Memorandum

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To
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Subject
Indication of the number of electric trucks required per (semi-)public charging point for cost-effective operation for the Living Lab Heavy Duty Charging Hubs (hereafter “Living Lab”), a Rijkswaterstaat project.

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This overview provides an indication of the number of electric trucks per charging point required to cost-effectively operate a (semi-)public charging station. This insight is valuable in determining the ratio between capacity utilisation expected among participants in the Living Lab at their charging hub, and the required capacity utilisation in the longer term. This then provides an insight into the extent to which the findings in the Living Lab are representative for the longer term situation.

1.1. Background

During the scaling-up phase of battery electric trucks (e-trucks), overcapacity will be required among (semi-)public chargers, such that the first electric trucks can complete their journey without being hindered by a shortage of charging infrastructure.
For the short to medium term, this means relatively low capacity utilisation, and possibly also unprofitable exploitation. In the longer term, capacity utilisation will have to be above a predetermined minimum in order to at least cover costs without subsidies.

As a result of this growth in capacity utilisation, the lessons from the Living Lab cannot be translated directly to the future. As a consequence of the low capacity utilisation, it will for example be uncommon for vehicles to have to wait for a free charging station. As the capacity utilisation rises, the likelihood of waiting times will grow. At some stage measures will have to be taken to avoid waiting times, such as a booking system. In a living lab, which simulates a future situation, it is important to ensure that the largest possible group of vehicles participate at each charging hub.

1.2. Aim

The aim of this memorandum is to provide an insight into the number of vehicles required to ensure cost-effective operation of a charging hub. The outcomes presented here are intended to provide an insight into the order of magnitude and are therefore merely indicative.

1.3. Approach

- Determine the required capacity utilisation or utilisation level to be able to offer electricity at an acceptable price for end users.
    - o Determine costs for the charging hub (fixed and variable costs) for different quantities of installed capacity and utilisation levels.
    - o Determine energy sales at various quantities of installed capacity and utilisation levels.
    - o Determine the electricity price at which it becomes more cost-effective for vehicle owners to use fast charging than to purchase a vehicle with a larger battery.
- Determine the required number of vehicles registered in the Netherlands to be able to achieve this level of capacity utilisation on the basis of:
    - o electricity sales per charging point per day;
    - o average e-truck travel distance;
    - o energy consumption;
    - o share of fast charging outside own site.
- Determine the number of unique users required at a charging point to be able to achieve this required capacity utilisation on the basis of:
    - o electricity sale per charging point per day;
    - o average duration of a charging session.

1.4. Assumptions and results

It is assumed that the chargers deliver a capacity of 350 kW.
This assumption was made because the costs of these chargers are available in the TCO model of the Topsector Logistiek[1]. This means that a charging hub with more capacity is made up of multiple 350 kW charging points.
Electricity sales for charging hubs of differing sizes appear in the table below.

Table 1: Sale of electricity per year as a function of the installed capacity and capacity utilisation.

Sold number of MWh/year		Installed capacity				
		350	**700**	**1050**	**2100**	**4200**
Capacity utilisation	**5%**	153	307	460	920	1840
	10%	307	613	920	1840	3679
	20%	613	1226	1840	3679	7358
	30%	920	1840	2759	5519	11038

kW per hub	350	350	350	350	350
# hubs	1	2	3	6	12

1 https://topsectorlogistiek.nl/tco-vracht/

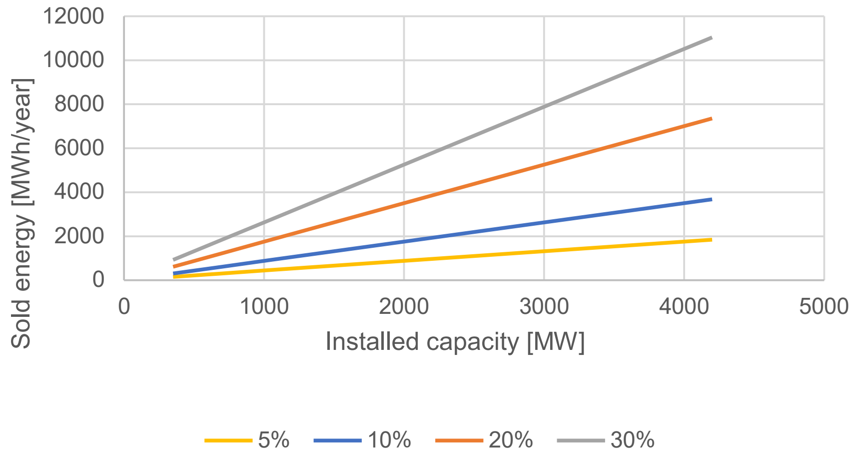

Figure 1: Sold quantity of energy as a function of the installed capacity and capacity utilisation.

The costs of the charging hub (CAPEX) are taken from the TCO model and include:
- purchase price of the charging hub;
- costs related to location setting, engineering, project management;
- civil engineering works/installation;
- excavation work;
- connection costs grid operator.

Based on a depreciation period of ten years.

Operating costs (OPEX), excluding the costs of the purchased electricity, include:
- periodic costs for grid connection;
- communication costs;
- insurance premium (damage);
- maintenance/repair;
- service in the event of user problems.

Finally, the costs for the purchase of electricity by the operator of the charging hub include:
- payment to supplier (purchase);
- energy tax.

The outcome is an overview of the costs per year of charging hubs of different sizes, as shown in the tables below. Costs relating to the purchase of the land and facilities besides the charging hubs themselves such as roof covering or indoor space are not included. The costs for the grid connection are included (see Table 3). These are also taken from the TCO model for the Topsector Logistiek[1] and depend on the connection capacity. A limited number of bandwidths have been defined within which these same connection costs are calculated. These costs will therefore not scale up in a straight line with the installed capacity.

Table 2: CAPEX per year per charging hub and energy costs per Kwh

	Installed capacity				
	350	**700**	**1050**	**2100**	**4200**
CAPEX installation per hub per year	€18,070	€18,070	€18,070	€18,070	€18,070
OPEX per hub per year	€16,195	€16,195	€16,195	€16,195	€16,195
OPEX energy costs per kWh	€ 0.068	€ 0.068	€ 0.068	€ 0.068	€ 0.068

Table 3: Costs per charging hub per year

		Installed capacity				
		350	**700**	**1050**	**2100**	**4200**
CAPEX charging station per year (excluding grid connection)		€18,070	€36,140	€54,210	€108,420	€216,840
CAPEX grid connection per year		€8,033	€8,033	€19,667	€29,833	€35,000
OPEX total (excluding energy)		€16,195	€32,390	€48,585	€97,170	€194,340
Energy costs	**cap.=5%**	€10,492	€20,984	€31,476	€62,951	€125,902
	cap.=10%	€20,984	€41,967	€62,951	€125,902	€251,804
	cap.=20%	€41,967	€83,935	€125,902	€251,804	€503,609
	cap.=30%	€62,951	€125,902	€188,853	€377,707	€755,413
Total costs	**cap.=5%**	€52,790	€97,547	€153,937	€298,374	€572,082
	cap.=10%	€63,282	€118,531	€185,413	€361,326	€697,984
	cap.=20%	€84,266	€160,498	€248,364	€487,228	€949,789
	cap.=30%	€105,249	€202,466	€311,315	€613,130	€ 1,201,593

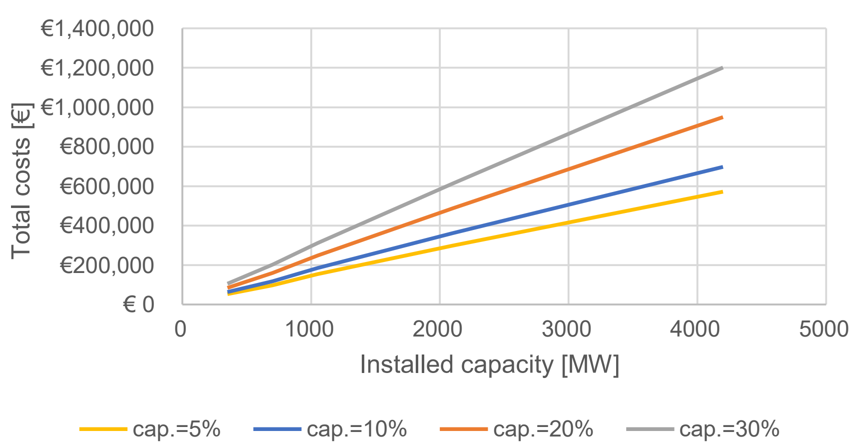

Figure 2: Total costs as a function of the installed capacity and capacity utilisation

Based on these costs, it is possible, for each level of capacity utilisation, to determine the required price for electricity in order to be able to cover the operating costs.

This can be calculated by dividing the total costs (Table 3) by the electricity sales (Table 1). The results appear in the table below.

If there are also other sources of income, for example from Renewable Energy Units (HBEs) or through the sale of other products or services, it may be possible to charge a lower price for the electricity than calculated here.

Table 4: Required sales price for electricity for cost neutrality for the charging hub operator

		Installed capacity				
		350	**700**	**1050**	**2100**	**4200**
Required electricity price to cover costs	**cap.=5%**	€ 0.34	€ 0.32	€ 0.33	€ 0.32	€ 0.31
	cap.=10%	€ 0.21	€ 0.19	€ 0.20	€ 0.20	€ 0.19
	cap.=20%	€ 0.14	€ 0.13	€ 0.14	€ 0.13	€ 0.13
	cap.=30%	€ 0.11	€ 0.11	€ 0.11	€ 0.11	€ 0.11

In theory, a vehicle owner may make the consideration to either fast charge more often, or to equip vehicles with a larger battery.

Based on the assumption that:
- charging at the operator’s own depot costs approximately 0.15 €/kW;
- the price for a kWh additional battery capacity in 2025 is approximately 232 euros;
- a vehicle consumes approximately 0.7 kWh/km or 1.2 kWh/km of energy (for a small truck in urban traffic or a tractor trailer unit for regional distribution respectively);
- the battery has a useful life of 3000 cycles,

a break-even point is reached at 0.19 to 0.26 €/kWh. This means that if the price for fast charging is higher than this amount, it would have been cheaper to equip the vehicle with a larger battery. It can be concluded from this calculation that a capacity utilisation of approximately 8% to 13% will be needed for an electricity price that can compete with a larger battery in combination with charging at the operator’s own depot.

If the electric truck fleet consists of smaller trucks primarily operating in an urban environment, approximately 300 electric trucks will have to be registered in the Netherlands for every MW installed capacity at (semi-)public charging hubs. This assumes that these vehicles have an energy consumption of 0.7 kWh/km and travel on average 150 km/day. It is also assumed that on average 10% will be fast charged at (semi-)public charging hubs.

If the electric truck fleet consists of tractor-trailer units that cover larger distances for regional or even international distribution, approximately 43 electric trucks will have to be registered in the Netherlands for every MW installed capacity at (semi-)public charging hubs. Due to the greater distance (350 km/day) and higher energy consumption (1.2 kWh/km), at the same share of fast charging (10%), far fewer vehicles will be needed to achieve the same level of capacity utilisation of charging points.

In 2022, around 236 electric trucks were registered in the Netherlands (200 trucks and 36 tractor trailer units). This would offer sufficient space for around 1.5 MW (or 4.3 chargers of 350 kW) of installed capacity at (semi-)public charging hubs to ensure a sufficiently high level of capacity utilisation.
Given that the energy demand for these 236 vehicles is spread right across the country, considerably more than this number of chargers will be needed in order to facilitate this operation effectively. As a consequence, capacity utilisation at the charging docks will be lower than needed in order to be able to operate them cost-effectively.

Table 5: Relationship between the number of electric trucks and installed capacity at (semi)public charging points at a level of capacity utilisation of between 8% and 13%.

	Installed capacity									
	Light trucks for urban distribution (13% capacity utilisation)					**Tractor-trailer units for regional distribution (8% capacity utilisation)**				
	350	**700**	**1050**	**2100**	**4200**	**350**	**700**	**1050**	**2100**	**4200**
Sales [MWh/year]	406	813	1219	2438	4877	232	464	696	1392	2783
Sales [KWh/day)	1113	2227	3340	6681	13362	635	1271	1906	3812	7625
Average travel distance e-truck [km/day]	150	150	150	150	150	350	350	350	350	350
Energy consumption [kWh/km]	0.7	0.7	0.7	0.7	0.7	1.2	1.2	1.2	1.2	1.2
Energy consumption [kWh/day]	105	105	105	105	105	420	420	420	420	420
Share of fast charging outside own site	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Charged electricity outside own site [kWh/day]	11	11	11	11	11	42	42	42	42	42
Required number of trucks registered in NL per charging hub	106	212	318	636	1273	15	30	45	91	182

Required number of trucks registered in NL per MW installed capacity	303	303	303	303	303	43	43	43	43	43

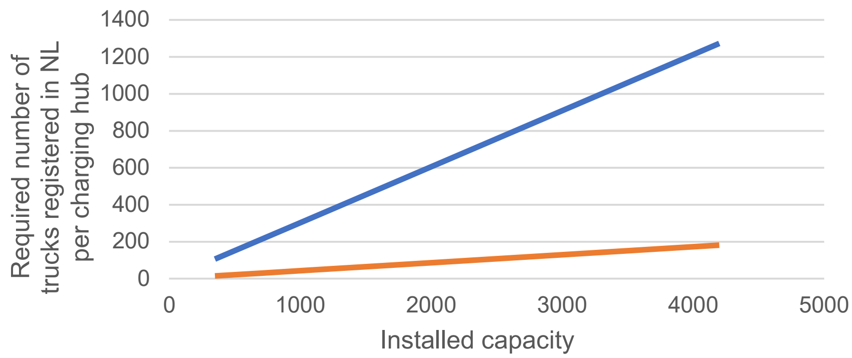

Figure 3: Required number of electric trucks registered in the Netherlands per charging hub.

Another indicator is the required number of users per day. At a sufficiently high level of capacity utilisation, each charging point will be in use between 1.8 and 3.2 hours per day. Based on the assumptions that the average charging session lasts 30 minutes, at a charging hub with one (350 kW) charger, around 3.6 to 6.4 charging sessions will be needed each day. At a charging hub with an installed capacity of 4200 kW (= twelve 350 kW chargers) that amounts to 44 to 76 charging sessions or unique users. Per MW installed capacity, that amounts to between 10 and 18 charging sessions or unique users per day.

Table 6: Number of charging sessions / unique users per MW installed capacity at capacity utilisation of between 8% and 13%

	Installed capacity Light trucks for urban distribution (13% capacity utilisation)					Installed capacity Tractor-trailer units for regional distribution (8% capacity utilisation)				
	350	**700**	**1050**	**2100**	**4200**	**350**	**700**	**1050**	**2100**	**4200**
Average duration charging session [hour/session]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Average charged per charging session [kWh]	175	175	175	175	175	175	175	175	175	175
Number of charging sessions / unique users	6	13	19	38	76	4	7	11	22	44
Number of charging sessions / unique users per MW installed capacity	18	18	18	18	18	10	10	10	10	10

These levels of capacity utilisation are comparable to those of existing petrol stations. Just as with existing petrol stations, capacity utilisation at night will be lower and during the day it will be considerably higher than the 8% to 13%. This means that waiting times may arise during the daytime. Ways of limiting the nuisance and costs of waiting time include the introduction of a booking system and the combination of multiple charging points at a single location.

This latter option will prevent a second vehicle that arrives shortly after the first vehicle has started charging and consequently being forced to wait for (almost) a complete charging session for a free charging point.

1.5. Conclusions

In the future, capacity utilisation of between 8% and 13% will be necessary in order to ensure the cost effective operation of a charging hub. This means that for every MW (around three 350 kW chargers) of installed capacity at (semi-)public fast charging points, between 43 and 300 electric trucks will have to be registered in the Netherlands. For every MW installed capacity, around 10 to 18 charging sessions or unique users will be needed each day.

During the scaling up phase of electric vehicles, proportionally more chargers and charging capacity will be needed in order to smoothly facilitate the electric vehicles. After all, a considerable volume of charging infrastructure will have to be made available throughout the country to make it possible for the first electric vehicles to move freely, without excessive detours.

In a living lab in which lessons need to be learned now for future application, the (expected) future situation will have to be simulated as accurately as possible in the present. This means that the preferred capacity utilisation will be between 8% and 13%. If that capacity utilisation is not achieved, it is possible to model this situation. But because not everything will have been tested in practice, it is possible that not all barriers will be identified in that situation.