowest costs**
  - Which approach yields the lowest operating costs for businesses in the various segments?
- **Power demand per location**
  - Given the charging strategies of businesses, where and when is electric power required for charging? And what is the resulting total energy demand?
  - Does a peak in the power demand together with other use of electricity lead to a total that exceeds the local capacity of the grid?

The answers turn out to be related and affect all parties: businesses of all sizes, local governments (public charging infrastructure, ZE zones, accessibility, economic necessity of supply, location of industrial site, location of hubs, location of car parks with charging stations), grid operators (infrastructure planning, ability to cover power demand).

Structure of the calculation module

In order to answer these questions, a calculation module was developed that can calculate results based on detailed basic data, in this case for the AMA.

Charging stations

First of all, the study focused on what types of charging stations are available and what the costs are for the energy supplied.

Table 1
Public charging stations.

	AC10	AC20	FC50	HPC150	HPC350
Power	11kW	22kW (11kW for 2 chargers)	50kW (25kW for 2 chargers)	150kW (75kW for 2 chargers)	350kW
Type	3-phase	3-phase	DC Fast charger	DC Super Fast charger	DC Ultra Fast charger
Usage	Public	Public	Public	Public	Public

Table 2
Private charging stations.

	AC3,7	AC20	FC50	HPC150	HPC350
Power	3,7kW	22kW (11kW for 2 chargers)	50kW (25kW for 2 chargers)	150kW	350kW
Type	1-phase Home charger	3-phase Company charger	DC Company charger	DC Company Super Fast charger	DC Company Ultra Fast charger
Location	Private land	Business site	Business site	Business site	Business site

Public charging stations are more expensive per kWh than private charging stations if the private charging stations are used fairly often. When calculating the total cost per kWh, it turns out that the effect of energy tax on the integrated cost price per kWh is surprisingly high. Rationally operating businesses will aim to keep charging privately as much as possible, preferably at a charging area (with multiple charging stations), where the power demand per year is so high that bulk consumer rates apply and the utilisation rate is high. It is quite conceivable that businesses will collaborate to achieve this.

Route profiles

The vast majority of all transport routes in the city are made in seven market segments: waste, construction, catering, courier/express, retail food, retail non-food and services. For each logistical segment, sets of transport route profiles were determined based on practical data. A set contains the spread that occurs in practice: from short to longer journeys, with many and few stops, and parking locations at a company or in the streets where the employees live. An 'average' journey rarely occurs in practice. The transport route profiles include the origin-destination relationships: where did the journey start, where does the journey go?

Developing charging strategies

Three charging strategies are basically conceivable:

- Overnight charging and performing the entire journey during the day without recharging;
- Overnight charging and performing the journey during the day, with the battery capacity being insufficient to complete the entire journey, so that a charging station along the route has to be used to recharge;
- Charging overnight and recharge during stops at customer's premises, and getting through the day in that way.

Route profiles (length of the journey, durations of the stops) and the availability of vehicles (battery capacity, range) are used to determine what is feasible. It has been assumed for the journey profiles that only BEVs are used, despite the limited availability of heavier BEVs for the time being (a limitation for retail, construction and waste collection) and the costs of public fast charging (important for catering, mail, parcels and couriers). Despite this, it was decided to opt for this approach to get a proper idea of the maximum charging infrastructure demand.

Optimisation to lowest costs

By adding labour costs for waiting times, an optimum calculation was made per journey profile: which combination yields the lowest costs, whereby all the journeys can still be completed? The assumption is that rationally operating businesses will make that choice.

Summation and aggregation

This choice that businesses are expected to make allows the energy demand for the logistical segments to be calculated. By aggregating the origin and destination relationships and the charging strategy, the total electric power demand over time can be determined for each postcode area.

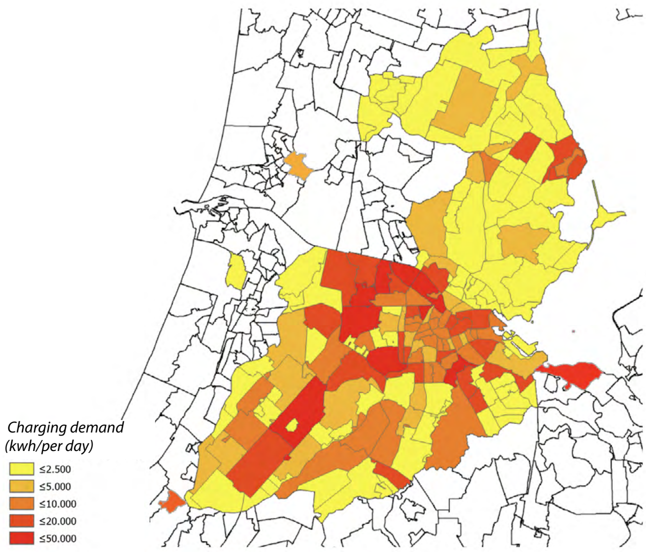


Figure 3
Heat map of daily charging demand.

Results and insights

- The concrete assumptions about the choices that businesses will probably make per segment dovetail well with the practical situation and allow them to be recognised and assessed. It also shows that businesses that want to invest in BEVs would do well to revise their working methods and not simply purchase electric versions of the same vehicles out of habit. A different approach is often sensible, especially if municipalities ask people to drive both with ZE vehicles and to drive less (traffic-restricted zones).

- The effects of energy tax and the rate structure for bulk consumers versus small consumers on the ultimate kWh costs are large and force businesses in a certain direction. If this rate structure were to change in the future, it would have major consequences for the charging strategies of businesses. For the time being, the cheapest option is private charging at locations where wholesale rates apply and where there are enough charging stations. Fast charging at public charging stations is a 'last resort'. In general, the tipping point for 'recharging during stops' is at a stop lasting about 30 minutes. For shorter stops it makes little sense to recharge.

- Operationally speaking, a lot is already feasible with the next generation of BEV delivery vans and box trucks. This depends on the segment. E-commerce, home delivery of food products, delivery of fresh produce, catering and parts of building logistics are quite feasible in terms of their journey profiles. Supermarket and retail deliveries with BEV trucks (tractor units + trailers) from national distribution centres are further away; with PHEV trucks or a transfer location at the edge of the city (switchover to a BEV tractor unit, or transferring the cargo boxes to a BEV box truck), this can be implemented sooner for the ZE area of the city.

- The results of the study are useful for local governments and grid operators.
  - In the AMA region, it can be seen that electric delivery vans are mostly parked just outside Amsterdam in residential areas and cities at night, and are charged at public charging stations. This knowledge is important for the rollout of public charging infrastructure.
  - Despite the conclusion that the total electric power demand of ZE city logistics is relatively low on average compared to other energy users, it is easier to predict peaks in the power demand, both geographically and over time. A peak can have major consequences locally, as this small additional peak could just push the overall demand over a critical limit. Expansion of the grid capacity at a specific location can sometimes take several years.

- It is relatively simple to modify the input for the calculation model based on a different policy and then calculate the effects.

Where will the ZE vehicles be charged?

Basically there are four possible locations where vehicles can be charged: the charging infrastructure available at companies, in the public space (including public charging infrastructure around building sites), at the destination on the customer's premises and at the homes of the employees. Based on what are called journey profiles, a calculation model was used to determine the best charging strategy. The calculation model includes the costs of electricity and the charging infrastructure. The calculation model makes a distinction between different types of delivery vans and trucks. For each sector, the optimum charging strategy (in terms of costs) depends on the type of vehicle and the capacity of the battery, the journey profile and the associated charging strategy. If the charging costs and the costs for waiting while charging are included, the solution with the lowest costs can be calculated.

In the case of Amsterdam/AMA, a total of almost 40,000 charges are expected per day, more than 90% of them involving delivery vans. Generally speaking, the greatest demand for electricity for charging occurs at business locations and depots - usually on industrial sites - (according to the model, 78% of the charging demand comes from trucks and 44% comes from delivery vans), spread out during the night when vehicles are parked. The largest number of charging stations appears to be required for delivery vans parked in residential areas at night. According to the model results, about 11,481 charging points should be available here for charging delivery vans during the night. That is twice as many as there are now present in the Greater Amsterdam COROP (Coordination Commission for the Regional Research Programme). Analysis of the spatial distribution in this case shows that a relatively high charging demand can be expected in the port area, Amsterdam West and industrial sites on the edge of Amsterdam. This mainly involves recharging trucks and delivery vans in depots. Furthermore, a high charging demand is expected in Hoofddorp and Edam-Volendam in particular, possibly because of the large number of construction companies there. As well as charging in depots, this often also involves charging delivery vans at home.

In most cases it turns out that a larger battery that does not require recharging during the day is cheaper than a smaller battery that does require recharging.
Charging at customer sites represents 16% of the charging demand for trucks and 6% for delivery vans. This occurs above all when supplying shops and at locations where several vehicles per day visit the customer, such as supermarkets, distribution centres, building sites and at company and government offices. Recharging at the customer requires proper arrangements between transporters, customers and shippers. Recharging along motorways is relatively expensive compared to having your own charging infrastructure and recharging at depots and/or customers. That is why vehicles are only recharged in these public locations if there is no alternative. If vehicles are recharged, the number of kWh charged is significantly less than average in the other locations. Recharging during the driver's working hours is relatively expensive. Recharging during breaks and while loading and unloading is therefore preferred.

The cheapest way of charging is by using your own charging points at the site of a business that is a bulk consumer of electricity and has a low rate. The highest-capacity charging stations (350 kW) are only required for a small proportion of all businesses. A lower-capacity charging station is usually sufficient for vehicles and less heavily laden journeys.

How much electric power is demanded from the grid?

A reasonably large ZE zone in Amsterdam, with all journeys being fully electric, would yield an energy demand of about 866 GWh per year, 248 GWh of it in Greater Amsterdam and the rest outside. The energy demand in Greater Amsterdam mainly comes from about 1,100 trucks, which are charged in depots every day, and about 15,000 delivery vans, which are charged in depots or at home every day. About half the electricity is required for trucks and half for delivery vans. In addition to this, about 4,700 trucks and 30,000 delivery vans that travel in the Amsterdam ZE zone are charged at the customer, public charging infrastructure and fast charging stations. The greatest charging and power demand is at depots (usually on industrial sites) and during the night.

The average power demand for ZE vehicles in city logistics within the Amsterdam region is relatively limited; the additional power demand at the 25 substations in Amsterdam is no more than 0.25% of the total power demand at peak times. Bottlenecks may, however, occur as the maximum capacity of the grid has now already been reached locally, and increasing the capacity may require a considerable lead time and costs.

Use of electric vehicles in city logistics is practically feasible

For delivery vans, the costs for daily use of an electric vehicle are by now comparable to those for a diesel delivery van. Electric delivery vans are more expensive to purchase, but their operating and maintenance costs are lower. The costs are expected to continue decreasing until 2030. Furthermore, journey data shows that the range and load capacity are not a problem for about 90% of the journeys.

However, the barrier for financing a BEV delivery van can be high, especially for a significant percentage of current owners, in particular for the parties who drive relatively old delivery vans and would not normally purchase a new delivery van. Examples of these are market traders, self-employed people for mail and parcels, and in construction.

The frequently occurring short journeys in city logistics make operational use of BEV box trucks feasible for those journey profiles. Incidentally, a lot is still unclear for trucks regarding the range of vehicles available in 2025 and the costs for daily use. For BEV trucks, the expected total costs will be at about the same level as for diesel vehicles in 2030 if the tax for both types of vehicles is at the same level and there are no tax benefits for a BEV. The feasibility of BEV trucks will have to be demonstrated in the next couple of years. PHEV variants could be an interim solution for vehicles to be used in ZE zones.

Recommendations

1 Developments are still required to obtain a robust charging infrastructure that is suitable for the demanding daily practice of the logistics sector. Remote diagnosis and configuration of the charging infrastructure, the vehicle and the combination thereof is a major wish-list item.

2 A sound strategy is required regarding the choices for on-board AC-DC converters versus external DC chargers. If the external charging infrastructure has a different design (e.g. aiming for cheaper 44 kWh AC charging stations) from that built into the cars by OEMs (e.g. aiming for external DC chargers), this causes lots of issues for carriers.

3 Collecting the actual practical consumption figures of BEV goods vehicles, especially the effect on consumption of:
- Outside temperature.
- Weight.
- Tyre pressure.
- Journey profile (speed, stops).
- Driving behaviour.

It is a known fact that these factors greatly affect the power consumption and range. Collecting this data from everyday practice will allow the following:
- Creating training programmes for drivers.
- Ensuring that software for journey planners takes these effects into account (predictability).

4 Supporting businesses in redesigning their logistics, modified for the combination of ZE zones and BEVs.

5 Collecting the data in other regions, performing the same calculations and using these results for the development of ZE zones in accordance with the Climate Agreement.

6 Assessing the assumptions and results with businesses in the logistical segments in order to refine the input data.

7 Paying specific attention to the target group that makes a living with relatively old delivery vans within the city as independent entrepreneurs in retail, the construction sector or with parcel deliveries. This relatively vulnerable group has less access to funding for (new) electric delivery vans, but will have to deal with the effects of the ZE zones.

8 The method used to model the power demand during the day, constructed from journey profiles and charging strategies, appears to be very fruitful. The same approach for BEV public transport buses was immediately proposed as a useful exercise, if only to see whether that typical demand for charging coincides with the peaks in the demand for charging for logistics or not. Continuing this line of reasoning, it would be advisable to set this up for all energy consumers (homes, offices, industry, data centres) per postcode area and in this way gain an insight into the local 'electric heartbeat' of the city.

Specific results MRA

- Charging infrastructure is a regional issue. Vehicles that enter the Amsterdam ZE zone mainly come from the Amsterdam Metropolitan Area; about 85 percent are from outside the municipality (source: Statistics Netherlands). After 2025, city logistics vehicles would be charged both at distribution centres and depots, and in the public space and at building sites during the day, to a limited extent at fast charging points, but predominantly at employees' homes in the evenings and at night.

- The charging infrastructure in the Amsterdam Metropolitan Area must be improved: at industrial sites and at office buildings, but above all in residential areas where vans are parked. The government must promote the construction of charging infrastructure by businesses and also, above all, facilitate this through zoning plans and licensing. Especially in locations where bottlenecks can be expected. It involves about 18,500 new charging points in Greater Amsterdam, with 1,350 of these being for trucks and 17,000 for delivery vans. An estimated 11,500 public charging points for delivery vans will be required in residential areas.

- The 30,000 delivery vans and 4,000 trucks that visit the ZE zone require a maximum of 866 GWh of electricity per year to carry out all their activities (395 GWh for delivery vans; 471 GWh for trucks). In the Greater Amsterdam region this yields a charging demand of about 248 GWh for vehicles in depots, at the customer and for delivery vans at home (125 GWh for delivery vans, 123 GWh for trucks). That is about 2 to 3% of the total power consumption in Greater Amsterdam.

- The impact on the power grid was assessed for the increased power demand on the substations of the power grid in the Municipality of Amsterdam. The increase in power demand by electric vehicles is less than 0.25% at 25 out of the 26 substations at the peak times of the existing power demand during the year (current situation). The increase is only 1.5% at one substation in the port area. It has been assumed here that the charging requirement is spread during the night by means of smart charging.

ABBREVIATION	DESCRIPTION
B2B	Business-to-Business
B2C	Business-to-Consumer
B&W	Municipal Executive (mayor and aldermen)
BEV	Battery Electric Vehicle
DC	Distribution Centre
DoD	Depth of Discharge
EV	Electric vehicles
FC	Fast charger
FCEV	Fuel Cell Electric Vehicle
GVW	Gross vehicle weight
HPC	High power charger
ICEV	Internal Combustion Engine Vehicle
LEZ	Low Emission Zone
MRA	Amsterdam Metropolitan Area (Metropool Regio Amsterdam)
NEDC	New European Driving Cycle
PHEV	Plug-in Hybrid Electric Vehicle
SOC	State of charge
TCO	Total Cost of Ownership
ZE	Zero Emission
kWh/MWh/GWh/TWh	kilo/mega/giga/terawatt-hour
MW	Megawatt
MVA	Megavolt-ampère

TERM	DESCRIPTION
Charging point	Point where a single vehicle can be plugged in. So a charging station can have several charging points (sockets).
COROP	A COROP area is a regional area within the Netherlands that is part of the COROP subdivision, a subdivision that is used for analytical purposes, once designed by the Regional Research Programme Coordination Committee.
Volt-ampère	The apparent power in a circuit is expressed in volt-amperes (VA). In a direct current circuit, this is equal to the real power (expressed in watts). For alternating current, the real power is less than the apparent power (taken from the grid), due to transfer losses to a device.

EXPLANATION ICONS

	Waste collection		Post, parcel, express
	Building Logistics		Retail food
	Facilities		Retail non-food
	Catering		Services
	Private person		

1 INTRODUCTION

In the Climate Agreement presented on 28 June 2019, electric transport plays a major role, including in city logistics (www.klimaatakkoord.nl/mobiliteit). Almost 12 per cent of CO_2 emissions are produced by road transport, and 30 to 35 per cent of the CO_2 emissions in road transport are related to city logistics. The Climate Agreement states that by 2050 road transport must have reduced CO_2 emissions in city logistics by 1 Mt. Zero-emission zones will be created in 30 to 40 cities.

Over the next 10 years, an increasing number of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) will appear on the roads in order to comply with the zero-emission requirements.
For businesses that have to deliver goods in the city or collect them, the challenge is not only making the step to zero-emission vehicles, but also minimising the number of delivery vans and trucks that enter the zero-emission zone. Walking, cycling and public transport will be given priority within the growing need for urban mobility.
City logistics is not only about supplying shops, offices and building sites, delivering parcels to consumers and companies, delivery vans of service companies, removal companies, but it is also about local shops, caterers and florists who deliver to their customers. Electric goods transport, where predictability of supply and low costs have the highest priority, has very different requirements for the charging infrastructure than passenger mobility.

The large-scale use of BEVs and PHEVs therefore gives rise to many questions, such as: Does the grid have enough capacity? How and where will companies be charging their vehicles in the future? Are there enough charging points in the right locations? What investments are required? Will the power grid have to be modified, either in the run-up to 2025 or thereafter? Will the demand be covered by the public charging infrastructure, or will companies be installing private charging stations?

The Topsector Logistics has asked six experts and knowledge institutes to investigate these questions and to present a concrete approach to how sensible and well-substantiated answers can be provided. To make things highly tangible, the Amsterdam region was investigated; the approach could however be applied anywhere.

The Municipality of Amsterdam has concrete plans with 'Clean Air': a large ZE zone in 2025 for trucks and delivery vans. The ZE zone not only has an impact within the Municipality of Amsterdam, but also within the region and even beyond. Almost half the ZE vehicles come from outside the Greater Amsterdam COROP. The demand for tangibility regarding what is required to allow these plans to succeed makes this region a rewarding subject for this study.

1.1 Introduction: use of electric vehicles in city logistics

Amsterdam's growth is exerting great pressure on scarce space and the growing need for passenger and goods mobility, including the growing numbers of visitors and commuters in the municipality. Amsterdam is working on an ambitious 'Clean Air' action plan (April 2019) and a programme to restrict traffic in the city (city logistics is part of this). Further specification of the ambitions of these plans should make traffic and the public space in the city more suitable for current and future needs with a high level of traffic safety, more room for pedestrians and cyclists and, last but not least, clean air. Work is ongoing to improve the air quality by banning polluting trucks and cars from parts of the city by means of ZE zones and parking spaces are removed to reduce the spatial impact of car mobility in the city.

Climate Agreement: 30 to 40 municipalities have opted for introduction of ZE city logistics

The volume of goods that enters Amsterdam every day will rise by about 10 to 20% over the next 10 years. Not only will city logistics have to become cleaner by means of a ZE zone in 2025, it will also have to become less (in numbers and use of space), quieter and safer. The Municipality of Amsterdam is closing off an ever-increasing part of the inner city in particular to heavy trucks. Many bridges and quays in the city are in poor condition and require maintenance.

Intelligent access control when granting access to the ZE zone is part of the Amsterdam 'Smart Mobility' programme. This optimises enforcement. It also allows customised solutions for exemptions in certain places and at certain times. Housing development plans also mean that there will be less space for logistics activities (like warehouses and hubs) in and around the city. Not only Amsterdam is opting for a ZE zone for city logistics by 2025; other cities like Utrecht, Arnhem and The Hague also want ZE city logistics by 2025. The Climate Agreement states that 30 to 40 municipalities will opt for ZE city logistics in their city centres by 2025. The detailed specification will follow in the period until the summer of 2020.

ZE zones raise many questions for businesses

The ZE targets raise questions for businesses, like which vehicles are suitable for making our journeys to the ZE vehicles; should we adjust our logistics concept? Housing development plans also mean that there will be less space for logistics activities (like warehouses and hubs in and around the city). What is the right charging strategy and what does driving battery or hydrogen electric or hybrid vehicles mean for the planning and the driver?

Local government: facilitating enough charging infrastructure for ZE city logistics

A local government has a role in facilitating enough charging infrastructure in its own municipality and the municipalities in the region, together with the grid operator. Electric goods vehicles require charging stations to recharge batteries in the right locations and with the right capacity to suit the daily way of working in city logistics. Goods transport, where predictability of supply and low costs have the highest priority, has very different requirements for the charging infrastructure than passenger mobility. For municipalities and grid operators, this is a much less tangible question: what is required and useful where?

Regional effect

The vehicles that enter Amsterdam usually depart from one of the municipalities within the Amsterdam Metropolitan Area. Non-food retail (Hema, Blokker, Bijenkorf and fashion chains) in particular comes from further away, as retailers mainly have centrally located warehouses in the Netherlands. Assessing the need for charging infrastructure should therefore start at the location of origin.

It may change under the influence of trends, but also because the ZE zone requires it. The basic assumption included in the Annual Outlook City Logistics (2017) is that in some sectors the distribution grids will hardly be able to adjust to the use of electric goods transport before 2030. Investment decisions about existing distribution centres and production sites are not easy. The following apply here: few locations available, long planning periods for relocation, stable market relationships (and players) and the major social consequences of relocation.

Sectors that do see a dynamic development of distribution grids are

- Parcel delivery and home delivery of food products (as part of mail and parcel services): more distribution centres close to urban areas.
- Facilities purchasing: with bundling of public purchasing.
- Building logistics: with the development of building hubs and water transport.
- Waste: bundling of the collection of commercial and other waste and water transport.

Other sectors are relatively 'inert'; the warehouses will remain where they are over the next 10 to 20 years.

1.2 Structure of the study

Estimating the required charging infrastructure starts by mapping out the utilisation profiles of delivery vans and trucks in this region. These utilisation profiles are characterised inter alia by the parking locations of vehicles, driving distances, number of stops, loading and unloading times, and vehicle characteristics.

These utilisation profiles provide the preconditions for the operational specification. However, various charging strategies are possible, with different charging locations and different charging prices and speeds. The (downtime) hours spent by personnel when charging are a factor in the decision-making process. Furthermore, the current and future business cases depends on the price (and development in pricing) of batteries and vehicles, charging infrastructure and electricity.

These details make it possible to perform an optimisation calculation that yields the lowest costs, whereby the utilisation profiles will still be achieved.

Adding up all the individual decisions yields the demand for charging infrastructure: the location, the time and the quantity.

This form of modelling makes it relatively simple to calculate the effects of other assumptions, e.g. a pricing development, a policy change or a technological innovation.

1.3 Project boundaries: Sectors, geography and numbers

In order to investigate the impact of electric urban distribution on logistics, charging infrastructure and the power grid, a number of choices were made in terms of the subdivision into sectors, geographical boundaries and, as a result, vehicle numbers. These choices are discussed below.

1.3.1 Sector boundaries

City logistics is highly diverse. The 'Outlook City Logistics 2017' (Den Boer et al., 2017) shows that the characteristics of city logistics vary greatly between sectors in terms of shipment numbers, customer requirements, volumes, vehicle types (from small delivery vans to heavy tractor unit/trailer combinations). Activities of logistics service providers with similar characteristics are bundled into a 'sector'. Table 1.1 provides an overview of the sectors in this study. The table presents a brief description of the key activity and the most frequently used vehicles per sector.

Table 1.1
Overview of sectors for city logistics.

SECTOR	BRIEF DESCRIPTION	VEHICLE
	Collection of waste from companies and households	Trucks
	Deliveries and installation/repair work at building projects (large and small)	Delivery vans and trucks
	Large and small deliveries to catering establishments, partially conditioned	Delivery vans and trucks
	Small deliveries to multiple addresses (B2B and B2C)	Delivery vans
	Large deliveries of food to retail	Trucks
	Large deliveries to a few addresses	Trucks
	Small deliveries, including (small) jobs and installation work	Delivery vans
	Deliveries, including (small) jobs	Delivery vans and trucks

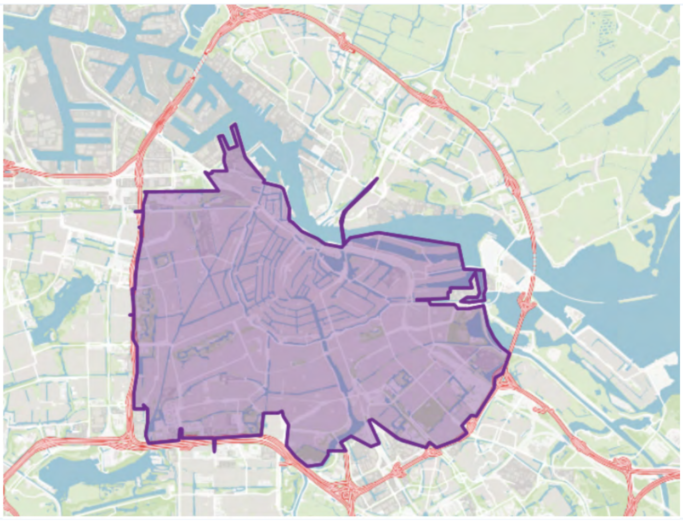
The Annual Outlook 2017 (Den Boer et al., 2017) shows that there are major differences in 'ZE readiness', e.g. between the mail and parcels sector, catering supply and building logistics. More and more electric delivery vans are available ex-works, but that is not yet the case for trucks. When calculating the optimum charging strategy, a distinction is made between these sectors, vehicles and associated journey characteristics.

The findings and model results of this report are based on the assumption that goods transport to the ZE zones is 100% electric. PHEV variants or transfer to a BEV truck via a hub, as well as the use of other modes of transport or modification of the utilisation profiles (different logistical structure) are not included in the calculations. This is a deliberate choice, first of all, to have a 'stress test' for the demand for charging infrastructure and charging capacity, and secondly, to have a reference calculation. Afterwards, scenarios can be calculated and assessed.

1.3.2 Geographical boundaries: Amsterdam ZE zone case study

This study investigates the impact of ZE city logistics based on a case study of a ZE zone in Amsterdam in 2025/2030, which matches the current environmental zone. The ZE zone consists of the A10 inner ring, except for the parts of the city north of the River IJ and the industrial sites that are inside the ring (Figure 1.2).

Figure 1.2
Amsterdam environmental zone[1]*.*



The study focuses on the effect of such a ZE zone on the charging requirements in the Greater Amsterdam COROP.

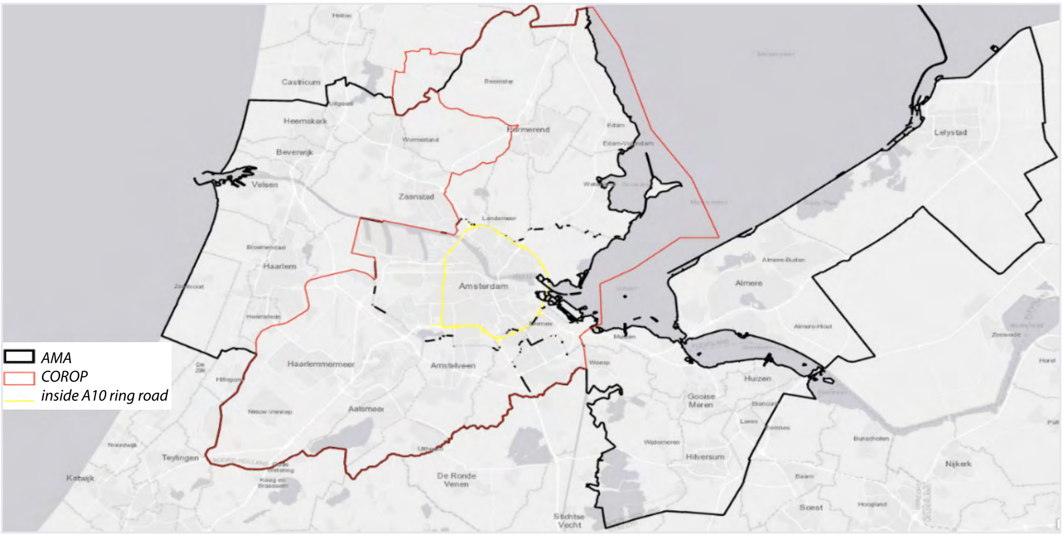
To functionally analyse the spatial impact and effect of electrification of city logistics, three levels are relevant; these are depicted in Figure 1.3.

1. **The first level** is the entire Amsterdam Metropolitan Area (AMA). This study area covers the territory of 33 municipalities located in the provinces of North Holland and Flevoland (see the area with the black border in Figure 1.3), which includes approach routes and distribution locations via which transport goes towards the city centre area;
2. **The second level** is the level of Greater Amsterdam or COROP area 23[2] (the area with the orange border), which includes key locations where cargo flows converge or depart. This also includes the industrial sites located around the city centre, where some of the logistics companies are based and where the transfer points for supplying goods to the region are located;
3. **The third level** is the local level of Amsterdam city centre inside the A10 ring road (this has the yellow border), where the final destinations for city logistics are located. To obtain a clear picture, we will sometimes use specific sections of urban areas.

[1] *Source: www.amsterdam.nl/parkeren-verkeer/milieuzone*

[2] *It includes the following municipalities: Aalsmeer, Amstelveen, Amsterdam, Beemster, Diemen, Edam-Volendam, Haarlemmermeer, Landsmeer, Oostzaan, Ouder-Amstel, Purmerend, Uithoorn, Waterland. Source: Statistics Netherlands.*

Figure 1.3
Spatial boundaries for charging infrastructure at three levels: Amsterdam Metropolitan Area, Greater Amsterdam and Amsterdam city centre inside A10 ring road.



The Amsterdam region was chosen in consultation with the Topsector Logistics. Based on this, other municipalities and regions will also be able to make an analysis of the charging infrastructure required for the ZES ambitions.

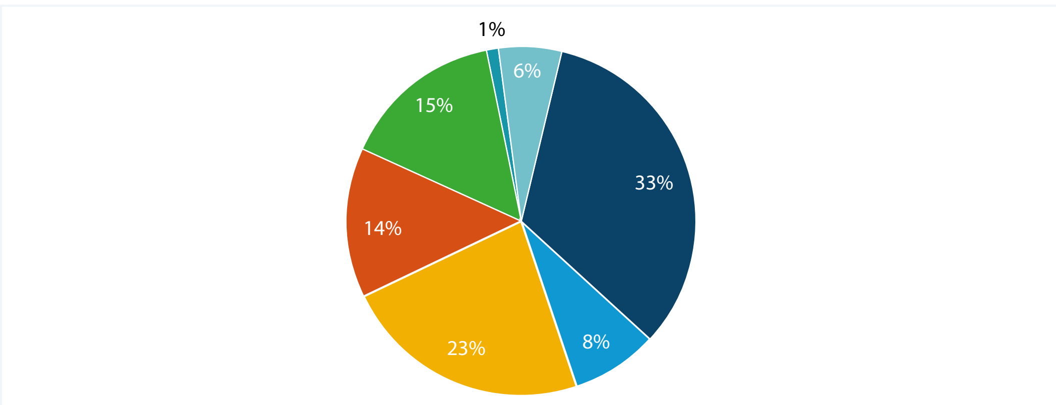
1.3.3 Number of vehicles, transport routes and kilometres

Based on Statistics Netherlands (CBS) data, the characteristics of journeys that include the ZE zone in Amsterdam were analysed. A subdivision was made here between two vehicle types: trucks and delivery vans. This is explained in more detail below.

Trucks

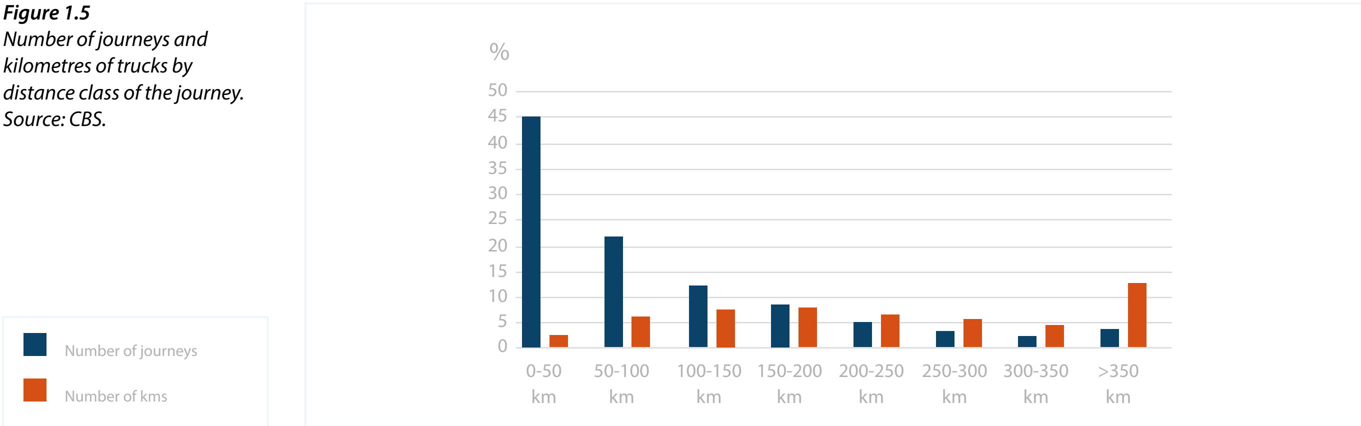
Based on CBS data, the number of trucks that (regularly) visit the Amsterdam environmental zone is estimated at 4,700 vehicles, which together complete 3.2 million journeys[3] per year, approx. 780,000 of which include the environmental zone (see Annex 5.1.A). Most of the journeys are made in the construction and catering sectors (see Figures 1.4 and 1.5). Most journeys (78%) cover a distance of less than 150 kilometres. However, there are also journeys (3%) that exceed 350 km, which make a significant contribution of 17% to the kilometres driven. It is assumed for the case study that all vehicles will become electric and all journeys are performed with zero emissions. About 35% of the activities (based on destinations) of the vehicles that enter the environmental zone take place inside the Greater Amsterdam COROP. 25% of the vehicles are based in Greater Amsterdam.

Figure 1.4
Breakdown of truck journeys by sector. Source: CBS.



[3] *A journey starts when the vehicle is loaded and ends when the empty vehicle gets to another loading location.*

Figure 1.5
Number of journeys and kilometres of trucks by distance class of the journey. Source: CBS.



Delivery vans

Based on CBS data, the number of delivery vans that (regularly) visit the Municipality of Amsterdam is estimated at 37,400 (see Annex 5.1.B). 30,000 of these vans regularly visit the environmental zone as well. These 30,000 delivery vans together complete about 27 million journeys per year. Most of these journeys are made in the building and facilities sectors (see Figures 1.6 and 1.7). Most journeys by far (97%) cover distances of less than 150 kilometres. However, the 3% of journeys that exceed 150 km do contribute one quarter of the kilometres. For delivery vans, it is also assumed in the case study that all 30,000 vans will become electric and all journeys are performed with zero emissions. About 50% of the vehicles are based in the Greater Amsterdam COROP and 50% of the activities of these vehicles take place in the Greater Amsterdam COROP.

Figure 1.6
Breakdown of delivery van journeys by sector. Source: CBS.

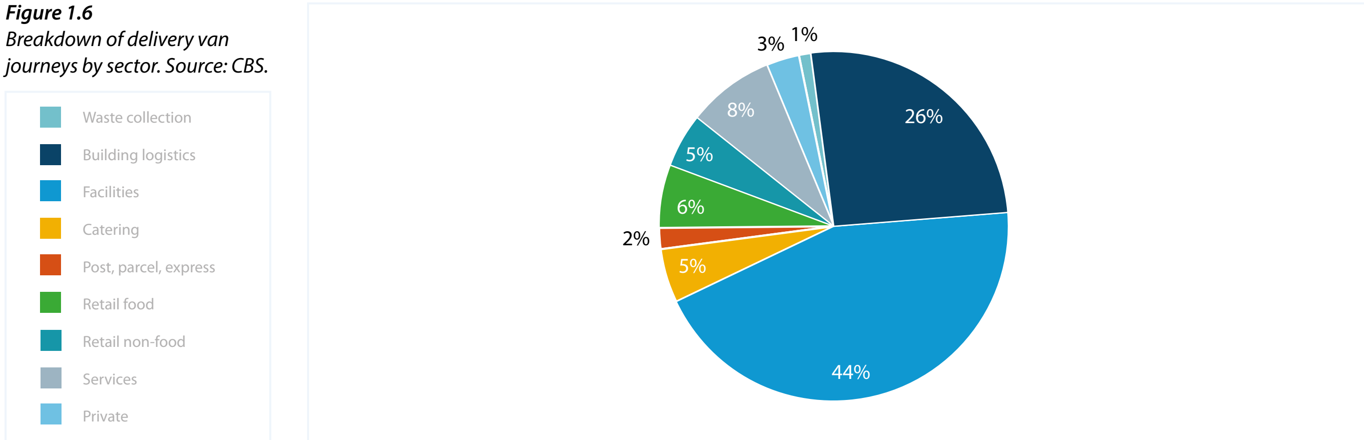
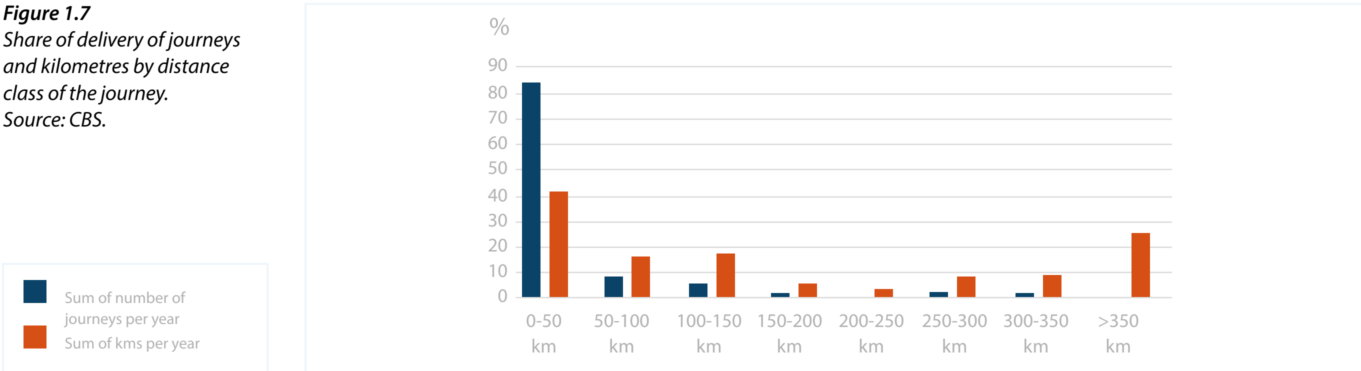


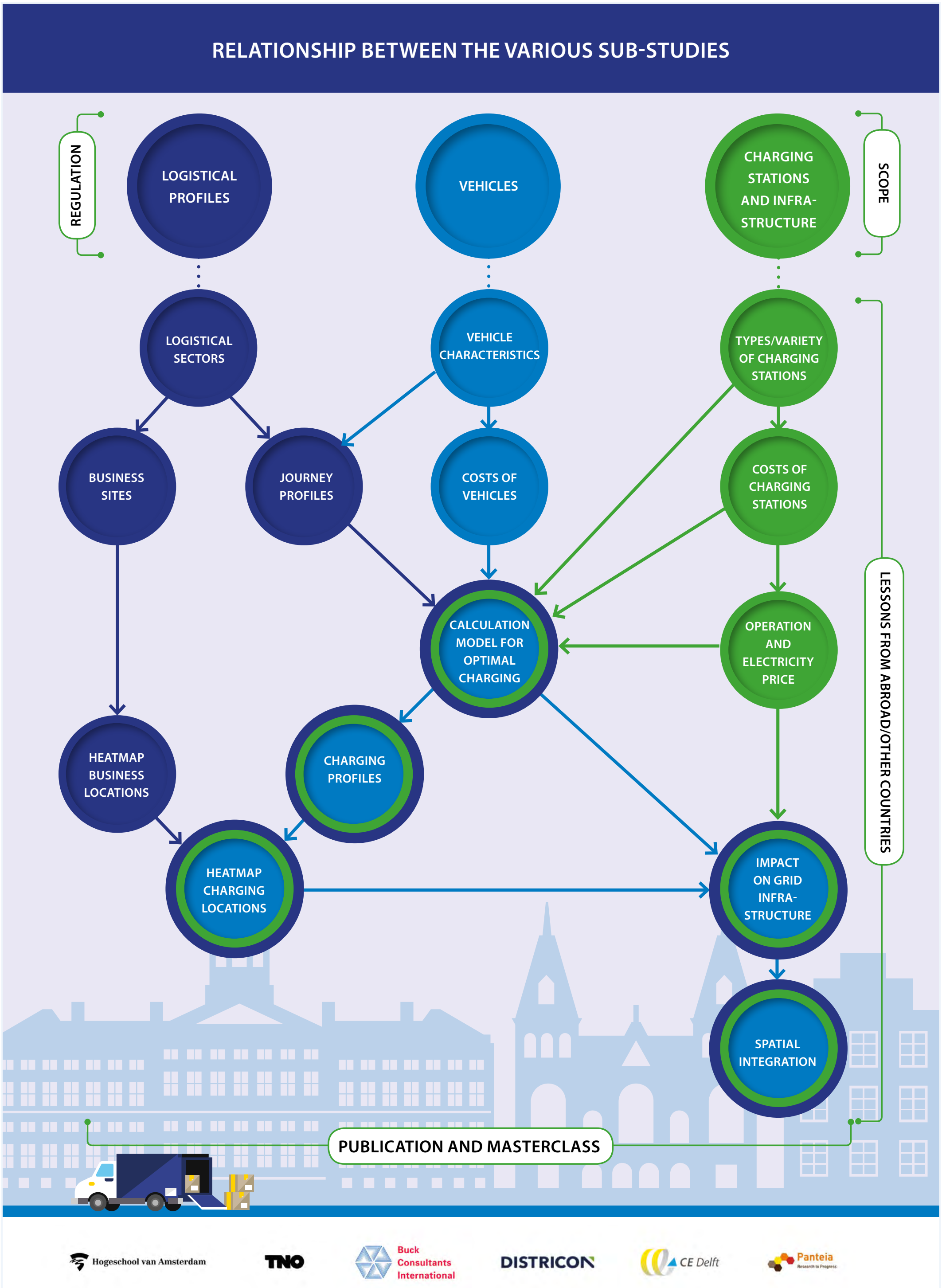
Figure 1.7
Share of delivery of journeys and kilometres by distance class of the journey. Source: CBS.



1.4 Project approach and reader's guide

This study was performed by Buck Consultants International, CE Delft, Districon, Amsterdam University of Applied Sciences, Panteia and TNO as a multi-party study on behalf of the Topsector Logistics. Statistics Netherlands (CBS) supported this study with data. Each of these parties managed one or more sub-studies based on its own expertise. The following picture (Figure 1.8) presents the relationship between the various sub-studies.

Figure 1.8
Relationship between charging infrastructure sub-studies.



The relationship between utilisation profiles, vehicles, battery capacity and charging infrastructure is complex. In this study, the following approach was used to provide a picture of the charging infrastructure required in the future.

- It starts with a general analysis of the policy context and experience with the use of electric vehicles in **Chapter 2**.
- **Section 3.1** then describes the logistical characteristics of the various sectors, the significance of this for electrification of the vehicle fleet and the challenges associated with this.
- Characteristic datasets were collected for these sectors. These datasets contain detailed information from a certain period and, together with the vehicle type, we consider this to be representative for a sector. In this study, we assume that an equivalent, fully electric vehicle type will be used in the future, with various battery capacities to choose from.
- A model is used to determine the optimum strategy per sector based on the journey profile data. The input required for this model (cost of electricity, charging stations, vehicles, etc.) is described in the rest of **Chapter 3**; the model itself is described in **Chapter 4**. For charging, we use a list of private and public charging stations with charging capacities, investments and electricity prices. We have used the calculation model to determine the optimum charging strategies for each business sector. This makes it possible to determine the palette of representative charging requirements per sector and assign them to private (at depot, customer or at home) or public locations (fast charging stations, in residential areas).
- **Chapter 5** then specifies the generic model results regarding the charging demand by location for the case of a ZE zone in Amsterdam. The distribution of the charging demand by postcode area and the required number of charging stations are specified in more detail for the Greater Amsterdam COROP. The impact on the power grid and the spatial impact are described here.
- The CBS data provides information about the breakdown by sector, annual kilometres and origin-destination relationships for the vehicles that visit the planned ZE zone. This allows a picture to be drawn of the charging requirements of these vehicles and, using the results from the model, the location type as well.
- The geographical distribution of the charging demand was then estimated based on parking and registration data from CBS and on origin and destination data from the VENOM model. The results of this were used to make a statement about the impact on the power grid and the spatial incorporation of charging points.
- In conclusion, recommendations for the various stakeholders are shared in **Chapter 6**.

In parallel with the aforementioned quantitative approach, qualitative information was gathered through interviews with relevant parties from the Netherlands and abroad, such as energy companies, charging station operators, shippers, transporters, public transport companies and public parties.

2 POLICY CONTEXT: THE ROAD TOWARDS ZE URBAN DISTRIBUTION

First of all, Section 2.1 will address the European and national policy that forms the basis for the introduction of ZE city logistics over the next decade. For the Netherlands, the designation of ZE zones plays a key role in this. Section 2.2 then focuses on a number of key policy considerations with regard to ZE zones. Section 2.2 addresses the experiences, barriers and expectations regarding charging strategies and infrastructure of various parties that already use electric vehicles.

2.1 Policy context of ZE city logistics

2.1.1 EU policy

The EU has committed to implementing the Paris Agreement. This means that the CO_2 emissions generated by transport must be drastically reduced towards 2050. City logistics plays a key role in this, as it will be able to reduce CO_2 emissions sooner than long-distance road transport. The Transport White Paper (2011) and the European Strategy for Low-Emission Mobility (2016) of the European Commission state that CO_2 emissions generated by transport must be reduced by 60% in 2050 compared to 1990.

The following two key objectives are formulated with regard to city logistics:

- Phasing out conventional goods vehicles in cities by 2050, halving them by 2030.
- Aiming for ZE city logistics in major city centres by 2030.

These objectives must be achieved by the Member States, but there are various EU regulations that support achieving these objectives. The most important regulations are about CO_2 standards for vehicles.

CO_2 standards for delivery vans

In December 2018, an agreement was reached between the European Commission, Parliament and Council with regard to the vehicle standards for new passenger cars and delivery vans for 2025 and 2030 (ICCT, 2019). For the year 2020, the average new delivery van must comply with a standard of 147g CO_2/km[4]. In 2025 and 2030, the standard will be reduced by 15% and 30% respectively.

Apart from the new standards, the Directive contains stimulus measures to increase the share of low-emission and zero-emission vehicles. These vehicles fall in the plug-in (PHEV), BEV or hydrogen (FCEV) category, with less than 50g CO_2/km. Manufacturers will be allowed to deviate by 5% from the standard if they market more than 15% of these vehicles in 2025 and more than 35% in 2030. In connection with this, the EU has permitted the Netherlands and other countries to apply a licence exemption for electric delivery vans. The exemption applies from June 2019 until the end of 2022 and means that drivers with a category B driving licence will be allowed to drive an electric delivery van of up to 4250 kilograms (Green deal, 2019), to prevent the additional weight of the battery from causing limitations to the use of the electric delivery van compared to conventional delivery vans (up to 3500 kg).

[4] *Based on New European Driving Cycle (NEDC)*

The amendment to the European Directive on driving licences includes the provision that Member States can continue to apply this exemption after 2022 (TLN, 2019).

CO_2 standard for trucks

In February 2019, the European Parliament and the EU Member States reached an agreement on CO_2 standards for trucks. Compared to 2019, CO_2 emissions must be 15% less by 2025 and 30% less by 2030 (EC, 2018). This reduction can be partly achieved with super-credits for the production of ZE vehicles. Truck manufacturers that sell more than 2% ZE trucks will be subject to more lenient CO_2 reduction standards (T&E, 2019). The deal also states that electric trucks may be 2 tons heavier.

Apart from the CO_2 standards for vehicles, there are other regulations that strengthen or support the demand for ZE city logistics, such as:

- **EU air quality standards:** an important reason for cities that cannot achieve the limits to implement a ZE zone.
- **The Clean Power for Transport Package:** This includes regulations with minimum requirements for Member States to develop infrastructure for alternative fuels.
- **The Clean Vehicles Directive (Directive 2009/33/EC):** This states that governments must take energy and environmental effects into account during tendering procedures for the purchase of vehicles (an update to the Directive will be published soon).

2.1.2 National and local policy

Based on the Energy Agreement, the ZE City logistics Green Deal ('Green Deal ZES') was concluded in late 2014. In it, the Dutch government made agreements with local governments, businesses and research institutions to achieve zero-emission city logistics as much as possible by 2025. The parties are jointly investigating how zero-emission supply of city centres can be put into practice, among other things by using living labs.

Within the context of the Paris Agreement, the Dutch cabinet has asked businesses and organisations to work on a Dutch Climate Agreement together with the government. The final version of the Climate Agreement was published in late June (Klimaatakkoord, 2019). The key starting points regarding ZE urban distribution discussed in the Mobility Forum, which form the basis for the draft Climate Agreement[5], are:

- Medium-sized ZE zones for delivery vans and trucks in 30-40 major cities by 2025.
- For existing trucks from before 1 January 2025, a transition scheme until 1 January 2030 is proposed in the shape of a centrally issued exemption at vehicle registration level for the ZE zone. Only Euro VI trucks that are no more than 5 years (box trucks) and 8 years old (tractor units) will be eligible for this;
- From 2030 onwards, ZE zones for delivery vans and trucks in all cities;
- To boost the transition, the national government has an incentive programme that has been agreed with the sector. For trucks manufactured until the end of 2025, the size of this incentive programme is 94 million euros and for delivery vans it is 185 million euros. The starting point for this incentive programme is a purchasing scheme that covers up to 40% of the additional costs of a ZE vehicle (and PHEV vehicles) compared to the fossil fuel alternative.
- It is expected that there will be a total of 50,000 zero-emission delivery vans and 5,000 ZE/PHEV trucks by 2025 and these numbers will continue to grow to 115,000 ZE delivery vans and 10,000+ ZE/PHEV trucks by 2030.

[5] *At the time of writing this report, the cabinet will still have to discuss its proposals with the House of Representatives. This may lead to adjustment of the intended agreements.*

The exception made for Euro VI trucks will affect a large section of the truck fleet. Currently more than 70% of trucks and 30% of HGVs are less than 8 years old (CBS). In order to cover the charging demand, charging infrastructure must be provided. Municipalities, provinces, the national government, grid operators, businesses and trade associations have jointly drawn up a National Charging Infrastructure Agenda. The agreements in this agenda should lead to national coverage of normal speed and fast charging points, cover the charging requirement of the growing number of electric vehicles and result in maximum standardisation (Klimaatakkoord, 2019). More information about how governments provide charging infrastructure can be found in the Annex to 2.1.

2.1.3 Local plans for ZE zones

A number of interviews were carried out to find out how a number of municipalities in the Netherlands (Utrecht, Rotterdam and The Hague) and elsewhere (Stockholm, Oslo, Madrid, London and Brussels) are developing plans for ZE zones. The Netherlands Enterprise Agency (RVO) was also interviewed. The Municipality of Amsterdam was unable to participate in the interviews, as it was in the middle of an administrative decision-making process with regard to the plans for a ZE zone at the time of the study.

Netherlands

In Utrecht, a framework was prepared to develop a ZE zone by 2025. In 2017, a study was performed together with TLN, Evofenedex and Centrummanagement Utrecht about how this could be set up. A good breakdown into phases was mainly mentioned as a key point, to allow businesses to participate in the process properly. In Rotterdam, the plan for the ZE zone was laid down by the Municipal Executive. Rotterdam wants to be one of the 30-40 municipalities with a ZE zone in 2025. In collaboration with parties such as TLN and Evofenedex, they are looking at how parties can be brought together and which ones should be involved. Organisations such as shopkeepers' associations will participate in the process as stakeholders.

The Hague has signed the Urban Distribution Agreement for The Hague with trade associations, in which the signatories agree to jointly specify and develop effective and cost-effective measures to make urban distribution in The Hague more efficient and ZE by 2025. For trucks, there must be at least 2 manufacturers for ex-works ZE vehicles. If this is not the case, vehicles that run on 100% biogas or 100% synthetic diesel (HVO) may also be designated as ZE.
Apart from Utrecht, Rotterdam and The Hague, several other Dutch cities are busy preparing ZE zones for 2025[6].

Abroad

Several European cities have low-emission zones (LEZs) whose standards are becoming increasingly strict[7]. In Stockholm, there has been an LEZ for HGVs since 1996. The zone covers the entire city centre. Euro V vehicles will be phased out from 2021. The LEZ is somewhat limited, because it only affects part of the vehicle fleet. The intention is to ban fossil fuels between 2025 and 2035. At a national level, it has been decided that lighter vehicles should also be included from 2020. This should be an incentive for lighter electric, hydrogen and gas vehicles. The Swedish government provides support to local governments for the introduction and observance of these LEZs.

[6] *www.greendealzes.nl/gemeenten/.*
[7] *http://nl.urbanaccessregulations.eu/.*

The Brussels-Capital Region covers 19 municipalities and has had an LEZ since 2018. Fines have only been issued since 2019. Cameras are used for enforcement. The LEZ will become increasingly strict until 2025. Goods vehicles heavier than 3.5 tons are exempt from the LEZ because they pay a kilometre charge based on national policy. This per-kilometre charge is higher in cities. Brussels does not yet have a policy for the LEZ after 2025, only the intention to eventually introduce a ban on diesel vehicles from 2030.

In London, there has been an LEZ in combination with charges since 2008. From 2020 the standards will be tightened again. London is focusing on making goods transport more efficient and safer. However, there is no specific policy with regard to the electrification of goods vehicles. This has been drawn up for other vehicles such as taxis and public transport.

An LEZ was recently introduced in Madrid. From 2020, goods vehicles without a label will no longer be allowed to enter the city centre. This is the first step towards ZE city logistics. In addition to this, ZE vehicles enjoy tax advantages, including lower taxes and no parking fees.

Oslo has had an LEZ in combination with charges since 2017. The price depends on the Euro standard and a distinction is made between rush hours. In addition to this, Oslo has an active policy to encourage ZE goods transport. It focuses both on the purchasing of vehicles and on the charging infrastructure (see Annex to 2.1).

2.1.4 Legal framework

The ZE City logistics Legal Guide (GreenbergTraurig, 2019) states that a ZE zone can be created by setting up an 'environmental zone' that only zero-emission ('ZE') vehicles are allowed to enter. Environmental zones can be set up pursuant to a traffic order, which can be issued by the Municipal Executive if it involves roads that are managed by a municipality. Such a traffic order may only be issued to protect certain interests, like preventing or limiting nuisance, inconvenience or damage to the environment. In order for it to pass the legal test, it is important that the ZE zone is introduced carefully. A few points mentioned in the guide that could contribute to a careful introduction are:

- Make the ZE zone part of a bigger set of measures as much as possible.
- Announce the intention to create a ZE zone early, for example, by means of new or modified policy documents and possible meetings for the public.
- Investigate broadly which interests could be affected by the ZE zone traffic order and how these should be included in the balancing of interests.
- Have the effectiveness of the ZE zone, the consequences for the general public and businesses and possible mitigation investigated in advance.
- Create support for the ZE zone by involving parties such as local and other businesses, the general public and relevant organisations in the preparation process for the traffic order. A local agreement on this, for example, can be concluded with these parties.
- Consider whether the ZE zone can be introduced in phases and with a transition period.

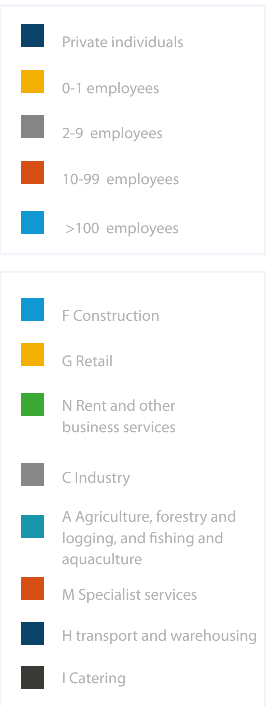
2.1.5 Consequences for specific vehicles and target groups

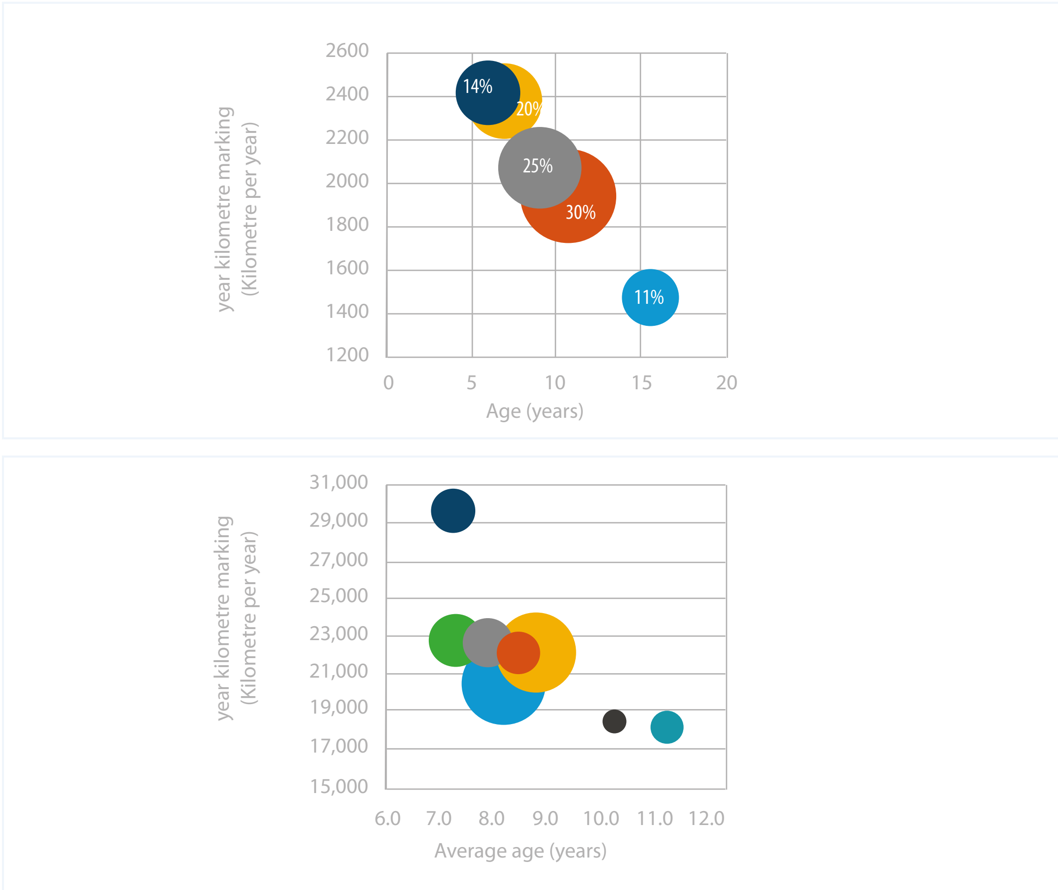
When working out how to introduce ZE zones, a social discussion is held about the balance between feasibility and accessibility on the one hand, and the need to create clarity that guides investments on the other. This is expressed in the variants 'small but tighter' versus 'bigger but more exemptions that are gradually withdrawn'.

Currently there are exemptions for privately-owned delivery vans that are used for medical reasons (for wheelchair transport) and for special goods vehicles. It is currently not clear which vehicles will be given an exemption.

It is clear, however, that there are groups of users for whom the switch to an electric vehicle will be a greater challenge than for others. RVO indicates that small businesses, such as plumbers and market traders, could be facing relatively high investments as a result of ZE zones. The TCO of an electric delivery van is getting closer to that of a new diesel delivery van (see Section 4.3), but second-hand electric delivery vans are not yet widely available. For businesses that normally purchase second-hand diesel vehicles, this limits the available options. Figure 2.1 shows that mainly private individuals, self-employed persons (0-1 employees) and smaller companies drive around in older, probably second-hand delivery vans. These are mainly delivery vans in the agriculture and catering sectors (Connekt, 2017).

Figure 2.1
Relationship between age of delivery vans and size of company , and between age of delivery vans and sector.





2.2 Logistics sector

Based on interviews with various parties that already use electric vehicles, this section covers experiences, barriers and expectations with charging strategies and infrastructure for logistics.

2.2.1 Vehicles, charging and charging infrastructure

Vehicles from the municipal vehicle fleet are charged overnight in depots as much as possible. In Stockholm (250 out of the 900 are ZE vehicles) and Oslo (600 out of the 1100 are ZE vehicles) these are mainly passenger cars and delivery vans. Generally speaking, vehicles are rarely charged by employees at home.

Electric buses that drive around in Eindhoven and at Schiphol are supplied by VDL with a battery capacity that matches the customer's wishes. This varies from small buses with a battery of 85 kWh to fully electric buses with 170 and 300 kWh batteries. The batteries can also be leased. The charging speed at bus depots is 30 kW, with a few possible fast recharges during the day. Fast chargers have been installed at (terminal) stations on a limited number of routes. Three methods are used for charging: a plug, a pantograph on the charging infrastructure and a pantograph on the roof. Major grid connections are required at the depot and these only function if the number of vehicles being charged is spread out during the day.
In the logistics sector, heavier electric vehicles in particular are not yet available. Most existing heavy electric vehicles have been converted to electric. There are hardly any 'turnkey' systems either at the moment. Regarding goods vehicles, it was noted in the interviews that the battery makes them significantly heavier than conventional equivalents. The charging strategy for carriers depends on the routes (see the results for various logistics sectors with associated journey profiles in 4.2). Heavy electric vehicles (40-ton tractor unit + trailer combinations) are currently mostly used on fixed (plannable) routes and are mainly charged at the depot. This eliminates the need for extensive interim charging solutions. 'Ultra-fast chargers' (350 kW) are installed at the depots of carriers at the delivery location to be able to recharge quickly during the day. Due to the high power draw, a liquid-cooled (CCS) plug is used for this. The trucks are charged overnight at the depot using 50 kW DC or 44 kW AC. In view of the high power requirements, trucks are expected to be equipped with on-board AC-DC converters less and less often, and to be only charged directly using DC high power (e.g. using a CCS plug).

2.2.2 Challenges

There is no policy with regard to charging infrastructure specifically for urban goods transport. For the time being, this is being left to private parties. In Oslo and Stockholm, the focus on delivery vans is slowly increasing, but it is almost entirely absent for HGVs.

There are various options for charging at depots, which are still subject to many questions and uncertainties:

- Reliability: in general, the equipment is handled quite roughly. Charging plugs are regularly not durable enough (yet) for the logistics sector.
- On-board AC-DC converter or DC charging station: a truck gets more expensive if it needs to have an AC-DC converter on board, but an external (44 kW) AC charger is much cheaper than, for example, an external 50 kW DC charger. The tipping point is currently at about 44 kW AC versus 50 kW DC. But it is a choice with major consequences.
- Optimum use of charging infrastructure to spread the costs is difficult due to a lack of 'smart charging'. Incidentally, smart charging only has added value if the vehicle can be connected to the charger for a prolonged period of time, allowing you to manage the power draw (e.g. at night).
- Using a pantograph instead of a plug (on the vehicle or on the charging infrastructure): easy to use, but relatively expensive and takes up a lot of space. In addition, with regard to HGVs, vehicle manufacturers are reluctant to allow such high power levels around the cab. For pantographs attached to the charging infrastructure, a wireless connection is required to operate it, which makes the system less robust. Experience also shows that the pantographs get damaged quickly.

- Battery swap: the current price per kWh of capacity makes the investment of purchasing a second battery too expensive. Swapping a battery also costs extra time and the battery may get damaged. This should therefore be automated, which requires yet another investment.
- Induction: Induction technology is not yet developed enough. Despite loss of efficiency, the charging technique is interesting, because it is easy to use: after all, the drivers do not have to do anything. Developing a high-efficiency (>95%) induction system is currently still very expensive. At present, such an efficiency has only been achieved in the laboratory. Furthermore, safety aspects relating to radiation will have to be carefully investigated if high power levels are to be used for charging.
- Scaling up the number of electric vehicles in a depot sometimes reveals issues with the local grid. This then requires smart charging to spread out the peaks, or a new transformer, which requires time and money, or moving new ZE vehicles to a different depot. According to grid operators, a higher capacity connection can be provided, but that takes time. As a result, arrangements often have to be made ¾-1 year in advance if no (medium-voltage) connection is yet available in the area. If one is available, the lead time for a new connection from the grid operator is usually 18 weeks after submitting the application.

For the logistics sector, there are various challenges relating to interim charging solutions in the public space or at stops:

- In densely populated areas, land is scarce and installing a charging station is therefore relatively expensive. There may also simply be no space (e.g. around stations and in shopping areas).
- In less densely populated areas, the costs of a high-power connection are often higher.
- In the case of fixed routes, a charging station could be installed at the customer. With an average unloading time of 15-30 minutes, this will have to be a fast charger. But this is a large investment for a single stop (see Section 3.3), especially if only a limited number of vehicles use it. Additionally, it remains to be seen who will make this investment and connections cannot be made in every delivery location due to the current being too low. Customers can also change quickly.
- For shared charging infrastructure at car parks with charging stations with users from different sectors (e.g. buses, goods transport and taxis), there is a risk of having to wait for your turn. Bus companies in particular are currently therefore still reluctant to join in due to their strict schedules.

2.2.3 Opportunities and recommendations

Based on these challenges, there are opportunities as well for vehicle manufacturers, municipalities, operators of ZE fleets and suppliers of charging infrastructure.

A major improvement with regard to charging technology is smart charging. The time that a vehicle is stationary may be longer than the time it needs to recharge, so the charging speed could be adjusted to match the vehicle’s departure time. This also allows the electricity demand to be spread out more.

At depots, automated contact charging is interesting, or induction in the more distant future, because it requires less maintenance and fewer actions. In case of automated contact charging, a large contact rises up from the floor underneath the vehicle when the vehicle is parked. In such a system, the contact surface of metal on metal is much less of a limiting factor than in a plug and socket. This makes it much easier to charge vehicles using massive power levels (>1 MW) with less cooling. Fewer components can fail as well.

An integrated charging system with monitoring of both trucks and charging stations would be a good development. One logistics service provider also indicated that someone has to go and take a look if an error occurs while charging. An integrated system that can be remotely controlled allows charging stations and trucks to be reset. This is currently only possible for the charging stations and not for the trucks, so this has to be done manually. Monitoring is also important for diagnostics if anything goes wrong. Vehicle manufacturers could also offer a turnkey system, including advice for charging strategies (from fabrication to data-based services).

The price of battery technology is dropping fast. The TCO becomes even more interesting if a depreciated battery can be used for storage. Costs can be spread out more by using solar panels at the depot and storing energy in batteries. Another option is to use a largely depreciated battery in a different sector where fewer kilometres are driven.

Sharing of charging infrastructure is an interesting option for spreading the costs. In the public space, this could be done by means of an online reservation system. Goods vehicles could, for example, be charged at bus stops overnight. Sharing of the vehicles themselves is also interesting. A logistics service provider indicated, for example, that vehicles are used during the day, but could be used to move containers at a terminal for a few hours during the night. Modifications will be required to make private providers like Fastned and Pitpoint suitable for heavier goods traffic. This mainly involves modified connections (at least 150 kW), higher stations for trucks and a correct distribution of charging infrastructure for the logistics sector.

Finally, the interviews also yielded a number of suggestions with regard to policy:

- In addition to promoting electric goods transport on the 'last mile', a focus on hinterland transport (incl. the 'first mile') could boost the development of electric trucks by OEMs.
- An increased number of electric vehicles also helps reach a break-even point for charging infrastructure sooner.
- The government can help by providing fast and proper procedures; how to facilitate in the case of an application regarding the grid (shorter application time for permit and installation of charging station).
- With a view to the further expected growth of B2C deliveries and smaller orders, it would be advisable not to ignore charging stations in residential areas for delivery vans.
- Electric goods transport in cities could be given an additional boost in the next couple of years by providing a fair and constant kWh price at public charging stations.

3 LOGISTICAL PROFILES, VEHICLES & BATTERIES AND CHARGING INFRASTRUCTURE

3.1 Logistical profiles and requirements

The logistical characteristics of the various journeys made by logistics service providers largely determine the options and challenges regarding the use of electric vehicles. Many different logistic activities are performed in city centres, with just as many different characteristics. Among other things, the logistical differences are reflected in the vehicle choice, the number of kilometres per journey and the number of journeys each day or the number of stops and the duration of the stops.

The underlying reasons for the differences are:
- The character of the sector: e.g. the use of conditioned vehicles for food services or special vehicles for waste collection.
- The reason for the logistics: does it involve a delivery (large/small) or a service or repairs/installation work?
- The network: is a local network being used with short approach distances or is a regional/national network being used with longer approach times?

In this study, an analysis was performed of the characteristics of logistics activities that take place in the city centre and the sectors involved. The focus here is mainly on the logistical characteristics that are a determining factor for the transition to electric transport. For the analysis, the following information is needed with regard to the logistical profiles and requirements:
- Composition of the sectors: The sectors combine activities with similar logistical profiles (and logistical requirements). This subdivision into sectors then makes it possible to perform a joint analysis of the logistical requirements for electrification of the logistics.
- Analysis of the logistical requirements for electrification: Practical journey details were collected using journey data and interviews/questionnaires among logistics service providers. This data was used to map out the specific requirements for each sector. The basic assumption here is that the form of logistics carried out with (diesel) combustion engines will not change due to the use of electric vehicles. This means that the choice of vehicle type (size), number of stops per journey and journey kilometres will remain the same.
- Analysis of possible battery charging activities: An essential question for the transition to electric transport in logistics is where and when the battery can be charged. The charging moment and location largely determine the required investments (in battery capacity and charging facilities), the energy costs and the planning of journeys and vehicles. A list has been drawn up of possible moments (and locations) when the batteries can be recharged. This list is used in the model to be able to determine the optimum battery charging strategy.

3.1.1 Sectors

The activities of logistics service providers with similar characteristics are combined to form a 'sector'. This subdivision into sectors makes it possible to perform a joint analysis of the (logistical) requirements for the charging network. The starting points for this subdivision are the sectors, global characteristics of shipments, the use of vehicle types and the (global) specifications of a journey. A distinction is made between eight logistics sectors: waste, building logistics, facilities, catering, mail/parcels/couriers, retail (food), retail (non-food) and service logistics.

Vehicle type

Various types of vehicles are used in each sector. Heavy vehicles (small and large box trucks of less than 20 tons and trucks (tractor units + trailers) of less than 40 tons) are used for large deliveries to catering and retail, and deliveries in the construction sector and for waste collection. The delivery vans are used for small deliveries in sectors such as mail and parcels, services, facilities and construction logistics.
In the transition to using electric vehicles, the vehicle choice plays a major role. First of all, the heavy vehicles have a much higher energy demand. This requires more battery capacity or the vehicles will have to recharge their batteries more often. The available range of heavy vehicles is also limited at the moment. Light vehicles are already available on the market. The transition is expected to be easier for these vehicles because the energy demand of the vehicles is lower (see Section 3.3).

Journey characteristics

A key logistical characteristic is the journey type. A distinction is made here between point-to-point journeys ('full truck load') and milk runs ('less than truck load'): Point-to-point journeys are made between two locations. These journeys are usually made for deliveries with full trucks or if the driver remains at the destination for a prolonged period of time (e.g. service engineers or in the construction sector).

Figure 3.1 to 3.3
Illustration of various point-to-point and milk run journey characteristics.

In case of milk runs, a fixed route is covered, with stops being planned at several addresses. Milk runs occur in almost every sector (catering, retail, service logistics, mail & parcels). A key distinction is between journeys to fixed addresses (e.g. when supplying shops) or journeys that follow a fixed route (e.g. mail & parcels or services). The journeys to the fixed addresses are more reliable and it is possible to make use of the facilities on site, e.g. a battery charging point.

A second characteristic is the journey length. This is a key aspect mainly from the perspective of logistics electrification. For longer journeys, chances are that the vehicle will have to be recharged during the journey. This may lead to additional costs due to waiting times or detours. It also is an additional challenge for the planner to minimise the extra costs. The journey length is less sector-specific and mainly linked to the geographical scale of the journey. Local and regional journeys are generally short due to the limited approach and exit kilometres (20 -120 km), whilst national journeys can be over twice as long. Local, regional and national journeys occur in almost all sectors.

Delivery characteristics

The deliveries are characterised by the size of the deliveries (number of items), the number of deliveries planned during a journey and the duration of the stops. The size of the deliveries and the number of deliveries per journey is related to the vehicle. After all, when choosing the vehicle, optimisation takes place based on the total volume planned for each journey (delivery size) and the number of deliveries that can be made. The duration of stops is important for the latter. In the mail & parcels sector, the deliveries are made as quickly as possible (stop & go). The driver can therefore make a large number of deliveries per journey. For large deliveries to catering establishments or in non-food, several rolling containers are often delivered. These stops are relatively short (less than 30 minutes). The longer stops (more than 30 minutes) usually occur in case of large deliveries with full trucks (retail food) and also if additional services are required (e.g. engineers). For the transition to electric transport, the duration of the stop is a key element, as a longer stop would present the opportunity to recharge the battery during the stop. This makes it possible to avoid waiting times and detour kilometres.

3.1.2 Logistical requirements for electrification

Specific logistical requirements apply within each sector: the key factors each journey must meet in order to comply with the requirements of the customer and the logistics service provider. Examples of these are the required service level of the logistics service and the cost efficiency of the operation. Using available journey data and interviews and surveys with logistics service providers, the logistical requirements per sector were mapped out. The Appendix to 3.1 presents a full overview of the logistical characteristics for the various logistic activities. In addition, Table 3.4 below presents a full overview of the logistical requirements per sector.

Table 3.4
Specific requirements in relation to challenges for electric transport.

	LOGISTICAL REQUIREMENTS	CHALLENGES FOR ELECTRIC TRANSPORT
	Use of specialist, large vehicles with high energy demand. Short journeys with high drop density and short stops. Vehicle completes several journeys per day.	Availability of large vehicles is limited. Knowledge of and experience with investments in vehicles and batteries and TCO are limited. Charging infrastructure required at depots. Uncertainty regarding battery capacity and charging speeds when carrying out several journeys a day.
	Use of large, heavy vehicles with high energy demand for transporting building materials. Use of delivery vans for contractors and installation companies. Long stops and limited number of stops/journeys p/day. Approach kilometres both national and regional/local.	Not enough vehicles for heavy transport available yet. Charging facilities for heavy vehicles at depots and building sites. Charging facilities for delivery vans at home and at building sites.
	Use of large conditioned vehicles. Large range required for regional transport. Short stops (<30 minutes) when delivering.	Availability of large vehicles. Knowledge of and experience with investments in vehicles and batteries and TCO are limited. Interim charging would appear to be necessary due to the high energy demand (vehicle type and journey distance). Stops are too short for charging during the stops. Additional costs when using public charging facilities due to detours and (additional) waiting times.
	Use of delivery vans and light trucks. Short journeys with high drop density and several journeys a day. Many fixed routes and deliveries at one-off addresses. National distribution journeys with a large range (200-300 km). Stop & go for mail & parcels. Home delivery short stop (<30 minutes).	Battery charging speed when making several journeys a day. Additional costs for interim recharging when using public charging facilities due to detours and (additional) waiting times for longer journeys.
	Use of large conditioned vehicles. Large shipments, but only a limited number of addresses per journey. Vehicle can make several journeys a day.	Availability of large vehicles is limited. Knowledge of and experience with investments in vehicles and batteries and TCO are limited. Interim charging would appear to be necessary due to the high energy demand (vehicle type and journey distance). Charging infrastructure appears necessary at delivery addresses.
	Use of large vehicles. Many national distribution journeys. Large range required for national transport (200-300 km). Large shipments, but only a limited number of addresses per journey. Long stops (>30 minutes).	Availability of large vehicles is limited. Knowledge of and experience with investments in vehicles and batteries and TCO are limited. Interim charging would appear to be necessary due to the high energy demand (vehicle type and journey distance.) Charging infrastructure appears necessary at delivery addresses.
	Use of large and small delivery vans. Vehicles with lots of equipment have a high load and high energy demand. Long journey distances and long journey times. Many stops at office locations, but also at one-off addresses.	Battery charging activities to be planned with the work (preferably during stops/work). Charging infrastructure appears necessary at delivery addresses (office locations).

3.1.3 Analysis of battery charging actions

The logistical planning is aimed at making the journey as efficiently as possible. For electric transport, it is important that the recharging of the battery is planned as efficiently as possible. Additional waiting times for the drivers and detour kilometres to a battery charging point must be minimised for this. From a logistical perspective, the batteries are charged in depots/DC or during the stops. This will not be possible for all journeys, such as during long journeys with relatively short stops. In that case a driver will have to recharge in the interim, e.g. at a public or private battery charging location.

The calculation model used in this study (see Chapter 4) calculates the optimum battery pack (power) in combination with the battery charging strategy based on minimum costs. The basic assumption used by the model is that batteries can be recharged in four locations, namely at the depot/DC, in residential areas/at the homes of owners or users of commercial vehicles, during stops and at public battery charging locations.

The analysis of the sectors and the specific logistical requirements shows that these options for recharging the battery are not suitable for every sector. Recharging during the stops is limited in particular. First of all, the duration of the stops may be too short to recharge efficiently. Furthermore, large vehicles require battery charging points with high power levels. These will mainly be unavailable when delivering to one-off addresses (e.g. in the construction logistics sector) or for home deliveries. In the Appendix to 4.1, this list has been converted into the number of charging actions for each location and sector.

3.2 From spatial effect of journey patterns to logistical hot spots

The journey profiles for urban distribution have a spatial effect. Based on this, a number of generally logical locations can be indicated where the demand for charging infrastructure can be expected to increase as vehicle fleets are electrified. This section will first address the spatial effect of journey patterns. Afterwards, the logical locations or 'hot spots' will be covered in more detail.

Most journeys start at a home base (or depot), at the logistics service provider, wholesaler or DC. These are usually located at industrial sites. The destination locations vary from supermarkets and public unloading locations from where catering and retail are supplied in the city centre to building sites, large office buildings and residential areas and the surrounding area. The most logical locations for recharging the battery are at the home base or at the destination. In these locations, the battery can be charged cost-efficiently without additional costs for waiting times or detours. A third option is to recharge the battery in public locations along approach routes.

The analysis in Section 3.1 shows that there are four main location types where a substantial increase in the demand for charging infrastructure is expected to occur. These hot spots are:

1 At the carrier’s home base.
2 Along the main route towards the Amsterdam region.
3 At unloading addresses/destination locations.
4 In residential areas/at the homes of owners or users of commercial vehicles for urban distribution.

Point for attention.

Even though the departure and unloading locations provide opportunities for battery charging, there are a number of problem areas that prevent electric vehicles from being used just like that. The current journey profiles are based on diesel engines. When using electric vehicles, the planned journey distances must be achievable with the vehicle and the available battery capacity. Furthermore, the need for additional interim charging could lead to extra waiting times and detour kilometres, which could result in higher logistics costs. The conclusion is that use of electric vehicles could lead to different choices for logistical optimisation, which could give rise to different journey profiles (shortening of journeys, fewer/more deliveries per journey, etc.).

Table 3.5 below presents a summary of the key characteristics of the four types of hot spots and the potential charging strategy.

Table 3.5
Characteristics of general locations for charging demand.

CATEGORY		CHARACTERISTICS	EXPECTATIONS FOR FUTURE CHARGING PATTERNS
Hub/depot: Home base at industrial site	Logistics industrial sites.	Easily accessible sites with trade, logistics/DCs along the A10 ring road. Relatively large volumes between city centre and industrial sites.	Overnight recharging at home base (private). Briefly recharging at home base during day (private).
	DC's in de MRA.	DCs spread out over the AMA region. Concentrations along motorways in northwest and southwest Amsterdam.	Briefly (fast) charging at a customer address during the day (private/public).
Public charging stations: Along main route towards the region	Service stations. Rest areas (private/public). Logistical uncoupling points (LUP's).	Charging location for longer distance journeys. For instance from building sector/production locations or national and international DCs.	Briefly (fast) charging during day (public). Higher capacity charging stations required for larger vehicles.
At customer: Unloading/ destination locations	Public unloading locations catering and shop concentrations.	In the city centre, there are catering and shop concentrations which could be supplied from a public unloading location.	Recharging during day during unloading/visiting times at destination location (private/public).
	Supermarkets and large office buildings.	Larger supermarkets (with a loading dock) present an opportunity for electric trucks to recharge while unloading. Large office locations with 500+ people provide room for car parks with charging stations for their own vehicles and visitors (parcel services, delivery vans, service engineers).	
	Building sites.	Temporary building sites are located throughout the city centre. Electric building vehicles can recharge here during the visiting period.	
At home: in residential areas		Sectors such as parcel delivery services and building and maintenance include employees or self-employed persons who park their company vehicles in their own residential area. Residential areas are destination locations for service providers, service engineers and parcel deliverers.	(Prolonged) overnight charging. Briefly recharging during day.

The Appendix to 3.2 contains a further in-depth description of the above table, including the logistic hot spots.

3.3 Vehicles and batteries

The major difference in cost between electric and conventional vehicles is that the purchase of an electric vehicle (EV) is more expensive, but the operating costs per kilometre are lower. However, there is also a variation in the TCO between individual EVs. Depending on the logistics sector and the journey profile, there are various options for the vehicle and the battery pack. A service engineer in the building sector who covers relatively short distances and has only a few stops a day may, for example, opt for a small delivery van with a 30 kWh battery, with overnight charging being sufficient. A parcel deliverer with more daily journey kilometres could use the same delivery van in terms of space, but would need a 50 kWh battery because of the longer distance and because there may not be (enough) time to recharge the battery quickly while on the road.

- **Category N1:** Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tons. Selected vehicles: one small, two medium-sized and one large delivery van.
- **Category N2:** Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tons but not exceeding 12 tons. Selected vehicle: a 12-ton box truck.
- **Category N3:** Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tons. Selected vehicles: A 19-ton box truck and a 37-ton truck + trailer.

A variety of battery packs can be selected for each vehicle. The assumption is that car manufacturers will be increasingly offering a wider range. The only limitation here is that the maximum gross vehicle weight (GVW) should not be exceeded by a larger battery pack. A Renault Kangoo is currently sold with a 33 kWh battery. In the future this vehicle could be available with a 30, 40 or even a 50 kWh battery.

In 2019, the number of electric vehicles in the N1 category being manufactured is increasing sharply. In the N2 and N3 categories, however, conventional vehicles are often still being converted, which makes the costs of a battery variant relatively high. In this case the costs include the purchase price of a conventional vehicle + the purchase price of a battery + EV-specific parts + labour costs for the conversion. In addition, it is difficult to achieve large economies of scale in this way. The manufacture of various types of electric trucks has been announced since 2017, but this was often followed by postponement or only the presentation of a prototype. From 2019, Tesla is supposed to be manufacturing the Semi and DAF and VDL will soon be supplying prototypes for 19-ton (LF Electric) and 37-ton (CF Electric) trucks.

The battery and the vehicle are separated out for the analysis of the costs. First of all, this is because different battery packs can be selected for each vehicle. Furthermore, the depreciation of batteries and vehicles is different. Whereas vehicle depreciation is expressed in years, charge cycles are used for batteries. This is because, after intensive use, a battery can be replaced. If the battery can still be used after the end of the vehicle's depreciation period, it will have a substantial residual value.

3.3.1 Battery

The maximum size of a battery (in kWh) in a certain vehicle is mainly limited by the maximum permitted weight and, to a lesser extent, by the volume taken up. Also, the larger the battery, the lower the weight or volume of the load can be. This mainly applies to the N1 and N2 vehicle categories.

A greater overall weight due to a battery also affects the power consumption. A fixed price per kWh and per year has been used for the battery purchase. In 2018, the base year, this is €288 and it will drop to €121 in 2030 (average value based on various sources (TNO, 2018). For the time being, the battery price is therefore still determined by multiplying the price per kWh in a certain year by the total kWh amount. The necessary (electrical) components of the vehicle that are required to use the battery are part of the vehicle price.

The consumption of the vehicle is expressed in kWh/km, with the efficiency being expected to improve until 2030. This can be used to determine the maximum range. An efficiency improvement of 0.5% per year has been assumed for the batteries. This may either be due to an increased energy density (kWh/kg) and/or the vehicle becoming lighter, as a result of which the same battery can be used to driver further (average assumption based on various sources: Fischer et al., 2009; Krause et al. 2016; Liimatainen et al. 2019). The consumption of a vehicle in combination with the size of the battery determines its range. For a small delivery van with a 33 kWh battery and a consumption of 0.229 kWh/km, this means that its theoretical range is 144 km. However, the range is shorter in practice due to the following factors:

- The maximum range presented here is based on the empty weight of a vehicle and good driving conditions like the weather. Ideally, the average charging capacity should be included. The temperature also affects the range; both cooling and heating reduce the range. Due to a lack of sufficiently validated data in this regard, the calculations are based on the empty weight.
- Manufacturers are not always clear or explicit about whether the indicated figure is the actual one or a net value.
- A battery is never used fully (Depth of Discharge; DoD). In order to maximise the battery's lifespan, it is not used any further than 20% of the remaining capacity (State of Charge; SoC or 80% of DoD).
- When making use of fast charging in particular, a battery is not fully recharged, but only to 80-90% (Schücking et al., 2017), which leaves a net DoD of 70%.

The service life of the battery is expressed in the number of charge cycles: 'Many battery cell manufacturers state a ten-year lifetime based on calendar life and at least 3000 full charge and discharge cycles before reaching their end of life at 80% capacity (Azadfar et al., 2015; Kley, 2011). For the presented charging strategies and the associated DoD per trip, neglecting effects due to fast charging or different SoC levels regarding the cell chemistry, which goes beyond the scope of this work, the estimated cycle life of 3000 cycles varies from 4.2 to 11.1 years.' (Schücking et al., 2017).

In the base year 2018, an average lifespan of 3000 charge cycles is used for a battery. In case of regular charging, a full charge cycle will then equal 80% DoD (SoC range 20-100%) and, in case of fast charging, this will be 70% DoD (SoC range 20-90%). The latter case means that, if a vehicle is briefly fast-charged up to 50-60% of its capacity three times a day, this would be about 4/10 of a charge cycle. A charge cycle never exceeds 80% of the capacity. If a battery is always fully drained to a DoD of 10%, its lifespan in charge cycles will quickly drop. The depreciation costs are determined by the size of the battery in kWh, the cost per kWh in the battery's year of purchase (€288/kWh in 2018), the lifespan of the battery in charge cycles (3000 in 2018), the DoD and the annual distance driven. The residual value is determined by the number of journey kilometres for which the battery can still be used when the vehicle is depreciated after 8 years.

3.3.2 Vehicles

The basic price of each vehicle consists of the rolling chassis and 'EV-specific components', which allow a battery to be installed and used. The price of batteries will drop until 2030 and this is also expected to be the case for the 'EV-specific components' (see Connekt, 2018). The depreciation of the vehicle is expected to cover 8 years, after which a residual value of 19% remains. An inflation rate of 2% per year is applied to the vehicle's basic price. The operating costs primarily consist of energy costs. These depend on the kilometres driven in combination with the charging location and (price of) charging infrastructure. The insurance costs and (future) taxes are jointly estimated to be 3.5% of the total price of the vehicle including a battery (Bubeck et al., 2016). Maintenance costs for EVs are significantly lower than those for conventional vehicles. They are estimated at €0.02/km for delivery vans (Lebeau, 2016) and at €0.10/km for a truck (tractor unit + trailer) (37t) (Meszler et al., 2015). For box trucks, these costs were linearly estimated based on these extremes. The selected goods vehicles presented in Table 3.6 below cover the various logistics sectors.

Table 3.6
Overview of vehicles with key assumptions for TCO.

	VEHICLE	CONSUMPTION	BATTERY PACKS	BASIC PRICE OF VEHICLE IN 2018	MAINTENANCE COSTS (€/KM)
N1	Small delivery van	0.229	30, 40, 50	18,500	0.0215
	Medium-sized delivery van	0.298	30, 40, 50	20,000	0.0215
	Medium-sized luxury delivery van	0.298	40, 50	30,000	0.0215
	Large delivery van	0.370	41, 55	40,000	0.0215
N2	Small box truck (12t)	0.769	80, 120, 160	165,000	0.0321
N3	Large box truck (19t	0.909	120, 200, 240	190,000	0.0643
	Truck (tractor unit + trailer) (37t)	1.75	170, 240, 320	250,000	0.0974

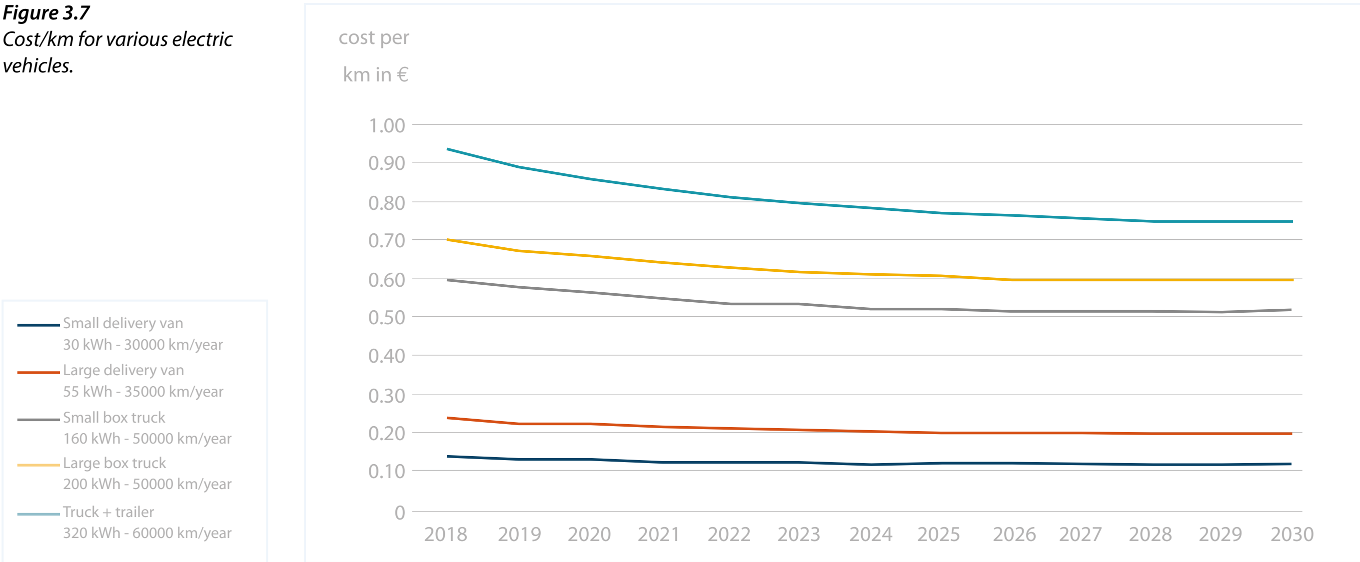
3.3.3 TCO - Vehicle and battery

In Section 4.3, the costs of the vehicle and the battery are combined with the costs of the charging infrastructure and electricity (see Section 3.4). These are used to carry out a TCO analysis, in which a sensitivity analysis is performed on various parameters. The costs are presented per year and per km over the depreciation period. The components of this TCO are the following:

- **Vehicle depreciation:** basic price of vehicle purchased in a certain year, excluding the battery, minus the residual value after the depreciation period.
- **Battery depreciation:** first of all, this depends on its size in kWh and the year of purchase. Over the years, the factors that determine the lifespan of the battery will improve significantly, which will make batteries cheaper relatively quickly. First of all, the purchase price per kWh will decrease. Furthermore, the capacity of the battery will be used more efficiently, so that more km can be driven per charge cycle. The battery's lifespan in terms of the number of charge cycles will also increase.
- **Vehicle maintenance costs:** these are determined by the number of kilometres driven in combination with the maintenance costs per kilometre for a certain vehicle (see table above).
- **Tax and insurance:** these are 3.5% per year of the total price of the vehicle including the battery. The initial purchase price is used for this during the entire depreciation period.
- **Energy costs:** these depend on the number of km driven, the charging infrastructure used and the location (private or public; see Section 3.4).
- **Charging infrastructure:** these are based on the analysis, as explained in Section 3.4. The various types of charging stations are not suitable for all vehicles. An HPC 350 is too powerful for a small delivery van and it would take too long to charge a truck (tractor unit + trailer) with a DC 20. If charging infrastructure is public, the costs of the charging infrastructure are not included in the TCO. After all, for an individual user the investment in the charging station is incorporated in a higher charging station rate. The depreciation is charged through indirectly. If a charging station is located on private land, the costs are included in the TCO. If the charging station is used by a single vehicle, the costs are allocated to the vehicle in question during the depreciation period. If several vehicles use a charging station, the (fixed) costs are spread out, which reduces the cost price per kWh for this charging station.

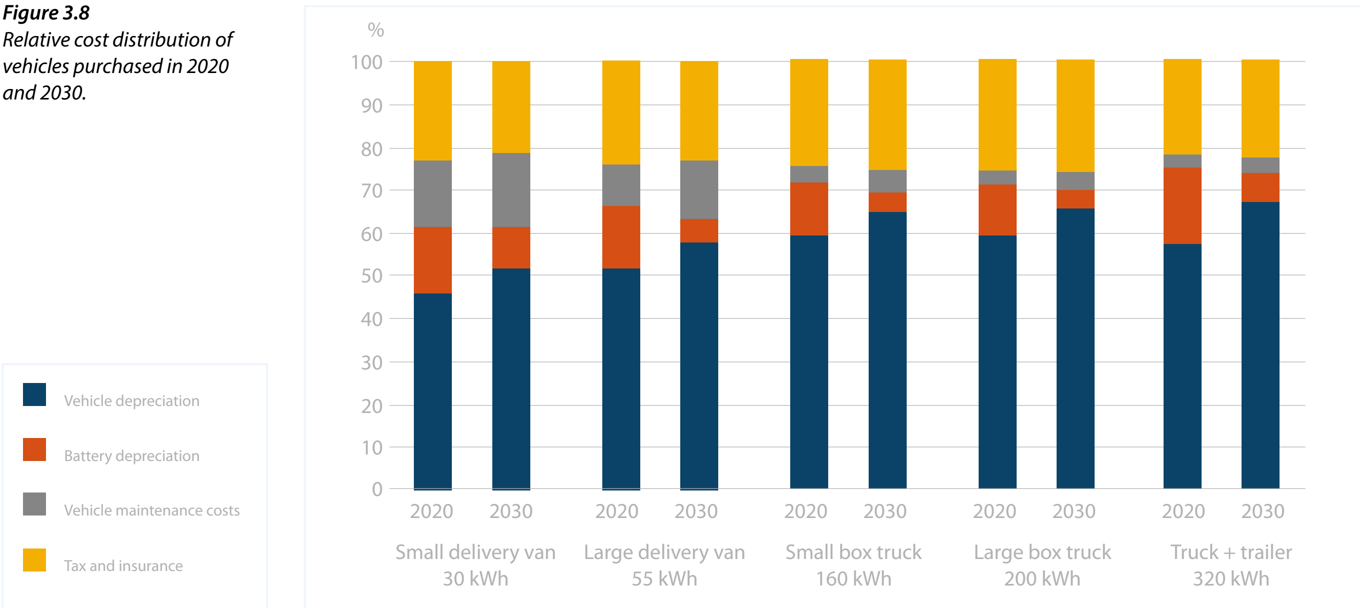
This greatly depends on the year in which a vehicle (and a battery) is purchased. A vehicle purchased in 2020 will be depreciated until 2028. In the intervening years, the costs are expected to drop relatively quickly, especially those of the battery. Figure 3.7 below presents the costs per kilometre for five vehicles with an annual distance driven that suits the capacity of the battery. The costs drop faster as the size of the vehicle and the battery increases. The costs of a large box truck with a 200 kWh battery and an annual distance driven of 40,000 km purchased in 2019 are 2.84% lower than for the same vehicle purchased in 2018. A vehicle from 2028 is only expected to be 0.09% cheaper than one from 2027. A vehicle purchased in 2030 will even be slightly more expensive than one from the year before. This is caused by a vehicle becoming relatively more expensive and the effect of inflation.

Figure 3.7
Cost/km for various electric vehicles.



For the same vehicles as in the above figure, Figure 3.8 below shows the relative cost breakdown of a vehicle purchased in 2020 and the same vehicle purchased in 2030. The vehicle becomes relatively more expensive, whilst the price of a battery drops significantly. As the absolute costs drop, but the maintenance costs per km remain the same, their share increases.

Figure 3.8
Relative cost distribution of vehicles purchased in 2020 and 2030.



3.4 Charging stations and infrastructure

A balanced network of charging stations with different capacities and locations is an essential part of goods logistics based on electric goods vehicles. This applies especially in view of the fact that, for the time being, the range of electric vehicles will remain quite a long way below that of petrol or diesel vehicles with a similar load capacity.
This paragraph will first explain the difference between public and private charging stations (Subsection 3.4.1), followed by the various types of charging stations (low and high-capacity charging stations; see Subsection 3.4.2). The results of the TCO calculation are presented in Subsection 3.4.3, followed by a few conclusions in Subsection 3.4.4.
Appendix 3.4.A contains relevant background information about charging station technology and usage. Furthermore, Appendix 3.4 presents the underlying costs for charging stations, various assumptions and considerations, an explanation of the TCO calculations and further background information about charging station technology and usage. A few expectations regarding long-term developments are also outlined.

Figure 3.9
Fastned (50 kW).

3.4.1 Public and private charging stations

Charging stations can be subdivided by use: private or public. Private charging stations are intended for own use and are located at an (enclosed) business site or at the user's home or at a delivery location or customer. Public charging stations can be used by anyone and are located in public places.

The difference between public charging stations and private charging stations is mainly related to costs required for an installation. As these charging stations are installed in public space, they often require additional permits and traffic orders. In addition, extensive excavation work often has to be carried out due to a new grid connection being required.

Public charging solutions

The key characteristics and cost items for public charging stations are:

- These kinds of charging stations are installed in the public space by commercial market parties, sometimes after winning a concession from a municipality or on behalf of a municipality (in a tender).
- In urban environments, the preparation of locations, excavation work, traffic orders and integrated environmental permits are major cost items.
- Charging at public stations is generally subject to a fixed sales rate per kWh (set by the municipality). For publicly accessible fast chargers (like those of Fastned), there is a choice between a fixed sales rate and a subscription model (subscription costs + kWh rate).

Table 3.10
Public charging stations.

	AC10	AC20	FC50	HPC150	HPC350
Power	11kW	22kW (11kW for 2 chargers)	50kW (25kW for 2 chargers)	150kW (75kW for 2 chargers)	350kW
Type	3-phase	3-phase	DC Fast charger	DC Super Fast charger	DC Ultra Fast charger
Usage	Public	Public	Public	Public	Public

Private charging solutions

In the case of private charging solutions, the charging stations are installed on private land. This may be at someone's house, at a company or at an enclosed industrial site. As these are not publically accessible locations, no additional permits are (usually) required to install the charging station. In many cases, only limited excavation work is required as well. The private charging stations are normally connected to existing grid connections. The highest capacity stations are an exception to this. An additional transformer may have to be installed for these charging solutions or the grid may have to be reinforced. Whether these costly modifications are required depends on the local conditions, e.g. whether or not a connection to the medium-voltage grid is available.

Table 3.11
Private charging stations.

	AC3,7	AC20	FC50	HPC150	HPC350
Power	3,7kW	22kW (11kW for 2 chargers)	50kW (25kW for 2 chargers)	150kW	350kW
Type	1-phase Home charger	3-phase Company charger	DC Company charger	DC Company Super Fast charger	DC Company Ultra Fast charger
Locatie	Private land	Business site	Business site	Business site	Business site

3.4.2 Capacity of charging stations in relation to logistical profiles

Depending on their charging capacity, charging stations can be subdivided into two categories:

- **Low-capacity charging stations** with a charging capacity of up to 20 kW. Among these we distinguish two main types: AC3.7 (3.7 kW), AC20 (22 kW). The latter charging station is often equipped with two plugs. This results in a capacity of 11 kW in case of concurrent use.
- **High-capacity charging stations** with a charging capacity of 50 kW or more. Three classes are currently distinguished among these: FC50 (50 kW), HPC150 (150 kW) and HPC350 (350 kW). Higher capacity charging stations are possible, but require costly additional facilities, e.g. in terms of the power grid and the charging station itself.

[7] *The four largest municipalities in the Netherlands have set the rate to 28 eurocents/kWh (excluding VAT). In other municipalities, a starting rate or connection rate may also be applied.*

Six of the total set of charging solutions are private and four are public. For the AC solutions (AC3.7 through AC20), the charging is performed (and controlled) via the charger in the car. For the DC solutions (FC50 through HPC350), the control system is in the charging station.

- **AC3,7kW (private):** these are regular charging stations that are installed in the driveways of EV users themselves. These are hooked up to the house connection on a separate fuse with a single-phase AC voltage. Charging a delivery van with a capacity of 25 kWh requires a charging time of approx. 8.5 hours. This is usually enough to recharge the battery overnight.
- **AC10/20 (private/public):** this type of charging station is used for public charging points, but is also used on private land of companies. The relevant distinction between the AC10 and AC20 is that the grid connection costs differ significantly (approx. €300 versus €900 per year). With a power of 20 kW, the above example (delivery van with 25 kWh) would be 90% recharged within the hour (AC10 would require two hours). AC20 stations are often equipped with 2 plugs. When using both, the current is halved and the charging time is doubled. This basically turns the AC20 into two AC10s.

Note: these chargers can also be installed at home on a different group, provided that three-phase power is present (especially in newly built houses; older houses are mostly fitted with 25 single phases of up to 35A).

- **FC50 (private/public):** This 50 kW charger is still the standard for current fast charging stations along motorways (FC = fast charging). Apart from public applications, it can also be supplied to companies (semi-public or private) – even though this is not a target market for companies like Fastned. Both AC and DC solutions are available here (Chademo, CCS Combo). At this power level, a delivery van would receive 80-90% of its charging requirement (25 kWh) within half an hour.
- **HPC150 (private/public - High-performance charging).** This is basically the same piece of equipment as the DC50, but with 3 times the power (by tripling the current; the voltage remains the same). This standard is currently being rolled out by companies like Fastned. The first EVs that can charge so quickly are being expected over the course of 2019. These are mostly publicly available. 80-90% of 25 kWh can be charged within 10 minutes.
- **HPC350 (private/public):** This standard is currently being developed by a consortium that includes BMW, Audi and Shell (Ionity). In theory, 25 kWh could be charged within 5 minutes (comparable to regular refuelling with diesel). These charging systems are also being used already in public transport to charge the batteries of electric urban buses.

Rough breakdown of vehicles by charging station type

- **Delivery vans:** these mainly use charging solutions of up to 50 kW. In due course with larger battery capacities they could possibly also use 150 and 350 kW in the wake of the passenger vehicle market.
- **Trucks and buses up to a GVW of 10 tons:** these will also mainly use solutions of up to 50 kW. Due to the bigger required battery packs, they will probably switch to 150-350 kW solutions sooner.
- **Heavier goods transport (from a GVW of 10 tons)** will mainly use faster charging solutions (starting at 150 kW). Charging solutions of up to 1 MW are under development, but their implementation is limited, so they have not yet been included in this study.

3.4.3 TCO: Charging costs for various charging solutions

The costs for a charging station consist of a fixed part that is basically independent of the level of use and variable costs that do fluctuate with this. The fixed costs consist of investment costs, such as the purchase price and installation cost of the charging stations, and the operating costs, such as service costs, grid connection costs and insurance. Most of the variable costs are incurred by purchasing electricity. Taxes take up a large part of this. Incidentally, it is important to state for the cost calculations that the share of taxes drops significantly as the annual power consumption increases.

Cost elements that contribute to a realistic electricity price per kWh include (i) hardware costs, (ii) installation costs, (iii) operating costs and (iv) electricity costs. Determining the level of each of these cost categories is accompanied by assumptions. Appendix 3.4.B covers this in more detail.

The general formula for calculating the cost price per kWh is the variable costs per kWh plus the fixed costs divided by the annual total in kWh. Determining the charging costs per kWh therefore requires an estimate for the total quantity sold per year for the charging solution. Applying the quantities sold estimated in Appendix 3.4.C then yields the (integrated) cost price per kWh. The results are presented in Table 3.12 below. These tables once again make use of three scenarios. A number of basic assumptions were used for the cost price calculations (see Appendix 3.4.D).

A few conclusions are:

- Generally speaking, a kWh charged at a public station can, from the viewpoint of the **provider**, be almost twice as expensive as a kWh charged at a private ('own') charging station.
- For the **purchaser** of a kWh, a significantly different rate may apply. This (commercial) rate can be much higher than the cost price rate or lower if subsidies are involved.
- For higher capacity charging stations, the cost price of a kWh is generally lower than that of the lower capacity versions. However, the extent to which the quantity of kWh expected to be sold annually is actually achieved also affects this greatly. If this quantity is not achieved, the cost price per kWh for high-capacity charging stations increases rapidly.

The total costs for a charging station are expressed as a fixed amount per year plus a variable amount per kWh supplied. The TCO increases from €147 per year and €0.21 per kWh for the lowest capacity charging station (3.7 kW) to almost €37,000 per year and €0.10 per kWh for the highest capacity charging station included here (350 kW). The cost price per kWh varies from €0.14 (the AC20 for private use) to €0.42 (see Table 3.12 below).

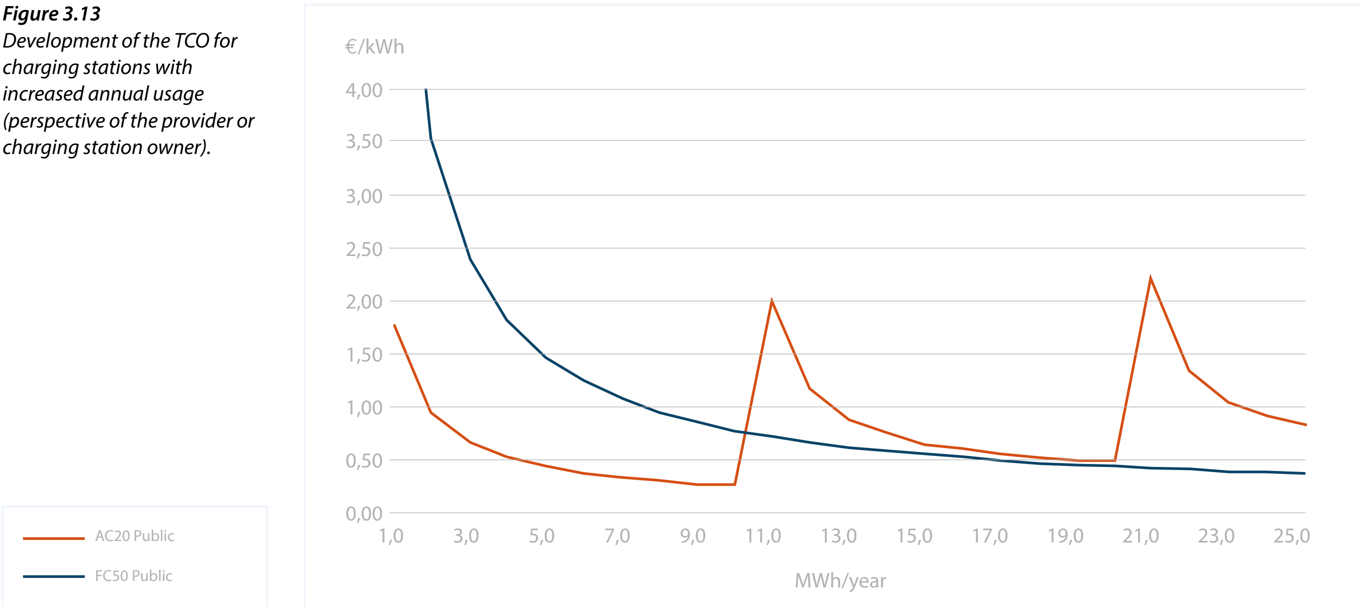
Table B.3.7 in Appendix 3.4.F shows the resulting TCO of the various types of charging stations, and an example of TCO development is presented in Figure 3.13 below. Appendix 3.4.E also includes various considerations for the presented TCO calculation. The left side of the table (TCO fixed and variable) is also further explained in Appendix 3.4.F. The right side (cost price at given annual consumption) is further explained in Appendix 3.4.G.

Table 3.12
Overview of the TCO and cost price per kWh for a given annual consumption.

** The public charging stations have a maximum rate set by the local government (in Amsterdam). The cost price rate is given in brackets.*

	TCO (FIXED AND VARIABLE)		COST PRICE AT GIVEN ANNUAL CONSUMPTION	
INDICATION OF CHARGING STATION TYPE	FIXED COSTS PER YEAR €	VARIABLE COSTS PER KWH €	COST PRICE AT KWH €	TOTAL ANNUAL CONSUMPTION IN KWH
AC3,7 Home	147	0.21	0.22	7,500
AC10 Public*)	982	0.11	0.28 (0.31)	5,000
AC20 Public	1,677	0.11	0.28 (0.45)	5,000
AC20 Private	447	0.13	0.14	30,000
FC50 Public	6,838	0.11	0.37 (0.26)	45,000
FC50 Private	6,370	0.12	0.19	87,500
HPC150 Public	14,625	0.10	0.37 (0.26)	90,000
HPC150 Private	13,146	0.08	0.23	90,000
HPC350 Public	36,575	0.10	0.42 (0.30)	180,000
HPC350 Private	33,429	0.08	0.27	180,000

Figure 3.13
Development of the TCO for charging stations with increased annual usage (perspective of the provider or charging station owner).



Finally, Appendix 3.4.H presents an overview of the developments that are expected with regard to charging stations.

3.4.4 Conclusions

- Public charging can be much more expensive than private charging. Let's assume that someone is a service engineer, drives 24,000 km per year and charges 6,000 kWh per year from the public charging grid: they will pay approx. €2,100 per year in charging costs. Charging only at fast chargers can total almost €3,200 per year.
- Charging at home will then be significantly cheaper, where you benefit from the favourable depreciation on the investment for the charging station. The total costs per year will then be approx. €1,600 (assuming that the availability of the charging point is guaranteed).
- Own (business) site: Charging on private land is another step cheaper. Both a regular charger (AC20) and a fast charger (FC50/HPC150) lower the costs if they are used every day. Lower energy costs and energy tax, and no extra grid connection costs, make the charging costs half of those for public charging. That represents annual savings of up to €1,000 per vehicle. However, these savings only apply if the charging station at the business site is sufficiently[9] used. That means: in accordance with the sales forecast, e.g. expressed in the number of working days multiplied by the utilisation rate. The higher the level of use or energy demand, the more favourable a high-capacity charging station becomes.
- Shared use of charging stations is highly recommended. At higher volumes, the importance of the investment drops rapidly, whilst a lower purchase price for electricity can be demanded. This is not least due to the favourable (lower) tax rates for bulk consumers.
- The following question may arise: Is fast charging and super-fast charging with high-capacity charging stations (FC50, HPC150/350) a serious option? This depends on a number of factors, like the need for short waiting times, the battery's charging capacity and the total energy demand expressed in kWh per year. So: The shorter the desired charging time, the higher the capacity of the battery to be charged and the higher the total energy demand, the more favourable the installation of a high-capacity charging station becomes. Another point is that these charging stations (it may be better to speak of charging solutions) are still very much under development, not very widely available and therefore possibly still relatively expensive.

[9] *'Here 'sufficiently' means: in accordance with the sales forecast, e.g. expressed in the number of working days multiplied by the utilisation rate.*

4 CHARGING STRATEGIES AND CHARGING PROFILES

This chapter provides a summary of the explanation of how the mathematical model used works (4.1) and the main conclusions (4.2). Section 4.3 then presents the sensitivity analysis.

4.1 Calculation model for optimum charging

Using the parameters described in Chapter 3 as input, a mathematical model was developed to optimise the charging strategy of a carrier or vehicle fleet. Many factors play a role in defining an optimum charging strategy, including journey duration, number of stops, stop duration, battery type and vehicle type.
This section describes how in the model the input described above is translated into an optimum charging strategy. Firstly, the purpose of the model is explained (4.1.1), followed by the possible charging scenarios (4.1.2) that could be generated as the model's output. The next section then explains how the (complex) input for the model is translated into input parameters (4.1.3). The functioning of the model is also explained in detail based on an optimisation formula (4.1.4). Finally, a summary is presented by means of an Infographic (4.1.5).

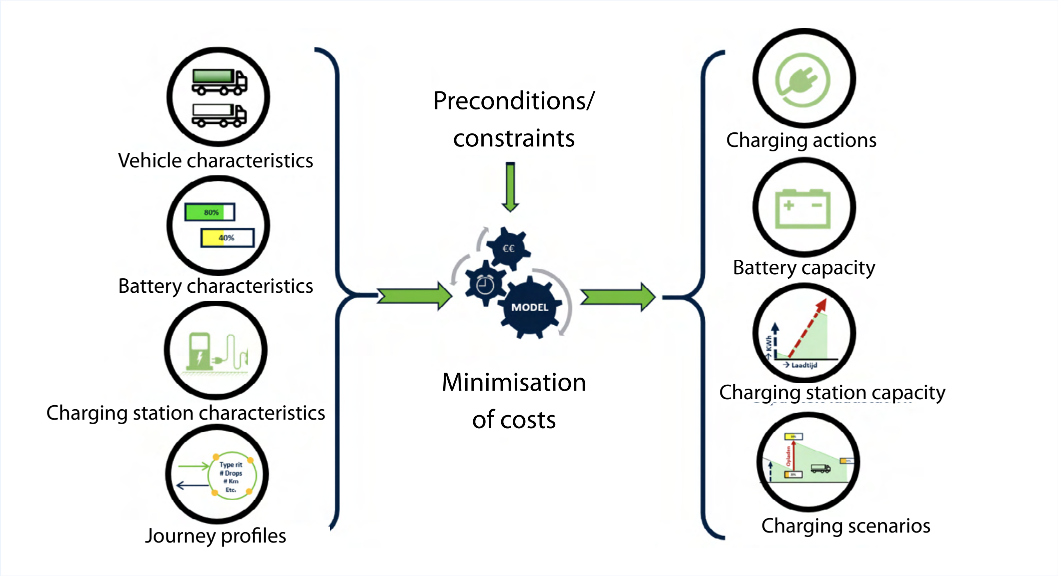
4.1.1 Purpose of the calculation model

The purpose of the calculation model is to arrive at an optimum charging strategy for a carrier or vehicle fleet based on detailed journey profiles from the sectors described above (with information about journey length and duration, number and duration of stops). This charging strategy optimises the following things:

1 **Battery type** in the vehicle.
2 **Charging station type** (charging station capacity) used for charging.
3 **Location** (charging scenario) used for charging and the number of **charging actions**.

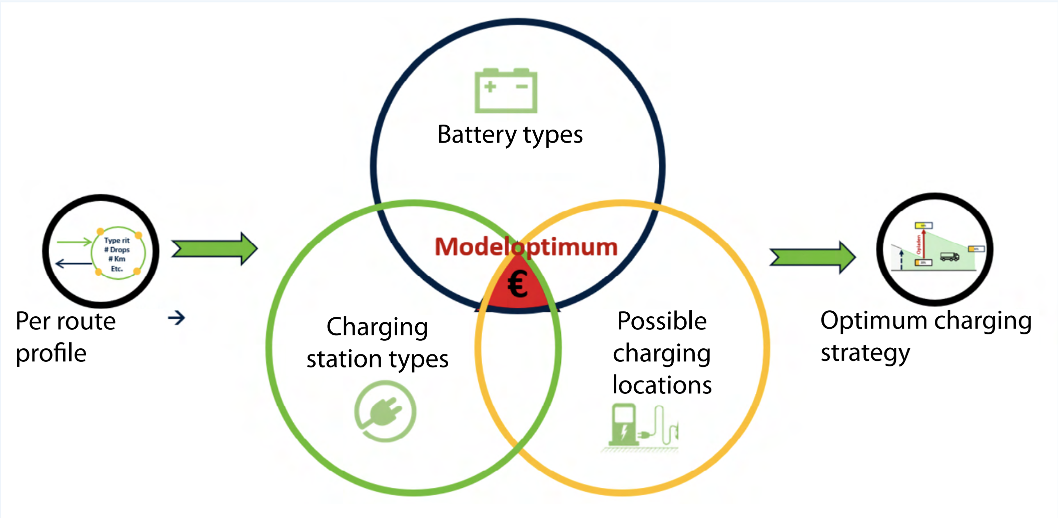
The following diagram (Figure 4.1) visualises this description of the model. By combining the input parameters of the model with various preconditions (e.g. which station is compatible with which vehicle and at which address may a certain type of charging station be installed or not, etc.), a model was developed that takes into account the parameters a company will also have to deal with. The vehicle type is determined by the logistics sector.

Figure 4.1
Model explanation - Part 1.



It is important to note that the model was designed in such a way that it involves an optimisation. This means that both the costs and the time can be minimised. In this project, it was decided to minimise the costs. Or: within the possible options for battery types, charging station types and charging locations a model optimum is sought for which the costs are minimal. That is visualised in the following picture.

Figure 4.2
Model explanation - Part 2.



Making the model suitable for analysing detailed stop information was a deliberate choice. Or in other words, the optimisation in the model described is not based on an average (or typical) journey profile, but is genuinely based on detailed stop information. This allows the model to provide a picture of the spread within the results.

For example: let's assume that, within a certain sector, long and short journeys are made. The result of the model will not be that vehicles will always have to be recharged at the depot. Or that a certain type of charger will always have to be chosen. The model will calculate the optimum for each journey, sometimes even choosing different types of charging stations or different charging methods within a journey. This allows the model to provide an accurate picture of the spread within the results.

The optimisation is seen from the viewpoint of a logistics service provider or a shipper that opts for a charging profile. In other words, the TCO of this station is irrelevant for recharging at a public charging location; a commercial charging price is used instead. In concrete terms this means that, if a truck in the model opts for recharging at a public charging station, the charging costs including the margin applied by the operator should be included in the calculation rather than the investment costs. This means that the commercial price is used.

4.1.2 Charging scenarios

The charging location is a decisive factor in whether the logistics service provider can make their journey with an electric vehicle, for the duration of the journey and for the costs associated with use of an electric vehicle. Three scenarios are considered in the calculation model:

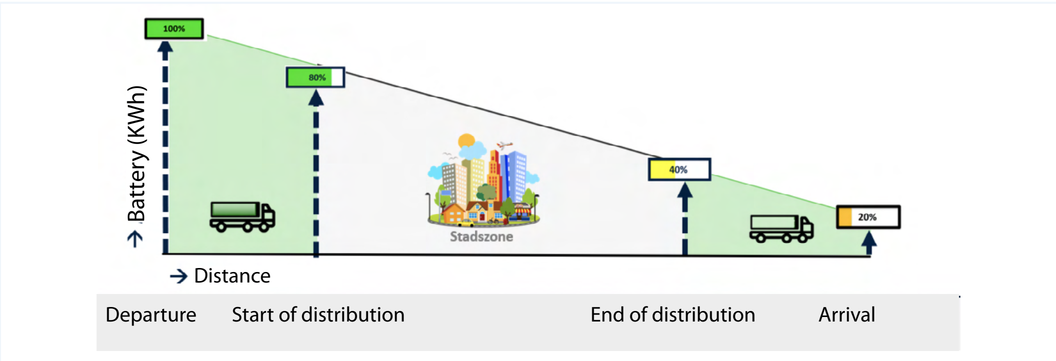
- **Scenario 1:** No recharging.
- **Scenario 2:** Additional charging stop.
- **Scenario 3:** Charging at the customer (delivery address/stop address).

These scenarios are explained in more detail below.

Obviously, a result may also be a combination of the factors stated above. Or in other words, a journey may involve recharging both at the customer and on the road. Or a journey profile (set of multiple journeys) may sometimes include a journey without recharging (Scenario 1) and sometimes journeys that do involve recharging (Scenarios 2 and 3).
The following pictures visualise the charging scenarios in question.

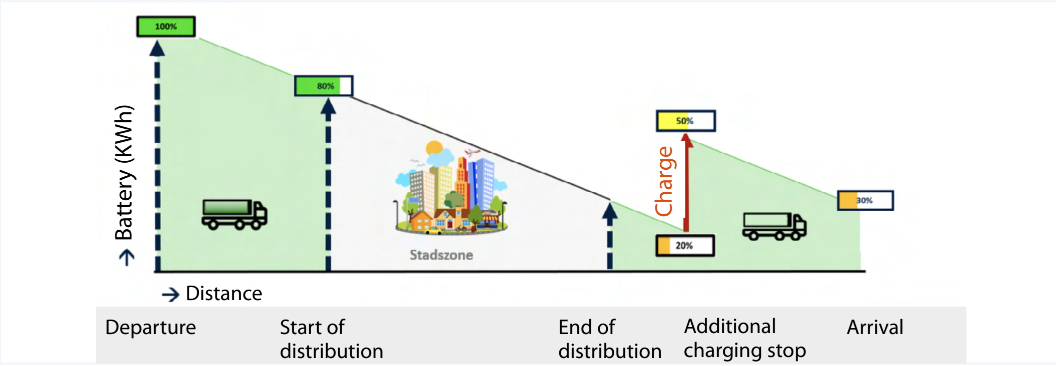
Scenario 1: no recharging: this means that the selected battery has enough capacity, or that the journey is short enough, so that recharging can be done at the home base rather than on the road, i.e. at the depot or at home.

Figure 4.3
Scenario 1: no recharging.



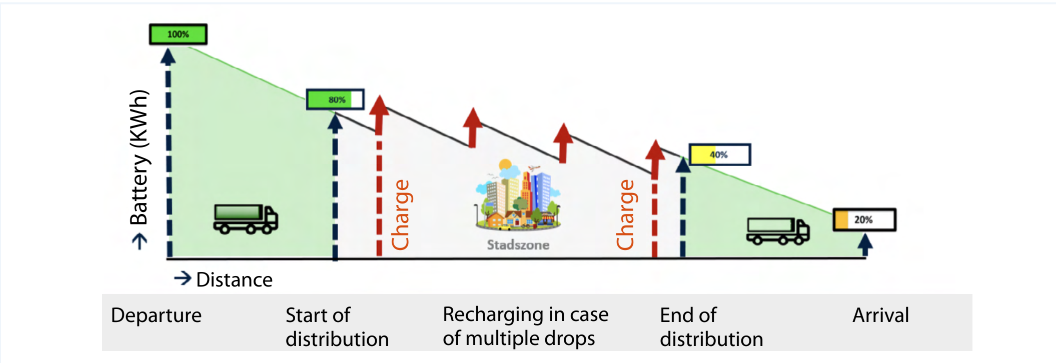
Scenario 2: additional charging stop: this means that the battery capacity is insufficient to finish the journey, so the vehicle has to be recharged at a charging station found on the road (location = public charging station).

Figure 4.4
Scenario 2: additional charging stop.



Scenario 3: charging at 'the customer': this means that the battery capacity is insufficient to finish the journey, so the vehicle has to be recharged at a charging station installed at the customer site (location = private charging station).

Figure 4.5
Scenario 3: charging at the customer.



4.1.3 Calculation model input

The input for the model includes the following aspects:

- **Vehicle characteristics:** these are the costs of the vehicle, battery and lifespan;
- **Charging station characteristics:** these are the fixed and variable costs of the charging station, plus the capacity/charging speed;
- **Battery characteristics:** these are the costs of the batteries, compatibility with charging stations and characteristics of charging stations;
- **Journey profiles:** these are the stop/journey information that is analysed in the model.

The Appendix to 4.1 presents an extensive overview of the aforementioned aspects, based on the input from Chapter 3.

4.1.4 How the model works

This section contains the full optimisation formula, which shows in more detail how the calculation is performed. The optimisation model minimises the costs. This means that the model will weigh every possible combination of input parameters and then present the most attractive solution in financial terms (i.e. the cheapest one).

Table 4.6
Optimisation formula.

MINIMISATION OF COSTS PER VEHICLE PER DAY:	FORMULA	OPTIONS/VARIANTS
Battery costs +	*Purchase costs of the battery x* / *(service life (KWh/charge cycles)* ** kwh or charge cycli (journey)*	• Battery price (€) • Charging capacity (kWh) • Service life (kWh and/or years) • Max. DoD of 80%
Vehicle costs +	*Purchase costs of the truck* / *service life (operational days)*	• Vehicle price (€) • Vehicle consumption (kWh/km) • Service life (years)
Driver costs +	*hourly rate x amount of hours*	• € 30/hour
Motorway recharging costs +	*kWh x € /kWh (only variable)*	• Electricity costs (€ /kWh) • Charging speed (kW)
Costs for customer recharging, fixed +	*Purchase costs of the charging station* / *number of charging activities service life* *x number of charging activities of truckday*	• Purchase prices (€) • Service life (years) • Charging activities at customer (#)
Costs for customer recharging, variable +	*kWh x € /kWh (only variable)*	• Electricity costs (€ /kWh) • Charging speed (kW)
Costs for hub recharging, fixed +	*Purchase costs of the charging station* / *number of charging activities service life* *x number of charging activities of truckday*	• Purchase prices (€) • Service life (years) • Charging activities at customer (#) • *Charging actions a day = optimisation result*
Costs for hub recharging, variable =	*kWh x € /kWh (only variable)*	• Electricity costs (€ /kWh) • Charging speed (kW)
Total costs		

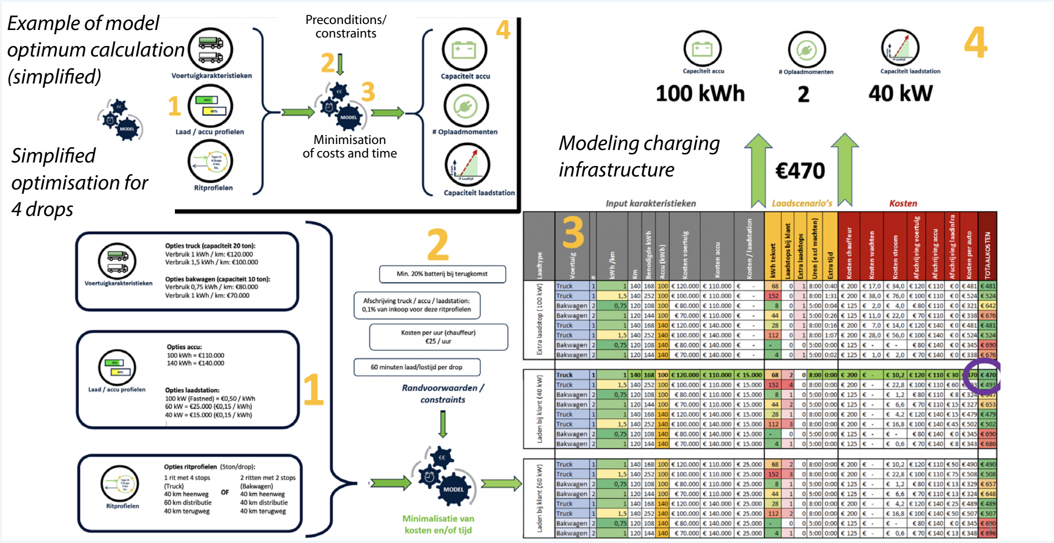
4.1.5 Example/infographic

The following infographic (Figure 4.7) gives a picture of the optimisation. A calculation was done here in Excel to illustrate the mathematical model, with limited input and a simple dataset. The functioning of the model, as explained above, is shown in the top left corner.

The numbers in orange in the figure refer to the following descriptions:
1 Input information (see Subsection 4.1.3)
2 Preconditions/constraints (see end of Subsection 4.1.3)
3 Model (see optimisation in Subsection 4.1.4)
4 Results (see next section, 4.2)

Figure 4.7
Example of model optimum calculation (simplified).*

Note that this infographic is only being used to explain how the model works; the stated costs are indicative. For the actual input and output, please refer to the information elsewhere in this report. Note also that the choice of vehicle was not optimised in this report; the vehicle type was kept the same.



In the example presented, a journey profile with four stops has been optimised. This results in 24 possible combinations (in reality this number will be much higher, as only a limited number of batteries or trucks are included here). Out of these 24 possible combinations, the line circled in purple is the optimum one, resulting in a total cost of €470 (for this example). The result yields a vehicle type (tractor+trailer), the battery capacity (100 kWh), the number of charging actions (2) and the capacity of the charging station (40 kW).

Example routes

Three routes with different characteristics are presented below. The model results for these routes are provided, both in the following tables (4.8 and 4.9) and in a number of figures (graphs 4.10, 4.11 and 4.12).

Table 4.8

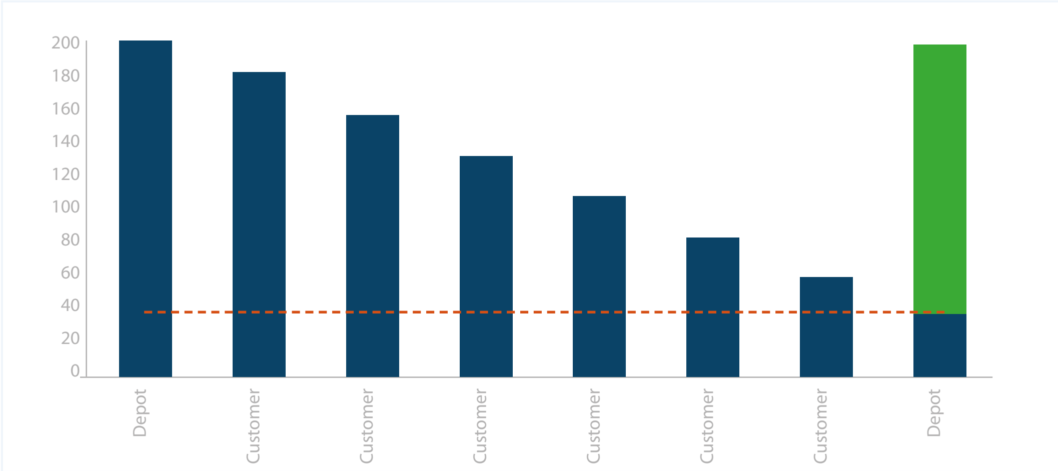
JOURNEY	VEHICLE TYPE	SECTOR	# STOPS	DISTANCE DRIVEN
A	Large box truck	Catering	8	175
B	Large delivery van	Service logistics	23	240
C	Large box truck	Retail - non food	14	123

Table 4.9

JOURNEY	BATTERY	# CHARGING STOPS	CHARGING SCENARIO	CHARGING STATION
A	Battery_Gba_200	1	1. At depot	_AC20_Private
B	Battery_GB_50	1	2. On the road	_FC50_Public
C	Battery_Gba_120	2	3. At customer	_AC20_Private

Catering wholesaler Bakker departs Amstelveen in a large box truck and drives a route along 8 restaurants in the Amsterdam region. He recharges when he arrives back in Amstelveen after 175 km. That is not required in the interim.

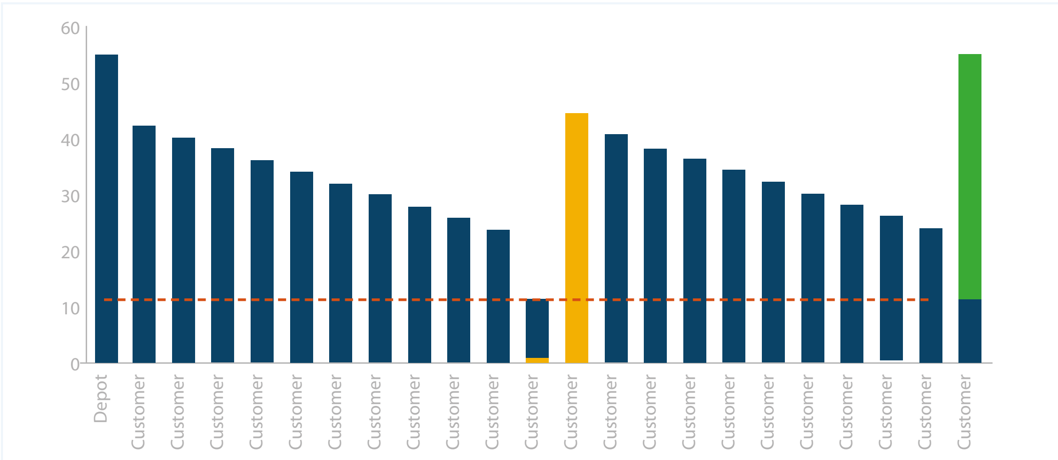
Grafiek 4.10
Output for Journey A.



Energy at departure
Energy at arrival
Loaded inbetween
20% Lower bound

Service engineer Anton leaves early in the morning and has a busy day. At 23 of the stops he has short loading times and no opportunity to recharge. His battery is almost discharged around his lunch break. That is why he decides to recharge on the motorway during his break. The extra recharged capacity lets him get through the day easily and he recharges again at the depot.

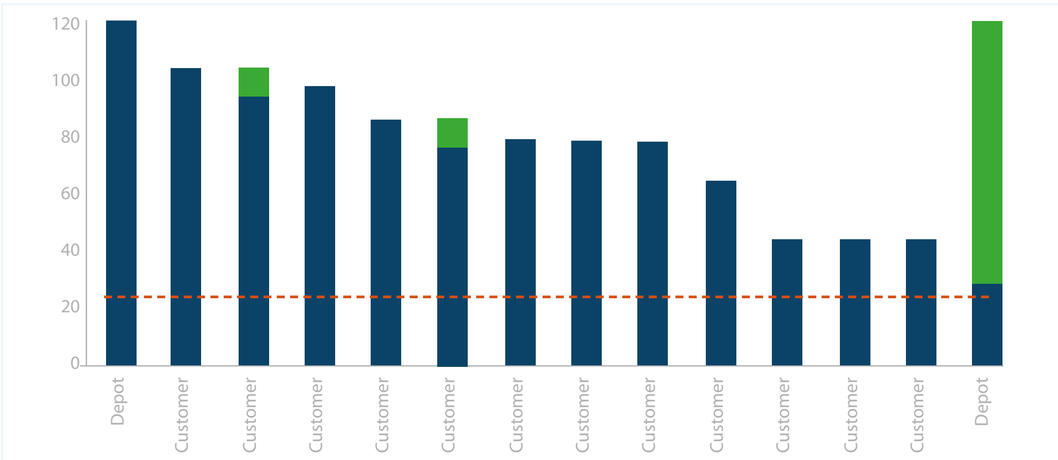
Grafiek 4.11
Output for Journey B.



Energy at departure
Energy at arrival
Loaded inbetween
20% Lower bound

Retail company W.C. Paper supplies toilet paper to many office addresses. The driver just fails to reach the end of the day without recharging. Some office buildings do, however, have charging stations facilitated by these premises. Recharging twice at these stations (while unloading) gives him enough battery capacity.

Grafiek 4.12
Output for Journey C.



Energy at departure
Energy at arrival
Loaded inbetween
20% Lower bound

4.2 Results and analyses

A total of 48 journey profiles were analysed in the model developed for this project. This involved 18 extensive datasets and 30 typical journey profiles. The typical journey profiles are considered to be characteristic for the sector (sector-specific) or contain a summary of company-specific and other data from a specific company that did not grant permission to use their stop information in the model.

To be able to draw final conclusions per sector and per vehicle type, a weighting was assigned to the various datasets and an expert panel then validated the results. After all, not every dataset is equally representative for the sector. Additionally, it is not desirable either for a dataset over a prolonged period to be weighted just as heavily as a dataset for a short period.

Appendix 4.2.A includes an overview of basic principles and assumptions used for the developed model. The conclusions regarding charging infrastructure and battery capacities are also presented in it.

4.2.1 Detailed results and conclusions for the vehicle type 'Trucks'

Based on the results and the review by the expert panel, we see the following results per sector for trucks:

Table 4.13
Detailed results and conclusions for vehicle type 'trucks'.

	% CHARGING ACTIONS				% KWH			
	AT HOME	BY THE ROAD (FAST CHARGING)	DEPOT	CUSTOMER	AT HOME	BY THE ROAD (FAST CHARGING)	DEPOT	CUSTOMER
	0	20	80	0	0	15	85	0
	0	20	60	20	0	5	80	15
	0	10	85	5	0	5	85	10
	0	10	75	15	0	5	85	10
	X	X	X	X	X	X	X	X
	0	20	60	20	0	5	75	20
	0	25	30	45	0	10	60	30
	X	X	X	X	X	X	X	X

For all sectors except retail non-food, vehicles will mostly be charged in depots during the night. This is the longest period that a vehicle is parked and can charge. Charging in depots is also the cheapest option. Additionally, a number of specific differences in charging strategies can be named for each sector. These are presented in the following table; see also Appendix 4.2.B for underlying data and a justification of the above results.

Table 4.14
Detailed results and conclusions for vehicle type 'Trucks'.

SECTOR	CONCLUSIONS
	Charging at the customer is not possible for waste. These vehicles will usually be recharged in depots. In the case of insufficient battery capacity/long journeys, vehicles will have to be recharged along the road. Analysis of CBS data shows that about half the waste journeys still cover more than 100 km. It involves more than simply collecting rubbish from private individuals, e.g. also collecting commercial waste, office waste, transport between regions, etc.
	For construction, it is important to distinguish between the various forms of construction transport. Deliveries to building sites often involve longer distances and relatively long stop times. In these cases, the vehicles are recharged at the customer (the building site) using a private charging station. However, if the deliveries are at other (one-off) locations, recharging is more likely to take place by the roadside. We can see that this involves relatively few kWh; it only applies if recharging at the customer is not an option or if the stop time is too short.
	Charging in depots overnight is likely for this sector. Charging at the customer is theoretically possible (see also retail non-food, where this probably also happens), but because the destination locations vary greatly it is not considered likely that it will be possible to recharge at the customer each time/the opportunity does not always arise. After all, vehicles will not always be unloaded at a dock, like they are in retail. That is why recharging will sometimes also occur by the roadside, so the business must be willing to include extra time in the journey to wait while charging. Recharging at the customer is more likely at locations such as hotels and large office buildings, so this may still occur.
	As stop times are relatively long, it is financially interesting to use this stop time to recharge. It will probably not be so easy in practice. Where possible, vehicles will therefore be recharged at the customer (this may also be at a public unloading area with charging stations) or by the roadside if the range is insufficient.
	Vehicles will mostly be charged overnight in depots. Recharging takes place at the customer and by the roadside. It is important here to make a distinction regarding deliveries over short distances (DCs close to the major cities, mainly supplying supermarkets), where the vehicles are almost always charged in depots. Journeys over longer distances (bread, dairy, vegetables, etc.) will involve recharging at the customer more often. For deliveries to supermarkets this will be at a private station at the dock; for other deliveries (addresses visited less frequently) the vehicles will also be charged at public charging stations by the roadside.
	Retail non-food is the sector where recharging at the customer would appear (and turns out) to be most likely. The journey distances are relatively long (often more than 100-200 km), so the range of the batteries simply is not enough. The stop times are relatively long and the locations are visited frequently, hence the high percentage of recharging at the customer. The rest will be recharged on the road, but that still is relatively limited in kWh. It is important to note that (in practice) it will not be possible to install charging stations at every unloading site. This requires facilities such as unloading areas with charging stations to be set up at shopping centres. Additionally, electric charging will probably also result in the basic form being modified for the sector: the logistical concept with logistical uncoupling points close to cities.

4.2.2 Detailed results and conclusions for the vehicle type 'Delivery vans'

Based on the results and the review by the expert panel, we see the following results per sector for delivery vans:

Table 4.15

	% CHARGING ACTIONS				% KWH			
	AT HOME	BY THE ROAD (FAST CHARGING)	DEPOT	CUSTOMER	AT HOME	BY THE ROAD (FAST CHARGING)	DEPOT	CUSTOMER
	0	0	100	0	0	25	75	0
	70*	15*	0	15	75	10	0	15
	30**	5	55**	10	35	1	60	4
	0	0	100	0	0	0	100	0
	40***	20	40***	0	25	15	60	0
	0	0	100	0	0	0	100	0
	X	X	X	X	X	X	X	X
	70*	10*	20	0	80	10	10	0

* *Recharging at these home locations may also take place on the public road, at public rather than private charging stations.*
** *For this sector, a choice will have to be made between taking the delivery van home and leaving it at the depot in the future. This may affect the division between charging at home and in depots.*
*** *The parcels sector will mainly encourage recharging in depots.*

Delivery vans will also be mainly recharged overnight at the vehicle's home base. In contrast to trucks, the vehicle's home base is sometimes not in the depot, but in a residential area in front of the owner's or driver's front door. The differences in charging profiles per sector are shown below. They are presented in the following table.

Table 4.16
Detailed results and conclusions for vehicle type 'Delivery vans'.

SECTOR	CONCLUSIONS
	For these journeys (e.g. municipal cleaning services) the vehicles will probably only be recharged at the depot/departure location. The stop time is relatively short at customers, and it is better to recharge at the depot during the day than at the hub (if this is necessary at all).
	Most delivery vans used in the construction sector will be charged overnight at their home base. The home base for construction vans currently still is the driver's home address in a residential area.
	Recharging at the home/depot location (location where the vehicle stays overnight) is most likely. This may be the home location (where recharging is also possible at public rather than private charging stations at the home location, as assumed in the model). Recharging along the roadside is not very likely, as this is relatively expensive compared to the other available alternatives. Recharging at the customer will only happen for journeys over longer distances in which the stop location occurs frequently.
	In view of the short distances, the vehicles used for these journeys will mainly be charged and recharged in depots. After all, it mainly involves deliveries in the city (e.g. bakers, suppliers, etc. who supply using delivery vans).
	They will not recharge at the customer (recipient) due to the short stop times. The sector will encourage recharging in depots in view of the long stop times (parcel loading time). Additionally, vehicles need to be recharged in the public space during long-distance journeys.
	In view of the short distances, almost everything will be recharged in depots for this sector.
	In view of the short stop times or due to the many changing addresses (including private individuals), charging at the customer is not an option (often repairs/servicing). Vehicles will often be charged at home, which could also be in the public space. Recharging by the roadside happens relative rarely and only for journeys over longer distances.

Generally speaking, people choose to recharge in depots more often due to the lower power costs. A second important effect then is the choice between a private or public charging station. The owner of the delivery van will often not have their own driveway or their own charging station, even if this model is the cheapest option due to the lower costs of the charging station and power. Note that it was explicitly assumed in the model discussed that the vehicle always leaves with a full battery in the morning, so it charges 'at home', regardless of the choice between a private and public charging station. If a vehicle is charged at a public charging station, this will generally be more expensive than a charging station 'on the driveway'.

Overall it can be seen that vehicles are still frequently recharged by the roadside. In-depth analyses have shown, however, that the kWh quantities for these charging locations are significantly lower than for the other locations. Appendix 4.2.B includes a justification that shows the results for each dataset analysed. It also includes a justification why these sometimes deviate from the tables explained above. Furthermore, Appendix 4.2.C presents the capacities of charging stations and batteries.

4.3 Sensitivity analyses

A TCO calculation has been drawn up for a number of vehicles used in various logistics sectors and for which the optimum charging strategy is analysed in Section 4.2. The total costs are then calculated in a number of scenarios. This reveals the impact on the total costs if, for example, the electricity price rises or drops faster than expected. The following table presents the values for the various vehicles in the basic scenario plus information about the other scenarios, with several parameters being varied.

Table 4.17
TCO scenarios.

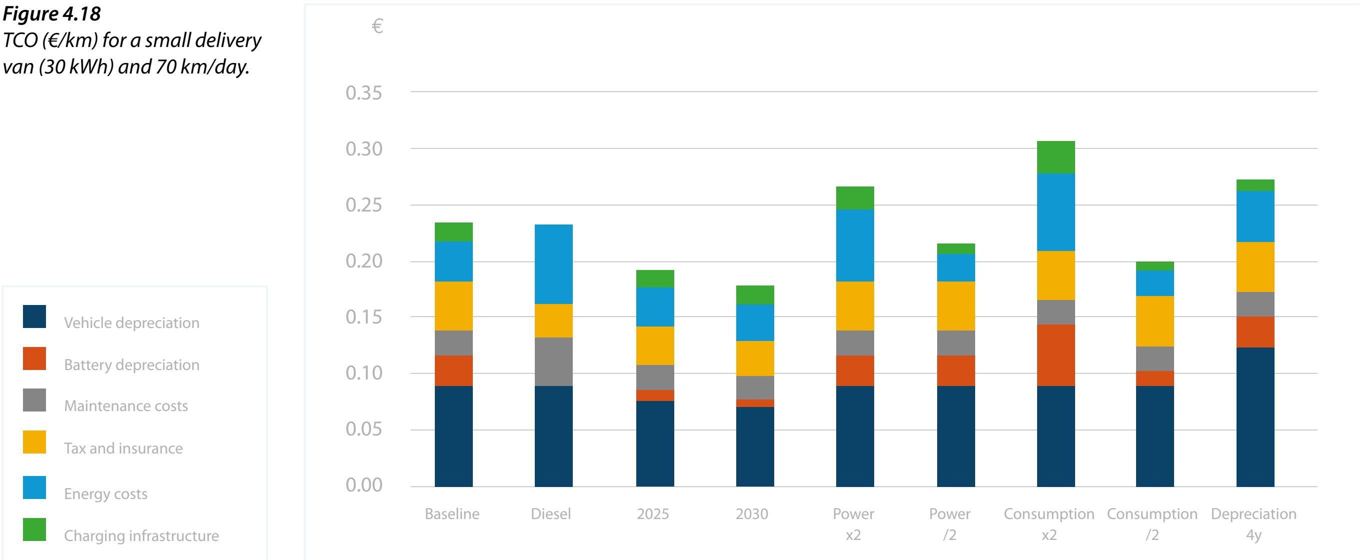
VEHICLE	SMALL DELIVERY VAN	MEDIUM-SIZED DELIVERY VAN	SMALL BOX TRUCK	LARGE BOX TRUCK	TRUCK TRACTOR UNIT + TRAILER
SECTOR	SERVICES	FACILITIES	RETAIL (NON-FOOD)	RETAIL	CONSTRUCTION
Km/day	70	100/198	169	152	156
Battery capacity (kWh)	30	30/50	160	200	240
Dominant charging strategy	At home/ Depot	At home/ Depot	Depot	Depot	Customer/ Public/Depot
TCO (€/km) baseline	0.23	0.22/0.16	0.73	0.92	1.33
Consumption (kWh/km) baseline	0.229	0.298	0.769	0.909	1.75

Scenario 1 - Diesel	A similar conventional diesel vehicle that can also meet the functional requirements.
Scenario 2 - 2025	The vehicle and battery costs are expected to drop as the supply and demand increase. This scenario uses the costs for purchasing a vehicle in 2025 (see Section 3.2). In addition, the technology has been further developed, so the energy consumption per vehicle is lower and the lifespan of the battery is longer. The electricity price remains the same. The expected cost development of charging stations and electricity was not included.
Scenario 3 - 2030	The vehicle and battery costs are expected to drop as the supply and demand increase. This scenario uses the costs for purchasing a vehicle in 2030 (see Section 3.2). In addition, the technology has been further developed, so the energy consumption per vehicle is lower and the lifespan of the battery is longer. The electricity price remains the same. The expected cost development of charging stations and electricity was not included.
Scenario 4 - Power x2	The electricity price per kWh doubles in this scenario.
Scenario 5 - Power ÷2	The electricity price per kWh halves in this scenario.
Scenario 6 - Consumption x2	The energy consumption for each vehicle doubles in this scenario. Higher consumption may have various causes, including congestion (which mainly occurs frequently in cities), low temperatures, high loading levels and refrigerated transport.
Scenario 7 - Consumption ÷2	The energy consumption per vehicle halves in this scenario.
Scenario 8 - Depreciation in 4 years	The vehicle's usage period halves to 4 years. Afterwards, the vehicle is sold together with the battery.

4.3.1 TCO - Delivery vans

A 30 kWh battery is enough for a small delivery van with an average use of 70 km per day. These are mostly charged in depots and at home using AC3.7 and AC20 charging stations. The following figure shows the costs per km for the various scenarios.

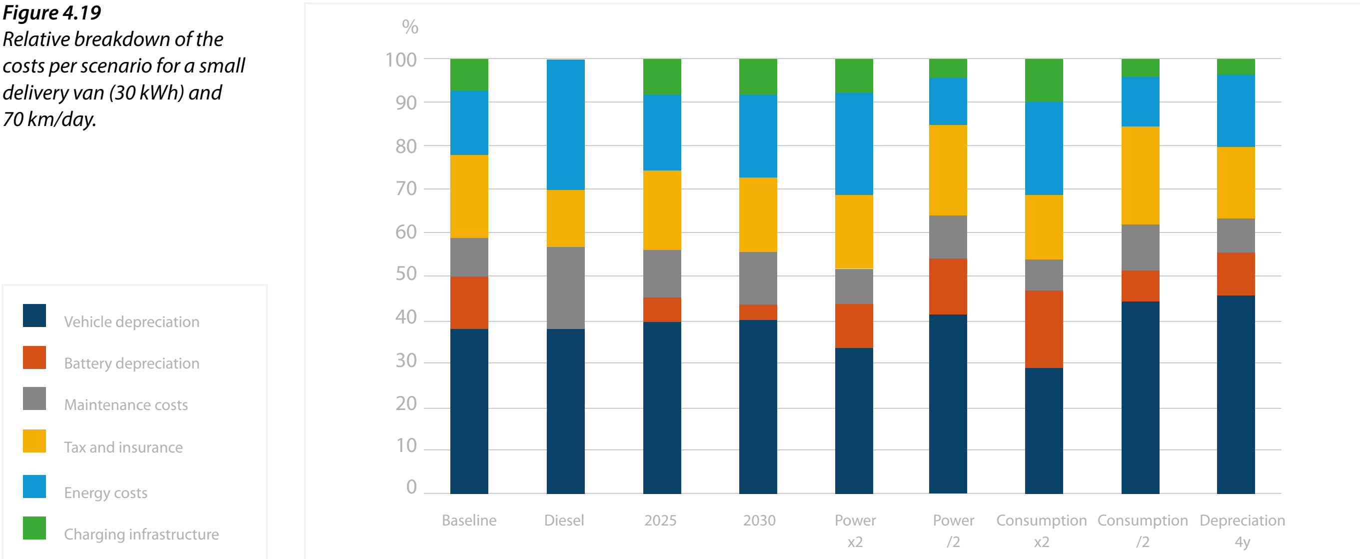
Figure 4.18
TCO (€/km) for a small delivery van (30 kWh) and 70 km/day.



The baseline costs per km are €0.23 per km (€16.40 per day), with the 50% depreciation of the vehicle (incl. 12% for the battery) being the largest cost item. For this annual distance, a diesel vehicle (internal combustion engine vehicle; ICEV) is equally expensive at €0.23/km. The vehicle is cheaper, but its fuel and maintenance costs are higher. Fuel makes up 30% of the costs, whilst this is only 15% for electricity. In 2025 and 2030, the costs per km for a 'battery electric vehicle' (BEV) will drop to €0.19 and €0.18 per km respectively. The price of the vehicle and the battery are expected to drop considerably. Tax and insurance will also be reduced as a result.

In addition, batteries will become more efficient, so the electricity costs will reduce slightly. In a scenario where electricity becomes considerably more expensive, the energy costs will make up 23% of the total costs. Doubling the energy consumption leads to the highest total costs. In the case of higher consumption, not only do the charging costs increase significantly, but also the depreciation of the battery and charging infrastructure. In contrast, a higher efficiency of batteries and, as a result, a lower energy consumption leads to reduced depreciation costs for the battery, charging costs and the charging infrastructure. If a vehicle is depreciated in four instead of eight years, the depreciation costs of the vehicle increase significantly (46% of the total costs), but they remain the same for a battery.

Figure 4.19
Relative breakdown of the costs per scenario for a small delivery van (30 kWh) and 70 km/day.



The TCO of a medium-sized delivery van with a 30 kWh battery and a daily distance of 100 km shows that an ICEV is €0.02 cheaper than the BEV. Here we can also see the same trend for the costs: the TCO for a BEV will drop significantly in 2025 and 2030; scenarios with a higher electricity price and higher consumption have a big impact on the TCO (Figure B.4.11 in the Appendix to 4.3). If the distance increases to 198 km per day for the same (medium-sized) delivery van and a 50 kWh battery is therefore required, the BEV and ICEV will be equally expensive at €0.16/km . This is mainly caused by the fact that the costs for using the EV per kilometre are low: electricity is cheaper than diesel per kilometre. The higher price of the larger battery is compensated by saving on the additional kilometres (Figure B.4.12 in the Appendix to 4.3).

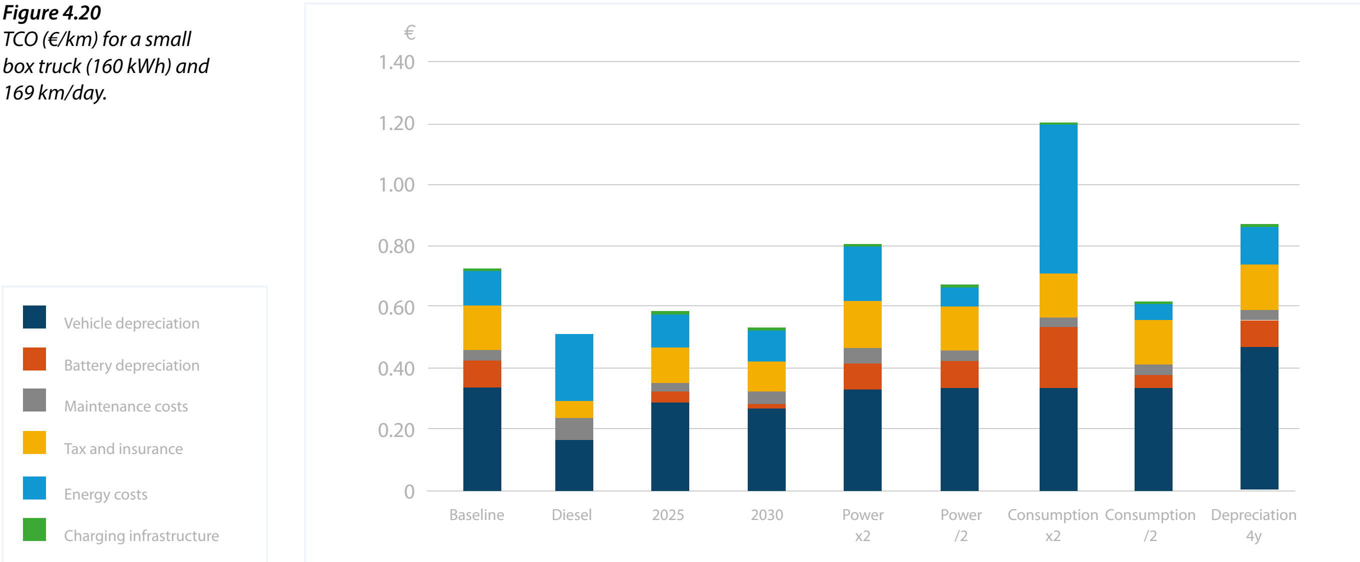
[10] *This is an extreme scenario, but it serves to illustrate the impact of this parameter on the cost structure.*
[10] *Despite the greater distance, a residual value of 19% was still assumed after 8 years. This could also be 0% due to the greater number of km, which would slightly increase the cost per km. However, the ratio between the depreciation costs for a BEV and an ICEV remains the same.*

4.3.2 Heavy goods vehicles

In contrast to delivery vans, conventional (diesel) box trucks (12t) are considerably cheaper than the electric variant. The difference per km is €0.22 (€0.73 compared to €0.51). This is mainly due to the fact that OEMs are not yet manufacturing electric trucks; the electric versions are made by converting diesel trucks, which makes them relatively expensive (see 3.2). The purchase price is also higher due to the higher capacity battery. The battery and vehicle together make up 59% of the costs for a BEV. For an ICEV this is only 22%. Based on current forecasts, BEVs in this category would also appear to remain more expensive in 2025 and 2030 (Figure B.4.13).

Like for other vehicles, it should be noted that the purchase price does not include any current and future subsidies for BEVs and possibly higher taxes for ICEVs. The price development of ex-works trucks is also more uncertain than for delivery vans. Furthermore, Figure 4.20 shows that, similarly to delivery vans, the maintenance costs for diesel are higher.

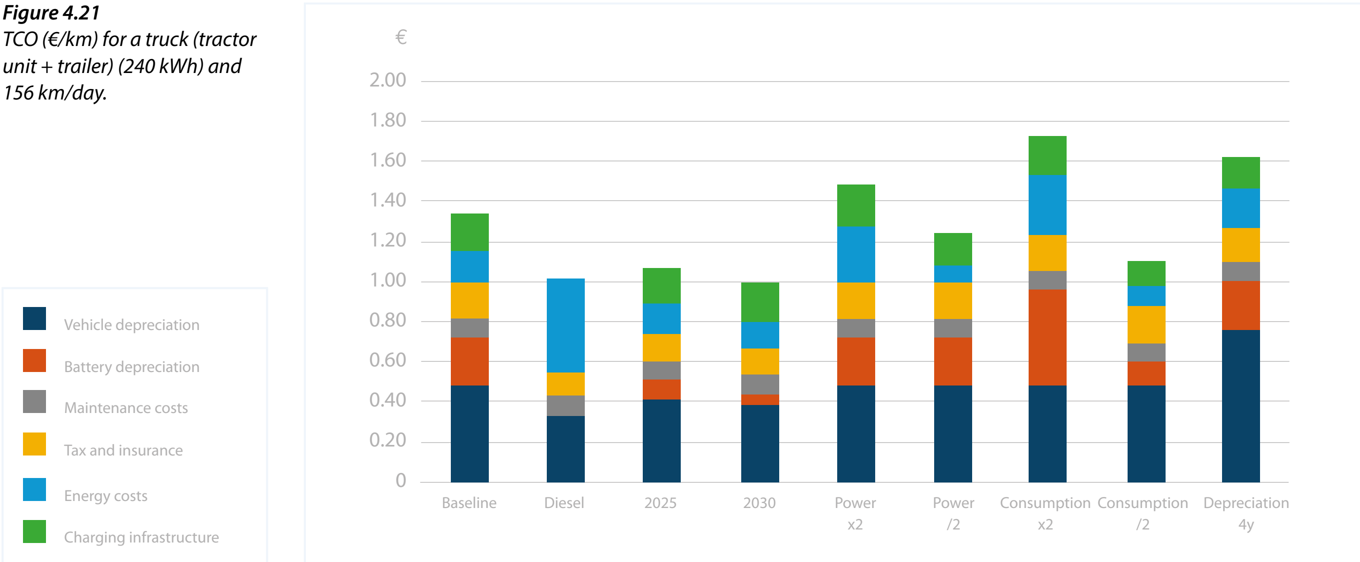
Figure 4.20
TCO (€/km) for a small box truck (160 kWh) and 169 km/day.



We see the same cost breakdown for a larger box truck (19t) with a 200 kWh battery (Figure 19 in the Appendix to 4.3). Based on the current cost estimate and in contrast to a small box truck, a BEV will be cheaper than an ICEV in 2030. This is because the energy costs for a larger vehicle with a higher consumption are cheaper for the BEV than for the diesel. The energy costs for a small box truck are €0.12 for the BEV and €0.22 for the diesel. For a large box truck these are €0.12 and €0.33 respectively. The costs for diesel therefore increase relatively quickly as the vehicle's size increases.

Further to the above, we can see the same cost breakdown in the TCO of a truck (tractor unit + trailer) (Figure 4.21). One notable point here is that the costs for charging infrastructure are almost negligible for the box trucks. This is caused by the different type of charging station used for this vehicle (see Section 3.4). For a truck (tractor unit + trailer) in the selected logistics sector, its 150 kW capacity is a lot higher and it is a lot more expensive than a 20 kW station. However, this cost estimate is more uncertain and depends on two factors. The first is the price development for higher capacity charging stations, which were only introduced recently and for which it is difficult to estimate their costs in the future. Secondly, this analysis shows the costs for the dominant charging location and station as calculated in Section 4.2. For the same vehicle, this may change if the journey profile changes.

Figure 4.21
TCO (€/km) for a truck (tractor unit + trailer) (240 kWh) and 156 km/day.



4.3.3 Conclusions regarding TCO

The following table presents an overview of the costs per kilometre for the various vehicles in the relevant sectors with the associated distances in this analysis, with a distinction between a BEV (now and in 2030) and an ICEV.

Table 4.22
Overview of TCO results (€/km).

	SMALL DELIVERY VAN	MEDIUM-SIZED DELIVERY VAN	SMALL BOX TRUCK	LARGE BOX TRUCK	TRUCK (TRACTOR UNIT + TRAILER)
BEV - now	0.23	0.22	0.73	0.92	1.33
ICEV - now	0.23	0.20	0.51	0.72	1.02
BEV - 2030	0.18	0.16	0.53	0.69	1.00

In summary, further analysis of the total costs in a number of scenarios leads to the following conclusions:

- For all vehicles, the costs for an electric goods vehicle are expected to drop significantly until 2030.
- When comparing a BEV against an ICEV, we can see considerable differences in total costs between delivery vans on the one hand – where both vehicle types have almost identical costs - and heavier goods vehicles on the other.
- For longer distances, a higher capacity battery could be a solution. For conventional delivery vans, the energy costs of an ICEV increase relatively quickly, which counterbalances the extra costs for purchasing a higher capacity battery.
- For larger vehicles, the total costs for a BEV in 2030 are expected to be at about the same level as for a diesel. Note that this analysis assumes that the tax on both vehicles types is the same and that there are no tax advantages for a BEV.
- The energy costs per kilometre are higher for an ICEV than for a BEV. At greater distances, this makes ICEVs more expensive relatively quickly. In an urban context with slower traffic flows and lower speeds, a BEV offers better efficiency (in terms of energy consumption) than an ICEV, which has advantages on the open road with better traffic flows and higher speeds.
- The proportion of the charging infrastructure in the TCO depends heavily on two factors. First of all, there is the charging location: charging in the public space leads to higher energy costs and no depreciation for charging infrastructure, as this is incorporated in the former. Secondly, higher capacity charging stations are (currently) very expensive, but how their prices will develop is uncertain.
- Doubling the electricity price leads to higher energy costs, but they will not double in practice because electricity gets cheaper quickly as the overall consumption increases. Similarly, halving the electricity price leads to lower energy costs, but they are not halved in €/km.
- Doubling the energy consumption leads to higher energy costs and faster depreciation of the battery. Additionally, the costs for charging infrastructure may increase if a higher capacity station is required in the depot or at home (e.g. from AC3.7 to AC20).
- A shorter depreciation period leads to a higher TCO for a BEV, because the depreciation costs of the vehicle and possibly also the charging infrastructure increase. On the other hand, the battery depreciation is expressed in charge cycles.

5 GEOGRAPHICAL SPREAD OF CHARGING REQUIREMENT AND IMPACT ON CHARGING INFRASTRUCTURE

In Chapter 4, we used the 'Optimum charging' calculation model to provide information about the types of locations (in depots, at home, etc.) where vehicles are charged, depending on the vehicle type (delivery van or truck) and the sector in which these vehicles are active (Section 4.2). In this chapter, we will apply these results to the ZE zone in Amsterdam defined for the case study (see Subsection 1.3.2) and indicate where we expect a charging demand to occur and its effects on the power grid and the public space.

The first section (5.1) presents a forecast of the total energy demand generated by vehicles that visit the ZE zone if they are electrified. It also states the consequences of this for the charging requirements and the number of charging actions within the Greater Amsterdam COROP . The basic assumption used for this study is that 100% of transport to and from the ZE zone will become electric. The figures are based on custom data from Statistics Netherlands (CBS) about delivery vans and trucks that visit the Amsterdam environmental zone. The use of the CBS data is explained in Appendices 5.1.A and 5.1.B. Section 5.2 indicates in which locations a demand for charging is expected to occur. For this, the energy requirement was spatially allocated by postcode area (using the higher-level numbers only) inside the Greater Amsterdam COROP. This is based on CBS data about parking locations and origin and destination data (custom data), and based on origin-destination data from the VENOM traffic model. The description of the data and its allocation can be found in the Appendix to 5.2. Following this, the impact on the power grid (5.3), the required number of charging stations (5.4) and the impact on the public space (5.5) are discussed. Finally, the conclusions are presented in Section 5.6.

5.1 Charging requirement as a result of ZE zone

Trucks

At the moment, an expected 4,700 trucks regularly visit the defined ZE zone (current environmental zone). These trucks drive an annual distance of about 70,000 km, so they jointly cover 325.5 million kilometres. These kilometres not only include journeys to and from the ZE zone, but also journeys to other locations. However, many of the origins and destinations fall within the Greater Amsterdam COROP (35%) or neighbouring COROPs. Figuur 5.1 presents an overview of the origin and destination locations for the journeys vehicles made during a year (source: CBS, see Appendix to 5.1).

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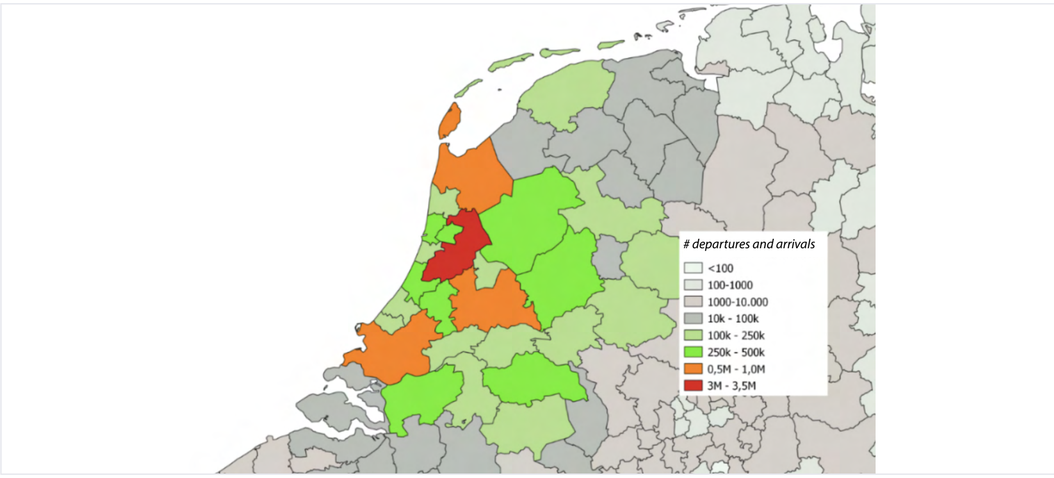
[12] *The Greater Amsterdam COROP includes the following municipalities: Aalsmeer, Amstelveen, Amsterdam, Beemster, Diemen, Edam-Volendam, Haarlemmermeer, Landsmeer, Oostzaan, Ouder-Amstel, Purmerend, Uithoorn, Waterland. Source: Statistics Netherlands.*

Figure 5.1
Number of departures and arrivals per year by COROP for vehicles that visit the environmental zone.



Total annual charging demand for trucks

If all of these journeys are made electrically, this results in a total energy demand of 470.8 million kWh per year. The column 'Total' in Table 5.2 presents an overview of the annual energy demand per sector. Based on the results from Section 4.2, the total charging requirement per sector was then allocated to the various location types where vehicles are expected to be charged: by the roadside during the journey (fast charging), in the company's depot and at the customer at the destination location. As drivers will generally not take a truck home, there will not be any charging demand for trucks at the home addresses in residential areas. Table 5.2 shows that the charging demand for trucks is mainly expected to occur in depots (78% of the charging demand) for all the sectors together (see Appendix to 5.1 for background information on the figures).

Table 5.2
Expected charging requirement as a result of ZE zone for electric trucks by location type.

	TOTAL (MWH/ YEAR)	AT HOME (MWH/YEAR)	ALONGSIDE THE ROAD (FAST CHARGING) (MWH/YEAR)	DEPOT (MWH/YEAR)	CUSTOMER (MWH/YEAR)
	14,617	-	2,193	12,425	-
	141,761	-	7,088	113,409	21,264
	39,329	-	1,966	33,430	3,933
	125,076	-	6,254	106,315	12,508
	-	-	-	-	-
	78,453	-	3,923	58,840	15,691
	62,848	-	6,285	37,709	18,854
	8,694	-	435	6,955	1,304
Total	**470,778**	**-**	**28,143**	**369,081**	**73,554**
Share in total	**100%**	**0%**	**6%**	**78%**	**16%**

Charging demand for trucks within Greater Amsterdam COROP

Table 5.3 indicates the fraction of the total energy requirement for the trucks visiting the ZE zone expected to yield charging demand inside the Greater Amsterdam COROP. The charging demand in depots in Greater Amsterdam was determined using the number of trucks that are based within the Greater Amsterdam COROP . The charging demand at the customer and by the roadside was determined based on the number of departure and destination locations within the Greater Amsterdam COROP. The resulting charging demand per year is presented in Table 5.3.

Table 5.3
Allocation of charging requirement for trucks per location type within Greater Amsterdam COROP.

	TOTAL CHARGING REQUIREMENT (MWH/YEAR)	SHARE IN GREATER AMSTERDAM	CHARGING DEMAND IN GREATER AMSTERDAM (MWH/YEAR)
Alongside the road (fast charging)	9,850	35[a]	3,448
Depot	87,434	24[b]	20,713
Customer	25,381	35[c]	8,758
Total	**122,665**	-	**32,919**

[a] *Proportion of departure and destination locations in Greater Amsterdam COROP*
[b] *Proportion of locations where vehicles are based on Greater Amsterdam COROP*
[c] *This is based on 260 active days per year.*

Charging actions of trucks within Greater Amsterdam COROP

The number of charging actions was determined by dividing the total charging demand by the charging requirement per charging action. The charging demand per charging action is taken from the 'optimum charging' model (Section 4.2) and is presented in Table 5.4, with a subdivision by charging location type. For charging in depots, a distinction is made between charging during the day and overnight. The model shows that 82% of the energy demand in depots occurs at night, with an average charging demand of 238 kWh. The remaining energy demand occurs during the day, with an average charging demand of 87 kWh per charging action. The weighted average of this is an average charging demand per charging action of 181 kWh.

Table 5.4
Charging requirement per charging action for trucks by location type and time.

CHARGING REQUIREMENT (KWH) PER CHARGING ACTION	AVERAGE	DURING DAY	AT NIGHT
Truck in depot	181	87	238
Truck at customer	124	-	-
Truck by the roadside (fast charging)	54	-	-

The charging demand and the number of charging actions per day calculated based on the above figures are presented in Tabel 5.5

Table 5.5
Charging demand for trucks and number of charging actions per day.

	ENERGY DEMAND PER DAY (MWH)[a]	NUMBER OF CHARGING ACTIONS
By the roadside (fast charging)	38	698
Depot	335	1,848 (1157/691)[b]
Customer	97	784
Total	**470**	**3,330**

[a] *The energy demand per day was calculated based on 260 active days per year.*

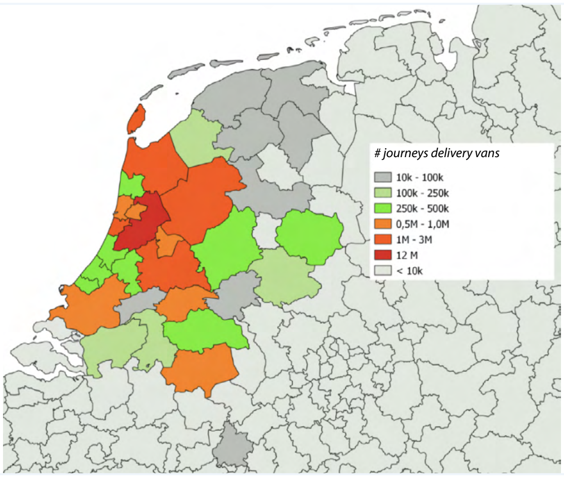
[b] *Division of charging actions between night and day (night/day).*

[13] *It is implicitly assumed here that the trucks based in Greater Amsterdam cover the same annual distance as all of the vehicles that visit the environmental zone.*

Delivery vans

Every year, 30,000 to 40,000 delivery vans currently visit the defined ZE zone (current environmental zone). We have assumed that 30,000 visit the environmental zone on a regular basis and will be replaced with electric delivery vans. These 30,000 delivery vans drive an annual distance of 46,000 km and jointly cover 1.4 billion kilometres per year (source: CBS, see appendix). The annual distance covered by the delivery vans active in Amsterdam is relatively high compared to the average annual distance of about 26,000 km for delivery vans. (Further research is required to find out the reason for this.) The 1.4 billion kilometres not only include journeys to and from the ZE zone, but also journeys that have their starting and end points in entirely different locations. Figuur 5.6 presents the number of delivery van journeys per year based on where the vans are based (source: CBS, see Appendix to 5.1). A large proportion of the delivery vans are based in the Greater Amsterdam COROP (48%) and most of the others come from the neighbouring COROPs and the Rotterdam and Eindhoven regions.

Figure 5.6
Number of departures per year by COROP for delivery vans that visit the ZE zone.



Total annual charging demand for delivery vans

If all of these journeys are made with electric delivery vans, this results in a total energy demand of 493 million kWh per year. The first column in Table 5.7 gives an overview of the annual charging requirement per sector. Based on the results from Section 5.2, the total charging requirement per sector was then allocated to the various location types where vehicles are expected to be charged: at the driver's home address in a residential area, by the roadside (public charging station and fast charging), in depots and at the customer at the destination location. Table 5.7 shows that the charging demand for delivery vans is mainly expected to occur in depots or at home (90% of the charging demand) for all the sectors together (see Appendix to 5.1 for background information on the figures).

Table 5.7
Expected charging equirement (MWh/year) for electric delivery vans by location type as a result of a ZE zone.

	TOTAL (MWH/ YEAR)	AT HOME (MWH/YEAR)	BY THE ROAD (FAST CHARGING) (MWH/YEAR)	DEPOT (MWH/YEAR)	CUSTOMER (MWH/YEAR)
	1,484	-	371	1,113	-
	113,782	85,337	11,378	-	17,067
	134,938	47,228	1,349	80,963	5,398
	15,065	-	-	15,065	-
	19,418	4,854	2,913	11,651	-
	33,932	-	-	33,932	-
	29,359	-	-	29,359	-
	31,271	25,017	3,127	3,127	-
	15,969	14,372	1,597	-	-
Total	**395,218**	**176,808**	**20,735**	**175,209**	**22,465**
Share in total	**100%**	**45%**	**5%**	**44%**	**6%**

Charging demand for delivery vans within Greater Amsterdam COROP

The charging demand for delivery vans is primarily expected to occur at home or in depots (in other words, at the delivery van's home base). In order to determine the charging demand in Greater Amsterdam, the analysis is therefore based on delivery vans that visit the environmental zone and are based in Greater Amsterdam. Out of the 30,000 delivery vans that visit the environmental zone, about 14,300 are based in Greater Amsterdam (source: CBS/ Statistics Netherlands). The average annual distance covered by these vehicles is lower than that of all the delivery vans that visit Amsterdam as a whole, namely 33,600 km per year (instead of 46,000). This also reduces the charging demand per vehicle.

Table 5.8 presents the total charging demand for the vehicles based in Greater Amsterdam and the breakdown by location type. For these vehicles, the charging requirement at home or in depots will logically lead to charging demand in Greater Amsterdam. The charging requirement by the roadside and at the customer does not have to lead to charging demand within the COROP. Data from Statistics Netherlands, however, tells us that 70% of the locations visited by vehicles from the Greater Amsterdam COROP are also located within the Greater Amsterdam COROP. It is therefore likely that 70% of the charging requirement for these delivery vans also leads to charging demand in the COROP by the roadside and at the customer. It has been assumed that the other 30% of the charging requirement that leads to charging demand outside the COROP equals the charging demand within the COROP of the 17,300 vehicles based elsewhere. Tabel 5.8 presents an estimate of the charging demand as a result of a ZE zone by location type in the Greater Amsterdam COROP.

Table 5.8
Expected charging demand for electric delivery vans in Greater Amsterdam COROP as a result of a ZE zone.

	TOTAL (MWH/ YEAR)	AT HOME (MWH/YEAR)	BY THE ROAD (FAST CHARGING) (MWH/YEAR)	DEPOT (MWH/YEAR)	CUSTOMER (MWH/YEAR)
	204	-	51	153	-
	28,377	21,283	2,838	-	4,257
	38,607	13,513	386	23,164	1,544
	6,255	-	-	6,255	-
	7,626	1,907	1,144	4,576	-
	12,108	-	-	12,108	-
	10,956	-	-	10,956	-
	14,113	11,291	1,411	1,411	-
	6,923	6,231	692	-	-
Total	**125,170**	**54,223**	**6,522**	**58,623**	**5,801**

Charging actions of delivery vans within Greater Amsterdam COROP

Just as for trucks, the number of charging actions was determined by dividing the total charging demand by the charging requirement per charging action. The charging demand per charging action is taken from the 'optimum charging' model (Section 4.2) and is presented in Table 5.9, with a subdivision by charging location type. For charging in depots and at home, a distinction is made between charging during the day and overnight. It can be concluded from the model's results that about 50% of the charging demand in depots occurs at night, with an average charging requirement of 21 kWh. The remaining charging demand occurs during the day, with an average charging requirement of 9 kWh per charging action. The weighted average of this is an average charging demand per charging action of 12 kWh. 98% of the charging demand at home occurs at night, with an average charging demand of 19 kWh per charging action. During the day this is 2 kWh per charging action, which yields an average of 17 kWh per charging action.

Table 5.9
Charging requirement per charging action for delivery vans by location type and time.

CHARGING REQUIREMENT (KWH) PER CHARGING ACTION	AVERAGE	DURING DAY	AT NIGHT
Delivery van in depot	12	9	21
Delivery van at customer	11		
Delivery van at home	17	2	19
Delivery van by the roadside (fast charging)	9		

The charging demand and the number of charging actions per day are presented in Table 5.10. For charging by the roadside, half of the delivery vans are estimated to be charged at public charging stations and the other half at fast-charging stations. The charging requirement per charging action at public charging stations is assumed to be the same as for charging at the customer.

Table 5.10
Charging demand and number of charging actions for delivery vans per day.
[a] The energy demand per day was calculated based on 260 active days per year.
[b] Division of charging actions between night and day (night/day).

	ENERGY DEMAND PER DAY (MWH)[a]	NUMBER OF CHARCHING ACTIONS	
Langs de weg (snelladen)	13	1,449	
Langs de weg (public)	13	1,131	
At home	208	12,294	(11,481/813)[b]
Depot	225	18,444	(5,295/13,149)[b]
Klant	22	2,012	
Total	**480**	**35,329**	

Total for trucks and delivery vans

TTable 5.11 presents an overview of the total charging requirement per year (866 GWh/year) for delivery vans and trucks that are active in the ZE zone, plus the charging demand per year (246 GWh/year in total) within the Greater Amsterdam COROP. About 30% of the charging demand for delivery vans and trucks that will become electric due to the ZE zone occurs in the Greater Amsterdam COROP. The total charging demand in Greater Amsterdam of 248 GWh per year equals 2 to 3% of the total annual electricity demand in the Greater Amsterdam COROP expected towards 2025 and 2030, and 4% of the growth in electricity demand expected during the period 2020-2030[14].

Table 5.11
Overview of annual charging requirement and annual charging demand within Greater Amsterdam COROP by location type for vehicles active in ZE zone.

	TOTAL CHARGING DEMAND	AT HOME	BY THE ROAD	DEPOT	CUSTOMER
Annual charging requirement (GWh/year)					
Delivery vans	395	177	21	175	22
Trucks	471	-	28	369	74
Total	**866**	**177**	**49**	**544**	**96**
Annual charging demand within Greater Amsterdam COROP (GWh/year)					
Delivery vans	125	54	6,5	59	5,8
Trucks	123	-	9,9	87	25,4
Total	**248**	**54**	**16.4**	**146**	**31.2**

Table 5.12 presents the charging demand in the Greater Amsterdam COROP per day (950 MWh/ day in total), plus the number of charging actions per day (38,659 actions/day in total). A total of almost 40,000 charging actions per day are expected, over 90% of which are performed by delivery vans and over half of which occur in depots.

Table 5.12
Overview of charging demand and charging actions per day for vehicles active in ZE zone within Greater Amsterdam COROP by location type.

** Based on 260 active days per year*

	TOTAL CHARGING DEMAND	AT HOME	BY THE ROAD	DEPOT	CUSTOMER
Charging demand per day (MWh/day)*					
Delivery vans	480	208	25	225	22
Trucks	470	-	38	335	97
Total	**950**	**208**	**63**	**560**	**120**
Number of charging actions per day (#/day)*					
Delivery vans	35,329	12,294	2.579	18.444	2.012
Trucks	3,330		698	1.848	784
Total	**38,659**	**12,294**	**3,277**	**20,292**	**2,795**

[14] *The total demand is approx. 7.5 TWh in 2020 and 13 TWh in 2030 (Report of system study on energy infrastructure in North Holland 2020-2050, CE Delft 2019).*

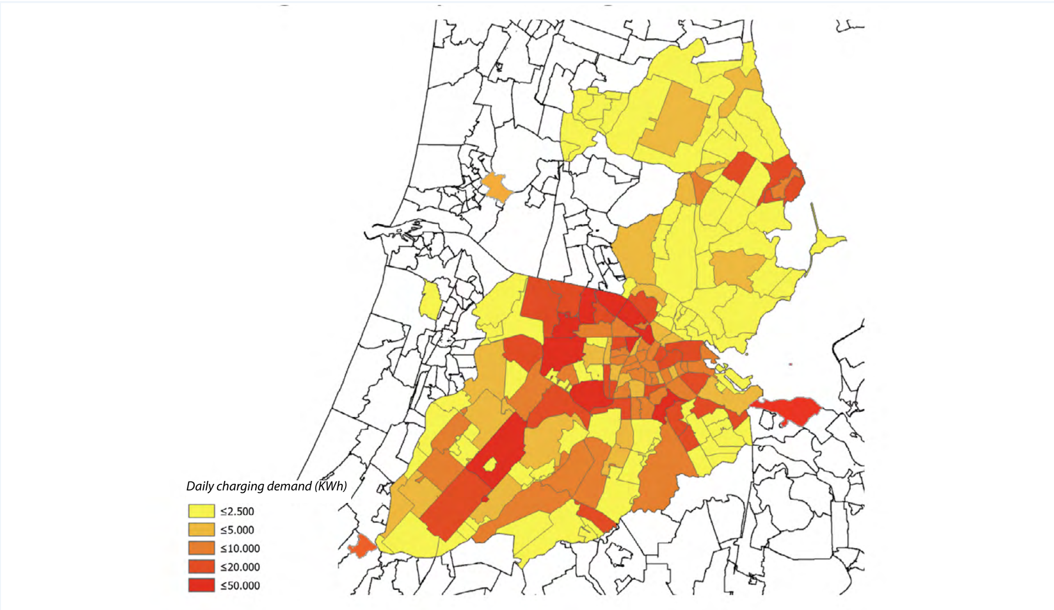
5.2 Geographical spread of charging requirement in Greater Amsterdam

The charging demand by location type was spatially allocated by postcode area (see Appendix to 5.2 for details). The method for allocating the charging demand to postcode areas (numbers only) differs for each location type:

- The charging demand in depots and at home was allocated based on the home base and registration details of trucks and delivery vans that visit the ZE zone.
- The charging demand at the customer was allocated based on the origin-destination relationships from the VENOM traffic model.
- For the fast charging stations along the route, 5 strategic locations were selected along the access roads towards Amsterdam at existing service stations and parking facilities, with the total charging demand at fast charging stations allocated based on the intensities of the traffic to and from the ZE zone according to the VENOM traffic model for the approach route in question.

The results of the allocation are presented on the map in Figure 5.13, which contains an overview of the daily charging demand in the Greater Amsterdam COROP for each postcode area. The coloured locations just outside the Greater Amsterdam COROP are the postcode areas of the locations selected for fast charging stations.

Figure 5.13
Heat map of daily charging demand.



The figure shows that a relatively high charging demand can be expected in the port area, Amsterdam West and industrial sites on the edge of Amsterdam. This mainly involves recharging trucks and delivery vans in depots. Furthermore, a high charging demand is mainly expected in Hoofddorp and Edam-Volendam. Apart from charging in depots, this often also involves recharging delivery vans at home.

Outside the Greater Amsterdam COROP, there are a few other locations where the charging demand for charging in depots is relatively high; in a number of cases this is higher than for postcode areas within the Greater Amsterdam COROP. These are the depots of a number of major transport companies.

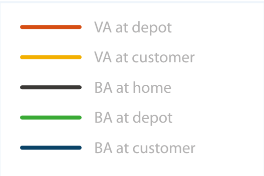
5.3 Impact of charging demand on the power grid

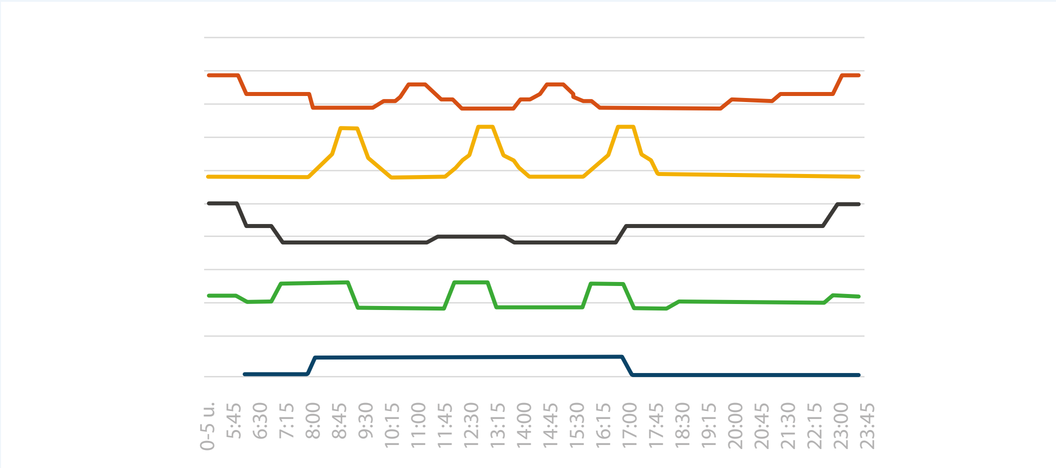
The impact of the charging demand in the Greater Amsterdam COROP on the energy grid is determined by the increase in the power demand that this yields at the peak times during the year. In order to determine the power demand of the electric vehicles, the total charging demand per day was converted into the power demand (kW) during the day. For this, the charging profiles presented in Figuur 5.14 per postcode area were applied for each type of charging demand. For charging of delivery vans by the roadside at public charging stations in residential areas, it was assumed that this is equal to the profile for charging at the customer. A brief explanation is provided for each type of charging demand:

- **Delivery van at customer** (and by the roadside, public charging station): It was assumed that the charging demand is spread out over the day from 08:00 to 17:00. Delivery vans that are charged at the customer are mainly active in the construction and facilities sectors, with the delivery vans being parked at the customer for longer periods of time.
- **Delivery van in depot:** A small part of the delivery vans are charged in depots overnight. The charging demand at night is evenly distributed over the period 18:30 to 07:00, whereby we assume that this is possible by make use of smart charging and that businesses will opt for this to limit the power demand and, as a result, the charging costs. It was also assumed that vehicles are recharged in depots in the morning at the start of the work (e.g. when the work is being allocated) and at break times during the day. The total charging demand during the day is divided over 3 periods during the day, totalling a period of 4:45 hours.
- **Delivery van at home** (public charging station): At home, delivery vans are mainly charged overnight during the period 17:00 to 07:00, whereby we assume that the charging demand peaks in the period 23:00 to 06:00. It was assumed that smart charging is used14 and that the charging demand is evenly distributed over the night.
- **Truck at customer:** It was assumed that trucks depart in the morning between 06:00 and 08:00. They will then arrive at the customer about 2 hours later (08:00 to 10:00). A journey cycle of about 4 hours was assumed, so there will be charging actions at the customers 4 and 8 hours later. The charging demand per day is divided over 3 periods of 2 hours during the day. In order to determine the maximum power demand during the day, it was assumed that, for every 6 charging actions at a location, simultaneous charging actions will occur and the power demand increases by 150 kW. For a location with 19 charging actions per day, the assumed power demand will therefore be 600 kW at peak times. For the power demand per charging action, a value of 150 kW was assumed based on the optimum charging model.
- **Truck in depot:** In depots, 82% of the charging demand is at night, whereby it was assumed that this is between 20:00 and 08:00, with an optimum between 23:00 and 06:00. Here we will also assume that businesses will opt for a form of smart charging in order to spread out the power demand over the night and limit the charging costs. During the day there are charging actions with intervals of 4 hours after departure. In order to determine the maximum power demand during the day, it was assumed that, for every 5 charging actions at a location, simultaneous charging actions will occur and the power demand increases by 150 kW.
- **Delivery vans and trucks at fast charging stations:** It was assumed that the charging demand is evenly distributed between 09:00 and 21:00. (not depicted in graph).

[15] *Whereby smart/postponed charging ensures that the charging demand is spread out over the night.*

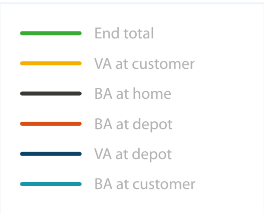
Figure 5.14
Charging profiles applied for different types of charging demand and vehicles.
** VA = truck.*
BA = delivery van.

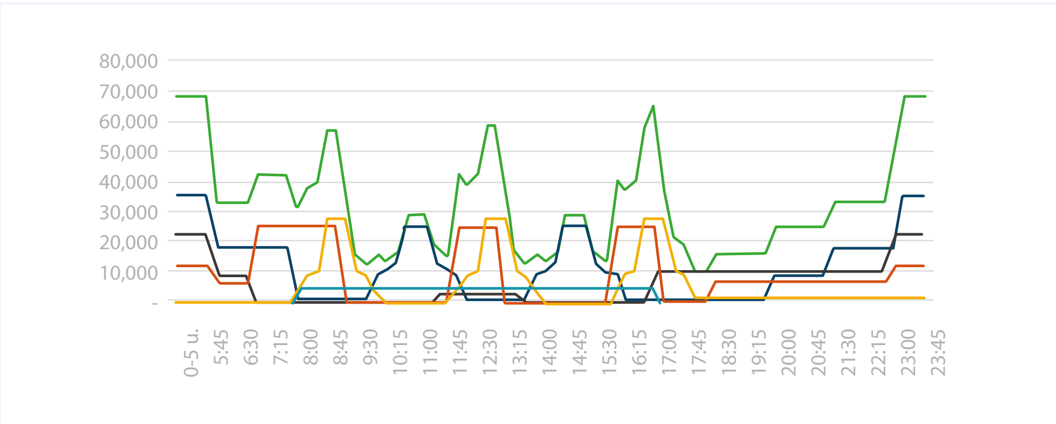




Based on the above profiles, the power demand during the day was determined for each postcode area. Within the Greater Amsterdam COROP, this leads to a maximum power demand of 2600 kW in a location. Maximum power levels are generally reached at night and in rare cases around 08:00/08:45 and at 17:00. These peaks can also be recognised in the total power demand in the Greater Amsterdam COROP (Figure 5.15).

Figure 5.15
Total power demand during the day by charging vehicles in ZE zone.





Load on the power grid

The power demand per postcode area was presented to Liander, the grid operator in Amsterdam. Liander investigated the impact of this power demand on the substations in the Municipality of Amsterdam. The impact appears to be very limited in relative terms. At peak times of the existing power demand during the year (current situation), the increase in power due to charging demand is less than 0.25% at 25 out of the 26 substations. In 2030 this is only expected to be 0.17%. At one of the substations in the port area, the impact is slightly higher, namely 1.5% compared to the current power demand and 0.6% in 2030.
If smart charging is not used for delivery vans in residential areas and they are all charged at once between 17:.00 and 20:00 in the evening, this will lead to a charging demand that is a factor 2.6 times higher on average around 17:00. (see Appendix to 5.3).

The impact on the substations is probably still limited (at approx. 0.65% at 25 out of the 26 substations), but could in a single case (Port Area) rise to a few percent (4%, based on the average factor of 2.6). It is therefore certainly important to make use of smart charging to limit the impact on the grid. This applies both to businesses (in terms of connection costs) and to the grid operator.

The conclusion based on the above analysis is that the impact of the total charging demand on the capacity of the grid and the substations is not surprisingly large compared to either the current demand or the expected additional demand. For the grid operator, this means that a ZE zone would not substantially increase the challenges it faces to make the power grid futureproof. For municipalities it is important, however, to facilitate smart charging of delivery vans, to prevent large peaks in the charging demand.

Providing connections

The fact that the average increase in power demand due to the ZE zone is relatively limited does not mean that it will always be easy to install the required charging infrastructure. For connections below 10 MVA, grid operators have a statutory connection period of 18 weeks. However, due to the major growth in the number of applications for connections and a shortage of technical personnel, it is becoming increasingly complex to stick to the planning.

For connections below 2 MW, the low and/or medium-voltage infrastructure already present will generally be used. Connections with a power demand of more than 2 MW will be provided by connecting directly to a substation. The additional investments for connections above 2 MW are about 200,000 euros for a business. Whether a connection can be provided at the substation without transport limitation depends on whether any capacity (MW) is still available and whether any fields (connection options to substation) are still available. If not enough free fields are available, the lead times for expansion in the field may rise to between 1-3 years, depending on the situation. Furthermore, the additional costs for this connection also need to be taken into account. If not enough power capacity is present at a substation, the lead times for grid expansion may rise to between 3-8 years, depending on the situation.

The analysis shows that there are 9 postcode areas (number part only) for which the total power demand exceeds 2 MW. Within these areas, there are expected to be 3 addresses where the total charging demand (approx. 2.5 MW) exceeds 2 MW in any case. As described previously, there are also a few locations outside the COROP that have a greater charging demand due to the ZE zone, where the power demand at night is estimated at 5 to 7 MW.

It would generally be advisable to contact the grid operator at an early stage. They will be able to provide the most current and accurate estimate for the availability, costs and lead time.

[16] *www.liander.nl/grootzakelijk/factuur/tarieven?ref=18681.*
[17] *Limitation of the power to be supplied*

5.4 Number of charging points and charging stations

In this section we have made an estimate for the number of charging stations. As the number of charging stations partly depends on the number of charging points (used) per charging station, the number of charging points was also determined. The number of charging points does not depend on assumptions about vehicles using a charging station simultaneously. The number of charging points and charging stations was estimated based on the type of charging demand.

For charging delivery vans at home, it was assumed that every delivery van charged overnight requires a charging point at a public charging station. The number of delivery vans charged at home during the day does not cause any additional demand for charging points. The assumption is that delivery vans taken home by their users do not have any option to recharge on private land at home, so that public charging stations are required for this. The number of required charging points is equal to the number of charging actions overnight (= number of vehicles being charged), which comes down to 11,481 charging points (see Table 5.10). Based on 20 kW charging stations with 2 connections that are used by 1.5 vehicles on average, a total of 7,654 charging stations would be required (see Table 5.16).

For delivery vans and trucks in depots, the number of charging points equals the number of charging actions overnight. Of these, there are 5,295 for delivery vans and 1,157 for trucks. For the charging stations we assume that 150 kW stations are used for trucks and 20 kW stations for delivery vans. The number of charging stations depends on the number of charging points per charging station. In depots, there would be the option of several charging points per charging station, to allow several vehicles to be connected to a charging station overnight and to use the charging station's capacity to cover the charging demand of several vehicles during the night (by making use of smart charging). During the day, the charging station's capacity can then be fully used to quickly recharge a single vehicle. A business could also choose two charging points per charging station and make use of a smart charging application to spread out the power demand of the charging stations during the night. In this case, several charging stations would be required. The minimum number of charging stations required in depots was therefore determined by dividing the maximum power demand per area by the capacity of the average charging station. This is used to calculate for peak times how many charging stations are minimally required to meet the power demand. The maximum number of charging stations in depots is based on 2 charging points per charging station. This yields a range of 235 to 579 charging stations for trucks and 1,715 to 2,648 charging stations for delivery vans in depots (see Table 5.16).

For delivery vans and trucks at the customer and by the roadside, we assume that the number of required charging points and stations is equal. The assumption is that the vehicles will be using the maximum capacity of the charging station during the day in order to recharge as quickly as possible, so that only one charging point will be used per charging station.

[18] *Based on the results of the 'optimum charging' calculation model*

[19] *The calculation for trucks was performed for areas smaller than postcode number areas, where there are only a few locations with trucks and required charging stations. As a result, this method yields a good approximation for the minimum number of charging stations. The number of charging stations has always been rounded up here. This compensates for the fact that there are several locations over which the charging demand is divided. For the number of charging stations for delivery vans in depots, a multiplication factor of 1.3 was used to compensate for the fact that the charging demand at different locations within a postcode area cannot be met by a single charging station.*

In this case, the number of charging points and charging stations was calculated by dividing the maximum power demand per area by the capacity of the average charging station. This results in the maximum number of vehicles that will be charging simultaneously. At the customer we assume that 20 kW (delivery vans) and 150 kW charging stations (trucks) are used. At fast charging stations we assume that 50 kW (delivery vans) and 350 kW charging stations (trucks) are used[20].

Table 5.16 presents the results of the total expected number of charging actions and charging stations per location type. It also states the charging station type assumed for the calculation. 150 kW stations were therefore used for charging trucks in depots and at the customer. This is because the optimum charging model shows that in depots and at the customer 80% of the charging demand is covered by 150 kW stations (15% by 350 kW stations and 5% by 50 kW stations). For delivery vans in depots and at the customer, 20 kW charging stations are the most optimum (in 80-90% of cases). For fast charging, it turns out that 350 kW charging stations are the most optimum for trucks and 50 kW stations for delivery vans.

The charging stations required for delivery vans charged at public charging stations during the day are not expected to result in additionally required charging stations. In many cases, the utilisation rate of public charging points is lower during the day than at night, as these are mainly used by residents to recharge overnight.

Table 5.16
Expected charging demand, charging actions and number of charging stations required for trucks and delivery vans in Greater Amsterdam as a result of a ZE zone.

** For public charging stations and charging points by the roadside, it was assumed that there is no additional requirement. These were therefore not included in the totals.*

	NUMBER OF CHARGING POINTS	NUMBER OF CHARGING STATIONS	CHARGING STATION TYPE (TYPICAL)
By the roadside (fast charging)	10	10	350 kW
Depot	1157	235-579	150 kW
Customer	183	183	150 kW
Total	1350	418-772	
By the roadside (fast charging)	28	28	50 kW
By the roadside (public)*	(292)	(292)	20 kW
At home (public e-charging in a district)	11,481	7,654	20 kW
Depot	5,295	1,715-2.648	20 kW
Customer	326	326	20 kW
Total	**17,130***	**9,723-10,656***	

Most of the charging points and charging stations are expected for charging delivery vans in residential areas overnight. The number of charging points required for delivery vans is twice as high as the current number of charging points in the Greater Amsterdam COROP. These are mainly delivery vans in the construction and facilities sectors. The spatial distribution of the public charging stations in the residential areas is presented in Figure 5.17. Many public charging stations are expected to be required in Amsterdam near the Houthavens, in Hoofddorp and in Volendam. This could be because many deliver van users from the construction or facilities sector live here[22].

[20] *Based on the results of the 'optimum charging' calculation model*
[21] *5,703 charging points in Oct 2018 according to https://www.livinglabsmartcharging.nl/nl/laadinfrastructuur/rang-lijst-laadinfrastructuur-nederlandse-gemeenten*
[22] *Further research would be required to substantiate this with facts.*

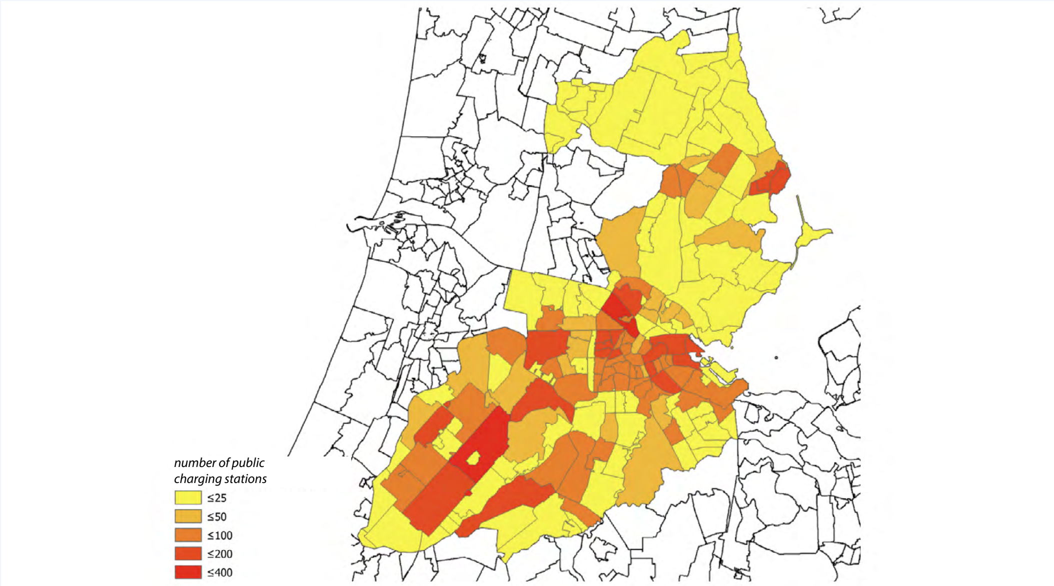


Figure 5.17
Number of public charging stations by postcode area.

5.5 Impact of charging demand on public space

Section 5.1 describes the need for a certain number of charging stations and electricity described for each postcode area (numbers only). This section covers several spatial aspects and the impact of expanding the power grid and public and private infrastructure. A practical format was prepared for this (among other things), aimed at implementing charging infrastructure in logistics hot spots and at industrial sites. See also Section 6.2 and the Appendix to 6.2.

Space for public infrastructure

Four types of public charging points can be distinguished: (i) at the customer in the city centre, (ii) along the approach routes in the trunk road network, (iii) at (temporary) building sites inside the A10 ring road and (iv) at the home base in residential areas. As explained in the previous section, the model shows that the highest demand for public charging stations will occur in residential areas.

Usually, public charging points are created at existing parking spaces in the city centre, in residential areas or car parks, or existing service stations along the trunk roads. This means that in the future the existing parking capacity could be put under pressure, and loading and unloading sites could be subject to increased pressure, which is currently already quite a challenge in city centres. In some cases, specific car parks with charging stations could be set up in city centres, along approach routes or at industrial sites, where vehicles can be efficiently charged on a larger scale. This would require proper spatial integration. Another point for attention is that municipalities use predictive models for expansion plans for charging infrastructure. In the distribution models (showing which areas charging demand is expected in), the 'income' factor is currently the dominant predictor. For the logistics sector, other factors are expected to be dominant, so the distribution models would have to be modified. Here, public charging points for logistics are expected to end up in other areas.

Space for private charging infrastructure

The previous section makes it clear that the highest demand for electricity will occur at business depots, which are mainly located at industrial sites. This requires private charging infrastructure. The development of charging points on private land at business sites or industrial sites (private land) has two formats: a private land owner installs charging points (at the request of the leasing company or otherwise) or a private operator (examples of these providers are Allego, Greenflux and New Motion) leases land at the industrial site and develops and operates a publicly accessible charging station there. In the former case, existing parking spaces at the business site can be used and no additional space will be required; the spatial impact (for the land owner or tenant) would therefore appear to be minimal. In the latter case, a specific area would have to be leased to create new space for charging points.

Spatial impact when expanding the power grid

The increase in charging infrastructure may be accompanied by necessary modifications to or expansion of the power grid, provided that the demand exceeds 2 MW or there is insufficient capacity at substations, as described in Section 5.3. A direct connection to a substation or expansion of the capacity of fields or the medium-voltage grid requires additional space both underground and aboveground, e.g. for extra cables, transformer stations and the installation of systems that provide the necessary power distribution in the case of a major increase in charging stations in a limited area (for example, an increase in charging stations in a street/ residential area).

5.6 Conclusions and recommendations

Based on the results of the analyses in the previous sections of this chapter, we have drawn the following key conclusions.

5.6.1 Effects of a ZE zone in Amsterdam on urban distribution and electricity demand

By having a ZE zone that matches the current environmental zone in Amsterdam, our calculations show that about 30,000 delivery vans (which cover 1.7 billion km per year) and 4,700 trucks (which cover 325.5 million km per year) would have to become zero-emission to be allowed into the zone.

If this number of vehicles is replaced with EVs, it would yield a total electricity demand of 248 GWh per year within Greater Amsterdam. The electricity demand from delivery vans is calculated at 125 GWh per year and electric trucks are expected to require 123 GWh per year. The total charging demand of delivery vans is almost equal to that of trucks, because the number of electric delivery vans required for the ZE zone is over six times as high.

5.6.2 Effects on the power grid

The total energy demand in Greater Amsterdam of 248 GWh per year equals 2-3% of the total annual electricity demand in the Greater Amsterdam COROP expected towards 2025 and 2030. The charging demand will make a limited contribution (4%) to the expected growth in the electricity demand during the period 2020 - 2030 in the Greater Amsterdam COROP[23].

[23] *Based on Report of system study on energy infrastructure in North Holland 2020-2050, CE Delft 2019.*

Apart from a few industrial sites with major charging requirements, the electricity demand and the demand for the number of charging stations is spread out over the region (provided that no regulation is implemented by a government party for so-called City Hubs). No major problems with the grid capacity are expected for the grid operator in addition to the existing challenges associated with increased grid loads. Parties that want connections for charging infrastructure should, however, take into account that (depending on the conditions) it may take a few months to a few years to provide a connection, depending on the situation. Normally speaking, connections below 2 MW will be provided within a few months. For connections exceeding 2 MW that are connected directly to a substation, it may take much longer if the capacity in the substation is insufficient. It is important that businesses contact the grid operator well in advance, especially those that require a high-capacity connection.

When charging overnight in residential areas and in depots in particular, it is important to spread out the charging demand by making use of smart charging to limit the load on the grid. For public charging stations, smart charging can be facilitated by municipalities (e.g. as a precondition for tenders).

Research recommendations

Based on the results, we can conclude that no large-scale problem areas would appear to be developing. There are a few aspects that could be studied in more detail to improve the picture of the possible impact:

- To study the impact on the grid, we used charging profiles in this analysis where smart charging was used during the night. This applies to delivery vans that are charged overnight at public charging stations and to vehicles in depots. Without smart charging, peaks in the power demand may occur and would be expected between 17:00 and 20:00 in the evening. The effects of not using smart charging were not extensively investigated in this study. The impact on the grid of alternative charging scenarios could be further investigated in a follow-up study.
- Another point for attention is that the actual situation may differ from the assumptions made regarding the charging actions during the day, as described in Section 5.3. Potential peak loads could have been missed as a result of this. At the same time, smart charging offers the opportunity to spread out the charging demand to more favourable times, which could mitigate the peak times that were identified based on the assumptions. One recommendation for a follow-up study would be to work with more detailed, practice-based charging profiles and to include realistic smart charging strategies. A greater number of different scenarios for charging profiles could also be studied for this.
- The current analysis focuses on a ZE zone in Amsterdam and the effects thereof within the Greater Amsterdam COROP. However, there are plans for other ZE zones as well. If several ZE zones are set up in the Netherlands and the region, this will affect the charging requirement and the impact on the grid in the Greater Amsterdam COROP. The size of the zones will also have an influence on the effects. In the recently published 'Clear Air Action Plan', the Municipality of Amsterdam indicates that it may want to expand the zone. An indication of the effects of the zone size is presented in the appendices (Appendix to 5.6).

5.6.3 Locations where a high or specific charging demand can be expected

A total of almost 40,000 charging actions per day are expected, over 90% of which are performed by delivery vans and over half of which occur in depots. Generally speaking, the greatest charging demand occurs at business locations and depots (usually on industrial sites) (78% from trucks and 44% from delivery vans), spread out during the night when vehicles are parked. This would require about 235-559 charging stations of 150 kW (trucks) and 1,715 to 2,648 charging stations of 20 kW (for delivery vans).
However, the largest number of charging stations is required for delivery vans that park in residential areas at night. According to the model results, about 11,481 charging points should be available here for charging delivery vans during the night. That is twice as many as there are now present in the Greater Amsterdam COROP (Coordination Commission for the Regional Research Programme). The demand for passenger car charging stations will also increase in residential areas, but these may be completely different from the areas where charging demand occurs due to delivery vans. A charging system in residential areas would preferably require smart charging systems, good spatial integration and incorporation in the parking policy.

The analysis of the spatial distribution shows that a relatively high charging demand can be expected in the port area, Amsterdam West and industrial sites on the edge of Amsterdam. This mainly involves recharging trucks and delivery vans in depots. Furthermore, high charging demand is expected in Hoofddorp and Edam-Volendam in particular, possibly because of the large number of construction companies there. As well as recharging in depots, this often also involves charging delivery vans at home.

Installing additional charging stations and electricity capacity will have the greatest spatial impact in the city centre and in residential areas, where space is already under great pressure and the spatial integration requires more aesthetically acceptable solutions. A solution currently being rolled out in several cities is the clustering of public charging points into car parks with charging stations. Advantages include the fact that car parks with charging stations create less clutter on the streets, are more likely to be available to users and spread out the periodic connection costs over several charging stations (better margin). Especially in cities with a high charging station density, this is a good alternative whereby the disadvantage of longer walking distances remains limited. A strategy of spatially facilitating charging infrastructure in a few strategic hot-spot locations could be very useful.

Connections exceeding 2 MW require a separate connection to a substation. Within the COROP, there are only a few locations at industrial sites where such a high level of demand is expected. The expectation is that the space required for these functions and capacity expansion can be more easily found at industrial sites than, for example, in the city centre.

6 RECOMMENDATIONS FOR STAKEHOLDERS

Based on the working method, results and conclusions presented in this report, this chapter contains concrete recommendations for the various stakeholders that are directly or indirectly involved in city logistics.

6.1 Professional carriers and in-house carriers

The effects of introducing a traffic-restricted ZE zone go beyond purchasing a different vehicle. In concrete terms this is about becoming '5x smarter': smart selection of a vehicle, smart driving, smart charging, smart purchasing of energy services and smart planning of the journeys. Training personnel and experimenting (e.g. with different charging strategies) would be advisable.

The recommendations for these stakeholders are subdivided into general recommendations and recommendations specifically for professional transport and in-house transport.

Carriers - general

- Depending on the size of the battery, the investment costs for the purchase of electric delivery vans are currently about 40% higher than for conventional vehicles. Some of these additional costs can be recovered through the lower operating costs. Even though the price is expected to drop quickly once delivery vans and ex-works electric trucks are mass-produced, logistics service provides are not excluding that, for the time being, electric transport will remain more expensive than transport using diesel vehicles due to the additional investments and costs. This requires a dialogue with the clients.
- In transport planning, combining a driver's periods of rest with charging actions will become important. This makes it possible to avoid extra operating costs (labour costs and detour kilometres).
- The consumption per km may vary greatly depending on the outside temperature, speed, tyre pressure and weight. In the winter, a battery requires additional capacity to come to the right temperature and keep it there. This affects the range so much that it will have to be taken into account during transport planning. It would be advisable to train drivers in the use of electric vehicles.
- For the AMA, the number of approach kilometres is relatively low for most sectors. This means that most of the vehicles (trucks and delivery vans) can be charged in depots. This option is also the cheapest and the easiest to incorporate in the logistics process. This is also expected to apply to other urban regions.
- In terms of costs and logistical integration, users often prefer a larger battery that can be fully recharged at the depot. As a result, recharging on the road will be required less often (this is relatively expensive in terms of kWh price and wages).

- At depots where many trucks are parked overnight, it would be advisable to use a form of smart charging to spread out the energy demand as much as possible and avoid peaks, and to limit the connection capacity (and therefore the costs).
- It is important to contact the grid operator well in advance about the connection they think they will require in the future to find out more about the lead time and costs in time. The lead time for providing a connection may vary between a few months and a few years, depending on the situation.
- Switching to electric transport is the right time to think about other logistical concepts, like concepts where cargo is uncoupled (e.g. a hub at the edge of a city).

Professional transport

- Companies in professional goods transport may consider purchasing their own high-capacity charging stations or constructing a car park with charging stations, possibly together with neighbouring companies. After all, the higher the consumption, the lower the cost price per kWh will be.
- Except for briefly recharging, use of public charging stations is not recommended due to the high commercial cost price per kWh.
- Optimum use of BEVs is a learning process. Sharing the results within the sector will accelerate the transition.
- Diesel delivery vans and trucks should not simply be replaced directly with BEVs that have the same capacity. Even within a company, it is important to use a differentiated approach. As the price of BEVs is expected to drop quickly until 2030, it would be advisable to replace a vehicle fleet gradually rather than over a relatively short period.
- In view of the (currently still limited) range of BEVs, different journey planning will be required in a number of logistics sectors with relatively long distances. This may also have consequences for the logistics process, e.g. a shift to smaller vehicles with more frequent use.

Own managed transport

- Even though goods transport is important to these companies, this is not their main activity. In contrast to professional transport, optimisation will therefore not (always) have the highest priority. Thoroughly evaluating the replacement of a diesel vehicle and/or opting for charging at home or otherwise may lead to the selection of a BEV with different specifications.
- It is useful to consider the logistics process carefully within which the vehicles are used. Questions such as: Is my current goods vehicle not over-dimensioned? Would it be better for me to collaborate with my neighbours regarding transport? Should I outsource transport to a professional transport company?
- For a certain group of delivery van owners, the purchase of a new electric delivery van could require an excessive investment and the available range of cheaper second-hand electric vehicles is still too limited. This will require support.

6.2 Local authorities

A local authority plays a key role in:

- The long-term strategy for selecting charging infrastructure locations.
- The improvement and facilitation of charging infrastructure, including in residential areas and at industrial sites with depots.
- Traffic flows, ITS and availability of loading and unloading sites.
- Creating incentives/subsidies for the use, provision, pricing and facilitation of charging solutions.
- Setting requirements for public and semi-public charging infrastructure with regard to aspects such as pricing, smart charging options, interoperability and data sharing with a view to monitoring and optimisation.

Collecting the basic data and calculating the expected charging demand when setting up a ZE zone based on the method presented in this report is the basis for developing a sound policy and to be able to hold the right discussions about it with the other stakeholders.

That insight can be used to develop concrete plans, such as:

- The provision of public charging infrastructure in the locations that are required for goods transport. For example, a significant level of demand for charging in residential areas may come from delivery vans. This will probably lead to a faster increase in the charging demand in areas different from those where the demand for passenger cars occurs.
- Promoting the development of private charging infrastructure (see the Appendix to 6.2 for tips for industrial sites).
- A possible funding scheme for purchase costs or electricity prices.
- Preparing an integrated plan with the grid operator for the future demand for electricity and grid requirements, and using this to keep space available in the zoning plan for the future grid infrastructure.
- Including the installation of charging infrastructure as a spatial requirement for building projects.
- When setting up a ZE zone for distribution traffic, it would be sensible to introduce measures that prevent old diesel passenger cars from becoming an alternative to delivery vans. An environmental zone for passenger cars (as planned in The Hague) is a possible measure for this.

6.3 Shippers, recipients and property managers

Shippers, recipients and property managers have to deal with delivery vans and trucks from service providers or their own transport, which fulfil a vital function on behalf of themselves or others. They play a key facilitating role in allowing the logistics process with BEVs in a ZE zone to proceed smoothly, among other things, by making other logistical concepts possible and installing charging infrastructure.

Major shippers and recipients

- Facilitate charging stations for carriers and enter into discussions about the required numbers, capacity and location of charging stations (e.g. at the delivery location).
- Major companies generally have more options to actively focus on ZE transport, e.g. when selecting a professional carrier. More proactively, a company may consider rewarding transport companies with proven sustainability agendas.
- Lots of goods are loaded and unloaded at major companies, especially those that have their own distribution centres. Fast charging at that time can make a big difference; this requires charging infrastructure with a high capacity. High capacity with the associated investments requires a high utilisation rate per fast charger to achieve acceptable kWh prices. A systematic approach is required to match supply and demand.

Smaller shippers and recipients

- Individually, smaller parties only affect the logistics process to a small extent. However, they can actively opt for ZE carriers.
- Collaboration may give them greater influence on the logistics process. It also provides options to optimise or limit the number of journeys, for example.

6.4 Vehicle and battery manufacturers

The demand for electric vehicles currently exceeds the supply. However, people not only need more vehicles with lower purchase prices, but also smarter vehicles and more robust charging infrastructure.

The focus should be on:

- Robust charging infrastructure that suits the demanding logistics process, in which predictability and reliability are essential. Smart Charging is a major wish-list item.
- Remote diagnostic options and configuration options for both charging infrastructure, vehicles and the combination thereof.
- Predictability of consumption and range in changing conditions (weight, temperature, etc.) is necessary for a reliable process. This data is required for the journey planning software. It requires collaboration with suppliers of TMS and journey planning systems.
- A sound strategy regarding the choices for on-board AC-DC converters versus external DC chargers. If the external charging infrastructure has a different design (e.g. aiming for cheaper 44 kWh AC charging stations) from that built into the cars by OEMs (e.g. aiming for external DC chargers), this causes lots of issues for carriers.

6.5 Recharging infrastructure providers

A sound (economic) assessment regarding the purchase of an ICE vehicle or a BEV requires reliable data about the costs of charging stations. After all, the TCO of a charging station makes up a significant part of the TCO of a BEV in the form of a cost price per kWh.

- For carriers it is challenging to collect sufficiently robust data about the total costs (investment, installation, maintenance, etc.) of the higher capacity charging stations in particular. This makes purchasing decisions difficult.
- Not much information is available either about the additional costs, such as: purchasing of land, required permits, possible increased grid capacity. Another challenge is that these costs can often differ from one situation to the next. This means that the amounts involved depend on the situation on site. In any case, purchasing land will be more expensive in the city centre than in the outlying areas. Whether the charging station is installed at a company site or in the public space also has a major effect on the TCO.
- There are opportunities for private providers of fast charging stations to provide specific charging solutions for logistics service providers. This mainly involves modified connections (at least 150 kW), higher stations for trucks and a correct distribution of charging infrastructure for the logistics sector, as well as the development of bulk consumer contracts.
- Sharing of charging infrastructure is an interesting option for spreading the costs. In the public space, this could be done by means of an online reservation system. Goods vehicles could, for example, be charged at bus stops overnight. Sharing of the vehicles themselves is also interesting.

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Topsector Logistiek

Appendices

Charging infrastructure for electric vehicles in city logistics

Buck Consultants International · CE Delft · Connekt · DISTRICON advisory solutions professionals · Hogeschool van Amsterdam · Panteia Research to Progress · TNO innovation for life

Charging infrastructure

When electric transport increases substantially in urban distribution over the next couple of years, the current charging infrastructure will have to be expanded during that same period. This applies both to private charging points (e.g. charging points in locations where companies are based and at office buildings and supermarkets) and to public charging stations (along approach routes, in the city centre and in residential areas for delivery vans). Apart from the necessary investments in charging infrastructure, this also requires good spatial integration and a strategy to have the charging capacity match the supply. The spatial planning and regulation policies of governments can ensure that the development of the necessary infrastructure is accelerated (or decelerated).

Municipalities and provinces

Municipalities can play a key role in the development of public charging infrastructure in the public space by facilitating this through space allocation and construction. Provinces can facilitate the development of charging infrastructure on a regional level through their environmental planning policy.

Spatial management

So-called spatial heat maps are being developed to an increasing degree by (mainly large) municipalities, which include the intended expansion of charging stations being planned by the municipalities. The Municipality of Arnhem is one of the areas that uses such a heat map. The aim is for these to be administratively approved in one go, allowing the installation of charging points to proceed much sooner. For each city, there are still specification differences, in some cases even within the various urban districts, which also have their own administrative responsibility. In Amsterdam, no space is currently reserved in the zoning plan specifically for charging points, but heat maps are being developed at the municipality and within the urban districts.

The Hague indicates they do immediately include the charging locations for new housing estates (Vroondaal). The potential charging demand as a result of a ZE zone was also considered regarding logistics. However, heavier trucks are not expected to create a demand for public charging locations in the city. Most vehicles are expected to charge in depots. Furthermore, charging stations for heavy vehicles in the city that are only used a few times during the day are much too expensive. It may be interesting for delivery vans to install a few charging stations at strategic locations in the city, where several delivery vans need to recharge. However, it should be noted here that a charging station at more than 100 metres from the destination location is no longer interesting.

Preconditions

Municipalities often facilitate public charging infrastructure on request, within certain preconditions. The relevant conditions are usually that:

- The applicant has no option to park and charge on their own land.
- No charging points must be installed nearby, usually within a radius of 200 to 300 metres.
- The need must be demonstrated and the fact that the location does not cause any friction within the parking policy[25].

[24] *www.nklnederland.nl/kennisloket/artikelen/iii-aanvraag-en-realisatieproces.*
[25] *www.nklnederland.nl/kennisloket/artikelen/2-richtlijnen-voor-het-toekennen-van-laadpunten.*

It is often also preferred to install charging points in high-profile locations (for a positive effect) and in locations with two available parking spaces intended for general use. In certain cases, municipalities place responsibility for the installation, management and layout of the charging points in the hands of the manager and take on the development of parking spaces and their management themselves. The number of charging points and their locations follow the number of vehicles. A policy of this kind is also applied by the Municipality of Amsterdam. The Hague indicates that it is not possible to provide extended house connections in this municipality. This would lead to claiming behaviour for the parking space. Having plugs alongside the pavement is not permitted either, because the municipality is responsible for safety in the public space. This is not arranged so clearly in every municipality. However, when the charging demand at home from delivery vans (and passenger cars) increases, this may become a key point.

Permits

For charging points in the public domain, municipalities usually issue an integrated environmental permit at the request of a resident or the supplier of infrastructure and make (two) existing parking space available (within the parking policy and with a traffic order), whereby the municipality takes responsibility for the management of the parking spaces and the supplier for the management of the charging point. Charging points developed on private land do not require a permit. The application process for a charging station in the public domain is as follows based on Figure B.2.1 below[26]:

Figure B2.1
Application process for charging point in public domain.

Operating of charging stations

Some cities, like Rotterdam and Utrecht, outsource the operating of charging infrastructure to market parties. In other cities, like The Hague, the municipality does this itself.
The four largest cities (G4) are trying to focus on maximum availability of data on the availability of charging stations. The draft Climate Agreement also suggests that, by 1 August 2019 at the latest, all service providers and all charging station operators share the basic static and dynamic information on all public and semi-public charging stations with a central national access point for data on charging stations (National Access Point, NAP)4. This basic information is also mutually shared. The basic information should in any case include data on the location and availability of the charging stations and the prices for charging.

National government

Key roles for the national government are plotting a course and developing a long-term vision for the future EV network and a policy regarding the development of the trunk road infrastructure. The Electric Transport Green Deal is used by the government and stakeholders to bring together various policy commitments[27].

For the development of publicly accessible fast charging points by private parties along the trunk road network, the government has modified the facilities policy and the permit conditions of these charging points include the provision that they must be interoperable (and therefore publicly accessible)[28].

[26] *www.nklnederland.nl/kennisloket/artikelen/iii-aanvraag-en-realisatieproces.*
[27] *www.greendeals.nl/sites/default/files/uploads/2016/04/GD198-Elektrisch-Rijden-2016-2020.pdf.*
[28] *Vision on the charging infrastructure for electric transport, Ministry of Economic Affairs, 2016.*

Abroad

In Stockholm, charging infrastructure in the public space is accessible to both passenger cars and goods vehicles. For goods vehicles, the option of installing charging infrastructure at loading and unloading sites is being considered, but this has not yet been made concrete.
In Oslo, 58% of the cars are electric. All the charging infrastructure is owned by the city. For fast chargers, there are partnerships with private operators. Investments are shared. This does not apply to private land. Initiatives that work for passenger cars cannot always be applied to goods vehicles (e.g. VAT).

So far, there is no specific policy in Brussels and London for charging infrastructure for goods vehicles. In London it is assumed that carriers - with delivery vans in particular - charge in depots or at home. Infrastructure should come 'from the market'. Recently, the realisation has come that a lack of charging infrastructure is slowing down the growth of electric goods vehicles. The city's general policy is that heavy goods vehicles cannot enter the city centre. They are therefore looking at fast charging infrastructure on the edge of the London along the motorways, in combination with consolidation centres and hubs in strategic locations. These are also called 'charging hubs'. Currently there are several charging stations for passenger cars in the city (2000 7 kW chargers in the city). It is still unclear, however, whether these will also be used for goods vehicles. The recommended charging strategy for the districts has been laid down in strategic documents and consists of 3 types of chargers (not specifically for logistics): charging infrastructure in residential areas for lighter vehicles (passenger cars and deliver vans; 3 kW and 7 kW); to reduce the use of public space they are also considering lamppost charging, fast-charging points (700 in 2020) specifically for taxis, private hire drivers and goods vehicles, and 'destination charging points' for occasional short-term use (incl. at hotels, airports, supermarkets). In Brussels, a 10-year concession has been granted to Pitpoint for the installation and operating of charging infrastructure. One of the conditions is a maximum kWh price.
In Madrid, the municipality is purchasing fast charging infrastructure for a number of locations. For this, agreements have been concluded with transport companies to use them freely for 4 to 8 years. The companies will then be responsible for maintenance. When a company stops using the infrastructure, the municipality will take over the maintenance. One of the first charging stations for goods vehicles has been installed at a market (MercaMadrid). Companies have small depots here and can make use of charging infrastructure. In addition, the municipality is entering agreements with service stations to install fast charging stations.

Segment name	Catering	Retail food
Brief description	Large deliveries to catering	Large deliveries of food to retail
Sectors	Catering	Retail food
Sources	Data of 256 journeys from 2 companies	Data of 127 journeys by 2 companies
Description	The deliveries from wholesalers to catering are carried out with large conditioned trucks. The approach kilometres for the deliveries are limited. Deliveries are mainly performed by wholesalers (or logistics service providers) within the municipality or region. The journeys are planned according to a milk run, with several deliveries being carried out each journey. On average, 7- 8 deliveries are made per journey. The milk run makes the journeys relatively long, up to 175 km per journey. The drop density (distance between delivery addresses) is high in the city centres, but quickly drops when deliveries are also made in the region.	Deliveries of fresh produce to the retail sector are carried out with large conditioned trucks (city trailers). Fresh produce DCs for supermarkets are based in the region, so the approach kilometres in this segment are limited. The fresh produce deliveries to the retail sector have a high volume. Each journey, 1 or 2 shops (max) are supplied. In practice, mainly point-to-point journeys are therefore planned between a DC and the supermarket. The average journey distance is 55 kilometres and the total journey time is 3:30 hours. A truck in this segment completes 2 to 3 journeys per day. An average of 30-40 rolling containers are delivered each time. At the same time, waste and packaging are returned. This means that a truck is parked at the delivery address for more than 30 minutes.
Vehicle		
Vehicle type	Heavy truck, box truck (<18 tons)	Truck (tractor unit + trailer) (<40 tons)
Conditioned (Yes/No)	Yes	Yes
Additional facilities	Tailboard	Tailboard
Journey characteristics		
Type of journey	Milk run	Point-to-point
Routing	Fixed addresses	Fixed addresses
Distance Local/regional	130 km	55 km
Distance - National	N/A	N/A
Journey time	7 hours	3.5 hours
Number of journeys per day	1 journey	2 - 3 journeys
Delivery characteristics		
Number of stops per journey	8 stops	1 - 2 stops
Distance between stops	10 km	N/A
Duration of the stops	Short stop (<30 minutes)	Long stop (>30 minutes)

Segment name	Large non-food deliveries	Small conditioned deliveries
Brief description	Large deliveries to a single address	Small conditioned deliveries to several addresses
Sectors	Retail non-food, General cargo	Catering, Retail food, Pharma/medical
Sources	Data of 24 journeys from 1 company	2 interviews/survey and data of 20 journeys from 1 company
Description	Large deliveries of non-food products are characteristic for the retail sector. These deliveries are carried out with large trucks. Due to the locations of the DCs, the journeys in this segment are both regional and national. Journey distances vary from 120 to 240 km. In practice, mostly point-to-point journeys are planned between a DC and the shops. A truck in this segment can complete an average of 2 regional journeys per day. An average of 45 - 50 rolling containers are delivered each time. This means that a truck is parked at the delivery address for more than 30 minutes.	Small deliveries of conditioned goods are carried out with delivery vans and/or light trucks. The most important sector in this segment is catering, but pharmaceutical products are also represented in this segment. Deliveries to catering and food services are mainly local. Suppliers have supply locations around Amsterdam. Deliveries of pharmaceutical products can also be national, which greatly increases the approach and exit kilometres. For both sectors, several addresses are supplied by means of a milk run. The average journey distance for local deliveries is 50 km, the total journey time is 3:30 hours and 8 to 10 deliveries are made each journey. A vehicle can complete 2 journeys per day. Journey distances for national journeys are much greater (250 km on average). More drops are performed per journey (15) and the journeys are longer. The duration of the stops is short (< 30 minutes).
Vehicle		
Vehicle type	Truck (tractor unit + trailer) (<40 tons)	Large delivery van/Light truck
Conditioned (Yes/No)	No	Conditioned
Additional facilities	Tailboard	N/A
Journey characteristics		
Type of journey	Milk run	Milk run
Routing	Fixed addresses	Fixed addresses
Distance Local/regional	120 km	55 km
Distance - National	240 km	250 km
Journey time	3.5 - 7 hours	3.5 - 8 hours
Number of journeys per day	1 - 2 journeys	2 -3 journeys
Delivery characteristics		
Number of stops per journey	7 stops	8 stops
Distance between stops	10 - 20 km	5 km
Duration of the stops	Long stop (> 30 minutes)	Stop & Go, Short stop (< 30 minutes)

Segment name	Small non-food deliveries	Service logistics
Brief description	Small deliveries of dry shipments	Performing repairs at one-off addresses
Sectors	Retail non-food, mail & parcels B2B, facilities purchasing	Construction, Service logistics
Sources	3 interviews/survey	3 interviews/survey and data of 50 journeys by 2 companies
Description	In this segment, small deliveries are made to companies. This segment consists of the retail and facilities purchasing sectors. For deliveries in this segment, larger delivery vans and light trucks are mainly used. The journeys are planned according to a milk run from a regional or local supply location. The average journey distance is 120 km (varying from 100 to 240 km). A high drop density is achieved, but the number of stops is also relatively high (20 per journey on average). The journey time varies between 3:30 and 5 hours. A vehicle can complete 2 journeys per day. The duration of the stops is short (< 30 minutes).	In this segment, (small) jobs are mainly performed on site. Examples are the installation of equipment or repairs. Many delivery vans are used for this (up to 3.5 tons). This segment has a wide variety of journey characteristics. The work is performed at locations that are visited once. The journeys can be local, regional and national. Journey distances can be as long as 280 km (outward and return). The number of stops can also vary greatly, depending on the work arrangements. In the building sector, an engineer could be working at a site all day long, while other service engineers have a maximum of 12 stops. The total journey time usually covers an entire working day. For this segment, the time spent at the work location is relatively long.
Vehicle		
Vehicle type	Large delivery van / Small box truck	Small/large delivery van
Conditioned (Yes/No)	No	No
Additional facilities	Small box truck with a tailboard	N/A
Journey characteristics		
Type of journey	Milk run	Milk run
Routing	Fixed route	One-off addresses
Distance Local/regional	100 km	45 km
Distance - National	240 km	120 km
Journey time	3.5 - 5 hours	7 - 9 hours
Number of journeys per day	1 - 2 journeys	1 - 2 journeys
Delivery characteristics		
Number of stops per journey	20 stops	8 - 10 stops
Distance between stops	2 - 5 km	5 km
Duration of the stops	Stop & Go, Short stop (< 30 minutes)	Long stop (> 30 minutes)

Segment name	**Small home deliveries**	**Waste collection**
Brief description	Small home deliveries	Collection of waste from companies and households
Sectors	Catering, food services, mail & parcels B2C	Waste processing
Sources	2 interviews/survey and 1300+ journeys by 1 company	1 interviews/survey
Description	This segment consists of mail and parcel deliveries, and home deliveries of food services and shopping. Large and small delivery vans are mainly used here (up to 3.5 tons). The journeys are planned according to a milk run from a regional or local depot. The average journey distance is 150 km, varying from 80 to 225 km. Long national journeys are generally made for deliveries of special products, like white goods, brown goods or furniture. These deliveries are carried out from a central supply location (NDC). The driver's working day is often normative for the number of stops. The journey time can rise to 7 to 8 hours. More than 100 deliveries can be made during this time. The stops for each delivery are short (stop & go or < 30 minutes).	Large trucks (refuse collection vehicles) and light vehicles with a superstructure (< 3.5 tons) are used for waste collection. The large refuse collection vehicles are used to collect household waste and commercial waste. The lighter vehicles are used to empty rubbish bins on the streets. The journeys are local and are planned according to a fixed route (milk run). The average journey distance is 40 to 50 km and the journey time is 4 hours. The limiting factors for the journey length are the volume of the vehicle and the working hours of the employees. A vehicle can be used 2 times a day.
Vehicle		
Vehicle type	Small/large delivery van	Refuse collection vehicles
Conditioned (Yes/No)	No	No
Additional facilities	N/A	Crusher/compactor vehicle or crane
Journey characteristics		
Type of journey	Milk run	Milk run
Routing	One-off addresses	Fixed route
Distance Local/regional	80 km	45 km
Distance - National	225 km	N/A
Journey time	6 - 8 hours	4 hours
Number of journeys per day	1 - 2 journeys	2 journeys
Delivery characteristics		
Number of stops per journey	80 stops	Still unknown
Distance between stops	2 km	Still unknown
Duration of the stops	Stop & Go, Short stop (< 30 minutes)	Stop & Go, Short stop (< 30 minutes)

At the carrier's depot

These are the locations where the vehicles are parked during the time that they are not used for transport. Examples are companies with large numbers of vehicles, like (building) wholesalers, warehouses and logistics service providers and DCs.

The sites are generally located at industrial sites, both on the edges of the urban area and spread out over the AMA region (for regional suppliers, wholesalers and distribution companies). Some of the logistic movements to the AMA also involve national journeys that come from outside the AMA. The locations of distribution centres and industrial sites where several warehouses and wholesalers are based play a key role, as relatively large volume flows (and traffic movements) are generated here, both incoming and outgoing.

Logistics industrial sites

A number of logistics industrial sites are located around the A10 ring road. These strategic locations are easily accessible to suppliers and have short journey distances to the city centre. Figure B.2.2 gives an overview of the logistics industrial sites around Amsterdam. Trade, logistics and distribution centres are well-represented here. The current number of businesses based at each site is shown.
When the vehicles fleets of these companies are electrified, a sharp increase in the demand for charging infrastructure can be expected. Vehicles are charged overnight at these locations. Due to the available space at the sites and their strategic location, the logistics industrial sites also provide opportunities for operating public car parks with charging stations. Various logistics parties will then be able to use these to recharge their batteries during the day.

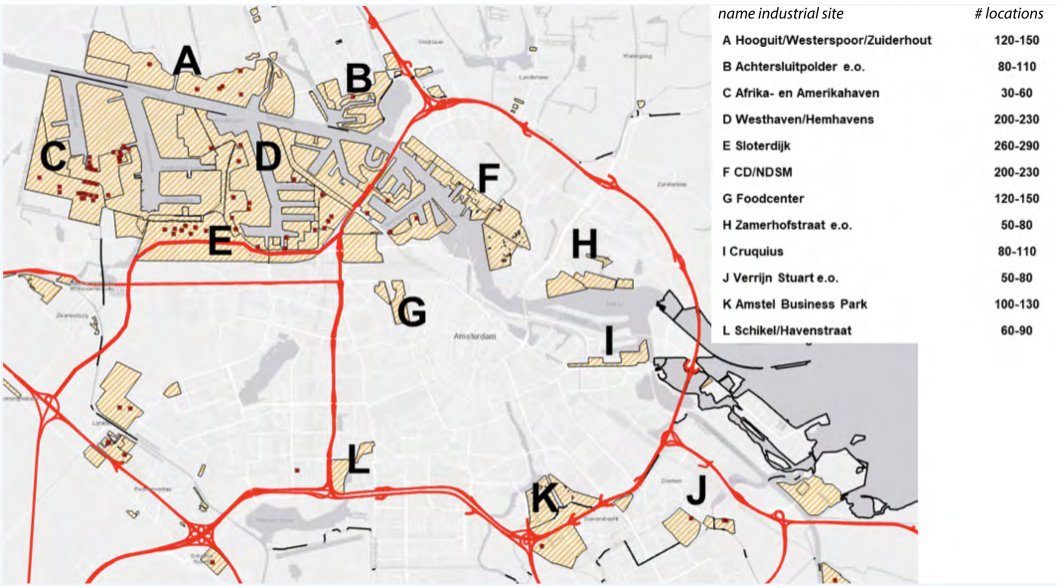


Figure B2.2
Strategically located logistics industrial sites along motorways[29].

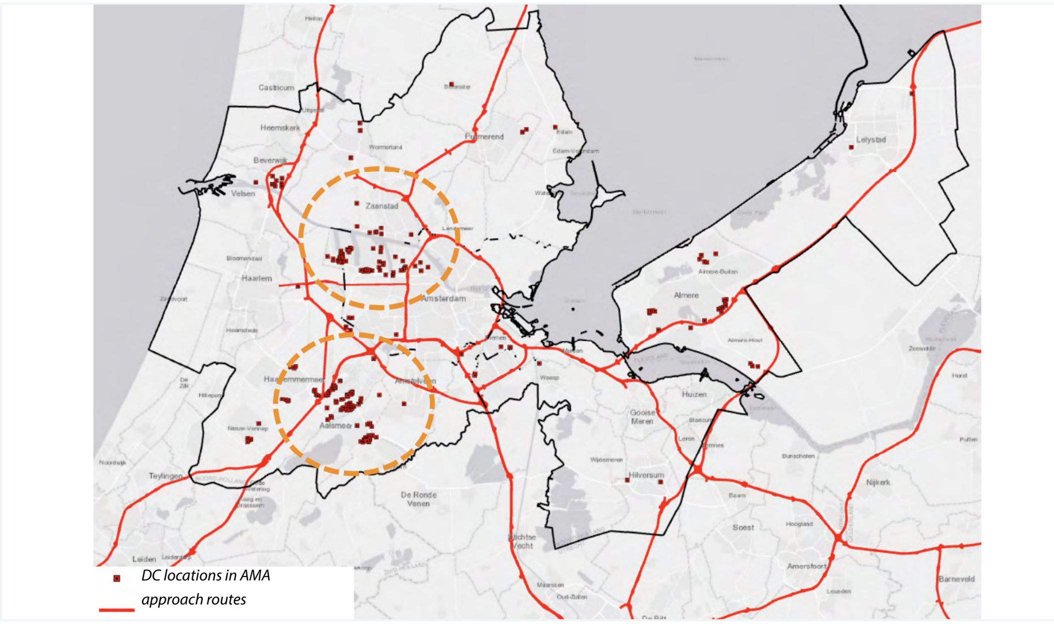
[29] *Ministry of Infrastructure and the Environment, edited by BCI 2019.*

DCs in the AMA

Figure B.2.3 shows an overview of the distribution centres in the AMA region. Large transport flows will also depart towards Amsterdam city centre from the DCs. The DCs are spread out over the whole region, with concentrations to the south-west and north-west of Amsterdam and located close to motorways. They are mostly located outside the urban area, so these locations may also have space for private charging points or public car parks with charging stations.

When the vehicle fleets of the DCs are electrified, overnight charging may become a key part of the charging strategy. The locations also provide an opportunity for brief charging of electric vehicles from other logistics service providers that arrive to drop off or collect cargo. If a DC is further away from the final destination in the city centre, the vehicle would have to be briefly recharged along the approach route.

Figure B2.3
Overview of DC locations in the Amsterdam Metropolitan Area[30]



Along the main route towards the region

For long national journeys from and to the AMA, the approach routes run via the trunk road network. These journeys start from a DC or production site elsewhere in the country; larger trucks with a high energy requirement are mainly used for these. If the battery capacity of these vehicles is insufficient to cover the distance, they will have to be recharged during the journey. This is done along the approach route at service stations, rest areas (car parks) and Logistical Uncoupling Points (LUPs) .

Regarding rest areas, a distinction is made between public rest areas - these are owned by Rijkswaterstaat - and commercial rest areas, which can be found in locations such as the Port of Amsterdam or at Schiphol.

[30] *Ministry of Infrastructure and the Environment, edited by BCI 2019.*
[31] *For an explanation, see www.truckbreak.nl.*

In some cases, there is an option to recharge at a carrier's home base if it is located along the approach route. One example of such a journey profile can be found in the building sector. Here large vehicles are driven directly from the industrial production sites located throughout the country to wholesalers and DIY stores (mostly at industrial sites around the A10 ring road) or to building sites in Amsterdam city centre. This involves longer journeys. Vehicles can be recharged (incl. fast charging) in the interim along the approach route.

Figure B.2.4 below presents an overview of the approach routes and the nearby rest areas, service stations and LUPs. The motorways that branch off the A10 ring road around Amsterdam were used as approach routes.

Figure B2.4
Public rest areas, service stations and LUPs along the trunk road network[32].

At unloading addresses and destination locations in the city

While unloading at the delivery addresses in Amsterdam city centre, the vehicle is parked for a longer or shorter period of time. The battery can be recharged during these stops, but that will mainly be interesting for the longer stops (more than 30 minutes) and if this is possible at the unloading location.

Many unloading addresses are in the sectors of retail, catering, wholesalers, larger office buildings and at building sites. For unloading locations we have defined three subcategories, which are described below:

1. Public unloading locations, catering and shop concentrations

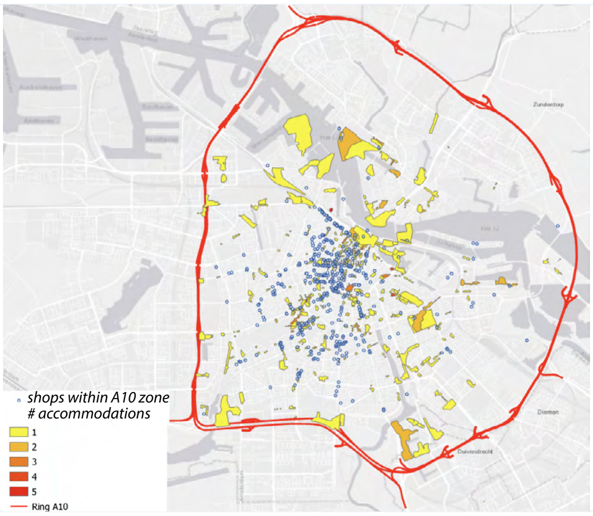
Catering establishments and shops are found in concentrations in the city centre and are frequently provided with new supplies. Distribution vehicles usually supply these sectors one address at a time, but in case of concentrations several establishments could also be supplied using a public unloading location. In these public locations, electric vehicles could then be charged during the unloading time. One example is supplying the catering sector, whereby the service wholesaler delivers to several pubs and restaurants on the same square or street section. This case was used in Utrecht and Maastricht, among other places, for separate power supplies in refrigeration units. In current practice, suppliers usually still deliver to the doors of catering establishments and shops.

[32] *Source: Truckbreak.nl, Directlease.nl, edited by BCI 2019.*

[33] *In the future, these could become so-called service lanes for coaches, taxis and logistical distribution in traffic-restricted zones.*

Figure B.2.5 presents an overview of catering and shop concentrations. There is a high density of shops and catering establishments (accommodation) in the city centre; the density and concentration drop outside of it. There are more catering establishments outside the city centre and they are more widely distributed.

Figure B2.5
Public unloading locations at catering and shop concentrations[34].



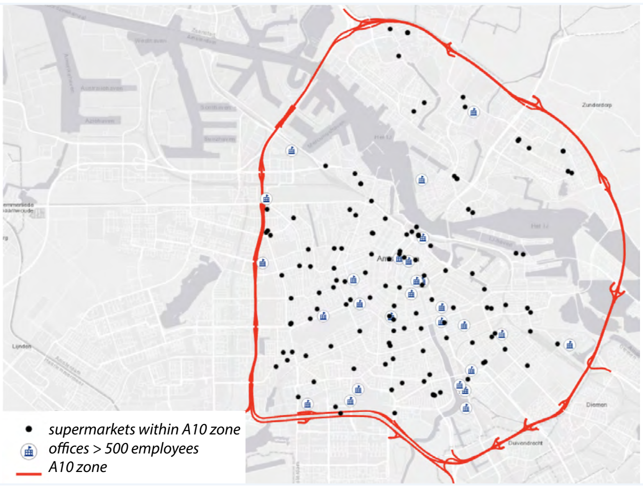
2. Supermarkets and large office buildings

Larger supermarkets with a loading dock[35] present an opportunity for electric trucks to recharge while unloading. This involves journeys where a full truck is unloaded at a major buyer. These occur in retail, e.g. at supermarkets or multistore chain sites.

Large office locations with 500+ employees are usually destination locations for parcel services, delivery vans or service engineers. These locations have space for car parks with charging stations to charge their own vehicle fleet and visitors can also (briefly) charge here during their visits.

An overview of supermarkets and large office buildings can be seen in Figure B.2.6. It shows an even distribution of supermarkets over the city. The northern section of the A10 has relatively few supermarkets. Large office buildings are spread out over the city, but are highly concentrated on the Southern Axis, the southern section of the A10 zone.

Figure B2.6
Supermarkets and large office buildings.

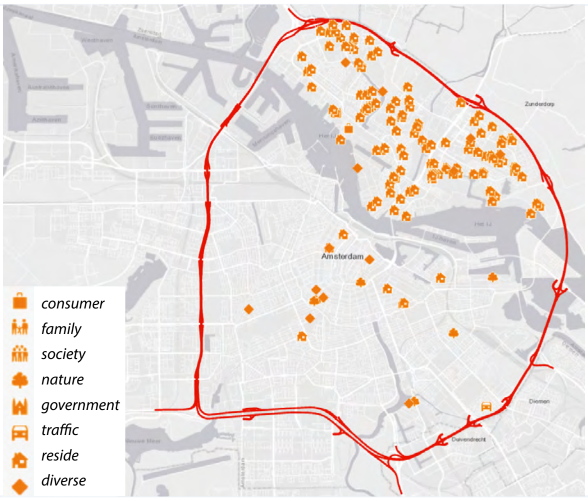


[34] *Source: KvK, LISA, Municipality of Amsterdam data portal, customised and edited by BCI 2019.*
[35] *Loading and unloading a trailer requires a maximum of 30 to 45 minutes.*

3. Building sites up to 2030

For the next couple of years towards 2030, a number of municipal permits have already been issued for new developments. These are shown in Figure B.2.7. The future building sites can be derived from this. It will be possible to charge electric building vehicles at these building sites. After completion, the building sites will transform into residential areas, which will already have an energy requirement for which the grid operator will have to increase the capacity of the power grid; a possible promising strategy would be to install this already before the building site is created.

Figure B2.7
Building sites[36].



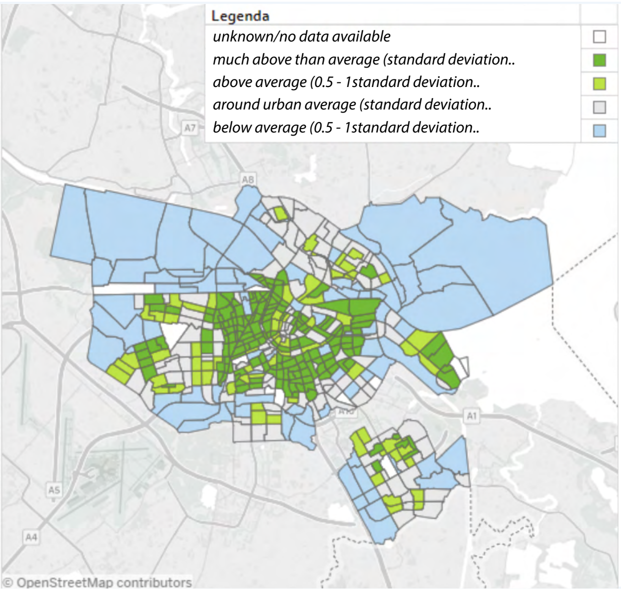
In residential areas

Sectors such as parcel delivery services and building and maintenance include employees or self-employed persons who park their company vehicles in their own residential area and can recharge them there (for a prolonged period) overnight (note: these employees do not always live in the Amsterdam districts). In addition, residential areas are destinations for parcel services, delivery vans and services like service engineers.

Figure B.2.8 presents the housing density within the City of Amsterdam: the higher the concentration of residents, the higher the demand for electric charging infrastructure will be both for passenger cars and for vehicles for commercial services.

Figure B2.8
Concentration of residents.

Indicator: population density
Source: Division of basic information/OIS.
Reference date:
January 1 (published yearly)
Code in BBGA: BEVDICHT
Definition: Number of residents per square kilometre of land.
The reference date of the number of residents is January 1in the year of reference, the reference date of the area is January 1 in the year of reference minus 1.



Appendix 3.4.A What you should know about: Charging station technology and usage

A good understanding of the challenges associated with a (large) network of electric charging points requires a rough idea of the technology used.

AC-DC

Batteries can only be charged with direct current (DC). However, the public (230V) mains use alternating current (AC). All the low-capacity charging stations (up to 20 kW) are alternating current models. Converting alternating current into direct current requires a converter. This converter is (usually) permanently mounted to the vehicle. A separate unit can cost up to €8,000. For charging stations with a capacity of 50 kW and more, direct current generally needs to be used.

High power levels

Providing higher power levels requires a higher current and therefore leads to greater resistance if the cable diameter remains the same. The effects of greater resistance include rising temperatures in the charging cable. To prevent this, thicker cables, higher voltages and/or cooling systems are used. However, the connectors (plugs) used for systems of up to approx. 150 kW are unsuitable for higher power levels. Vehicles that want to make use of both systems will then also have to be equipped with both connector types.

Currently there are three widely used systems for electric charging, namely:

- CHAdeMO is the trade name of a fast charging system for batteries of electric vehicles with a capacity of up to 62.5 kW at 500V and 125A (direct current), which makes use of a special electrical connector. A new version (CHAdeMO 2.0) is suitable for a maximum of 400 kW at 1000V and 400A DC. There are initiatives to turn this system into an industry standard (as part of IEC 62196);
- The Combined Charging System (CCS) relates to recharging electric vehicles using a maximum of 350 kW (Combo 2 plug type). In 2014, the European Union made the use of Combo 2 connectors mandatory within European charging networks.
- The Tesla Supercharger is a 480-volt DC fast charging station built by Tesla Inc. and intended for all of their fully electric vehicles. Each Supercharger has a connector with a maximum power of 135 kW (DC).

Figure B3.1
Various connectors.

from left to right:
CHAdeMO (IEC 62196 configuration AA, DC)
IEC 62196 combo2 (DC only)
IEC 62196 type 2 (AC).

Charging capacity classes

For electric goods transport, we will limit ourselves here to charging stations with charging capacities of up to 350 kW. The upper limit of the capacity is, however, expected to be raised quickly in the near future (within 3 years). Especially as heavier trucks become available (with batteries of 350 kW and more), there will be demand for this. A simple calculation tells us that a truck with a 350 kW battery using a 350 kW charging station can be charged in one hour (taking 350 kWh, although this takes longer in practice). For a realistic average consumption of 1 kWh per kilometre, the maximum range of the vehicle will then be 350 kilometres. However, as the optimum use of batteries lies between 20 and 80% of the battery capacity, the actual range will be about 210 kilometres.

On the market, charging solutions are often subdivided by power class. For passenger vehicles, delivery vans and (light) trucks, this varies between 3.7 kW (single-phase home charger), 10 to 20 kW (many public chargers), 50 to 150 kW (current fast charging standards) and future standards of approx. 350 kW (Ionity network). For heavier goods transport, the charging capacity starts at approx. 350 kW, but may rise to 800 kW to 1 MW (Tesla Semi[38]).
On an international level, attempts are being made to create a standard classification of charging stations by power class, e.g. through the Charin initiative[39].

Charging speed

The charging speed of a battery depends on several factors, including the capacity or charging speed of the charging station and that of the battery itself.
However, these speeds are commonly not used all the time. If the battery pack is empty or almost full, the charging speed will decrease (see Figure B.3.2). This is possibly not an issue, as charging from completely 'flat' to completely full would hardly (be allowed to) happen in practice (due to degradation of the battery). The optimum usage cycle of a battery lies between 20% and 80% of its charging capacity. Using a battery both below 20% capacity and above 80% capacity is damaging and has a very negative effect on the battery’s lifespan. During long journeys it is therefore better for the battery to stop a few more times rather than continuing until it is empty.

Figure B3.2

from left to right:
EV box (22 kW)
Fastned (50 kW)
Heliox (150 kW)

[37] *https://ionity.eu/.*
[38] *www.tesla.com/nl_NL/semi?redirect=no.*
[39] *www.charinev.org/.*

Appendix 3.4.B TCO calculations

Table B.3.3 presents the costs and the calculation basis for the AC3.7 and AC 20 kW charging stations. The lowest capacity charging station is basically only installed at people's homes. The AC20 is installed both at home and in the public space, often with 2 sockets. This makes its actual charging capacity 11 kW for simultaneous use. In addition, many AC20 charging stations are installed at business sites. Some cost items are irrelevant to certain charging station types. The item will then be set to zero.

Table B3.3
Overview of the TCO for low-capacity charging stations

	TYPE DESIGNATION USAGE TYPE	AC3,7 AT HOME	AC10 PUBLIC	AC20 PUBLIC	AC20 PRIVATE
Plaatsing					
Inkoopprijs paal	one-off	949	2.200	2.200	2.200
Locatiebepaling, engineering, project-management	one-off	270	580	580	270
Civil engineering works/installation	one-off	0	350	350	350
Connection costs from grid operator	one-off	0	690	690	0
Total	**one-off**	**1,219**	**3,820**	**3,820**	**2,820**
Depreciation period	year	10	10	10	10
Total	**per year**	**122**	**382**	**382**	**282**
Operating costs					
Periodic costs for grid connection	per year	0	305	1,000	0
Communication costs	per year	13	30	30	30
Insurance premium (damage)	per year	0	10	10	10
Maintenance/repairs	per year	13	230	230	100
Service in the event of user problems	per year	0	25	25	25
Total	**per year**	**25**	**600**	**1,295**	**165**
Financial costs					
Supplier charges (purchasing)	€/kWh	0.08	0.06	0.06	0.07
Energy tax	€/kWh	0.13	0,05	0,05	0,06
Total (excl. VAT)	**€/kWh**	**0.21**	**0.11**	**0.11**	**0.13**
Total costs	**'fixed' per year**	**147**	**982**	**1,677**	**447**
and	**'variable' per kWh**	**0.21**	**0.11**	**0.11**	**0.13**

Table B.3.4 gives an overview of the costs for high-capacity charging stations. These are the FC50, the HPC150 and the HPC350. When considering the data, it should be borne in mind that these charging stations are partly about to be rolled out on a larger scale. Reliable, freely available information about costs is therefore limited.
For the high-capacity charging stations or solutions, a distinction can also be made between charging points in the public space and at enclosed (business) sites. Regarding the cost data, it should be noted that any grid reinforcements (and the costs thereof) that may be necessary, such as transformers, are not included in the overview.

Table B3.4
Overview of the TCO for high-capacity charging stations.

TYPE DESIGNATION		FC50	FC50	HPC150	HPC150	HPC350	HPC350
	USAGE TYPE	PUBLIC	PRIVATE	PUBLIC	PRIVATE	PUBLIC	PRIVATE
Installation							
Station purchase price	one-off	25,000	25,000	55,000	55,000	140,000	140,000
Location selection, engineering	one-off	2,625	1,250	5,500	8,250	14,000	21,000
Civil engineering works/ installation	one-off	3,125	2,750	3,875	2,750	6,000	7,000
Connection costs from grid operator	one-off	750	0	2,250	0	11,250	0
Total	**one-off**	**31,500**	**29,000**	**66,625**	**66,000**	**171,250**	**168,000**
Depreciation period	year	10	10	10	10	10	10
Total	**per year**	**3,150**	**2,900**	**6,663**	**6,600**	**17,125**	**16,800**
Operating costs							
Grid connection costs	per year	1,196	978	2,419	1,003	4,966	2,145
Communication costs	per year	0	0	0	0	0	0
Insurance premium (damage)	per year	997	997	2,217	2,217	5,794	5,794
Maintenance/repairs	per year	1,495	1,495	3,326	3,326	8,690	8,690
Service in case of problems	per year	0	0	0	0	0	0
Total	**per year**	**3,688**	**3,470**	**7,963**	**6,546**	**19,450**	**16,629**
Financial costs							
Supplier charges	€/kWh	0.06	0.06	0.06	0.06	0.06	0.06
Energy tax	€/kWh	0.05	0.06	0.04	0.02	0.04	0.02
Total (excl. VAT)	**€/kWh**	**0.11**	**0.12**	**0.10**	**0.08**	**0.10**	**0.08**
Total costs	**'fixed' per year**	**6,838**	**6,370**	**14,625**	**13,146**	**36,575**	**33,429**
and	**'variable' per kWh**	**0.11**	**0.12**	**0.10**	**0.08**	**0.10**	**0.08**

Hardware costs: the price of the charging station itself

- The prices for home chargers (AC3.7) and public chargers of up to 20 kW are published and the cost benchmark of the NKL provides a good reference for these . Prices vary between €900 (home chargers) and €2,200 (AC10-20).
- Prices for fast chargers are more diffuse and more difficult to find out, mostly because this is still a small market (especially the 150+ kW charging stations). Furthermore, market parties usually invest in a network, whereby the purchase price of the charging station does not necessarily cover the actual hardware costs. Based on quotations, interviews and literature, prices of approx. €25,000 (FC50) to €140,000 (HPC35) are used.
- Depreciation period: The investment costs must be spread out over the number of years that the hardware is expected to be used in the form of depreciation costs. However, in view of the 'newness' of this equipment, only a limited amount of verifiable data is available. The depreciation period is currently expected to be between 10 and 15 years. However, in view of the rapid developments in the field of charging technology, the shorter depreciation period of 10 years would appear to be more obvious. For this reason, the latter number (i.e. an economic life of 10 years) was used in the calculations.

[40] *www.nklnederland.nl/projecten/resultaten/benchmark-2016-kostenanalyse-laadinfrastructuur/.*

Installation costs

This (one-off) cost item mainly applies to public charging and fast-charging stations, and includes location selection, creation of a parking space (in cities), grid operator costs, contractors' installation costs.

- Installation costs are mainly relevant for public charging stations (where the location has to be selected and a permit has to be issued by municipalities) and fast charging stations in the public space. Especially (i) grid connection costs from the grid operator and (ii) installation costs from a contractor may increase the price of a charging station considerably (or more than double it in case of public stations AC10-20).
- Installation costs at industrial sites are considerably lower, partly because there is generally no need to perform excavation work (charging points are installed on walls where possible) and no additional grid connection is required. A grid reinforcement would only be required if many charging points or high-capacity charging stations are to be installed.
- For home chargers (including models that can be 'wall-mounted') only the contractor costs for the installation are added to the purchase price of a charging point.

In the TCO calculations, averages were used for installation costs in a few cases. This mainly concerns integration costs for fast chargers. This type of charger is systematically installed in groups, in which case only one connection or power supply is required. The actual costs therefore depend on the number of stations being installed. In addition, specific integration costs are also considered, including the laying of cables to a substation, which is sometimes required, etc. For this, a new situation-dependent calculation is performed each time in practice. Additionally, the installation of stations in rural areas is many times cheaper than in Amsterdam city centre.

Operating costs

These recurring costs include periodic costs for the grid connection (paid to the grid operator), maintenance costs, insurance and service in case of malfunctions.

- For public stations (AC10-20), the most important part are the annual grid connection costs. The biggest difference between AC10 and AC20 chargers is that the AC10 requires a 3 x 25A connection (costs 300-500 euros, depending on the grid operator). The AC20 charging station requires a higher capacity 3 x 35A connection (costs 800-1200 euros). In addition, there are periodic costs for maintenance, communication (data), faults and service and insurance[41].
- A number of these costs do not apply to stations installed on private land. For low capacities, chargers can use the current grid connection directly without additional equipment, so the annual costs for the grid operator do not increase. For home chargers, the price of insurance and maintenance is often included in the purchase price. A back-office subscription can often be taken out for usage data, to claim expenses from an employer and in some cases for smart control of charging.
- Relatively little is known about the operating costs of fast chargers and charging stations of more than 150 kW. This has various reasons, like commercial interests (FC50) and limited numbers (HPC150 and HPC350). Grid connection costs will be higher compared to the low-capacity charging stations (indicative prices are available from grid operators). Increasing connection costs mainly apply if fast chargers are added and the grid load increases. This may lead to the necessary integration of buffer systems to absorb peaks in power consumption. In view of the uncertainties, ranges were used for the cost calculations for charging stations.

[41] *www.nklnederland.nl/projecten/resultaten/benchmark-2016-kostenanalyse-laadinfrastructuur.*

Energy costs

These are the costs paid to the energy supplier for the supply of electricity. The variable costs within the TCO mainly consist of this electricity purchasing (incl. taxes).

- For home chargers, we have assumed a price of €0.21 per kWh (approx. €0.13 of which is energy tax).
- For chargers on private land, the energy price paid by the logistics company applies. As these are often bulk consumers, these energy costs and the energy tax are significantly lower than for small consumers. We have assumed a price of €0.11 per kWh for AC10-20.
- The purchase price of electricity for the FC50-HPC150/350 depends strongly on the bulk consumption amount. For a consumption of 100 MWh per charging station per year, the price drops to about €0.08 per kWh. Note that the commercial price of a kWh for public charging stations can be both higher (along motorways) and lower (the mandatory maximum rate in Amsterdam) than the (gross) purchase price.

Appendix 3.4.C: Sales quantities for each type of charging station

For the high-capacity charging stations in particular, (directly) available information on this is fragmented at most. As the bottom line we decided to estimate a realistic total sales quantity for each type of charging station by multiplying the number of days it is used by the estimated number of kWh per charge. Three scenarios were used here: low, medium and high. These details are largely based on measured data for each charging station.
The following sections will cover the estimates for the annual sales quantities per scenario in more detail. Tables B.3.5 and B.3.6 present the annual quantities used to estimate the cost price per kWh.

Table B3.5
Estimated sales quantities for each type of low-capacity charging station and for three scenarios.

	TYPE DESIGNATION	AC3,7	AC10	AC20	AC20
	USAGE TYPE	AT HOME	PUBLIC	PUBLIC	PRIVATE
Low scenario	kWh/year	3,000	4,000	4,000	12,000
Medium	kWh/year	7,500	5,000	5,000	30,000
High	kWh/year	12,000	6,000	6,000	48,000

Table B3.6
Estimated sales quantities for each type of high-capacity charging station and for three scenarios.

	TYPE DESIGNATION	FC50	FC50	HPC150	HPC150	HPC350	HPC350
	USAGE TYPE	PUBLIC	PRIVATE	PUBLIC	PRIVATE	PUBLIC	PRIVATE
Low scenario	kWh/year	30,000	35,000	60,000	60,000	120,000	120,000
Medium	kWh/year	45,000	87,500	90,000	90,000	180,000	180,000
High	kWh/year	60,000	140,000	120,000	120,000	240,000	240,000

[42] *Energy tax varies between 9.8 cents/kWh (small consumer), 5.3 cents/kWh (public charging stations and connections of 10,000-50,000 kWh) and 1.4 cents/kWh (50,000-10,000,000 kWh) and 0.5 cents/kWh (10,000,000 kWh+). www.nuon.nl/grootzakelijk/klantenservice/belasting-subsidies/tarieven-energiebelasting/*

Appendix 3.4.D: Basic assumptions used for the rate calculations

Home charger (AC3.7)

A home charger on someone's driveway is basically only used by the logistics entrepreneur. The amount of electricity used depends greatly on someone's driving behaviour. Taking into account one charging session per day (night) and recharging using 10 ('low'), 25 ('medium') and 40 ('high') kWh respectively and 300 'working days' (including private use), 7,500 kWh is purchased every year in the 'medium' scenario. The total charging costs will then be approx. €0.22/kWh. For less intensive use, this could rise to approx. €0.25 per kWh.

Public charging (AC10-20)

In case of public charging, the charging costs are regulated by the municipality that issued the permit. Prices in the four largest cities are set to €0.33 per kWh, incl. VAT[43] i.e. €0.28 excl. VAT. For public charging points in less regulated cities (where, for example, the municipality does not make a financial contribution to the installation of charging points), prices may be higher[44]. In some cases, starting rates (of up to €0.61 per transaction) or hourly rates (of up to €0.35 per kWh) are charged[45]. Service providers may also charge on margins through their cards (on top of the price asked for the charging station). This may result in (significantly) higher prices. We assume that logistics entrepreneurs will be able to handle this smartly and will not (want to) pay more than €0.33 per kWh.

Charging point on private land (AC20)

The option for many companies is to install a charging station on their own land with a capacity of 11 to 22 kW (AC10-20). The quantity of electricity purchased per charging station depends on the distances covered by the vehicles, how often they recharge on their own land and whether several vehicles can make use of it. We assume that each charging point has 2 sockets and that each day 1 vehicle can be charged per socket (and that it is on the road the rest of the day). The distances covered will then dominate annual consumption, varying from 12,000 to 48,000 kWh per year. This translates into charging costs of between €0.14 and €0.17 per kWh. This is significantly cheaper than charging at home (and up to twice as cheap as public charging).

Fast charging (FC50, public)

Public use: The assumptions for quantities purchased are based on data from fast chargers in Amsterdam (250 - 400 kWh per day). Because of taxis, these figures are much higher and may not be (entirely) representative for the use of these charging stations. In other words: These are upper limits. The impression is that even having a lower limit of 120 kWh per day could currently be considered quite optimistic. Depending on the level of use, the costs vary between 25 eurocents for bulk consumers with a subscription and more than 50 eurocents for one-off customers.

Fast charging (FC50, private)

Installing a fast charger on their own land has benefits for logistics companies where vehicles not only have to be recharged overnight, but also during the day (e.g. taxi firms) or where delivery vans/trucks regularly return to the company's own land (e.g. to collect orders). Speed is important in that case and the recharging of the battery should not restrict operations.

[43] *It is known that the business case for operators will not be positive at this price in many cases. In order to guarantee a low price for residents, municipalities contribute to the price.*

[44] *www.idolaad.nl/gedeelde-content/blogs/robert-van-den-hoed/2016/varierende-kosten-om-te-laden-1-appels-en-peren.html?origin=3XGWbXwVSIO8xqssUpoN9g*

[45] *www.idolaad.nl/gedeelde-content/blogs/rick-wolbertus/2016/laadtarieven.html?origin=3XGWbXwVSIO8xqssUpoN9g*

Appendix 3.4.E Considerations regarding TCO calculation

To include the charging costs as a selection criterion, a TCO calculation was prepared for charging stations (charging station TCO). The most important result is the cost price per kWh for a certain type of charging station. This figure is then compared to the rates per kWh charged by commercial providers. High energy costs of specific charging solutions could make businesses decide to charge electricity in different ways or to invest in their own charging infrastructure. The 10 charging solutions described are used to determine the TCO of charging stations. The total costs of a charging station consist of annual costs (depreciation on the investment and operating costs) and the costs for purchasing electricity. The end result is an overview for each charging station type of the fixed costs per year and the variable costs per kWh. Table B.3.7 gives a summary of the results. A number of caveats can be made for these calculations, which will be covered in the next paragraphs.

The price paid by the user per kWh is roughly (i) the electricity price that the user pays to the energy supplier and (ii) the fixed costs, such as the depreciation of the charging point (including installation). A TCO calculation must be performed for (the cost price of) private charging stations. There is a range of companies that offer these charging solutions (incl. EV Box, Alfen, Allego, ABB).

It would seem obvious to assume that charging at a home charging station would be subject to a different (electricity) price than charging at a public fast charger. However, the relationship between these costs is not transparent. Only limited information about this is communicated by commercial suppliers, which is logical. For logistics companies or businesses it therefore remains to be seen, in terms of the TCO of an electric vehicle, what the best location is to charge the battery. And therefore whether investments should be made in a charging facility at home or at work. And if so, what the desired charging station capacity would be.

Appendix 3.4.F TCO fixed and variable

Table B3.7
TCO of charging stations.

CHARGING STATION TYPE	FIXED COSTS PER YEAR (€)		VARIABLE COSTS PER KWH * (€)	
Private charging stations				
AC3.7 Home charging	147	(131 / 163)**	0.21	(0.20 / 0.21)
AC20 Company charger	447	(438 / 456)	0.13	(0.11 / 0.15)
FC50 Company fast charger	6,370	(5,400 / 7,340)	0.12	(0.11 / 0.13)
HPC150 Company super-fast charger	13,146	(11,500 / 15,600)	0.08	(0.07 / 0.09)
HPC350 Company ultra-fast charger	33,429	(31,500 / 35,500)	0.08	(0.07 / 0.09)
Public charging stations				
AC10	982	(887 / 1,077)	0.11	(0.10 / 0.12)
AC20	1,677	(1,500 / 1,850)	0.11	(0.10 / 0.12)
FC50 Fast charger	6,838	(5,750 / 7,925)	0.11	(0.10 / 0.12)
HPC150 Super-fast charger	14,625	(12,650 / 16,600)	0.10	(0.08 / 0.11)
HPC350 Ultra-fast charger	36,575	(32,200 / 40,950)	0.10	(0.08 / 0.11)

* *The price per kWh depends greatly on the total annual consumption. The calculation of the rate stated here is based on an average utilisation of the charging station in question. See also Appendix 3.4.C.*

** *The spread in the data obtained (the 'input figures') is quite broad, especially for the fixed costs. This is mainly related to the developments in charging stations (higher capacities in particular), which have only recently started to gain momentum. That is why the results of the various charging solutions also include the spread in the results.*

Appendix 3.4.G Cost price at given annual consumption

Table B3.8
Overview of the cost price per kWh for the users of low-capacity charging stations.

	TYPE DESIGNATION	AC3,7	AC10	AC20	AC20
	USAGE TYPE	AT HOME	PUBLIC')	PUBLIC')	PRIVATE
Low scenario	euro/kWh	0.25	0.33 (0.36)	0.33 (0.53)	0.17
Medium	euro/kWh	0.22	0.28 (0.31)	0.28 (0.45)	0.14
High	euro/kWh	0.22	0.28 (0.27)	0.28 (0.39)	0.14

') For this type of charging station, the user pays a fixed rate (the maximum sales rate) set by the local government (Municipality of Amsterdam). The TCO cost price rate is stated in between brackets. If the cost price exceeds the sales price, funding will be required for the provider to have a positive business case.

Table B3.9
Overview of the cost price per kWh for the users of high-capacity charging stations.

	TYPE DESIGNATION	FC50	FC50	HPC150	HPC150	HPC350	HPC350
	USAGE TYPE	PUBLIC')	PRIVATE	PUBLIC')	PRIVATE	PUBLIC')	PRIVATE
Low scenario	euro/kWh	0.50 (0.34)	0.30	0.50 (0.34)	0.30	0.59 (0.40)	0.36
Medium	euro/kWh	0.37 (0.26)	0.19	0.37 (0.26)	0.23	0.42 (0.30)	0.27
High	euro/kWh	0.25 (0.23)	0.17	0.24 (0.22)	0.19	0.27 (0.25)	0.22

') For this type of charging station, the user pays a fixed rate (the maximum sales rate) set by the government. The TCO cost price rate is stated in between brackets.

Appendix 3.4.H. Developments regarding charging stations

Developments regarding the use of electric vehicles are very fast. (Almost) all major manufacturers of 'classically fuelled' vehicles are also working on electric vehicles in one way or another. This will not only increase the number of available vehicles; large gains are also being made with regard to battery technology. All of this makes it difficult to paint a picture for the next 10 years. A few developments are briefly mentioned below.

Electricity: cost price, taxes

The most important variable costs of an electric vehicle are the energy costs or: the number of kWh required multiplied by the cost price per kWh. It may seem very obvious that a vehicle with a larger battery has higher energy costs than a vehicle with a smaller battery. In practice, however, it is not that simple, as the cost price for one kWh varies quite a bit with the total quantity purchased. This price varies from more than 20 eurocents for a small consumer to about €0.075 for a bulk consumer (see Table B.3.10).
Providing a picture of the future price development is not easy either, because several factors can be distinguished, which partially have an opposite effect on the price.

These factors are (see also Table B.3.10):

- **Supply price:**
  This is the 'net' electricity price charged by the supplier. This price mainly consists of a fee for generating and transporting the electricity. It is currently at about €0.06 per kWh and, based on trend analysis, may drop to almost €0.04 per kWh in 2030.
- **Energy tax and sustainable energy storage:**
  In 2018, the total for this tax and storage was over 10.5 eurocents per kWh for small consumers and about 0.2 eurocents for bulk consumers. The future development of this cost item depends on the government policy with regard to this. Making reliable statements about this regarding future developments is very difficult. It is clear, however, that if (much) less fossil fuel is used, the government will lose a key source of income, i.e. fuel duty. They would want to or should compensate for this.
- **VAT rate:**
  The VAT on the total amount per kWh is 21%. For the time being, it is assumed that this rate will remain the same for the next couple of years. A small consumer currently pays VAT of almost 3.5 eurocents per kWh and a bulk consumer about 1.3 eurocents.

Table B3.10
Overview of the cost price per kWh by consumption category (status in November 2018)[46].

	PRIVATE			BUSINESS	
	0 to 10 MWh	10 to 50 MWh	50 to 10,000 MWH	>10,000 MWh	>10,000 MWH
Supply price	0.06000	0.06000	0.06000	0.06000	0.06000
Energy tax	0.10458	0.05274	0.01305	0.00116	0.00057
Sustainable energy storage	0.00100	0.00100	0.00100	0.00100	0.00100
Total excl. VAT	0.16558	0.11374	0.07405	0.06216	0.06157
Total incl. VAT	0.20035	0.13763	0.08960	0.07521	0.07450

Promoting the use of electric vehicles

For the same equipment, an electric goods vehicle will have a higher price per kilometre than a diesel version. To encourage the use of electric goods vehicles, a number of instruments are available.
The first option is to lower the cost price, e.g. by granting investment subsidies. However, covering the difference in cost price for a light truck would require an amount of up to €15,000 per year. If the costs for constructing and maintaining charging infrastructure should also be included, this amount can rise to €35,000[47] per year.
Another option is to introduce access restrictions for non-electric vehicles. A complete ban is also possible, but in that case customers will have to pay a 10 to 20% higher transport rate. That is the difference in cost price between an electric and a diesel version of a light truck.

[46] *CBS StatLine - Natural gas and electricity, average prices for end consumers.*
[47] *Panteia, 2018*

Technical limitation

Without claiming to be exhaustive in this regard, insofar as that is even possible, we would still like to cover a limitation regarding usage. A key bottleneck is the charging speed.
A 10 kW charging station, for example, can charge a maximum of 10 kWh in one hour. For higher capacity batteries, the charging time will then quickly become unacceptable. Despite the relatively low price per kWh of such a charging station, this charging solution will not be selected after all. On the other hand, high-capacity (and as a result, fast) charging stations require high investment costs. If these stations are not used sufficiently often, the (allocated one-off and operational) costs per kWh will rise very quickly.
Graph 5 presents the development of the TCO cost curves for two public charging stations.
All of this is seen from the viewpoint of the provider of the charging facility and is therefore basically not related to the sales price used for a kWh. It can be clearly seen that for lower annual amounts consumed, the lower capacity AC20 charging station is cheaper than the higher capacity FC50. From about 10 MWh, however, a second lower-capacity charging station will be required to cover the energy demand. Certain cost-reducing effects are included here. After all, it can be expected that some of the installation costs to no longer apply to the second installation, like the costs for the power grid connection.

Vehicle characteristics

The detailed information regarding the vehicle and motor characteristics was explained earlier in this report (see Section 3.3). Not all costs stated there, however, are relevant to the model. Only the consumption (kWh/km) and the investment costs are important. The table that serves as input for the model is shown below. It takes into account the price when new, residual value, etc. Put another way, the 'investment' shown is a net price, which already includes the 'purchase-and-sale'.

Table B4.1

MOTOR TYPE	COMPATIBLE TRUCKTYPE	CONSUMPTION (KWH/KM)	INVESTMENT (€)	LIFETIME (YRS)
Motor Type 1	Small delivery van	0.23	14,954	8.00
Motor Type 2	Medium-sized delivery van	0.30	16,282	8.00
Motor Type 3	Large delivery van	0.37	23,455	8.00
Motor Type 4	Small box truck	0.77	162,000	8.00
Motor Type 5	Large box truck	0.91	202,500	8.00
Motor Type 6	Truck + trailer	1.75	243,000	8.00

Charging station characteristics

Detailed information regarding charging stations was explained earlier in this report (see Section 3.4). For the charging stations, a distinction was made between public and private charging stations. After all, the perspective is that of a logistics service provider or shipper. They will pay a variable price per kWh at a public charging station. An investment is required for a private charging station (from the shipper, customer or in collaboration with the shipper/service provider/customer). This involves fixed costs, plus variable costs (the costs for the power (€/kWh). Both of these are presented in the table below.

Table B4.2

CHARGING STATION	POWER	LIFETIME	INVESTMENT (€)	OPERATIONAL PER YEAR (€)	COST PER KWH (€)
AC3,7_Private	3.7	10	1,219	25	0.21
AC10_Public	10				0.33
AC20_Public	20				0.34
AC20_Private	20	10	2,820	165	0.13
FC50_Public	50				0.50
FC50_Private	50	10	29,000	3,470	0.12
HPC150_Public	150				0.50
HPC150_private	150	10	66,000	6,546	0.08
HPC350_Public	350				0.59
HPC350_private	350	10	168,000	16,629	0.08

Battery characteristics

Apart from costs for the vehicle and for recharging, there are also obviously the costs for the battery installed in the truck or delivery van. These are depreciation costs. However, the depreciation of a battery is a complex matter. After all, the battery has not only a certain lifespan (in years), but also a lifespan in the number of charge cycles. In this project it was decided to depreciate the battery by considering the number of charge cycles and the number of years: First of all, the price per kWh was calculated based on a depreciation using the number of charge cycles. The lifespan of the battery was then calculated in years. If this lifespan (based on the number of charge cycles) exceeds the intended lifespan (in years), the depreciation based on the number of years will be guiding. If not, the depreciation based on the number of charge cycles will be guiding.

Table B4.3

BATTERY TYPE	COMPATIBLE TRUCK TYPE	ENERGY CAPACITY	INVESTMENT (€ / KWH)	LIFETIME # CYCLI	LIFETIME (YRS)	% TO LOAD PER CYCLE
_KB_30	Small delivery van	30	287.96	3000	8	70
_KB_40	Small delivery van	40	287.96	3000	8	70
_KB_50	Small delivery van	50	287.96	3000	8	70
_MB_30	Medium-sized delivery van	30	287.96	3000	8	70
_MB_40	Medium-sized delivery van	40	287.96	3000	8	70
_MB_50	Medium-sized delivery van	50	287.96	3000	8	70
_GB_41	Large delivery van	41	287.96	3000	8	70
_GB_50	Large delivery van	55	287.96	3000	8	70
_Kba_80	Small box truck	80	287.96	3000	8	70
_Kba_120	Small box truck	120	287.96	3000	8	70
_Kba_160	Small box truck	160	287.96	3000	8	70
_Gba_120	Large box truck	120	287.96	3000	8	70
_Gba_200	Large box truck	200	287.96	3000	8	70
_Gba_240	Large box truck	240	287.96	3000	8	70
_TT_170	Truck + trailer	170	287.96	3000	8	70
_TT_240	Truck + trailer	240	287.96	3000	8	70
_TT_320	Truck + trailer	320	287.96	3000	8	70

Journey profiles

As explained previously, journey profiles consist of detailed information: many journeys with many stops, which allows the model to present a spread in the model's output as well. This information was collected in a predefined format, with each line containing one stop and including the following columns:

- **Vehicle ID:** unique identifier for a vehicle on a specific day ('vehicle-day').
- **Vehicle type:** type as explained above: delivery van, box truck and/or truck (tractor unit + trailer) including the associated size (small/medium/large).
- **Date:** date on which the journey took place.
- **Time:** time at which the delivery occurred.
- **Route/trip ID:** unique identifier for a journey. One vehicle can therefore make several journeys on a single day.
- **Origin:** description of the origin, preferably with the addition of a postcode.
- **Destination:** description of the destination, preferably with the addition of a postcode.
- **Journey distance**: distance from the previous stop to the stop in question.
- **Journey total charging time:** total journey time (where applicable).
- **Journey time:** time until stop in question.
- **Stoptime:** unloading and/or stop time.

A total of approx. 20 extensive datasets were analysed in the model. An overview of these is presented below.

Other input

Apart from the input described, three other aspects are important:

Table B4.4
Compatibility of charging stations and vehicles.

CHARGING STATION TYPE	SMALL DELIVERY VAN	MEDIUM-SIZED DELIVERY VAN	LARGE DELIVERY VAN	SMALL BOX TRUCK	LARGE BOX TRUCK	TRUCK + TRAILER
AC3,7_Private	1	1	1			
AC10_Public	1	1	1	1		
AC20_Public	1	1	1	1	1	
AC20_Private	1	1	1	1	1	
FC50_Public	1	1	1	1	1	1
FC50_Private	1	1	1	1	1	1
HPC150_Public				1	1	1
HPC150_private				1	1	1
HPC350_Public					1	1
HPC350_private					1	1

Charging at the roadside (third-party) has not been included in this overview, as no depreciation costs are included for this in the model.

Table B4.5
Number of charging actions per location type (per day).

SECTOR	HOME ADDRESS	DEPOT/HUB	CUSTOMER ADDRESS
	0	3	0
	0-1*	3	5 **
	0-1*	3	1 **
	0	3	1
	0	3	1**
	0	3	1
	0	3	1 **
	0-1*	3	0

* Depending on whether delivery van is taken home or not.
** For private addresses, this was set to 0.

Appendix 4.2.A: Starting points and model assumptions

Below you will find a list of comments, which serves as an 'information leaflet' for the model. The implication for each point is also stated:

1 Home charging vs depot charging: as included in the results, a distinction is made between charging at home (1 vehicle per day) and charging in a depot (assumption often 3 vehicles per day per charging station?). For several datasets used in the model, the distinction between home charging and depot charging was unclear, so an assessment was made of the most likely variant to be used.
2 The optimisation is done per vehicle-day. This means that for each vehicle ID, no more than one day is considered. The reason for this is that for several datasets the car registration or vehicle ID was not available.
3 Planning and overhead costs are not included in the model.
4 Energy used by construction cranes was not included for the construction sector.
5 Energy for refrigerated/freezer trucks was not included for the retail sector.
6 The effect of the tailboard on consumption was not included in the model.
7 The usefulness of the model for other cities is high. However, there may be differences regarding the cost parameters. Subsidies are available in Amsterdam, for example, which caps the electricity costs for public charging stations. Such a parameter obviously affects the model results.
8 For food retail, not all transport flows are part of the datasets analysed (fresh produce and bread are excluded).
9 The model is operational: the actual situation may yield different risk considerations or different results for investment decisions.
10 Detour kilometres and detour times (for charging at public stations) were not included in the model.
11 The model assumes that the journey profile remains the same compared to the current situation.
12 Interest/financial covenants, which could be different for larger investments (especially for electric trucks), were not included in the model as an effect.
13 Delivery vans: private transport and hired transport were not analysed.
14 Private transport: the number of charging actions per day at a private station (customer location) affects the model results. In other words, more private charging leads to lower costs, which in turn leads to even lower costs, etc. Or put another way, an amplifying effect occurs. Assumptions and validation steps were used in the model to compensate for this.
15 Optimisation is based on model costs using the necessary basic assumptions and based on the journey. In practice, a business will opt for flexibility; you invest in vehicles for 8 years, not for a shorter period.
16 Investments in charging infrastructure at shops: high level of uncertainty about investment amounts, likelihood of this actually happening, etc.

Appendix 4.2.B: Details of model output

The results for each journey profile are presented below. The company names have obviously been anonymised. The datasets marked in pink are datasets with delivery vans; the others are datasets with data from trucks.

Table B4.6
Percentage of charging actions per dataset.

DATASET NAME		# TRUCK/ DAYS	SUM OF# STOPS	AVG. DISTANCE	% HOME	% PUBLIC	% DEPOT	% CUSTOMER
Journey profile	1	2	28	336	0	36	64	0
Journey profile	2	19	161	82	56	3	0	41
Journey profile	3	23	221	142	35	2	47	16
Journey profile	4	10	66	58	67	7	27	0
Journey profile	5	17	137	148	0	16	39	45
Journey profile	6	26	273	323	0	16	12	72
Journey profile	7	30	580	138	0	32	68	0
Journey profile	8	2194	11189	329	0	31	30	39
Journey profile	9	70	844	145	0	7	78	16
Journey profile	10	23	198	153	0	4	93	4
Journey profile	11	916	7703	97	71	9	20	0
Journey profile	12	551	4330	98	67	19	13	0
Journey profile	13	60	1652	149	0	32	68	0
Journey profile	14	25	301	339	0	26	21	52
Journey profile	15	20	2726	259	0	76	24	0
Journey profile	16	411	1423	281	0	30	39	31
Journey profile	17	28730	141420	219	0	25	61	14
Journey profile	18	274	2718	140	0	13	38	49
Characteristic	1	1	8	130	0	0	25	75
Characteristic	2	1	5	140	0	0	100	0
Characteristic	3	1	7	240	0	25	25	50
Characteristic	4	1	19	80	0	0	100	0
Characteristic	5	1	62	120	0	50	50	0
Characteristic	6	1	103	160	0	75	25	0
Characteristic	7	1	8	45	0	0	100	0
Characteristic	8	1	12	150	0	67	33	0
Characteristic	9	1	12	25	0	0	100	0
Characteristic	10	1	14	100	0	0	100	0
Characteristic	11	1	8	175	0	0	100	0
Characteristic	12	1	7	100	0	0	100	0
Characteristic	13	1	5	50	0	0	100	0
Characteristic	14	1	7	240	0	25	25	50
Characteristic	15	1	19	90	0	0	100	0
Characteristic	16	1	42	100	0	0	100	0
Characteristic	17	1	12	86	0	0	100	0
Characteristic	18	1	102	45	0	0	100	0
Characteristic	19	1	17	160	0	50	50	0
Characteristic	20	1	27	80	0	0	100	0
Characteristic	21	1	82	120	0	50	50	0
Characteristic	22	1	9	225	0	67	33	0
Characteristic	23	1	7	30	0	0	100	0
Characteristic	24	1	10	100	0	0	100	0
Characteristic	25	1	13	180	0	75	25	0
Characteristic	26	1	23	240	0	67	33	0
Characteristic	27	1	3	140	0	50	50	0
Characteristic	28	1	4	80	0	0	100	0
Characteristic	29	1	8	160	0	0	33	67
Characteristic	30	1	22	240	0	67	33	0

Table B4.7
Percentage van kWh per dataset.

JOURNEY PROFILES		# TRUCK/ DAYS	SUM OF# STOPS	AVG OF TOTAL DISTANCE	% KWH HOME	% KWH PUBLIC	% KWH DEPOT	% KWH CUSTOMER
Journey profile	1	2	28	336	0	36	64	0
Journey profile	2	19	161	82	49	0	0	51
Journey profile	3	23	221	142	52	0	41	7
Journey profile	4	10	66	58	91	0	9	0
Journey profile	5	17	137	148	0	3	84	13
Journey profile	6	26	273	323	0	26	58	16
Journey profile	7	30	580	138	0	5	95	0
Journey profile	8	2194	11189	329	0	14	54	33
Journey profile	9	70	844	145	0	1	88	11
Journey profile	10	23	198	153	0	0	99	1
Journey profile	11	916	7703	97	83	7	11	0
Journey profile	12	551	4330	98	80	11	9	0
Journey profile	13	60	1652	149	0	2	98	0
Journey profile	14	25	301	339	0	9	42	48
Journey profile	15	20	2726	259	0	48	52	0
Journey profile	16	411	1423	281	0	11	52	37
Journey profile	17	8730	141420	219	0	11	77	12
Journey profile	18	274	2718	140	0	13	67	20
Characteristic	1	1	8	130	0	0	79	21
Characteristic	2	1	5	140	0	0	100	0
Characteristic	3	1	7	240	0	6	40	54
Characteristic	4	1	19	80	0	0	100	0
Characteristic	5	1	62	120	0	1	99	0
Characteristic	6	1	103	160	0	26	74	0
Characteristic	7	1	8	45	0	0	100	0
Characteristic	8	1	12	150	0	21	79	0
Characteristic	9	1	12	25	0	0	100	0
Characteristic	10	1	14	100	0	0	100	0
Characteristic	11	1	8	175	0	0	100	0
Characteristic	12	1	7	100	0	0	100	0
Characteristic	13	1	5	50	0	0	100	0
Characteristic	14	1	7	240	0	6	40	54
Characteristic	15	1	19	90	0	0	100	0
Characteristic	16	1	42	100	0	0	100	0
Characteristic	17	1	12	86	0	0	100	0
Characteristic	18	1	102	45	0	0	100	0
Characteristic	19	1	17	160	0	26	74	0
Characteristic	20	1	27	80	0	0	100	0
Characteristic	21	1	82	120	0	1	99	0
Characteristic	22	1	9	225	0	26	74	0
Characteristic	23	1	7	30	0	0	100	0
Characteristic	24	1	10	100	0	0	100	0
Characteristic	25	1	13	180	0	34	66	0
Characteristic	26	1	23	240	0	50	50	0
Characteristic	27	1	3	140	0	0	100	0
Characteristic	28	1	4	80	0	0	100	0
Characteristic	29	1	8	160	0	0	72	28
Characteristic	30	1	22	240	0	31	69	0

Justification for differences between final conclusions and above tables

Trucks

As only 1 dataset was analysed with relatively long journey distances compared to the sector, the depot charging percentage was raised slightly compared to charging on public roads.

For construction, the model results were almost entirely copied, as the 3 datasets analysed are considered to be representative for the sector.

For facilities, only 1 (typical) journey profile was analysed. Due to a lack of representative datasets, this was therefore compared to retail (non-food). Charging at the customer was considered to be less likely than for retail non-food, but for the rest the sectors are quite similar in terms of route times/journey characteristics.

The model results show that vehicles will be recharged at the customer relatively often. Due to unloading in the public space, this is not always expected to result in investments in charging stations. That is why the customer charging percentage was lowered compared to the model results.

A typical journey profile may have been analysed for this sector, but these journeys will mainly be made with delivery vans, so they were not included in the results.

For retail food, the results of the 3 extensive datasets were almost fully copied, as they are deemed to be representative for the sector.

For retail non-food, the results of the 3 extensive datasets were almost fully copied, as they are deemed to be representative for the sector.

A typical journey profile may have been analysed for this sector, but these journeys will mainly be made with delivery vans, so they were not included in the results.

Delivery vans

The model results were modified here. As can be seen, the model also chooses recharging at the roadside. This is due to the fact that the model cannot choose to extend the stop time in depots, even though this is considered to be likely for this sector.

Unfortunately, it cannot always be concluded from the data whether the vans are taken home or not. The results do, however, show that approx. 70% are charged at the departure location; this has been copied to the results table. The results for public charging and charging at the customer were copied from the model, albeit as an average.

Home charging was often chosen in the model here, as in the datasets the vans are taken home relatively often. However, as stated in the comments (**), reconsidering whether vans are taken home or not will result in recharging in depots more often.

The model results were copied verbatim here.

The model results are similar to what is shown here. Out of the 6 datasets, 1 was excluded because it was possible to recharge at the customer, which is not representative for this sector. The number of charging actions in the starting location (home vs depot) was also modified, as for these specific datasets home charging was not included as an option in the model.

Retail food: For this sector, no data for delivery vans was included in the model. In view of the short distances, it was decided to have 100% charging in depots.

Retail non-food: Not applicable

One of the analysed datasets (Service1) was considered to be representative for this sector. These figures were almost fully copied to the results table.

Appendix 4.2.C Charging station types and battery types

The following table shows the number of charging actions for the various charging stations. The following conclusions can be drawn:

- In public charging locations, people often opt for fast charging at public charging stations. This may be related to the fact that the Municipality of Amsterdam has capped the costs for this.
- The lower capacity charging stations are mainly chosen at home.
- Charging stations with a 150 kW capacity are mainly chosen in depots and customer locations.

Table B4.8

CHARGING STATIONS	CUSTOMER	DEPOT	HOME	THIRD PARTY
_AC3,7_Private	0	0	41	0
_AC20_Private	1	2	59	0
_FC50_Private	5	9	0	0
_FC50_Public	0	0	0	10
_HPC150_Private	86	80	0	0
_HPC150_Public	0	0	0	1
_HPC350P_Private	6	9	0	0
_HPC350_Public	0	0	0	89

Battery capacity

The following table presents the selected batteries (in percentages) for all the data included in the model. It provides a good picture of the breakdown into battery types. The following conclusions can be drawn:

- The differences are big within the datasets analysed. It is difficult to formulate conclusions that apply to a certain vehicle type.
- What can be seen is that all available battery types are basically chosen. So people will not always choose the largest or the smallest battery.

Table B4.9
Battery capacity in %.

BATTERY TYPE	SMALL DELIVERY VAN	MEDIUM-SIZED DELIVERY VAN	LARGE DELIVERY VAN	SMALL BOX TRUCK	LARGE BOX TRUCK	TRUCK + TRAILER
_GB_41	0	0	27	0	0	0
_GB_50	0	0	73	0	0	0
_Gba_120	0	0	0	0	60	0
_Gba_200	0	0	0	0	21	0
_Gba_240	0	0	0	0	19	0
_KB_30	79	0	0	0	0	0
_KB_40	10	0	0	0	0	0
_KB_50	12	0	0	0	0	0
_Kba_120	0	0	0	35	0	0
_Kba_160	0	0	0	47	0	0
_Kba_80	0	0	0	19	0	0
_MB_30	0	58	0	0	0	0
_MB_40	0	11	0	0	0	0
_MB_50	0	30	0	0	0	0
_TT_170	0	0	0	0	0	6
_TT_240	0	0	0	0	0	14
_TT_320	0	0	0	0	0	81

Table B4.10
Input parameters for diesel vehicles.

	VEHICLE	BASIC PRICE OF VEHICLE 2018 ~	FUEL COSTS (€/KM)[48]	MAINTENANCE COSTS (€/KM)[49]	TAX AND INSURANCE
N1	Small delivery van	18,500	0.07	0.04	3.5% of the purchase price. No differentiation in tax policy to BEV.
	Medium-sized delivery van	20,000	0.07	0.04	
	Large delivery van	40,000	0.11	0.04	
N2	Small box truck (12t)	80,000	0.22	0.08	
N3	Large box truck (19t)	100,000	0.33	0.09	
	Truck (tractor unit + trailer) (37t)	150,000	0.47	0.11	

Figure B4.11
TCO (€/km) for a medium-sized delivery van (30 kWh) and 100 km/day.

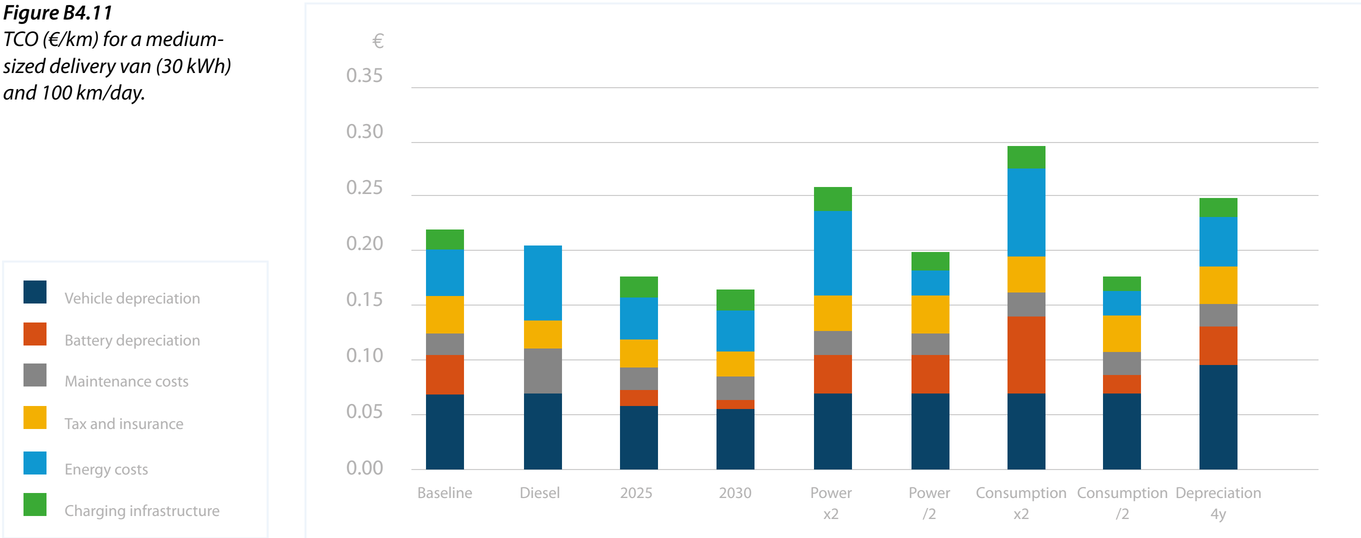
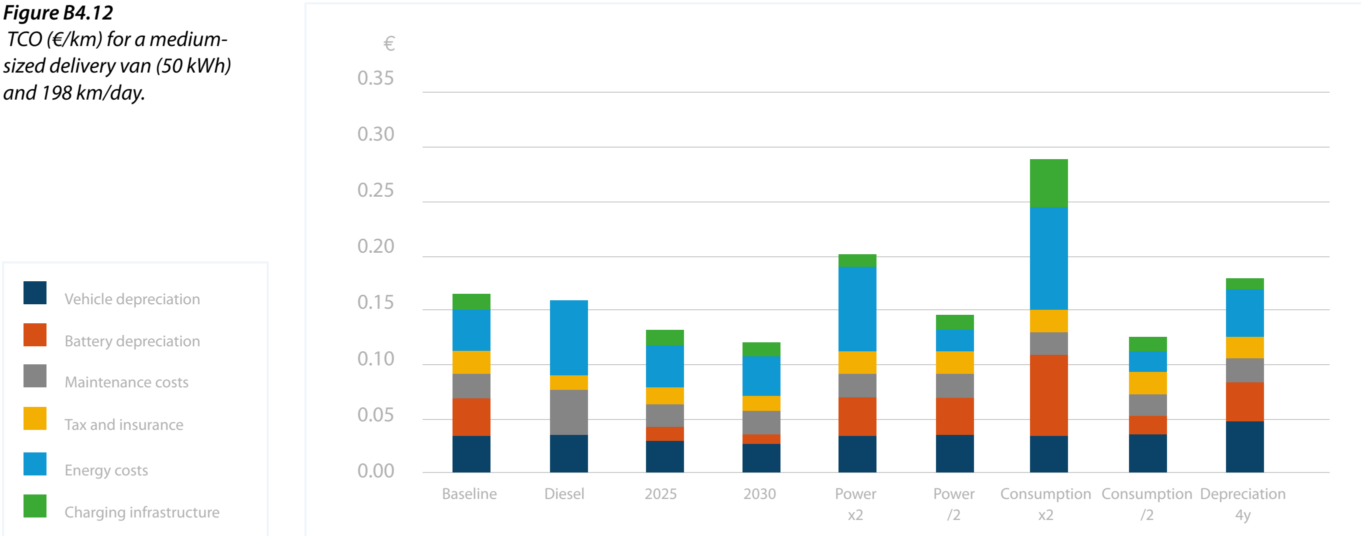
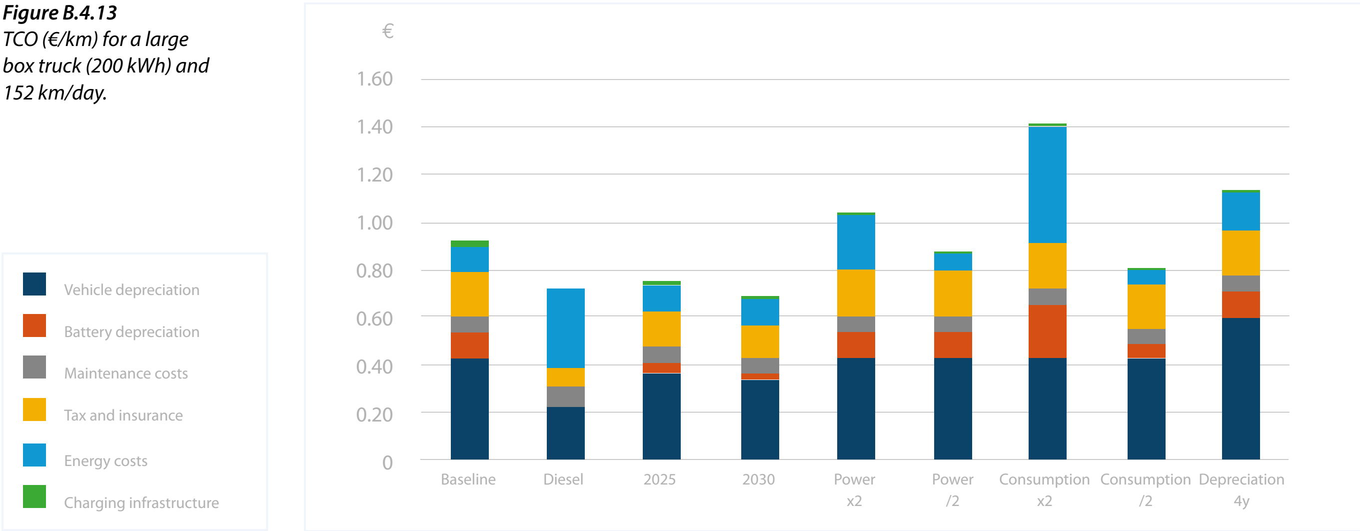


Figure B4.12
TCO (€/km) for a medium-sized delivery van (50 kWh) and 198 km/day.



[48] *Based on the consumption per vehicle type on an urban road (TNO, 2018) and a diesel price of €1.23/litre. Lower fuel prices when purchasing greater quantities were not taken into account.*
[49] *Maintenance costs per km for an ICEV based on AFLEET (2018) and Lebeau (2016).*

Figure B.4.13
TCO (€/km) for a large box truck (200 kWh) and 152 km/day.



Appendix 5.1.A: ZE zone background data for trucks

To estimate the charging demand due to the creation of a ZE zone in Amsterdam matching the current Amsterdam environmental zone, Statistics Netherlands (CBS) was asked for custom data.
Each year CBS conducts a survey among goods carriers about origin-destination relationships and cargo details. For about one quarter of the trucks, data is supplied every year for at least a week. CBS has techniques to then extrapolate this data to annual totals for the whole of the Netherlands, taking into account the representation of data in the survey based on different characteristics, like sectors, company size, location, etc.
For the current study, CBS supplied custom data for the extrapolated number of vehicles found in the Amsterdam environmental zone. For all of these vehicles, kilometres and journey numbers were supplied by origin and final destination of the journey at NUTS 3 level, indicating whether or not the environmental zone was visited during the journey. Here a division was made between cargo type (NST class), vehicle type and sector (SBI-1).
The NST classes were used to assign the data to the sectors defined in this study based on the conversion matrix in Table B5.1.

Table B5.1
Conversion table from NST classes to sectors.

NST CLASS								
Waste/sec raw materials	100							
Chem. Products	0	33	33	33				
Containers/mail/groupage	0	10	10	30		10	40	
Ore/minerals	0	100						
Fossil fuels	0							100
Raw materials (wood/metal/leather) and prod.	0	100						
Agriculture/Foodstuffs	0			50		50		
Machines/means of transport	0	35	35	20			10	

The electricity consumption figures from Table B5.2 were assigned to the different vehicles. These are based on the figures for a truck (tractor unit + trailer), large box truck and small box truck from Section 3.3. For vehicles with an installation (refrigeration, crane, etc.) an incremental factor of 1.17 was used.

Table B5.2
Electricity consumption figures per vehicle type.

VEHICLE TYPE	KWH /KM	VEHICLE TYPE	KWH /KM
Asphalt tipper	0.91	Cleaning truck	1.06
Recovery vehicle	0.91	Road tanker	0.91
Concrete mixer	1.06	Tractor unit	1.75
Conditioned vehicle	1.06	Cattle truck	0.91
Covered goods vehicle	0.91	For vehicle transport	0.91
Dump truck	0.91	For exchangeable superstructure	0.91
Sludge gulper	1.06	Refuse collection vehicle	1.06
Open truck	0.91		

For the vehicles from the environmental zone, CBS also supplied data about where they are based at postcode level separately from the data described above (so there is no link to the other characteristics). This data was used to determine how many vehicles are based in the Greater Amsterdam COROP and to create the geographical overview of charging in depots (see Appendix to 5.2).

Appendix 5.1.B: ZE zone background data for delivery vans

To estimate the charging demand due to the creation of a ZE zone in Amsterdam matching the current Amsterdam environmental zone, Statistics Netherlands (CBS) was asked for custom data.
Each year, CBS conducts a survey among delivery van owners about origin-destination relationships and cargo details. Each year the data for 3 days is collected in the survey. CBS has techniques to then extrapolate this data to annual totals for the whole of the Netherlands, taking into account the representation of data in the survey based on different characteristics, like sectors, company size, location, etc.
For the delivery vans, it is not exactly known whether they visited the environmental zone, but it is known whether they visited Amsterdam. For the current study, CBS supplied custom data for the extrapolated number of vehicles active in the Municipality of Amsterdam (37,425). Based on vehicle registration analysis, we know that about 30,000 delivery vans regularly visit the environmental zone in Amsterdam. The analyses based on the CBS data were therefore scaled by a factor of 30,000/37,425.
Numbers, kilometres and journey numbers were supplied for the vehicles from the CBS data. Here a division was made between cargo type (NST class), sector (SBI-2) and home base (at COROP detail level).
Based on SBI-2, the data was assigned to the sectors defined in this study based on the conversion matrix in Table B5.3.

Table B5.3
Conversion matrix for SBI branch to sector.

43 Specialised construction activities		100							
Private individuals									100
47 Retail trade (not in motor vehicles)						50	50		
41 Construction of buildings and development of building projects		100							
46 Wholesale trade and commission trade			0			40	40	20	
53 Postal and courier activities					100				
45 Sale and repair of motor vehicles, motorcycles and trailers								100	
81 Cleaning companies, landscape gardeners, etc.			100						
56 Food and beverage service activities				100					
90 Arts								100	
49 Land transport		25			50	25			
01 Agriculture						100			
84 Public administration and public services				100					
86 Human health activities				100					
73 Advertising and market research			100						
70 Holding companies and management consultancy firms			100						
74 Industrial design, photography, translation agencies								100	
52 Warehousing and support activities for transportation		25			50	25			
33 Repair and installation of machinery and equipment			100						
31 Manufacture of furniture			100						
68 Renting, buying and selling of real estate			100						
71 Architects, engineering firms, etc.			100						
82 Other business services			100						
96 Other personal service activities			100						
59 Motion picture and tv programme production; sound recording			100						
42 Civil engineering		100							
51 Air transport			100						
25 Manufacture of fabricated metal products		100							
64 Financial institutions			100						
93 Sports and recreation			100						
85 Education			100						
10 Manufacture of food products						100			
77 Renting and leasing of tangible goods			100						
78 Temporary employment and employment placement			100						
95 Repair of consumer goods								100	
32 Other manufacturing		100							
62 Support activities in the field of information technology								100	
80 Security and investigation activities			100						
88 Social work activities without accommodation				100					
37 Sewerage	100								
87 Residential care and guidance				100					
18 Printing and reproduction of recorded media								100	
69 Legal services and administration			100						
16 Manufacture of wood products		100							
28 Manufacture of machinery and equipment								100	
55 Accommodation				100					
23 Manufacture of building products		50					50		
50 Water transport			100						
61 Telecommunications								100	
38 Waste treatment and recycling	100								
27 Manufacture of electrical equipment							50	50	
94 World view/political, interest/ideological, hobby clubs							100		
30 Manufacture of other transport equipment							100		
39 Remediation activities and other waste management	100								
79 Travel agencies, tour operators and tourist information			100						
91 Libraries, museums and nature conservation			100						
13 Manufacture of textiles							100		
75 Veterinary activities				100					
14 Manufacture of clothing etc.							100		
72 Research				100					
58 Publishing							100		
66 Other financial services				100					
29 Manufacture of motor vehicles, trailers and semi-trailers							100		
22 Manufacture of rubber and plastic products		100							
26 Manufacture of computer, electronic and optical products		100							
11 Manufacture of beverages						100			
20 Manufacture of chemicals and chemical products		100							
92 Lotteries and betting			100						
63 Information service activities			100						
35 Energy companies								100	
24 Manufacture of basic metals		100							
03 Fishing and aquaculture						100%			
60 Programming and broadcasting activities			100						
17 Manufacture of paper and paper products			50				50		
65 Insurance and pension funding			100						
08 Mining and quarrying (other than oil and gas)	100								
15 Manufacture of leather and related products							100		
02 Forestry and logging	100								
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations			100						

Based on the electricity consumption figures from Chapter 3 for delivery vans (Table B5.4), a consumption figure per sector was calculated using the share of small, medium-sized and large delivery vans per sector (Connekt, 2017). For all the sectors, the average obtained appears to be about €0.28 kWh/km

Table B5.4
Energy consumption.

DELIVERY VAN TYPE	KWH/ KM
Small delivery van	0.229
Medium-sized delivery van	0.298
Large delivery van	0.37

Charging demand in depots and at home

The charging demand in depots was allocated based on the home base and registration details of the vehicles. For trucks, a file was used stating the locations where these are based using data from the CBS survey. The registration details were used to compare this to the associated postcode area. If the municipality of the stated home base matches the postcode area, it was assumed that the postcode registration matches the home base. This was the case for 84% of the vehicles. The total charging demand in depots was divided over these postcodes. This means that the 16% of the charging demand for which the postcode is unknown was divided over the known postcodes.
In order to allocate the charging demand of delivery vans geographically at home and in depots, a CBS dataset was used with the number of vehicles per postcode area and sector characteristic (SBI 2) for delivery vans in the Greater Amsterdam COROP. The relative breakdown by sector for delivery vans by postcode area was used to allocate the charging demand at home and in depots per sector (SBI-2) to the postcode areas.
As records often do not match the locations where vehicles are based, especially if a single location has a large number of registrations, a check was carried out for locations with the highest number of delivery vans prior to the above step. If it is likely to involve a leasing company, main office or e.g. a rental company, the delivery vans were reassigned to the other locations.

Charging demand at customer

The charging demand at the customer was allocated based on the origin-destination relationships from the cargo matrix of the VENOM traffic model, the traffic model for the Amsterdam traffic region. The cargo matrix basically relates to vehicles longer than 5.6 metres. These are mainly trucks, but a large proportion are also large delivery vans.
Using the CBS data, the number of truck arrivals in the Amsterdam ZE zone was set to about 400,000, with an average charging demand in the ZE zone of €5.6 million kWh/year[50]. This charging demand was allocated to locations based on the distribution of arrivals in the ZE zone from the traffic model. The remaining charging demand at the customer was allocated based on the number of arrivals and departures outside the ZE zone that have an origin-destination relationship with the ZE zone. For delivery vans, the total charging demand at the customer (which is very limited) is based on the relative breakdown of the charging demand by postcode of the trucks.

Charging demand by the roadside

For the total charging demand by the roadside, it was assumed for trucks that this is done at fast-charging stations. For delivery vans it was assumed that half are recharged in residential areas/industrial sites and the other half at fast charging stations. The charging demand of delivery vans in residential areas was allocated in the same way as the charging demand at the customer. For the charging demand at fast charging stations, it was assumed that these will be installed along the approach routes towards Amsterdam in locations such as current service stations, rest areas or overnight parking locations (see Chapter 3). The charging demand was allocated to the approach routes based on the distribution of the traffic flows towards and from the ZE zone.
This was done using the Mobility Scan (www.mobiliteitsscan.nl/mobscan/), into which the truck matrix of the VENOM model was loaded. The distribution over the routes is presented in Tabel 27.

50 14 kWh on average per stop, including stops where vehicles are not recharged.

Figure B5.5
Approach routes and possible locations for fast charging stations.

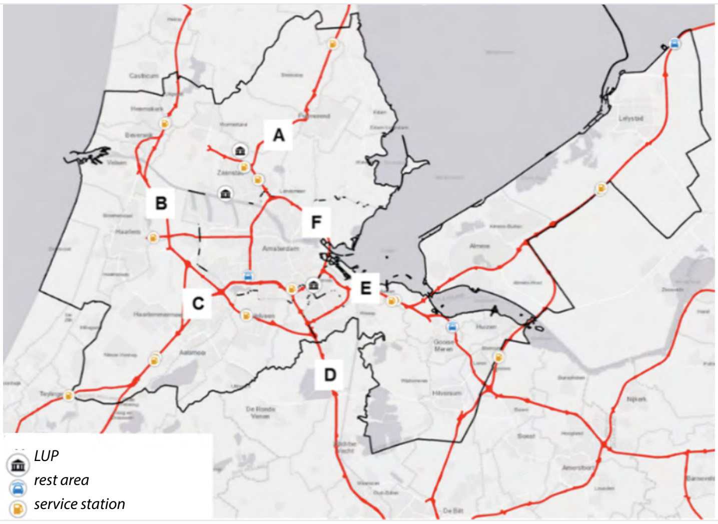


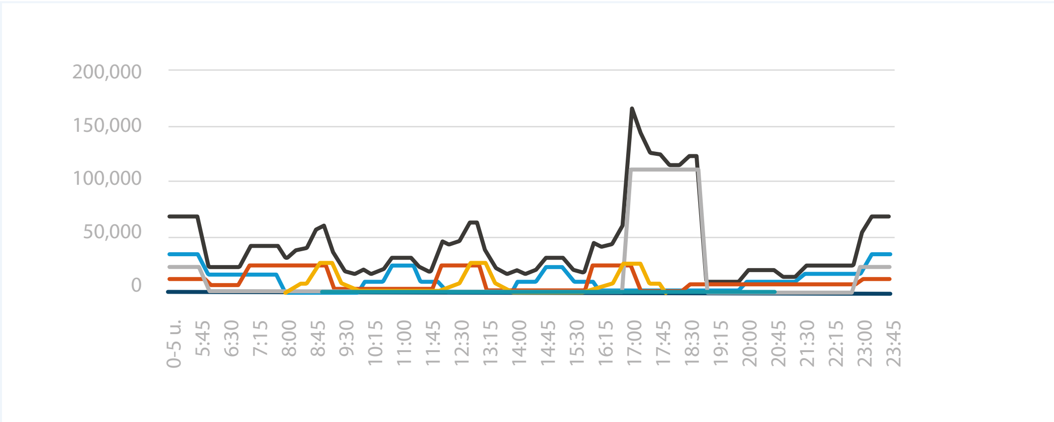
Table B5.6
Distribution of traffic intensity from and to ZE zone along approach routes.

	SHARE OF TOTAL CHARGING DEMAND (%)
A	10
B	10
C	21
D	19
E	41

In the analysis it was assumed that smart charging is generally used, with the charging demand being spread as much as possible during the available time. For charging at public charging stations, it is not yet entirely obvious that this will be done smartly. For charging in depots, where the businesses determine the charging strategy themselves, this would seem to be much more obvious.

Figure B5.7 presents the effect on the power demand if all the delivery vans are charged over a period of 3 hours from 17:00. This makes the power demand at 17:00 a factor 2.6 higher than in the basic scenario (see Figuur 8). It is therefore important to apply a smart charging strategy to limit the power demand. The impact on the substations will still remain limited, even if the power demand is 2.6 times higher.

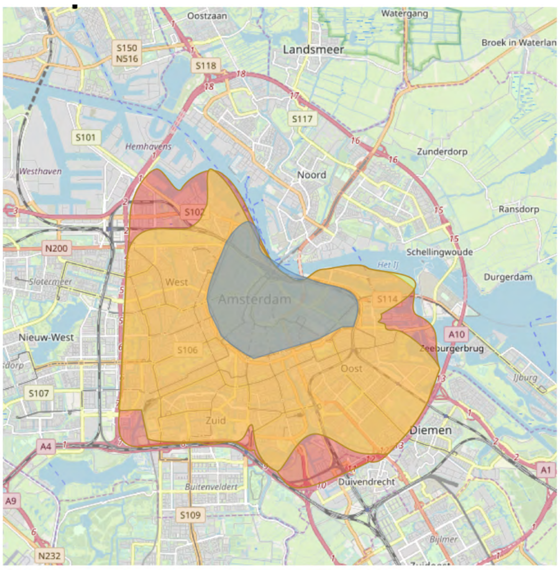
Figure B5.7
Charging demand in Greater Amsterdam COROP for simultaneous charging of delivery vans at 17:00.



The Mobility Scan was used to analyse the origin-destination matrices from VENOM. The effect of the ZE zone size on the number of vehicle movements that will have to become electric was investigated. The cargo data from VENOM relates to vehicles longer than 5.6 metres, which in practice means trucks and a smaller fraction (approx. 30-40%) of large delivery vans. To illustrate the effect of the zone size, three scenarios were defined for the zone, as depicted in Figure B5.8

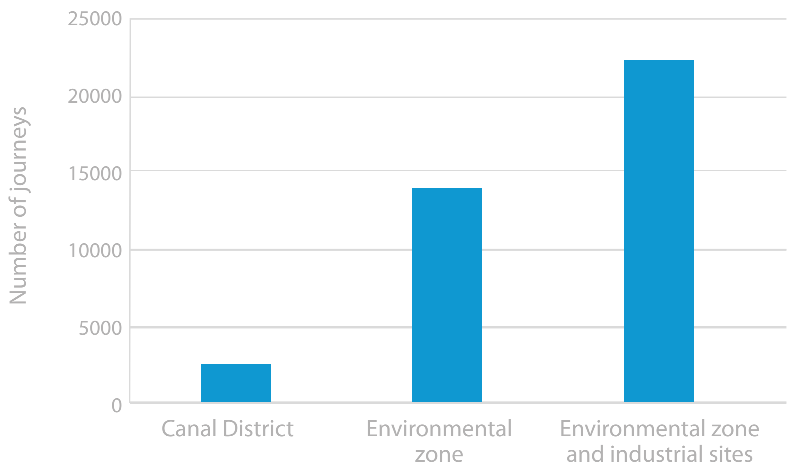
- Canal District zone (grey).
- Current environmental zone (yellow + grey).
- Amsterdam city centre inside A10 ring road (yellow + red + grey).

Figure B5.8



The red areas are industrial sites that are currently excluded from the environmental zone. The Mobility Scan was used to simulate a ZE zone by fully closing off the aforementioned areas. In the Mobility Scan, a reduction in the number of journeys can then be seen compared to the number of journeys that would normally be made. The reduction concerns journeys that would normally be made to, from or within the ZE zone and that will have to become zero-emission. The number of journeys affected by the zero-emission zone is presented in Figure B5.9 for the three scenarios.

Figure B5.9
Number of journeys affected by ZE zone, depending on zone size.

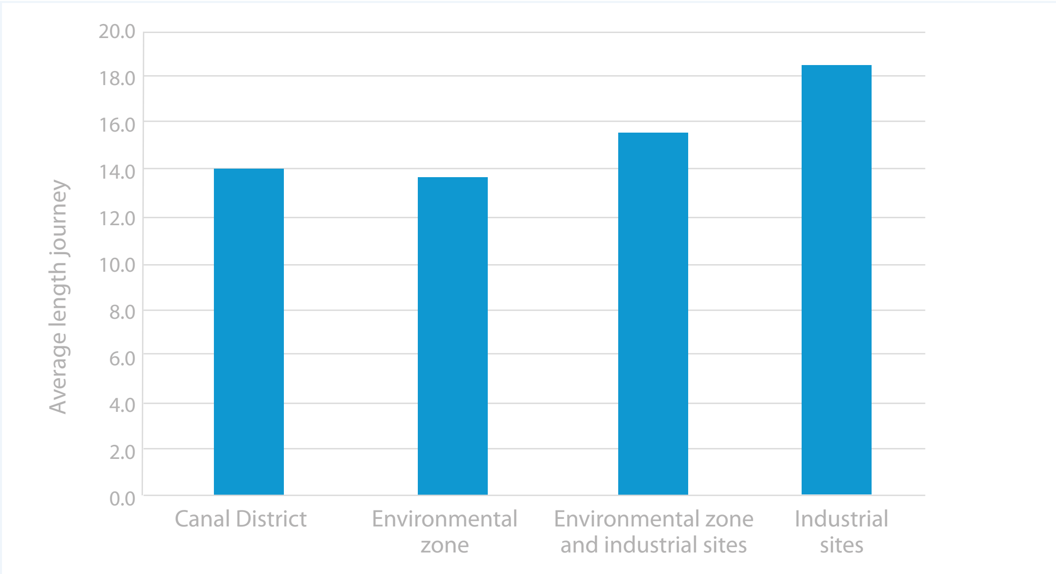


If the ZE zone is limited to the Canal District, it can be seen that relatively few journeys are affected. For a ZE zone that matches the environmental zone, there are significantly more (a factor of 5). If the industrial sites are also included in the ZE zone, a further increase can be seen (a factor of 1.6 more than an environmental zone). The size of the zone is therefore highly important for the number of journeys affected.
The 60% extra journeys to and from the ZE zone, which will be affected if the industrial sites are also included in the ZE zone, involve an estimated 15-20% extra vehicles (estimated based on CBS data).

Distances

If the ZE zone also includes the industrial sites, this will also affect journeys with a relatively greater journey distance (distance between origin and destination in this case). Figure B5.10 shows that the journey length between the zones 'Canal District' and 'current environmental zone' is about the same (approx. 14 km). For the largest variant, this increases to 15.5 km. This is because of the journeys to and from the industrial sites, which are 18 km on average.

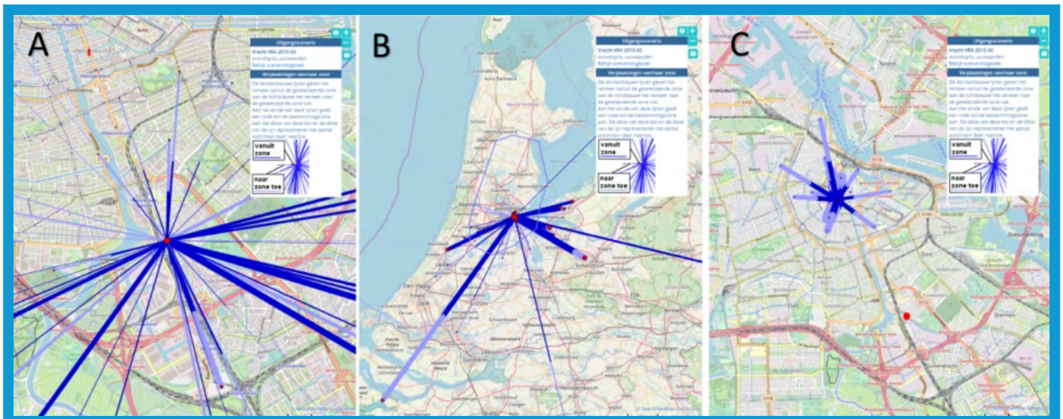
Figure B5.10
Average lenght journey per zone-size.



Morning and evening rush

The average distance of 15.5 km consists of a number of very long journeys, as illustrated in Figure B5.11. Figure B5.11 shows the origin-destination relationships from an area in the Omval business district (A and B) and for a location in the city centre. From the industrial site, there are relatively many journeys with a destination or origin >20 km away. When considering where to put the boundaries of a ZE zone, it is important to bear this in mind (as was done for the environmental zone in Amsterdam as well). Including these industrial sites in a zero-emission zone makes the challenge of carrying out all the journeys in the zone without emissions much bigger. At the same time, the effect will naturally also be much greater.

Figure B5.11



A
Origin-destination relationships from an area at the De Omval industrial site

B
A zoomed out

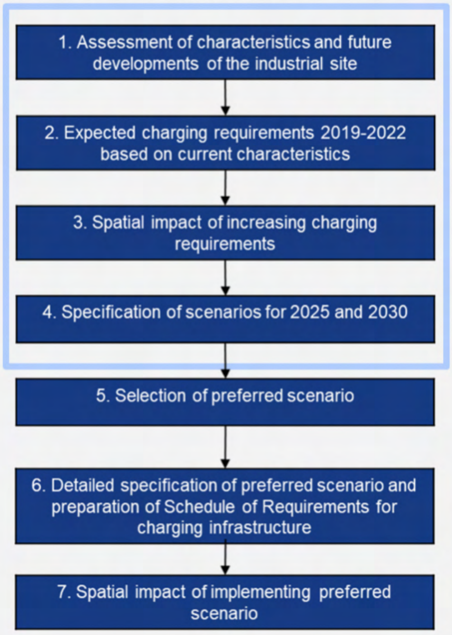
C
Origin-destination relationships from an area inside the Canal District.

Format for implementing charging infrastructure in logistic hotspots and at industrial sites

Format for implementing charging infrastructure in logistic hotspots and at industrial sites

When introducing ZE zones, the number of electric vehicle fleets for urban distribution will increase, and as a result also the demand for electricity and charging infrastructure. The locations of businesses and depots at industrial sites are key locations for electric charging. This format offers tips for preparing a plan for the development of charging infrastructure in these logistic hotspots and industrial sites.

A plan for a site can be made in 7 steps:



A manual will be provided for the first four steps. The specification of the first step will be illustrated by means of a concrete example.

Step 1: Assessment of characteristics of site, logistics companies and charging infrastructure

Characteristics of industrial site

Requested information	*Possible source*
Type of site	➢ IBIS
Surface area	➢ IBIS
Number of companies	➢ IBIS/Chamber of Commerce
# and location of parking spaces	➢ Municipality
# and location of public charging stations, capacity and operator	➢ www.chargepoints.com and others
# and location of private charging stations, capacity and operator	➢ Interview with trade association/park management
Utilisation rate of public charging stations	
Utilisation rate of public charging stations	➢ Charging station operator

Characteristics of companies

Requested information	*Possible source*
Sector	➢ Chamber of Commerce
Logistical segment factor	➢ Chamber of Commerce
Vehicle fleet with trucks / fixed location for vehicles	➢ NIWO permits ➢ RDW ➢ Counts ➢ Survey/interview
Vehicle fleet with delivery vans / fixed location for vehicles	➢ NIWO permits ➢ RDW ➢ Counts ➢ Survey/interview
Supply volume (# journeys)	➢ Indices ➢ Survey/interview with companies
Parking spaces on private land	➢ Google Maps/survey/interview
Usage pattern for own vehicle fleet	➢ Survey/interview with companies
Night location for own vehicle fleet (industrial site / driver's home address / elsewhere)	➢ Survey/interview with companies
Future plans for use of electric transport	➢ Survey/interview with companies

Characteristics of power grid

Requested information	*Possible source*
Current capacity	➢ Network manager
Current usage	➢ Network manager
Expansion plans	➢ Network manager
Bottlenecks at the industrial site	➢ Network manager

Stakeholder plans

Requested information	*Possible source*
Stakeholder plans	
Spatial and infrastructural developments	➢ Zoning plan
Business establishment/acquisition strategy	➢ Municipality/trade association
Developments at companies	➢ Survey/interview with companies

Step 2: Expected charging requirements 2019-2022 based on current characteristics

Activities

Specification of short-term development of demand for electric charging systems.

Research method

Use of Connekt project analysis tools (TCO model and EVEC) to get an idea of the following aspects:
- Size of BEV vehicle fleet, subdivided into the classes in accordance with the main report classification (to be supplemented). Where possible, this should be specified for the companies / logistical segments present at the site
- Analysis of journey profiles of companies currently present
- Forecast of short-term developments regarding electrification of existing vehicle fleet and existing companies
- Need for public and private charging stations on the site, subdivided by type designation and usage type (see Table 2)
- Total required capacity for use of the charging infrastructure

Table to be completed to estimate charging infrastructure required for logistic hotspot

Type designation	Usage type	Number	Required capacity
AC3,7	Home		
AC22	Home		
AC22	Private		
FC50	Private		
HPC150	Private		
FC50	Public		
HPC350	Private		
AC22	Public		
HPC150	Public		
HPC350	Public		

Step 3: Spatial impact of charging requirements 2019-2022

Activities

Specification of spatial consequences of the required infrastructure based on the forecast for public and private charging points for 2022
- Analysis of options in zoning plan for
  - Locations of charging points
  - Parking spaces at charging points
  - Safety and security
- Overview of required amendments to zoning plan and/or traffic plan and preparation of an implementation plan
- Streamlining of working method with relevant stakeholders / alignment of spatial procedures and tender process for facilities

Step 4: Specification of scenarios for 2025 and 2030

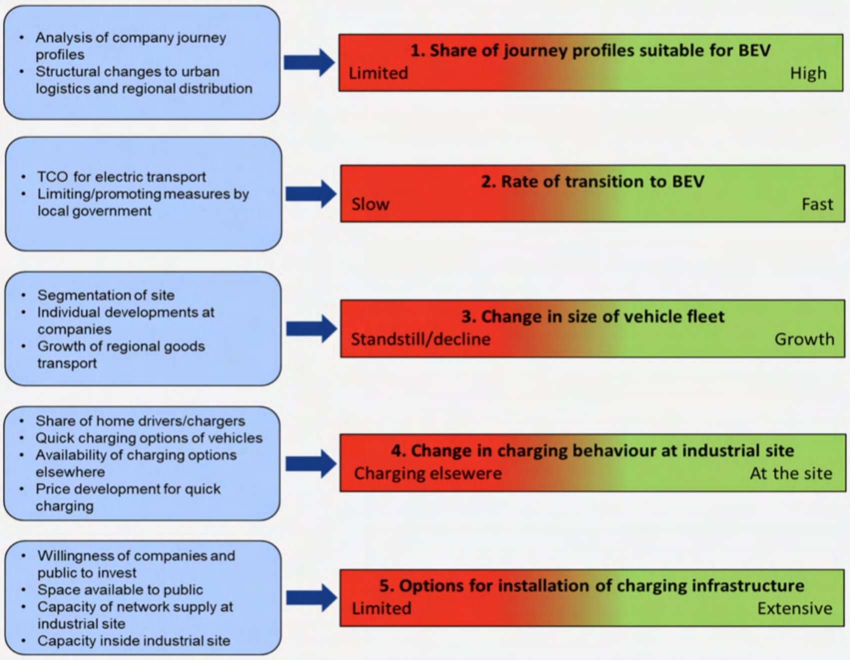
Notes

The use of scenarios provides an insight into the rate at which the need for charging infrastructure increases and the possible future distribution of the need for charging infrastructure. Key characteristics of the scenarios are presented in Figure 2, for example:

- ❖ Changes to journey profiles as a result of logistical structural changes
- ❖ Rate of transition to electric transport among companies at the industrial site
- ❖ Development of the traffic volume generated by the companies at the site
- ❖ Characteristics of the charging behaviour of companies as a result of cost developments and technical developments
- ❖ Possibilities to develop the charging infrastructure on the site.

The results of the scenarios lead to a forecast for the charging requirements at the site for:

- ❖ the medium term (2025)
- ❖ a window to the long term (2030)



Activities

- ❖ Collection of data as input for the 5 building blocks of the scenarios (see Figure 2)
- ❖ Analysis of data and translation into indices for the scenarios
- ❖ Modification of standard scenarios to suit characteristics of the site, the companies and the infrastructure
- ❖ Specification of the effects of the scenarios on the KPIs (block 2)

Approach

- ❖ Interviews with companies and local governments
- ❖ Desk research using various sources and results from block 1
- ❖ Use of Connekt project analysis tools (TCO model and EVEC)

A concrete example of a specification of step 1 by way of illustration

Characteristics of industrial site: Sloterdijk III

North: logistics / distribution and industry

South: mixed area with small-scale activities

East: mixed area with retail trade (incl. car-related) and home furnishings/DIY centre

Land area

227 ha gross

185 ha net

Characteristics of companies

Activities

517 companies

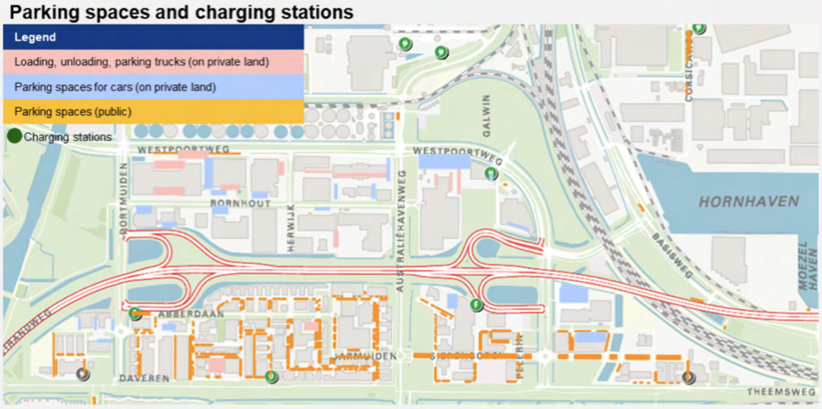
54 logistics

Employment

4.510 jobs

1.380 in logistics

Parking spaces and charging stations



27 permit holders

297 permit certificates

Survey for assessment of charging infrastructure for logistics companies

Company details
Company name ______________________________
Address ______________________________
Town/city ______________________________
Contact ______________________________

Characteristics of your company

1. In which of the following categories can this branch of your company be classified?
❑ No idea
❑ Retailer (retail chain)
❑ Wholesaler
❑ Professional
❑ Other, namely

Logistic activities at this location

2. What area is covered by this location?*
❑ No idea
❑ Amsterdam city centre
❑ All of Amsterdam
❑ Amsterdam/North Holland/Gooi/South Holland region
❑ All of the Netherlands
❑ International
**Note: you can choose several answers*

3. How many deliveries <u>per day</u> do you get <u>from third parties</u>?
Number of times per day______________x

4. Do you have parking spaces at your own site?
❑ No
❑ Yes, namely *Number of parking spaces*
- For cars or delivery vans
- For trucks

Characteristics of the logistic vehicle fleet for this location

5. Are any passenger cars, delivery vans or trucks stationed at this location?**
❑ No
❑ Yes, namely
- ______ Passenger cars
- ______ Delivery vans (up to 3.5 tonnes)
- ______ Light trucks (3.5-7.5 tonnes)
- ______ Trucks (7.5-18 tonnes)
- ______ Truck-trailers or trucks with a trailer (above 18 tonnes)

***Note: for each type, please enter the number of vehicles stationed permanently at this site*

6. If so, do drivers at this location take their delivery vans or trucks back to their home address at night?****
❑ Yes, ______ Delivery vans (up to 3.5 tonnes)
❑ Yes, ______ Light trucks (3.5-7.5 tonnes)
❑ Yes, ______ Trucks (7.5-18 tonnes)
❑ Yes, ______ Truck-trailers or trucks with a trailer (above 18 tonnes)
****Note: for each type, please enter the <u>number of vehicles</u> taken back to the driver's home address at night*

7. Do you currently have any electric vehicles at this location?
❑ Yes, continue with question 8
❑ No, continue with question 9

8. How many fully electric vehicles are stationed at this location?
❑ ______ Passenger cars
❑ ______ Delivery vans (up to 3.5 tonnes)
❑ ______ Light trucks (3.5-7.5 tonnes)
❑ ______ Trucks (7.5-18 tonnes)
❑ ______ Truck-trailers or trucks with a trailer (above 18 tonnes)

9. Do you have plans to invest in electric vehicles at this location?Nee,
❑ No
❑ No idea
❑ Yes, namely:

Soon (2019-2010)
Number of electric vehicles
______ Passenger cars
______ Delivery vans (up to 3.5 tonnes)
______ Light trucks (3.5-7.5 tonnes)
______ Trucks (7.5-18 tonnes)
______ Truck-trailers or trucks with a trailer (above 18 tonnes)

In the longer term (2021-2025)
Number of electric vehicles
______ Passenger cars
______ Delivery vans (up to 3.5 tonnes)
______ Light trucks (3.5-7.5 tonnes)
______ Trucks (7.5-18 tonnes)
______ Truck-trailers or trucks with a trailer (above 18 tonnes)

Charging of electric vehicles at this location

10. Do you have 1 or more charging stations for electric cars on your own site? (i.e. not on the public road)
❑ No, continue with question 13
❑ Yes, continue with question 11

11. What types of charging points (and how many) are you using now on your own site? *Number of charging points*
❑ Low-capacity home connection (wall box or standard charging station)
❑ High-capacity charge connection (>22 kW) for delivery vans of trucks

12. Are suppliers and/or customers allowed to use the charging stations on your site?
❑ No
❑ Yes

13. Do you have plans to invest in charging options for electric vehicles at this location?
❑ No idea, continue with question 16
❑ No, continue with question 16
❑ Yes, continue with question 14

14. If so, when are you planning to invest in charging options for electric vehicles?
❑ Soon (2019 or 2020)
❑ In the longer term (2021-2025)

15. If so, what types of charging points are you planning to install at this location?******
❑ No idea
❑ 3x25 A (standard house connection)
❑ 3x50 to 3x80 A (small business connection)
❑ More than 3x80 A (bulk consumer connection)

Contracted power: ____________ kWh per year
*****Note on power connection: see https://www.liander.nl/mkb/aansluitingen or energy supplier invoice. Note on contracted power: see <u>https://www.liander.nl/grootzakelijk/aansluitingen/wijzigen/gecontracteerd-transportvermogen-elektriciteit</u>.*

17. How much electricity do you consume per month or per year at this location?
❑ No idea
❑ ______________________________kWh per month
❑ Or,______________________________kWh per year

Example of completed survey for assessment of charging infrastructure for logistics companies

Company

Company name	Post NL
Adres	Australiehavenweg 100
Town/city	Amsterdam

Company characteristics

Type of business	Post

Logistic activities at location

Work area
- All of Amsterdam
- Amsterdam region
- North Holland
- Gooi
- South Holland

Number of third-party deliveries per day
0

Parking spaces at own site
- 300 for passenger cars or delivery vans
- 45 for trucks

Characteristics of logistic vehicle fleet at location

Vehicles stationed at location
- 47 delivery vans
- 4 trucks
- 38 truck-trailers or trucks with a trailer

Delivery vans or trucks remain at the location overnight

Currently no electric vehicles at location

Plans for investment
- In the longer term (2021 – 2025)
- About 10-30 electric vehicles

Charging of electric vehicles

Number of charging stations present at own site
- 0

Plans for investment in charging stations
- In the long term (2021 – 2025)

Investment in
- About 30 high-capacity charge connections (< 22 kW) for delivery vans or trucks

Current power connection at location:
- More than 3x80 A (bulk consumer connection)

Contracted power
- Unknown

Electricity consumption per year or per month
- Unknown

Charging infrastructure for electric vehicles in city logistics

Commissioned by Topsector Logistiek

July 2019

Authors

Buck Consultants International

Marije Groen

Kees Verweij

Gerard Vos

CE Delft

Matthijs Otten

Eric Tol

Connekt

Herman Wagter

Districon

Wim de Goffau

Wouter Nering Bogel

Ronald Schoo

HvA

Walther Ploos van Amstel

Susanne Balm

Robert van den Hoed

Panteia

Aad van den Engel

Manfred Kindt

TNO

Bram Kin

Nina Nesterova

Hans Quak

This report was made possible by the support of CBS and Liander.