Development of a blueprint for the charging network needed for Electrical Vehicles

Antero Alku M.Sc.
Iisakki Kosonen Dr.Sc.

3rd. October 2011

Version 1.0

Authors

Institution	Name	e-mail
Aalto University School of Engineering	Antero Alku	antero.alku (at domain) alkutieto.fi
<others>		

Revision History

Version	Date	Notes	Editor
0.1	1.10.2011	under work	Antero Alku
1.0	3.10.2011	final	Antero Alku

Document Identification

SIMBe WP Title	WPm – Environmental and Urban Impact
Document Type, Security	Deliverable – Public
File Name	SIMBe_D32_UK_111003.docx

Executive Summary

Electric vehicles fuelling differs from the fuelling of the combustion engine car. Electric fuel is available anywhere electric grid is existing, but electricity fuelling is slow and required often when compared to fuelling of gasoline.

Though EV's battery may be fully charged during the night with low power charging pole similar to the poles used currently for engine heaters, the parallel charging of several vehicles require updating for the wiring of existing poles. More powerful poles are required in the destination places of the trips based on EV's home location. In long term the total power of high power pole sets must be taken into account in dimensioning the electric grid.

The availability of the charging is one important factor in shifting from gasoline to electric propulsion. As the city planning is the responsibility of the authorities, the availability of charging infrastructure is also dependent of the rules and plans of the authorities. This can be compared to the rules to dimension the availability of parking space that is set in the city plans.

The current behaviour of car users show, that for daily use EV can be charged during the night at home. This is easily organized in suburbs where parking slot density is high and engine heater pole is already a common practice. In the city centre of Helsinki similar charging availability is not possible. Except some newly built areas, it is not possible to donate curb side parking slots for named EV's. The number of slots is much less than the number of cars owned by residents in the city centre. But also, the car usage is lower as relatively good public transport service is available. Some slots can be reserved for these EV's in the parking facilities in the city.

It seems that selling electricity like gasoline will not be a business. This leads to the situation, where charging elsewhere than at home will happen with the temporary parking like when shopping or during running errands. The price of the electricity is minor compared to the parking fees or to the real cost of offering parking space like for the customers of a shopping mall. Therefore a share of the parking slots in these places are to be equipped with medium power (22 kW) charging poles.

For delivery vehicles, taxis and other vehicles like car share vehicles medium and high power poles are required also at curb side in city centre and at delivery platforms.

The maps of other poles than those at parking slots for homes are represented. Maps are based on the one per cent EV share of the vehicles as set in the SIMBe scenario of the development of penetration growth. For the future the maps may be extended by increasing the share of electrified poles at the parking facilities both at public and private facilities.

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List of Acronyms and Abbreviations

AC	Alternative Current
CNG	Compressed Natural Gas
DC	Direct Current
E-REV	Electric Range Extender Vehicle
EV	Electric Vehicle
HRT	Helsinki Region Transport Authority
ICE	Internal Combustion Engine
LITU	Liikennetutkimus, traffic survey
LPG	Liquefied Petroleum Gas
P-EV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
VAT	Value Added Tax

1. Introduction

1.1. Scope

Electric vehicles fuelling differs from the fuelling of the combustion engine car. Combustion engine car is fuelled with a liquid fuel that is available only at certain points where there are tanks to store the flammable fuel. Fuel is delivered to fuel stations using lorries, there is no pipeline grid connection between the fuelling stations and the fuel industry. Electricity is available all around built environment. By it's nature, electricity grid is continuously connected to the power plant and storage of the electricity is exceptional. So there is basically no need and no practical technology to organize electricity supply as fuelling stations the liquid fuelling is done.

Still there are some limitations for picking up electricity to EV:s from what so ever plug available. Main problem is that the power in fuelling a gas tank in a car is app. 40 liters in minute, which equals to 25 MW electric power supply. The connecting power of a single family house is some 20 kW and a heating plug power for a car at park slot is 3,6 kW. The average power consumption of an EV is roughly 4 kW. Fuelling/consumption power ratio of a combustion engine car is near 1000 when with EV the same ratio is near 1 (one). But still, the need to fuel an EV is 3 to 4 time as frequent as with liquid fuel.

1.2. Industrial challenges

All the above mean that the fuelling of the EV:s must be re-designed compared to current fuelling service. To avoid peak loads in electric grid, stand still time of the EV:s must be benefitted when fuelling EV:s. The major share of charging EV:s should happen night time to balance the energy production power against consumption, that already is as it's highest during day time.

Some share of EV usage requires fast charging. This applies to service vehicles like delivery vehicles, buses, taxes and short time car rental and car share. The high power charging points seem to locate in denser places which is easier by means of the grid.

1.3. Objectives

Electric vehicles charging infrastructure development has a significant role for EV:s to become usable and popular. Charging network is a part of urban infrastructure, in which it differs from the fuelling station network. As a fuelling station is an independent unit that only requires support in form of fuel delivery, charging poles are dependent on the electric grid and cannot be located just where there is a suitable site.

Charging poles location must be included into urban planning the same way as other networks like gas, water and heat pipelines and information network cabling. It is similar difference for electric grid as if the housing area is meant to be for electric or district heating. For having required information for infrastructure planning, a scheme for charging poles must be planned.

2. Overview of charging technology

2.1. Charging poles

Charging poles are simply poles that have an electric socket in a place accessible with a car nearby. In simplest form the poles are similar to the ones used for car engine heaters today. The complexity and structure of the pole depends on the intelligence and power required. Simple poles offer only electricity connection from grid to vehicle and with low current like 16 amps and 230 volts. More sophisticated poles offer higher power, possibly very high current DC connection and IT-connection between the vehicle and the grid. For energy sales the pole may have interface for reading credit cards or collect coins or bills.

In any form the space required for a pole does not vary significantly. The pole does not need to be larger than any liquid fuel meter. The area requirement is practically the area needed for the vehicle to park near the pole. A charging pole does not need any safety structure like a liquid fuelling point to avoid the fuel to get into the ground. A pole is clean and safe and may be placed to any kind of a location outside or inside of an urban structure.

Figure 1. Sample of a Siemens charging pole with a Smart EV-version. Display at Innotrans fair, Berlin, at September 2010. File P1090934.JPG.

2.2. Charging connection

Electricity is delivered as AC and charging poles connected to the grid deliver also AC. Voltage and current that is available are those available to household and regular industrial use. Nominal voltage in Europe is 230 V AC. Poles may deliver one phase or 3-phase current with 32 amps maximum current.

The connection in the car may limit the charging power. As batteries require DC, car must have AC/DC-converter. Car also has control circuit to manage the charging for not to damage both the AC/DC-converter and battery. The devices in the car actually specify how the charging happen.

Smart charging connection means that the car can communicate with the pole and possibly adjust the charging with the energy production. The simple solution is that smart connection adjusts the maximum current and time of the charging. More complex connection may allow the battery to be used as a back-up for the grid. In this case a DC/AC-inverter is required to return electricity from battery to grid. Each EV has DC/AC-inverter as the usual electric motor solution is AC-motor. But the voltage level of the car motor may not be the same as AC voltage in the pole and then possibly a separate inverter for re-charging is required.

For the highest charging power EV:s may have DC-connection, in which case the DC/AC-function is stationary and outside the EV. For car manufacturer DC-connection is simple and cheap but the pole is complicated and expensive.

2.3. Charging time

Characteristic for EV:s is that charging power is low compared to vehicles power consumption and battery capacity. The limiting factor is the battery chemistry. The current target is that batteries tolerate charging power that is three times the battery's capacity expressed in kilowatthours.

To compare to a liquid fuel vehicle, fuelling power of 40 liters per minute equals to 25 MW power to move energy from tank to vehicle. And comparing that to the average power of a car, it is approximately 1000 times the power of a car. Same ratio with electric car is with best technology approximately 6 times the average power consumption. This figure is based on the fast charge pole to have 22 kW power and a car energy consumption is 0,2 kWh/km. In urban environment the average power of a car is 4 kW.

The highest possible charging currents may be achieved by DC charging. The limiting factors are the maximum current for the battery and mechanical solutions to connect high current charging with safe and reliable way. Also high charging currents decrease the battery life time and as the battery is very expensive part of the EV, decreasing the battery life should be avoided.

The practical situation is, that fastest reliable commercial charging service takes some 20 minutes to charge an empty battery after 150 to 200 kms use. This is too long time compared to current fuelling practice, where fuelling is required after 500 to 600 kms use and it takes totally less than 5 minutes. We may count that fastest fuelling time for an EV is 10 minutes per each 100 kms when it is 1 (one) minute per each 100 kms with combustion engine car. This can be expected to alter the fuelling practice of cars.

2.4. Charging practice

As EV:s are not yet in large scale production and use, there is no large scale experience of how EV:s are charged. Therefore the future charging practice must be forecasted based on the technical and economical characteristics of EV charging.

Current fuelling practice is to fulfill the tank and drive app. 80 % of the capacity until refuel. The average number of gas station visits with current cars in Finland is 32 times a year when counted from the mobility statistics. If EV might also be charged only from public sources, it should visit a pole at least 180 times a year, practically every other day. As fuelling time is just few minutes, fuelling practically do not increase the time used in traffic.

Fuelling gasoline takes about 5 minutes but 20–30 minutes is required for charging in good conditions. It is not difficult to estimate, that EV fuelling may not be based on current practice, because fuelling frequency is 3–5 times the current frequency.

German BMW organized a 650 cars field test in France, Germany, UK, USA, Japan and China. The result from this test was that 56 % of the users never used public charging point. Main reason for not using public charging point was the availability of home charging (Becker 2010). The result must be compared to the circumstances. Field test was done in the world that is not made for EV:s having public charging points widely available. Average daily distance travelled was 38 kms and the operating range of the test vehicle was over 150 kms. Furthermore the users had also combustion engine car and there were no need to try to operate EV for long distances.

The EV itself may also limit charging practices. AC-charging requires rectifier in the EV and it's power may be limited. Maximum charging current in the battery poles is also limited. High current shorten the battery lifetime and decrease charging efficiency.

As charging time is longer than fuelling time, it is evident that charging will be combined to parking. Main charging will be night time charging when there is plenty of time and simple and cheap low power charging is possible. To organize a charging pole is easiest for single family house owners. In apartment blocks parking is organized to open air fields or in houses or caves. If the slots are in open air, they are usually equipped with electric connection pole for engine heating. These poles are suitable for charging, but the cabling may require rebuilding for higher loads, because the heater power is limited to 0,5 kW.

These poles have often a simple 2 hours clock switch and the rent of the pole is based on the electricity consumption limited with the clock switch. Clock must be disabled and the renting policy adjusted. There may appear problems in financing the modifications, if only few of the residents are interested in charging.

Cars are widely used for shopping and cars are parked for 0,5 to 2 hours during the visit in a shop or in a mall. That is suitable time for charging and long enough to fill near empty battery. There must be available slots with at least 22 kW power. For those not having access to night time charging, charging while shopping may be the main electricity source when shopping frequency is 1 to 2 times a week. This kind of charging practice is not very recommended in long term by means of electricity production. Though it is not happening with the highest production load hours during the day, it may still increase the peak load in weekdays.

The role of fuelling stations may not convert to charging stations. First, the service is not satisfying when charging times are 20 to 30 minutes and there is no use than waiting for that time. Second, as the capacity of a charging point may be 2 to 4 cars per hour, it is significantly lower than the capacity of a fuelling point. From the business point of view, the sales margin of one EV-customer must be 2 to 4 times higher in currency than that of one gasoline fuelling customer. The required profit may end up to too high sales price for the station to be competitive against charging while parking during shopping or in home. Charging at fuel stations may not work as business.

Cars are also standing during the day if the car is used for travelling to work. This parking time is also long enough to charge the battery with low power. By means of electricity production charging during the day is not recommended as it increases the peak load of energy production.

All these aspects mentioned above lead to estimate, that main charging of EV:s happen in home during night time and in the morning EV has it's full operating range available. With 20 kWh net battery capacity the operating range is 100 kms which fulfills the daily needs of the majority of the EV users. Public charging is most important in free time destinations as free time travelling may increase the daily range after EV has already used for a work trip. 22 kW pole fills the charging requirement.

2.5. Invoicing the charging

In the early phase of chargeable EV:s they are allowed to use household electricity which means, that there is no special traffic energy tax for electricity charged into EV:s. EV:s are taxed with fixed tax called *käyttövoimavero* (propulsion tax) which is based on the weight of the vehicle. At the beginning of the year 2011 propulsion tax for chargeable EV is 1,5 cent per day for each starting 100 kilograms of the gross weight of the vehicle. F.ex. an EV with 1450 kg net weight and capacity for 5 passengers and 100 kg cargo must pay 109,50 € propulsion tax per year. Propulsion tax is invoiced from the owner of the vehicle.

Charging in home is invoiced with the household electricity invoice. Charging poles in the parking sites of the apartment blocks may be equipped with kWh-meter or invoicing of the consumed electricity may be included in the rent of the pole as is the case with current engine heating energy. Average annual energy cost of an EV is 470 € which is 40 € as a rent per month. With this volume it may not be economical to pay for kWh-meter for each park slot.

Invoicing the electricity may be included into the parking fee also in the parking facility. This is also quite correct if the charging power is constant and charging last as long as the EV is connected. The energy cost to load 25 kWh is app. 4 € which fits to current parking fees. In Helsinki the curb side parking fee is 4 €/h and 5 €/h in a cave.

Shopping malls and shops may want to offer both parking and electricity for free to attract customers. The cost of a slot per hour used is app. 1,5 € based on the building cost of the facility. When parking is offered for free, this must be covered from the sales income of each customer visit. To offer charging from 16 A socket for an hour causes 0,5 € extra cost, which probably is tolerable with all customers. If the mall offers more powerful charging, as 22 kW socket, cost per hour is 3 €. This may require to limit the free charging benefit to customers whose purchase exceeds certain limit, like 100 €.

If the pricing of the charging is to be bound to charging properties, like the time of the day, the speed (power) of the charging or vehicle-to-grid functionality, a smart charging connection may be required for the adjustable pricing. The functionality requirements for the smart charge system depends on the pricing and taxing scheme. In case the price differs based on the charging speed and available energy production, the system requires data from the status of the production and grid load. It may also be necessary to know the purpose of the electricity. If the electricity used for moving the vehicle has a special tax but not the heating when the vehicle stands still, consumption must be counted separately. And furthermore, if electricity is available free of charge in places like shopping malls, the system needs to recognize when charging will be invoiced and when not and what is the taxing rule in free charging.

3. Car use demand

3.1. Helsinki region definitions

Generally spoken Helsinki region is the urban area around city of Helsinki. But there are plenty of naming conventions used in speaking and media so that it is not exactly clear what is meant. In this work the definitions of the Helsinki metropolitan area mobility survey 2008 (Strömmer et al. 2010) are used. These definitions are based on the county borders and the indicated daily pendeling between the counties. Survey areas and collected survey answer numbers are shown in the following picture (Figure 2).

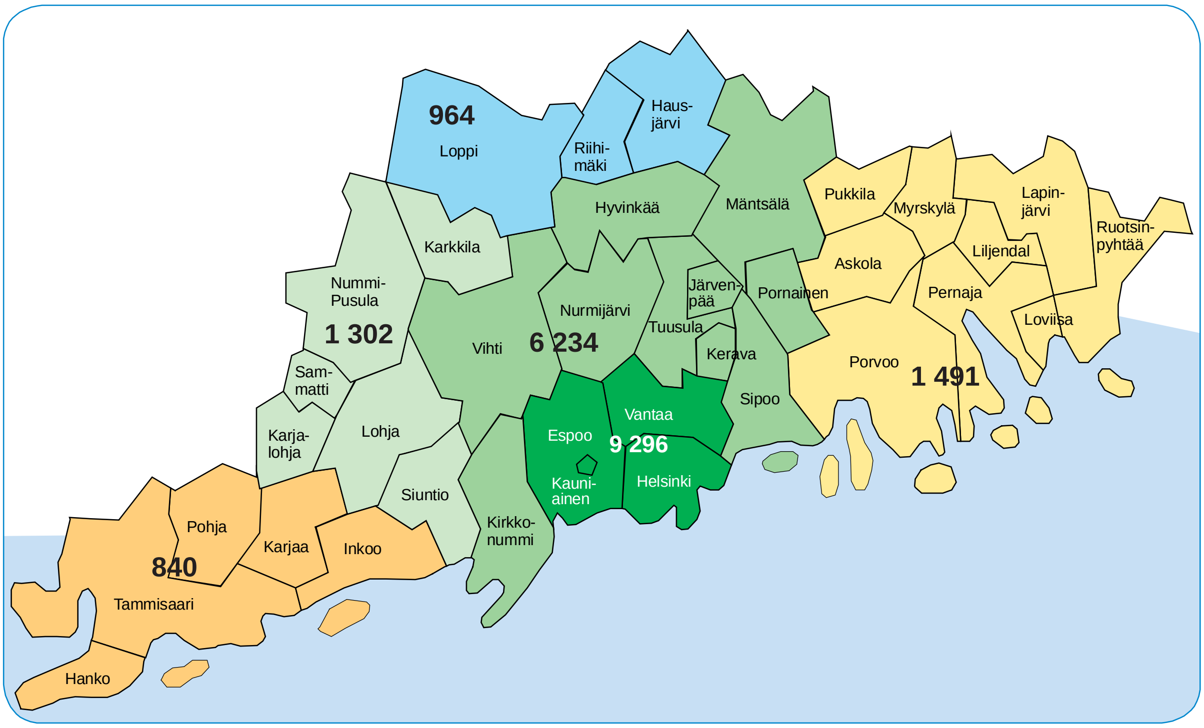

Figure 2. The survey area of the Helsinki metropolitan area mobility survey 2008. The numbers indicate the amount of answers collected from each partial area (Strömmer et al. 2010).

The dark green area is often called *pääkaupunkiseutu* and is called *capital city region* in this work. It includes the four core counties, Espoo, Helsinki, Vantaa and Kauniainen. The medium green area is called as *Muu Helsingin seutu (10 kuntaa)* in the survey. In this work the area of these 10 counties is called *Urban sprawl area*. Together these 14 counties form *Helsinki metropolitan area* which is called *metropolialue* in Finnish. *Helsinki metropolitan area* is a definition made by the Finnish government for legal and administration purposes. It is also the area which was specified as the competition area in an international planning competition *Greater Helsinki vision 2050* to develop the Helsinki metropolitan area up to year 2050.

The other areas are named as:

- Raaseporin seutu (Raasepori area), orange
- Lohjan seutu (Lohja region), light green
- Riihimäen seutu (Riihimäki region), blue
- Itä-Uusimaa (Eastern Uusimaa), yellow

All the above listed regions are named as *other survey area* in this work.

After the survey some counties shown in the map are joined. The map shows the state of year 2008.

Inside the city of Helsinki there is also a division made to separate the *Helsinki, kantakaupunki* that equals to *Helsinki city centre* and *Helsinki, esikaupunkialue* that equals to suburbs inside Helsinki city. This is because of the urban structure of the city centre that is the densest built area and the only traditional city structure. The following picture (Figure 3) describes the survey areas inside capital city region. All the other areas in capital city region than Helsinki city centre are considered as *suburban* area.

Figure 3. Survey areas inside capital city region in Helsinki metropolitan area mobility survey 2008. Cities of Espoo and Kauniainen are considered as one area.

To summarize the naming definitions in this work, see the following picture (Figure 4).

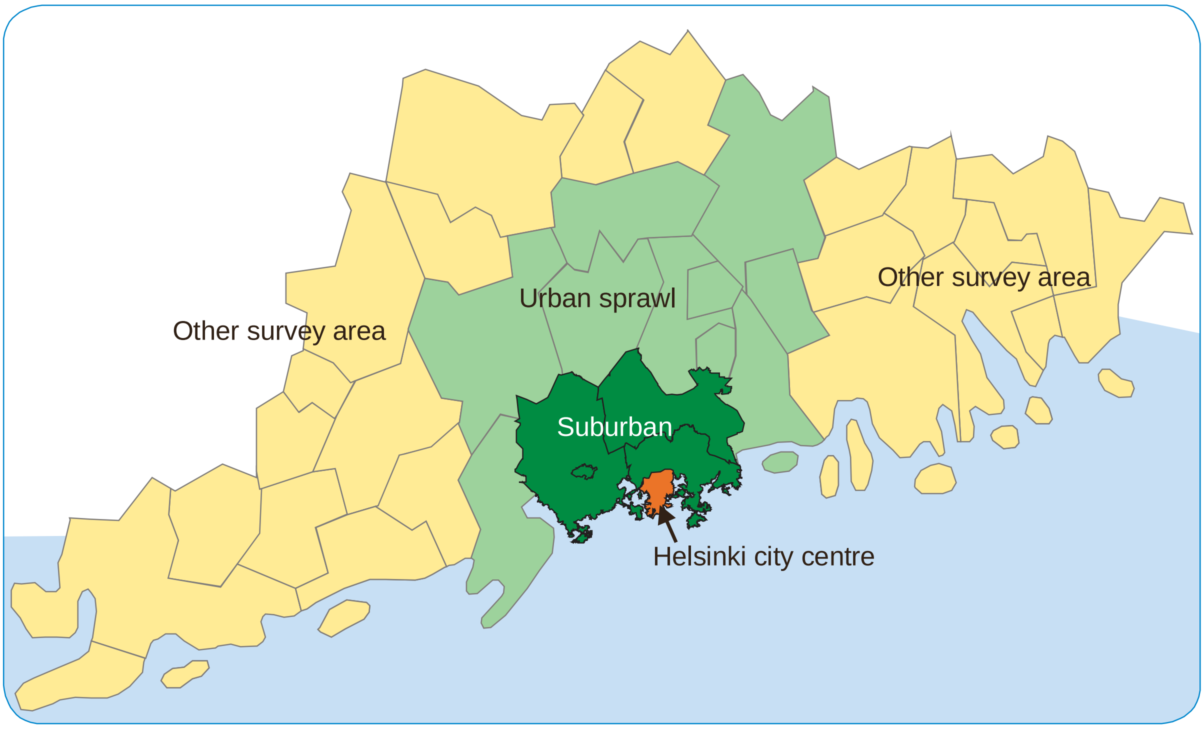

Figure 4. Area definitions in this work.

3.2. Helsinki region car use behavior

Car use in Helsinki region varies depending on the home location of the citizens. Those living in the city centre of Helsinki own and use less car and drive shorter trips than the ones in suburban and urban sprawl area (Strömmer et al. 2010).

In Helsinki capital city region (pääkaupunkiseutu) that equals to area of Espoo, Helsinki, Kauniainen and Vantaa, car ownership is less than 400 cars per 1000 inhabitants, but outside that area car ownership is over 500 both at urban sprawl area and nearby town regions (Figure 5). The number of cars per household follows the ownership rate. In capital city region 13 % of the households have more than one car but outside capital city area share is 29–32 %. The share of non-car households is also highest in capital city region and also in higher income households. Practically all the households outside capital city region have at least one car from income class 4 000 to 6 000 € per month.

The number of cars in register at capital city region in 2009 is:

- Helsinki 221 343
- Espoo and Kauniainen 113 854
- Vantaa 93 965

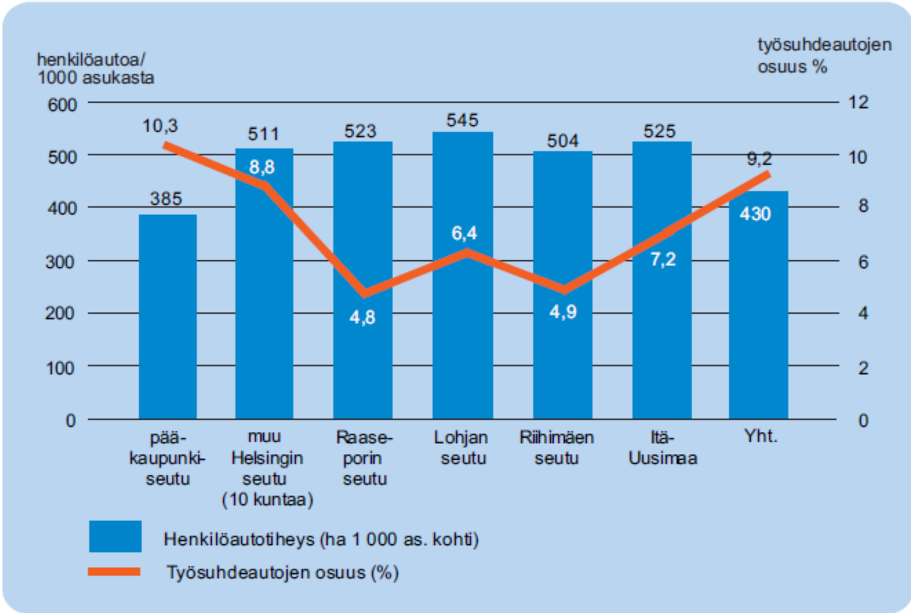

Figure 5. Car ownership and share of employee cars (Strömmer et al. 2010).

In the city centre of Helsinki the average number of car trips per inhabitant is 0,7 per work day and in urban sprawl area it is 1,9 trips (Figure 6 and Figure 7). Urban sprawl area has smaller town centers with urban structure, but the structure density as it's best equals to suburban structure in capital city region.

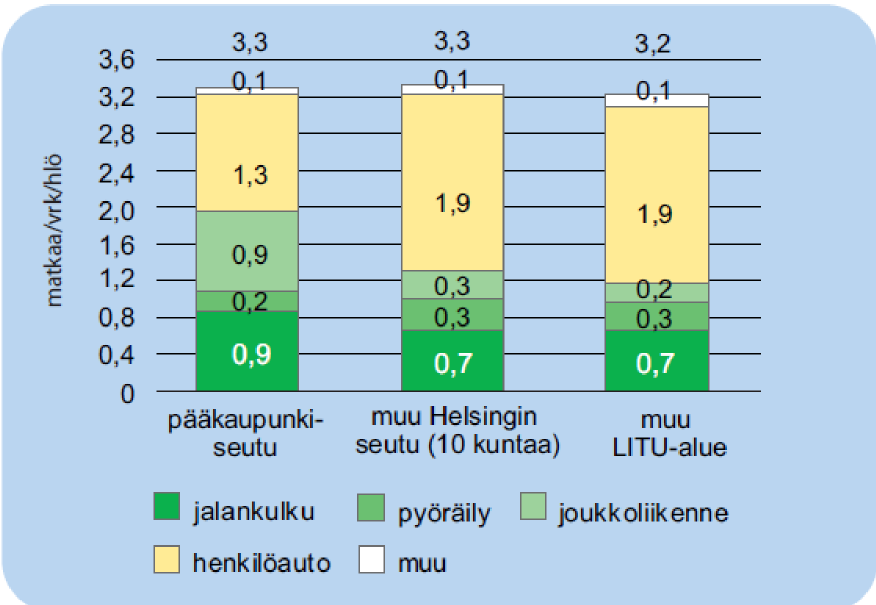

Figure 6. Number of trips per work day per citizen from HRT mobility survey 2008. "Pääkaupunkiseutu" (capital city region) equals to area of Espoo, Helsinki, Kauniainen and Vantaa. "Muu Helsingin seutu" equals to nearest 10 counties around capital city region and "muu LITU alue" rest of the survey area. Yellow is the share of car use (Strömmer et al. 2010).

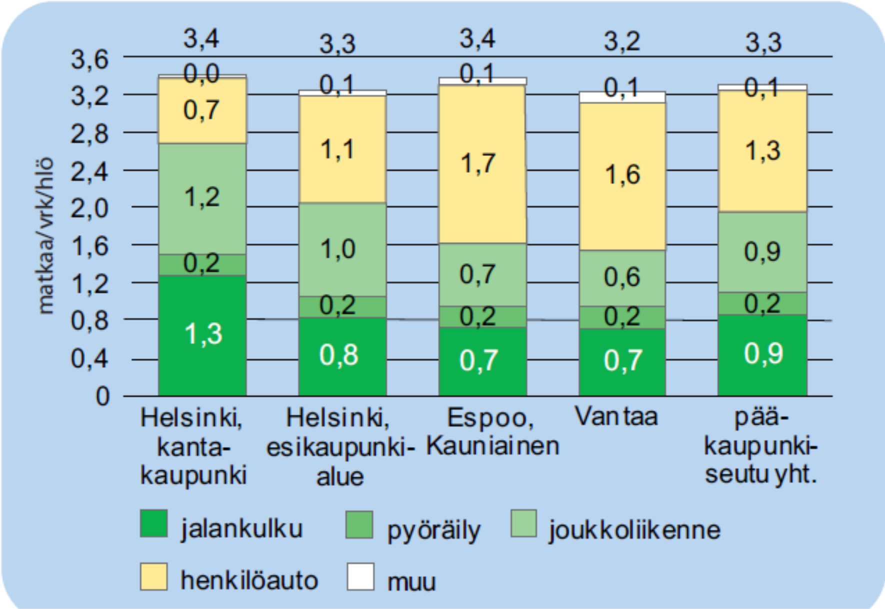

Figure 7. Number of trips per work day per citizen from HRT mobility survey 2008 at capital city region (pääkaupunkiseutu) that equals to area of Espoo, Helsinki, Kauniainen and Vantaa. "Helsinki, kantakaupunki" equals to Helsinki city centre and "Helsinki, esikaupunkialue" equals to suburbs inside Helsinki. Yellow is the share of car use (Strömmer et al. 2010).

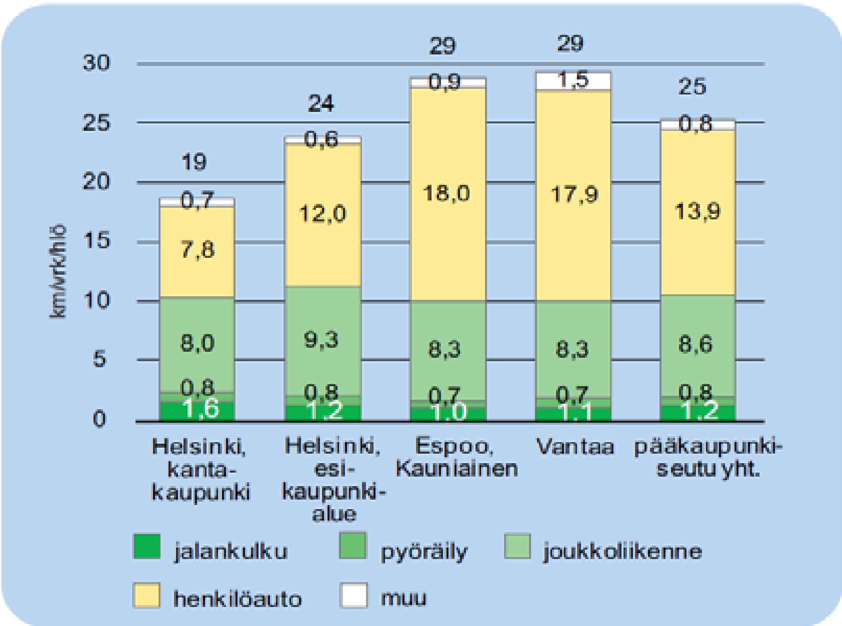

Figure 8. Kilometers travelled per work day per citizen from HRT mobility survey 2008 at capital city region (pääkaupunkiseutu) that equals to area of Espoo, Helsinki, Kauniainen and Vantaa. "Helsinki, kantakaupunki" equals to Helsinki city centre and "Helsinki, esikaupunkialue" equals to suburbs inside Helsinki. Yellow is the share of car use (Strömmer et al. 2010).

For EV charging needs the relevant data is the daily use of car. The average number of kilometers per day gives a figure of car use behavior. At Espoo and Vantaa car usage is more than double of that in city centre of Helsinki, outside this over three times as much (Figure 8 and Figure 9). Based on the survey data these average values are near the work trip lengths and a rough estimation is, that one car's daily use is twice the average reported kilometers.

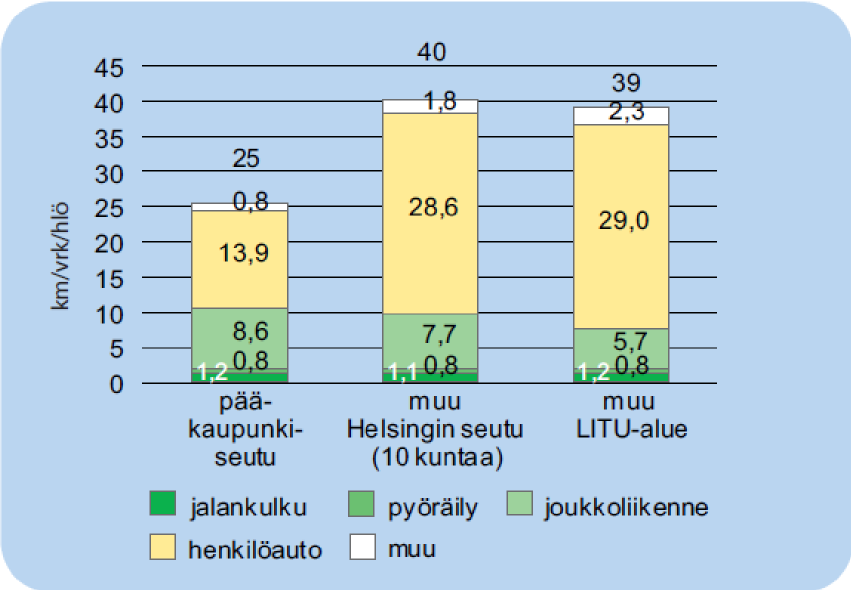

Figure 9. Kilometers travelled per work day per citizen from HRT mobility survey 2008 at capital city region (pääkaupunkiseutu) that equals to area of Espoo, Helsinki, Kauniainen and Vantaa, at ”Muu Helsingin seutu” that equals to nearest 10 counties around capital city region and ”muu LITU alue”, rest of the survey area. Yellow is the share of car use (Strömmer et al. 2010).

More general data about trip lengths for various purposes and at various living environment is found from the work of Ristimäki et.al. (2011). At capital city region the length of the work trip is 11.8 kms at public transport zone and 12.9 kms at car use zone. At other survey area in Figure 4 work trip length is 25.6 to 26.8 kms at car zones. This equals to the work trip lengths in other parts of Finland. The share of car in modal split is dominant, 80 to 90 % at car use zones.

Shopping trips are shorter. At capital city region the average length of the grocery shopping trip is 3.2 kms at public transport zone and 4.3 kms at car use zone. At other survey area shopping trip length is 8.9 to 9.5 kms at car zones. This is slightly more than the shopping trip lengths in other parts of Finland. The share of car in modal split is dominant, 65 to 75 % at car use zones of other survey area. In capital city area share of car trips is 37 to 52 %.

To summarize these results, the maximum daily use of a car might be app. 80 kms at the car use zone of other survey area. In this case the car is first used for work trip and then for shopping. This is safe for the average operating distance of an EV when the battery is fully charged in the morning. As the practice of shopping is not to shop daily, EV might be used two days with one charge, also when one shopping trip is included into these two days.

Interesting matter is the situation in the city centre of Helsinki, where night time charging is not possible for everybody. In the work of Ristimäki et.al. this area is considered as *pedestrian zone*. Work trip length is 5.8 kms and shopping trip length is 1.2 kms. The share of car in work trips is 15 % and in shopping trips 10 %. Motorized travelling has 60 % share in work trips but only 20 % share in grocery shopping. In other shopping motorized travelling share is 37 %.

This proves, that car is not necessary because of good availability of public transport and shops at walking distance, but also, that the charging availability is not critical. Operating distance of an EV covers average weekly travelling excluding week end trips to summer cottage. The EV user can charge the vehicle when shopping if a 22 kW medium power pole is available. This works as long as the battery does not need heating during winter time.

3.3. Parking in survey area

Organization of parking differs in various areas of the survey area. In the city centre of Helsinki parking is organized to caves which are operated by private companies (Figure 10). The capacity of these caves is app. 6000 places when the ongoing building is finished. Outside the city parking is curb side parking and in recently built buildings in private facilities built in cellars.

Helsinki city has marked the curb sides as *residence parking* (asukaspysäköinti) which is free for those having address in the city and purchased a sign to indicate the right to park. Residence parking is organized into 12 zones. Residence parking is over demanded. There is 1,5 signs sold per one slot. Number of slots is 19 200.

For those not having a residence parking sign parking is possible against fee in three price classes. Those paying parking fee share the capacity of the curb side slots with the ones having the residence parking sign. Outside the residence parking zones and parking fee zones curb side parking is free for charge but may be limited for time.

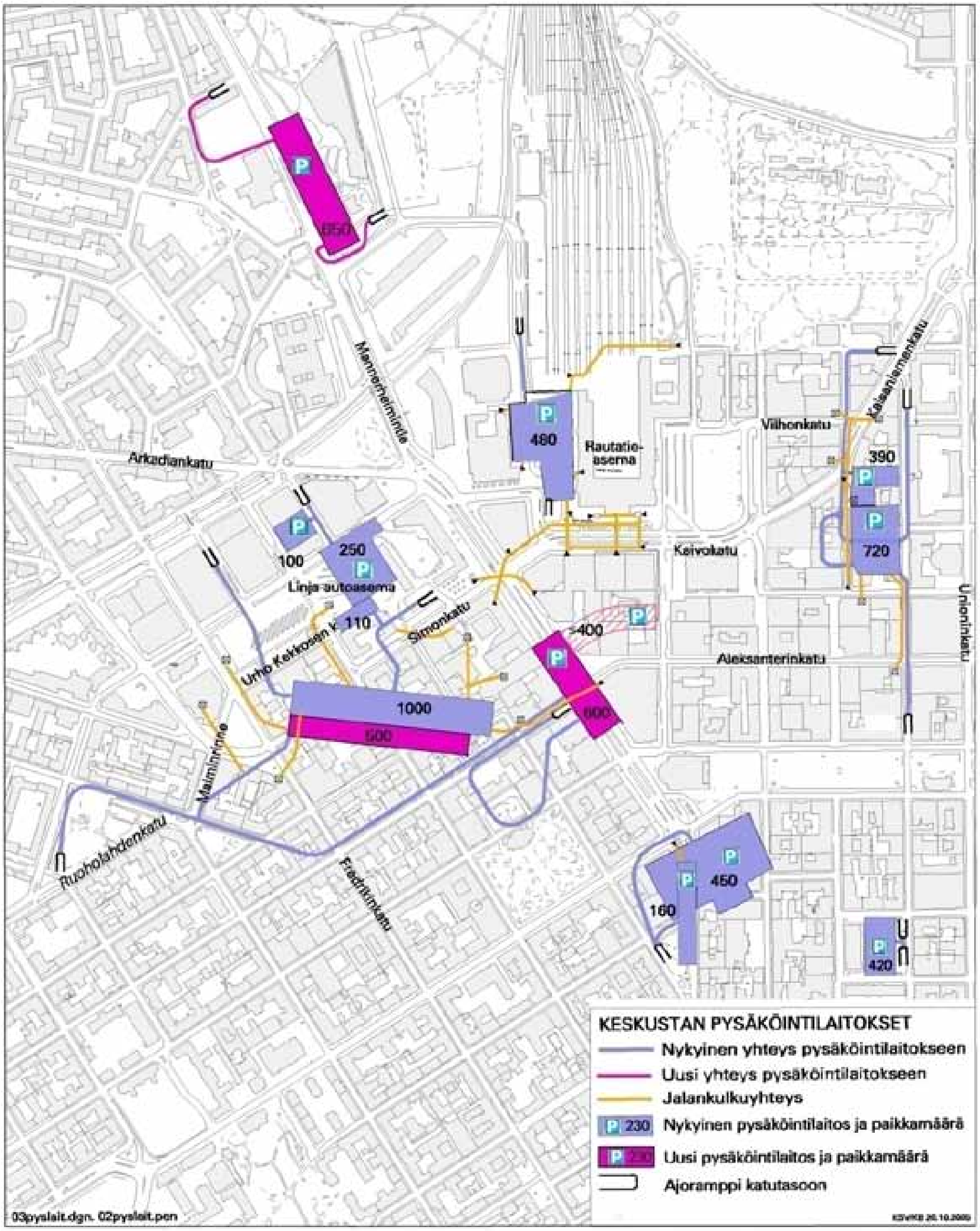

Figure 10. Parking sites in the city centre of Helsinki. Source KSV.

In elder suburbs curb side parking has important role. In suburbs built later parking norm has been used to force building of onsite parking facilities. Up to 1980’s onsite parking was open air fields and later in buildings or underground. In Arabianranta and Ruoholahti the ground makes underground parking very expensive and there are private parking sites beside streets in curb side style (Figure 11).

Figure 11. Dedicated curb side parking with heating poles in Ruoholahti at Kasuunikuja. The street is public street but the parking slots are private. While the poles are in row with the trees, there is no need to plough snow near the poles. This organization differs from the situation in the city centre by the dimensioning of the street width. There are no tree rows in the city and the lane width between parked cars may remain less than 3 meters.

Parking norm varies in cities and in different locations. Current base rule is to have one park slot per apartment. In urban sprawl area most of the housing is single family houses and they have parking space on site according to the need.

Parking for shopping in the city centre of Helsinki is in the public caves. Outside the city shopping centers have their own parking facilities. Density of parking slot varies being approximately one slot per 30 sqm of shop area which roughly equals to one slot per 30 daily visitors. Share of shoppers using a car in the city is low, 10–20 % but very high, 90 % in large malls outside the urban area. Parking of the shopping centers located outside the urban area is usually at open air fields, as the cost of parking is one factor in choosing the location.

The availability of parking is a major factor in choosing the mode of travel to work. Company parking is very limited in the city centre of Helsinki, though there are many park facilities that are 100 % permanently rented to company parking. And in newer buildings cellar parking is common practice. In the city centre rent price is 300–370 €/month (inc. VAT) and in suburbs like Pitäjänmäki 62–86 €/month (inc. VAT). Outside the city companies use to have 100 % availability for parking if not located near public transport corridors.

For public transport users Helsinki region has park and ride facilities mostly for heavy rail stations. Total number is 11 600 slots at 64 locations after two large projects as the metro extension to west and commuter rail ring to airport are finished. These slots represent still a minor part of commuters, as the capacity equals only a couple of per cent of the amount of commuters.

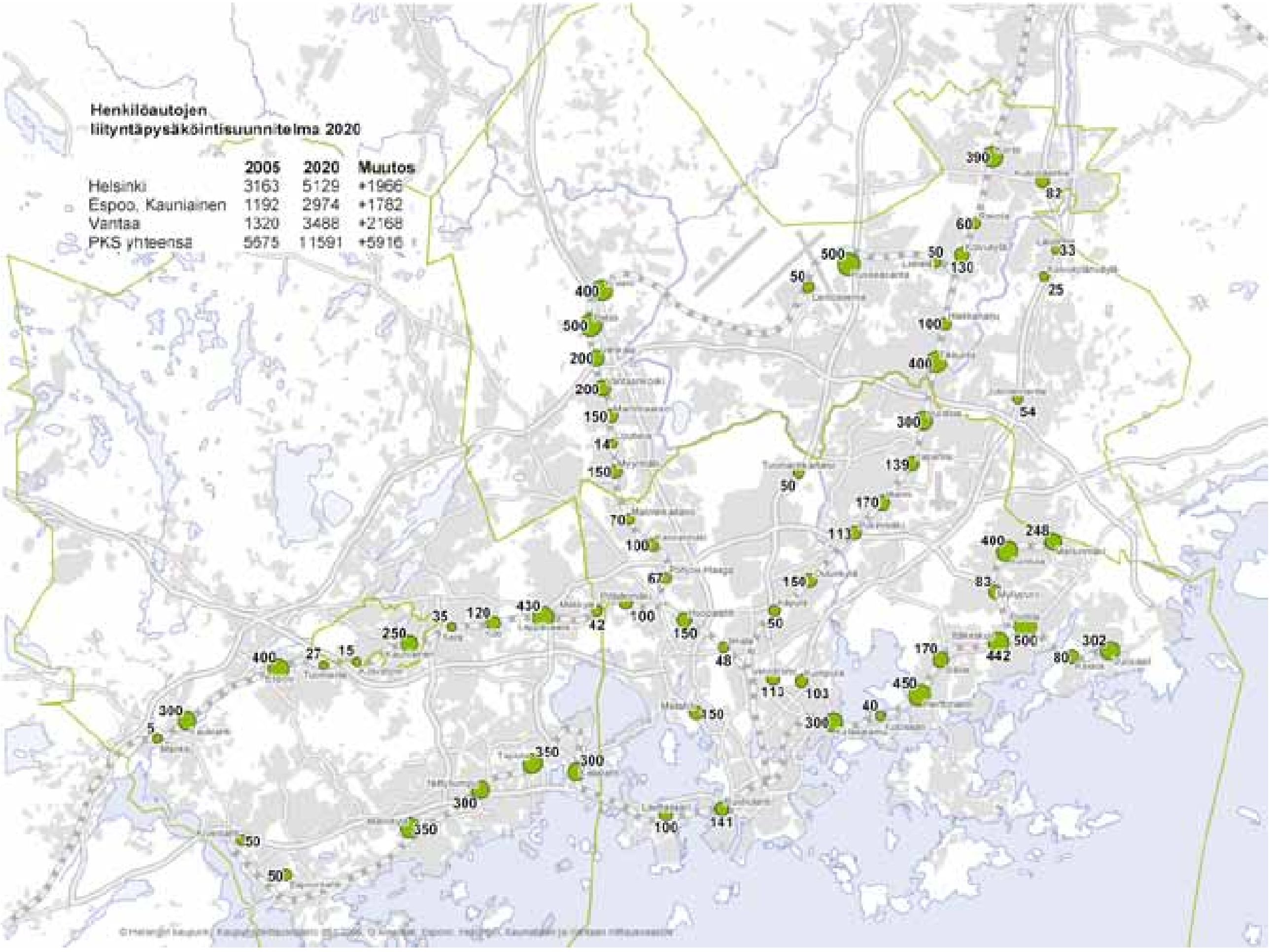

Figure 12. Park and ride facilities after the completion of the heavy rail network. Source KSV.

The region has currently 93 slots reserved for car sharing. Most of these are located in the city centre area. For delivery traffic there are 18 curb side slots in the city centre area. The number of taxi stations is 146. In the city centre these are curb side.

Helsinki-Vantaa airport is a special case having plenty of long term parking. Total number of parking is 12 400 distributed in multi floor building in front of the airport buildings and open air fields served with buses. At airport there is also large parking capacity reserved for car hire services.

3.4. Potential for EV use up to 2015

The survey result may be interpreted so, that in the city centre car use is both unnecessary and impossible for those living in the city centre area. It takes more time to move the car from one place to another, choose a park slot or drive to a cave than have a short walk or take a tram. Public transport network serves well for trips inside the city centre area and also for trips to city centre. Space for both car traffic and parking is limited in the city centre and the whole traffic infrastructure capacity is in use (Alku 2010).

In suburban and urban sprawl area the situation is much complementary to the situation in city centre. Good quality public transport service exists mainly in rail corridors and only towards city centre. If daily travelling heads to other directions, car is practically only way to travel. Two cars is required as often couples work in different places so that one car use is not practical. Population density is low and road network capacity is sufficient. This ends to long distances what for the kilometers travelled are high.

In two car households, EV with it's low operating distance still fits to the requirements of the travelling with the "second" car. Daily usage does not exceed the battery capacity and the charging facility at home fills the charging demand. It also fits to the principle to charge the battery during the night. If daily use is f.ex. no more than 80 kms, required charging time is four hours from 16 amps pole. With this time there is also flexibility for smart charging adjustment.

If the first car is a combustion engine car, that fills the need for long distance travelling like weekend travelling to summer cottage. So to have an EV as a second car is no problem for the living practice. But EV as a second car offers the best value in the long distance daily use at urban sprawl areas during energy cost savings.

In the city the reasons for having a car are different than in other survey area. A car may not be required for daily use. Car is more for week end and holiday travelling which means long trips what for current EV is not suitable. By means of economy the households in the city may well be capable to buy two cars, but it is difficult, expensive or impossible to find a park place for the second or even for the first car. The car ownership statistics prove this already with current cars.

In the city the potential for EV:s is in short time rental and car share but also in delivery. Common for all these is the operating in limited area and low average speed. Average speed in city area is 20 to 30 kph. To empty the average battery requires 5 to 8 hours continuous driving. In the dense urban structure medium or high power charging poles can be available so densely, that each time an EV is left standing to reserved car share or rental car park slot it can be plugged in. Park slots reserved for delivery use may also be equipped with charging poles to charge the delivery van during the time of loading and unloading. Larger shops with loading platforms already have high power available for lifts etc., so charging is easy to offer at platforms too. If poles are at least 22 kW 3-phase poles, standing time charges app. three times as long driving time.

3.5. EV policy choices up to 2015

It seems to be quite clear around the world that switching from combustion engine cars to EV:s happen very slowly as market driven process. May the reason for that be business interests of the oil fuel based car industry or technological challenges and need to finance the development, to speed up the process requires efforts from society. That is also necessary for setting up the charging network, as it is any way in control of the authorities. The question then is, what or which are the policies to use to speed up EV penetration.

To set up the charging network is the base policy which cannot be avoided. For not controlling the building of the charging network is easy to expect to lead to troubles both in energy production and grid loading in long term. Therefore to locate poles in suitable places must be taken as a part of traffic environment planning. It is similar task as to control the number of parking places with the city planning.

In short term, up to 2015, the number of EV:s is expected to be as following displayed in Table 1 based on the SIMBe scenario. Car usage is based on statistics. Use of light EVs is expected to be the daily travelling to work or studies and shopping. Same applies to the kilometers collected with an electric bike, though without any experience it is difficult to estimate the usage. An electric bike may be placed in between an ordinary bike and a scooter as a commodity. But the big question is, may the popularity of electric bikes follow the practices in European cities where bicycling is popular, if it will be easier here with the use of electric power in hilly circumstances and longer use periods with milder winters.

Table 1. Number of electric vehicles and their energy consumption from grid to vehicle at 2015 in capital city area. PHEV is a plug in hybrid vehicle and E-REV is a plug in electric vehicle with fuel operating range extender. Both these are assumed to be used with charged electricity for 13 000 of the annual 18 000 kilometers.

Vehicle type	**Number**	**Annual kilometers**	**Energy consumption**	**Annual consumption**	**Total annual consumption**
Battery-electric vehicles	1000	18 000	0,2 kWh/km	3,6 MWh	3,60 GWh
PHEVs or E-REVs	3000	13 000	0,2 kWh/km	2,6 MWh	7,80 GWh
Light EVs	900	6 000	0,12 kWh/km	0,72 MWh	0,65 GWh
Lorries	80	20 000	1,2 kWh/km	24 MWh	1,92 GWh
Buses	20	70 000	1,2 kWh/km	84 MWh	1,68 GWh
Electric bikes and scooters	3000	2 000	0,03 kWh/km	0,06 MWh	0,18 GWh
Total					**15,83 GWh**

Annual electricity usage in only Helsinki city area is app. 8 TWh. Compared to that the expected electricity usage of vehicles is small. Still it is worth for to have a plan on how to forward when number of EV:s and their charging demand grows.

The charging network grid policy may include following items:

- Program for establishing car share charging slots
- Program for establishing delivery charging slots
- Program for establishing short term rental car charging slots near or together with important public transport nodes
- Make a smart charging pole mandatory for households in urban sprawl areas
- Set up a program for growing amount of smart charging poles to be built into all existing parking facilities

Charging network set up policy is mostly under control of local county authorities, as the policy items listed above are part of the land use planning and building authorization processes. Smart charge technology is at least national or possibly international question.

Pricing of EV:s and energy used in vehicles is key promoter to speed up or slow down the penetration of EV:s. This is a question that must be solved at national level (See also about smart charging in chapter 2.3). The question comes relevant along with the setting up of the charging network. The charging network and smart charge technology separates the EV charging from using the household or industry electricity tariffs. At the moment household electricity is very cheap compared to liquid fuel energy for car use. But if this will remain the case and it is citizens benefit to charge from regular home socket, then the control to balance the network and power plant load is lost.

EV usage may be supported with traffic management practices. For the first some priorities may be offered to EVs. Cities may offer free or reduced parking fee or parking slots that are only reserved for EVs. At ”green” or ”emission free” zones only the use and parking of EVs is allowed. This can start already at the low level of EV penetration with low number of parking slots and only small areas. For example if a city has pedestrian area, the nearest streets and parking facilities may be EV-only and when the EV penetration exceeds the capacity of the priorities, priorities will be added. City of Helsinki decided in March 2011 to reduce parking fees with 50 % for vehicles that less or equal than 100 grams per km CO_2 emissions.

3.6. Long term development to 2050

Based on the current knowledge of technologies, raw material supply and industry's ability to switch from current car industry to EV industry, only 1/4 of the private car sales may be charge-only EVs in 2050 (see Figure 13).

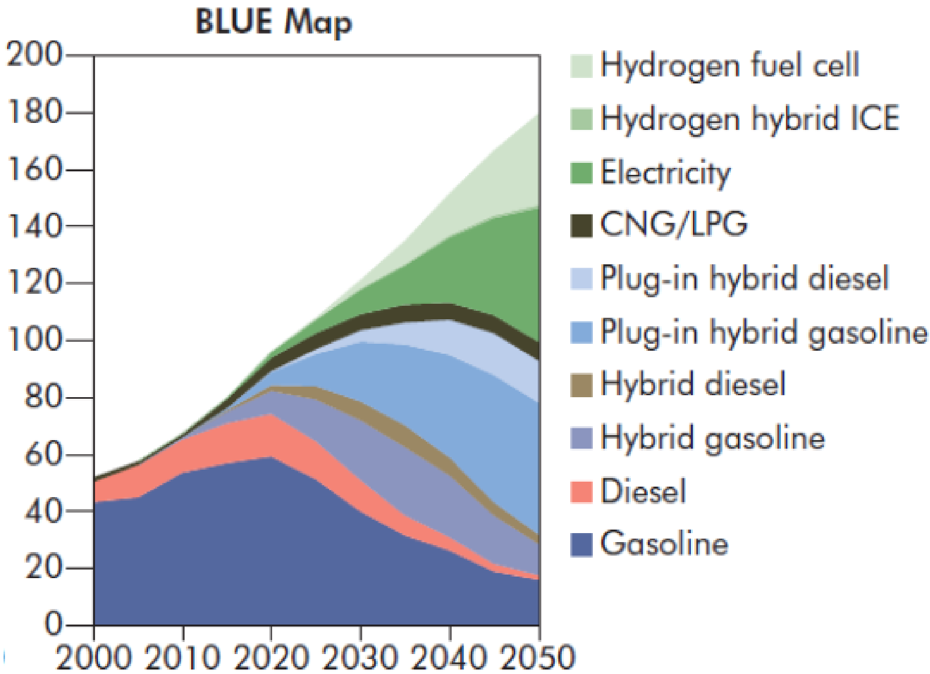

Figure 13. Worldwide share of various car energy technologies from the car sales up to 2050. Share of plug-in only (dark green) is minor compared to the whole car sales. (Cazzola 2010).

In SIMBe scenario work it is estimated that there is 180 000 electric vehicles in capital city area at 2050, including those plug-in only and the ones being plug-in hybrids or fitted with a range extender. As the car ownership is roughly 400 cars per 1000 inhabitants (see Figure 5) and the estimated number of citizens in capital city area is 1,4 million in 2050 (HSL 2011), the total number of cars will be 0,56 million. The SIMBe scenarios share of plug-in EVs is then 32 % of all cars.

For the charging network planning purposes it is important to forecast the deviation of various car technologies. Based on the need for a car and available space to store a car, the development may follow the guidelines in Table 2.

Table 2. Development trends in various parts of Helsinki region. EV car type refers to dominant type.

Area	Year 2015		Year 2050	
	Car density	EV car type	Car density	EV car type
Helsinki city centre	350 cars/1000	Plug-in Hybrid	350 cars/1000	EV with range extender
Suburban	400 cars/1000	Plug-in only EV	350 cars/1000	EV with range extender
Urban sprawl	520 cars/1000	Plug-in only EV	500 cars/1000	Plug-in only EV
Other survey area	560 cars/1000	Plug-in Hybrid	560 cars/1000	Plug-in only EV

In the table above, following assumptions are made:

- In Helsinki city centre area, most of the household that have a car, use it for free time and week end travelling. Trip distances are longer than the range of a plug-in only EV. For the first the motivation to switch to EV is to reduce the driving cost and a hybrid serves for that purpose. When more developed EV:s become available, suitable product to fit the customer needs is an EV with range extender.
- In suburban area many households have two cars and the ones to invest to EV are those households. The second car is for suburban daily use only and can therefore be plug-in only EV. There is no use to pay for hybrid or range extender, as for long trips a conventional car may be used. For 2050 public transport service becomes better because of denser urban structure and light rail network that can serve areas not covered with heavy rail corridors. Service level is near the level of city centre. Therefore number of two car households decrease. EV with range extender fits to customer needs that are similar to those in city centre.
- In urban sprawl area some improvement in public transport may reduce car ownership near heavy rail corridors in 2050. The share of two or more car households still remains high. Only one of the cars is required for long trips so in 2015 this first car is conventional and the second car can be a plug-in only EV. In 2050 the first car is an EV with range extender. The other cars used for urban travelling may be plug-in only EV:s. So at both time window, if there is an EV, it is the second car for local trips and therefore the majority of EVs are these.
- At other survey area most of the cars are used for long daily range that is difficult to current plug-in only. Therefore the dominant EV is a plug-in hybrid in 2015. For 2050 no remarkable public transport service growth is expected. Local daily travelling within small towns may be similar to current situation and car usage is dominant. For 2050 the range of a plug-in only EV has grown to cover daily range and therefore majority of EVs are plug-in only EVs for daily use. For long distance use an EV with range extender is the EV solution.

It is worth for to note, that in the previous scenario it is only discussed about the dominant technology of electric cars. There is no discussion about vehicle propulsion technologies in general and what is the share of EVs of all vehicles. So the general situation in 2050 is that for daily use a plug-in only EV is a suitable choice. As the operating range of a plug-in only EV is not adequate for week end travelling, there must be a wider range vehicle available. As seen in Figure 13, there are several technologies available, also others than EVs. EV with range extender is expected to be the number one choice of EV-technology for long distance use. The numbers of car density and multi car households are based on the HSL mobility survey (Strömmer 2010).

The development figure in the survey area follows the guidelines and targets set up in planning of the Helsinki region traffic system plan 2011 (HSL 2011). The background work of the plan includes scenarios of the development of the urban structure in the survey area. Common for all the scenarios is to guide the new development towards rail corridors and to improve the rail transport network in general. In the plan the vehicle technology is not a parameter when forecasting future traffic and mode share. The mode choice in the forecast model is based on the experienced statistics of existing traffic modes and the estimated cost and travel time development.

In SIMBe scenario for 2050 all city buses are expected to be electric. This is not considered to be a reason to alter the public transport service and patronage level, as the service level of a bus is not dependent on the propulsion technology. Public transport service level improvements that increase the patronage are experienced from conversion to direct access rail transport and branding improvements in bus transport. The latter means features like better precision, guaranteed arrival times and other features typical to rail transport (Soininen 2007). Therefore only availability of rail transport is considered as a reason to decrease the car density and car usage.

It is worth for to note, that the troubles of commuter train services in Helsinki region during the past two years are not considered to cause any reason to alter the plans, guidelines and strategies of the coming development. Commuter trains have operated well since 1885 when the first bi-directional steam locomotives for commuter trains were purchased. The survey of the Finnish Transport Agency (LiVi 2010) explained the problems and it is seen, that the troubles are mostly caused by the lack of experience of winter conditions after the organizational changes in track administration and train operation since previous heavy winter conditions of app. 15 years before the two difficult winters. Also, during last two winters commuter trains have had troubles, but technically similar Helsinki metro operated trouble free even though most of the track is under open sky.

4. Charging blueprint

4.1. General background

Charging blueprint means a plan to install EV charging poles and stations in capital city area. It is not only a chart of one moment but a plan to forward from SIMBe scenario 2015 to scenario 2050.

The blueprint does not specify the charging technology details other than the power of the pole or station. These are based on the needs of the usage of the vehicles. Nor does the blueprint specify where does the electricity come from and how is it produced. These are tasks of other SIMBe projects and papers.

In the planning of the blueprint there are plenty of variables that are hard or impossible to forecast to long term. One of these is the future of the car concept and the way to use a car. Therefore the blueprint is limited to the guidelines of the SIMBe scenarios which basically consider the vehicle called a car to remain quite similar as today though the combustion engine and mechanical transmission are replaced with electric propulsion that in best case does not require any transmission system at all.

There may also happen changes in the car use and traffic policy in general. While at the moment of this work there does not exist any program either in Helsinki, Helsinki region or in Finland to switch from car based society towards less traffic and energy demanding society, these general environmental targets are kept in mind. Though it is quite clear that switching from combustion engine to electric propulsion happens slowly and through first changing the propulsion system of the current car, the next phase is to benefit the advantages of electric propulsion to alter the concept of the car.

4.2. Planning guidelines

Most of the charging happens in night time when cars are parked in users home locations. No fast charging is required there. Only 3,6 kW poles similar to those used for engine pre heating today.

Usually the heater power of current poles is limited to 500 W. Newer cablings are designed to 1500 W to allow the use of saloon heater. In both cases cabling must be replaced to allow the full power of the 16 A plug.

Dimensioning of the grid load for these home charge poles must have capacity to pre heat the vehicle and it's battery in the morning when the park slot is in outside temperature.

In the city centre area night time charging poles can be placed to parking sites. We do not recommend to assemble night time charging poles to public street side parking. Technically they do not differ from the parking meter poles used in the past, though twice that much charging poles are required as there must be one pole per slot. We rather reserve curb sides for faster charging poles in chosen locations.

Faster charging needs in city area are for:

- Delivery traffic at delivery curb side slots and in city's underground delivery facilities.
- Taxis at taxi stations.
- Car sharing vehicles at reserved car sharing parking slots.
- Car rental services.
- Visitors of public places like offices and other public garages and parking lots.

Occasional fast charge points similar to current fuel stations are located with the public garages and in suburbs with park-and-ride places where high power electric supply is already available for public transport supply stations, or near other electric grid nodes with high power available.

4.3. Charging practices

As battery capacity seems to be an expensive investment, it is estimated that customers like to manage with as small battery as possible to cover the daily driving distance. Therefore the charging infrastructure needs to support use of small batteries and frequent charging. Main charging happens in home during the nights but faster charging at destinations is required to extend the operating range of a small battery EV.

Based on few experiences, low temperature of the battery may decrease the practical capacity up to 50 %. This increases the importance of the destination charging availability or at least the availability of low power supply to heat the battery.

As main purposes to use a car are free time travels like shopping and hobby and work trips all at equal share, all the destinations are as important by means to be able to charge EV battery.

For work trips there is plenty of time during the work day to charge. Eight hours charging time with 3,6 kW power may deliver 23 kWh to battery with 80 % efficiency. This equals to 100 kms drive distance.

For shopping and free time activities charging time in destination is limited. Shopping or some activity event may offer 30–90 minutes charging time. A concert, theatre or a movie offers 1,5 to 2,5 hours. Using 22 kW pole, loaded net energy is 9–44 kWh. A charging time of one hour roughly equals to the charging during a work day.

In case of company parking for employees offers 3,6 kW low power charging and free time activities offer 22 kW medium power charging, destination charging practically doubles the operating range of EV.

4.4. The one % map of 2015

4.4.1. General background

The SIMBe scenario is set for year 2015 and is based on the idea that there is 4000 car like EV:s that need or may be charged. It is app. 1 % of the number of cars currently used in capital city region. Anyhow the growth of the number of EV:s depends also on the availability of EV:s on the market, which depends on the willingness of the industry to manufacture EV:s. This seems to be the most difficult item to estimate. If the penetration of EV:s is not 1 % in 2015, this figure is to be applied to the moment when 1 % penetration is achieved.

Main charging is the night time charging in the home of the EV. In long term, all the household parking is equipped with 3,6 kW charging possibility. During the penetration growth of EV:s these sockets are used for combustion engine pre heating and are benefitted any way.

Public parking sites will have 22 kW charging poles according to the share of EV:s of the cars in use. Based on SIMBe 2015 scenario, this share is 1 % and in scenario for 2050 the share is 42 %. In the city centre of Helsinki where households do not have named park slot, 3,6 kW poles must be available for the share of EV:s from the number of residents parking signs. At the moment of the writing of the report that equals 270 charging slots which is less than 0,5 % of the cave capacity in the city centre.

Current gas stations are excluded from the planned locations of charging facilities. This is because EV charging is not expected to be a business opportunity for gas stations. To compare selling liquid fuel to selling electricity, the long charging time and low electricity price and sales price per visit ruin the business. If the owner of the station wishes to earn same way from EV:s as from fuel cars, each EV customer should pay 3–5 times the fuel sell profit in currency per visit as fuel customer. And the share of the profit make the price of the sold energy so high that customers are not interested in it.

In the early stage the total energy consumption of EV:s is so low that no smart charge arrangement is required. As the taxing is organized with the propulsion tax, sales and paying of the electricity is simple using existing payment methods.

The number of existing car sharing slots and delivery slots is so low that it is recommended to support electric mobility by equipping all these with 22 kW poles. All the taxi stations are also recommended to be equipped with 22 kW poles.

4.4.2. 3,6 kW low power poles

All the parking slots with housing. At the first phase in 2015 at least 2 % of these slots should be possible to use with full 3,6 kW power.

For housing companies (asunto-osakeyhtiöt) it is recommended to create a legal framework that prevent the decision making problems in these companies. Fortum has estimated that to convert a heating pole to charging pole costs 100 € without replacing the cabling. This way the small share that is required for the first is easily converted to charging the way the cost can be covered from the slot rent (Fortum 2010). For the longer term the cabling needs to be replaced. Fortum’s estimate is then 300 € per slot.

For the EV owners in the city centre area 270 slots in the public parking sites are to be equipped with 3,6 kW socket for renting to private customers.

For the airport it is recommended to install 125 poles into long time parking department.

For private and company parking it is recommended that the owners of these sites consider the need according to their and their customer’s needs.

4.4.3. 22 kW medium power poles

Total of app. 1800 poles is recommended to be placed in capital city region according to the following list. The maximum load of these when all used at the same time is 40 MW. This can be compared to the daily maximum consumed power in Helsinki of 730 MW. So the maximum power load of EV charging is only few per cent of the total load.

Shopping malls (av.10 pcs/mall)	369
Public parking sites (1,8 %)	134
Airport parking	12
Taxi stations (av.2,8 pcs/station)	405
Car share slots (all)	97
Delivery slots (all)	18
Park and ride (2,1 %)	248
Private park sites	500

There is no information available about the number of private parking sites. It is estimated that these sites are also used for cars that are frequently used during the day and therefore night time low power charging is not sufficient. In the list above the item *private park sites* includes also the charging poles for buses and delivery vehicles in their depots and sockets in delivery platforms of the shopping malls.

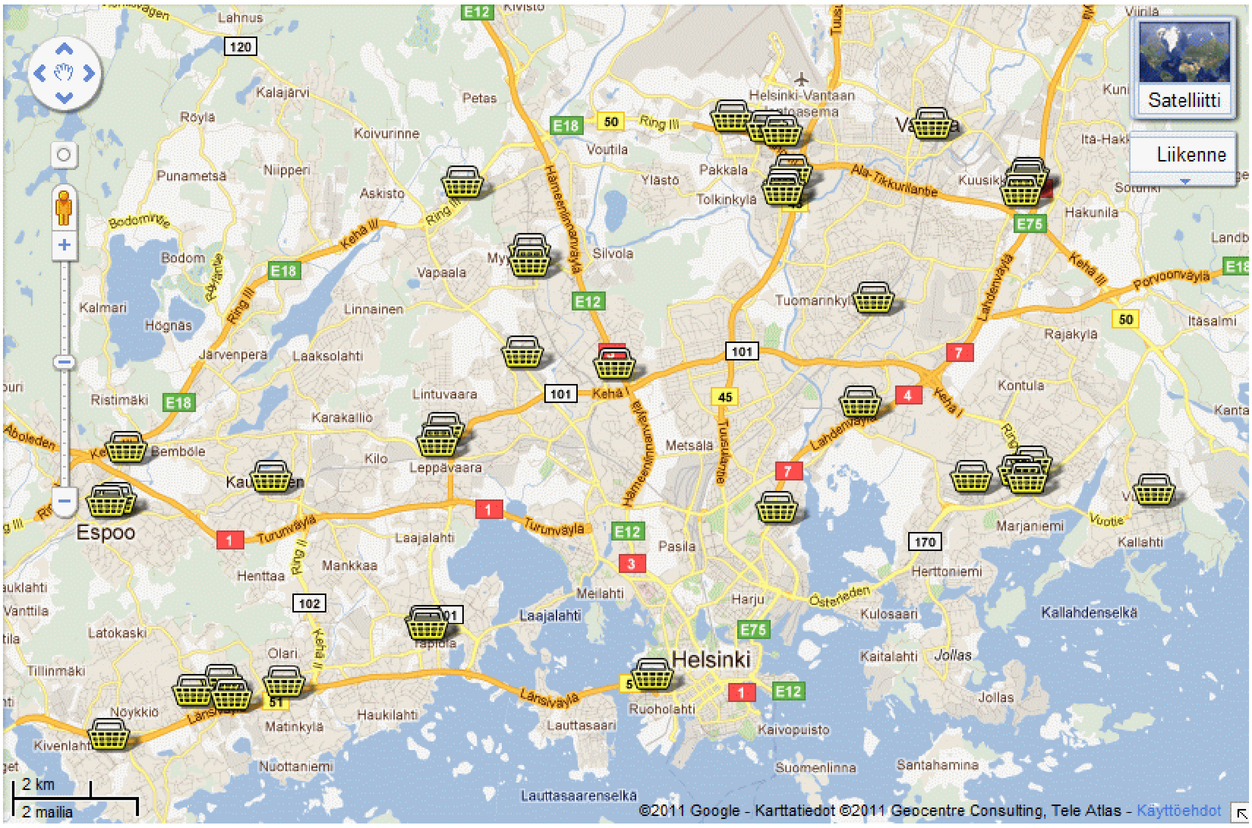

Figure 14. Shopping malls in Helsinki region. Status of the map is spring 2011. The map lists the parking facilities that are administrative parts of the shopping malls. Map Google maps.

Some parking facilities, especially those in the city centre of Helsinki, are known and considered as parking facilities of the malls, but are independent companies. These are listed in the map of public parking sites.

Map with street addresses is found in Google map service in address:

http://maps.google.fi/maps/ms?msid=203875956496978019836.0004a37aeec1d6aee2e75&msa=0&ll=60.230267,24.898453&spn=0.191603,0.587769

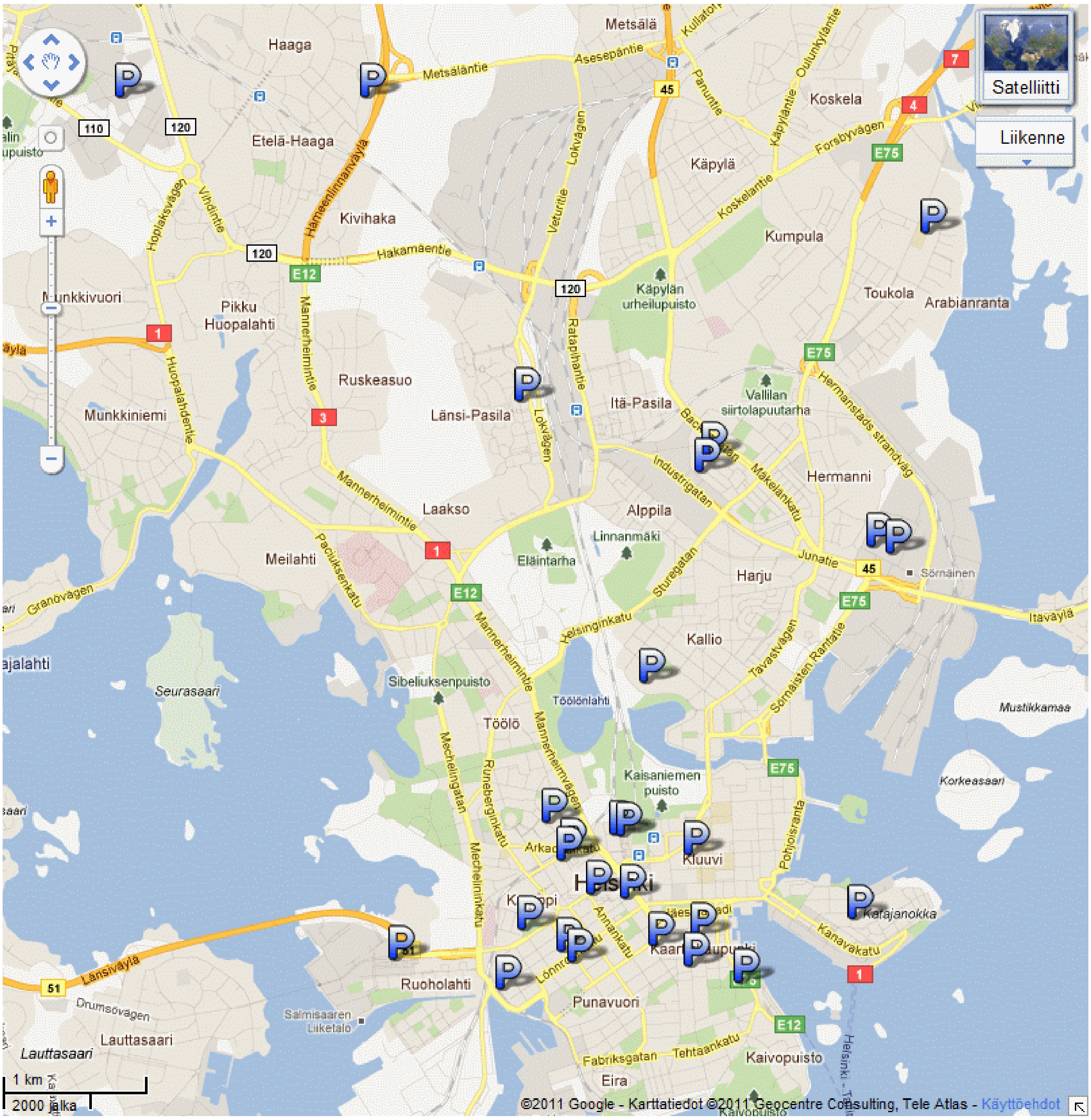

Figure 15. Public parking sites in Helsinki. Map status is spring 2011. Map Google maps.

Some of the parking facilities in the map above are known and considered as parking facilities of shopping malls. Anyhow these facilities are run by companies independent of the malls or department stores with which they are located and named.

Map with street addresses and site capacity information is found in Google map service in address:

http://maps.google.fi/maps/ms?msa=0&ie=UTF8&ll=60.189585,24.928837&spn=0.070489,0.139046&z=13&vpsrc=6&msid=203875956496978019836.0004a37a5f7b221274b63

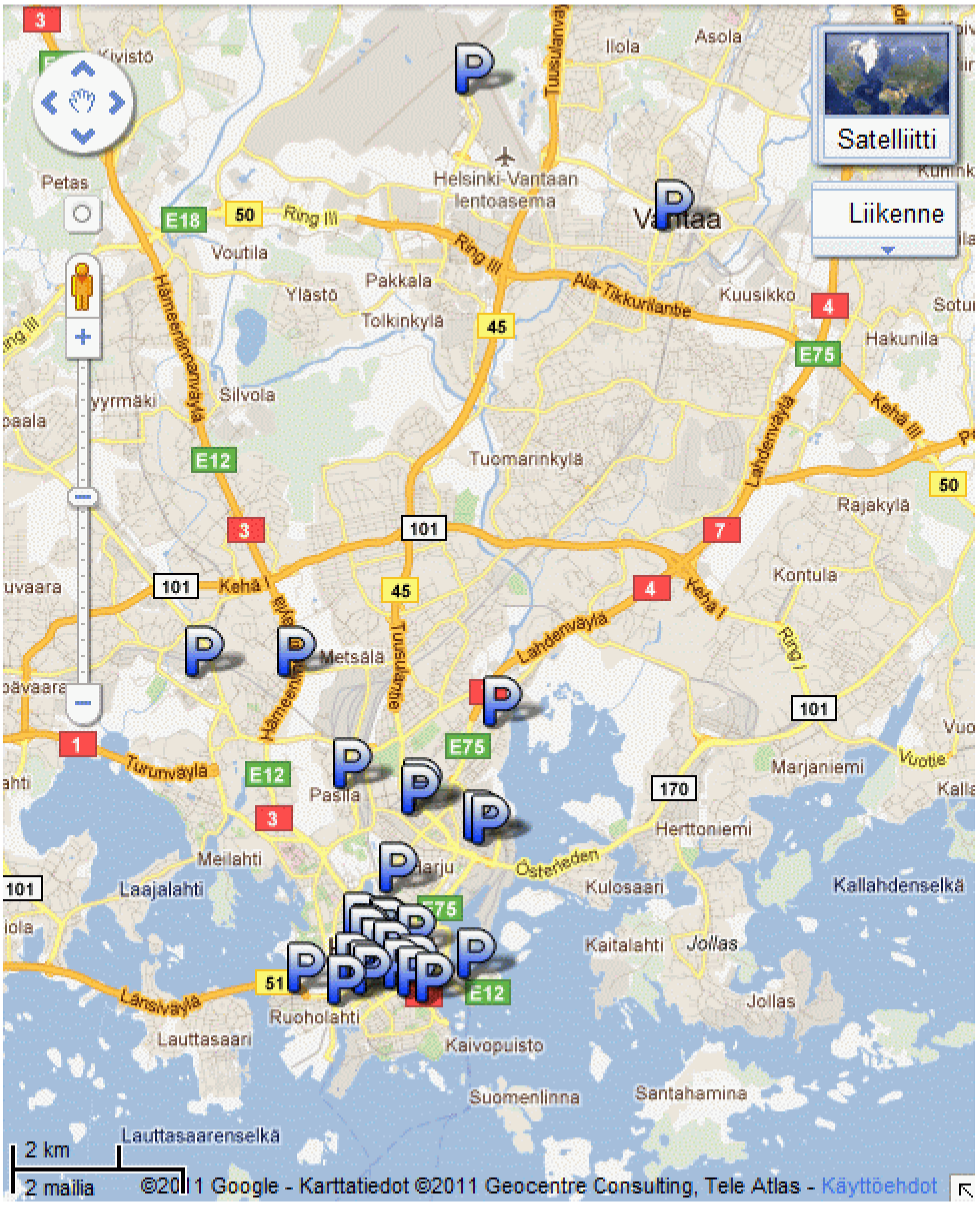

Figure 16. Public parking sites at Helsinki region. The image includes only two more sites at Vantaa compared to preceding map of Helsinki. The map is the same map in Google map service as the Helsinki map.

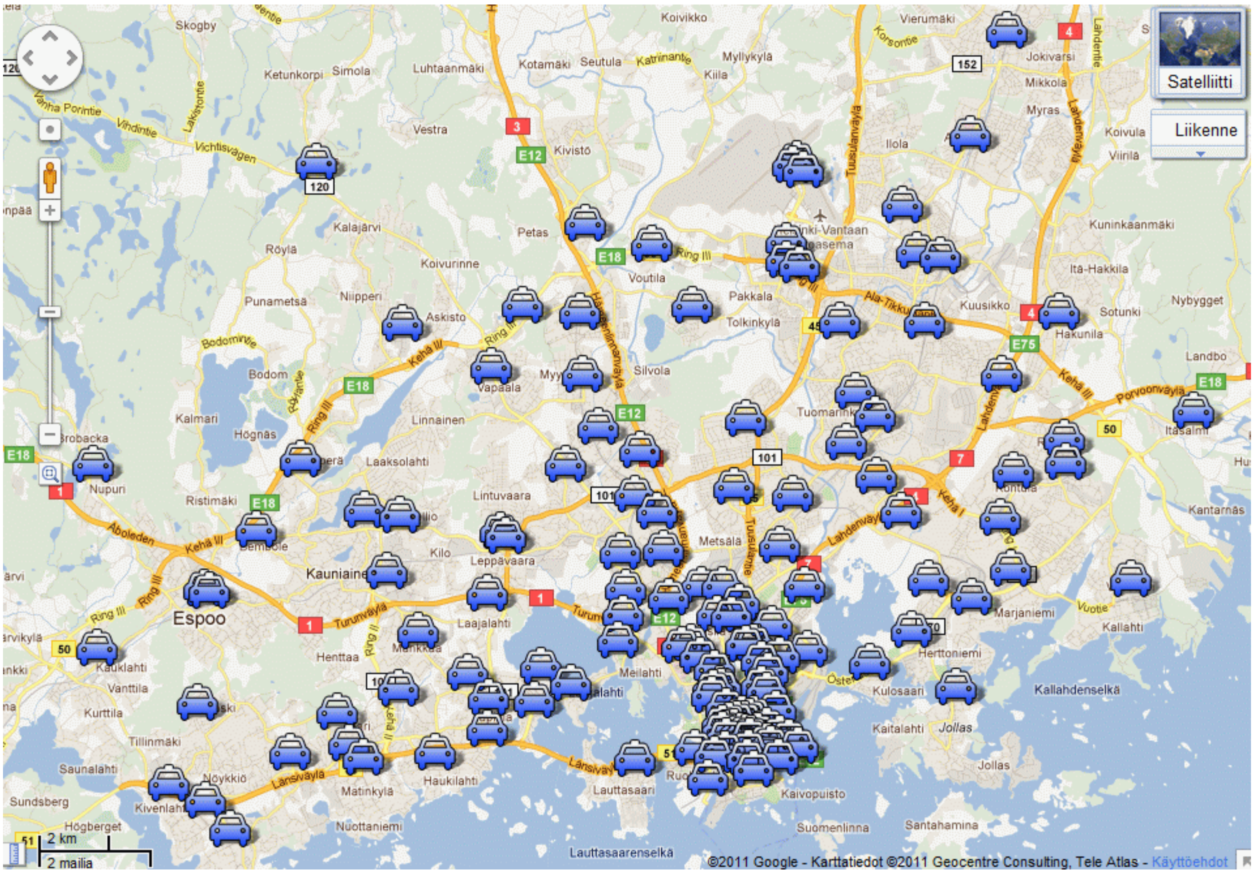

Figure 17. Taxi stations in Helsinki region. Map Google maps.

All the stations are recommended to have at least one 22 kW pole. The number of poles at each station depends on the usage of the station. The list of taxi stations is based on information available in spring 2011. Number of poles at each station is based on the size of the station (number of cars) and the location. Statistics about the usage of each station has not been available and is recommended to clarify for the final electrification plan.

Usually taxi station design is a row of curb side slots and cars forward to the proceeding slot after the first car of the row takes a customer. This is not the most suitable practice by means of taxi cars to be connected to charging poles. For a more convenient way to connect taxi cars to the poles some product development is required.

Map with street addresses and estimated pole number information is found in Google map service in address:

http://maps.google.fi/maps/ms?msid=203875956496978019836.0004a37b94fd7cc4b375d&msa=0&ll=60.250375,24.879913&spn=0.231009,0.668106

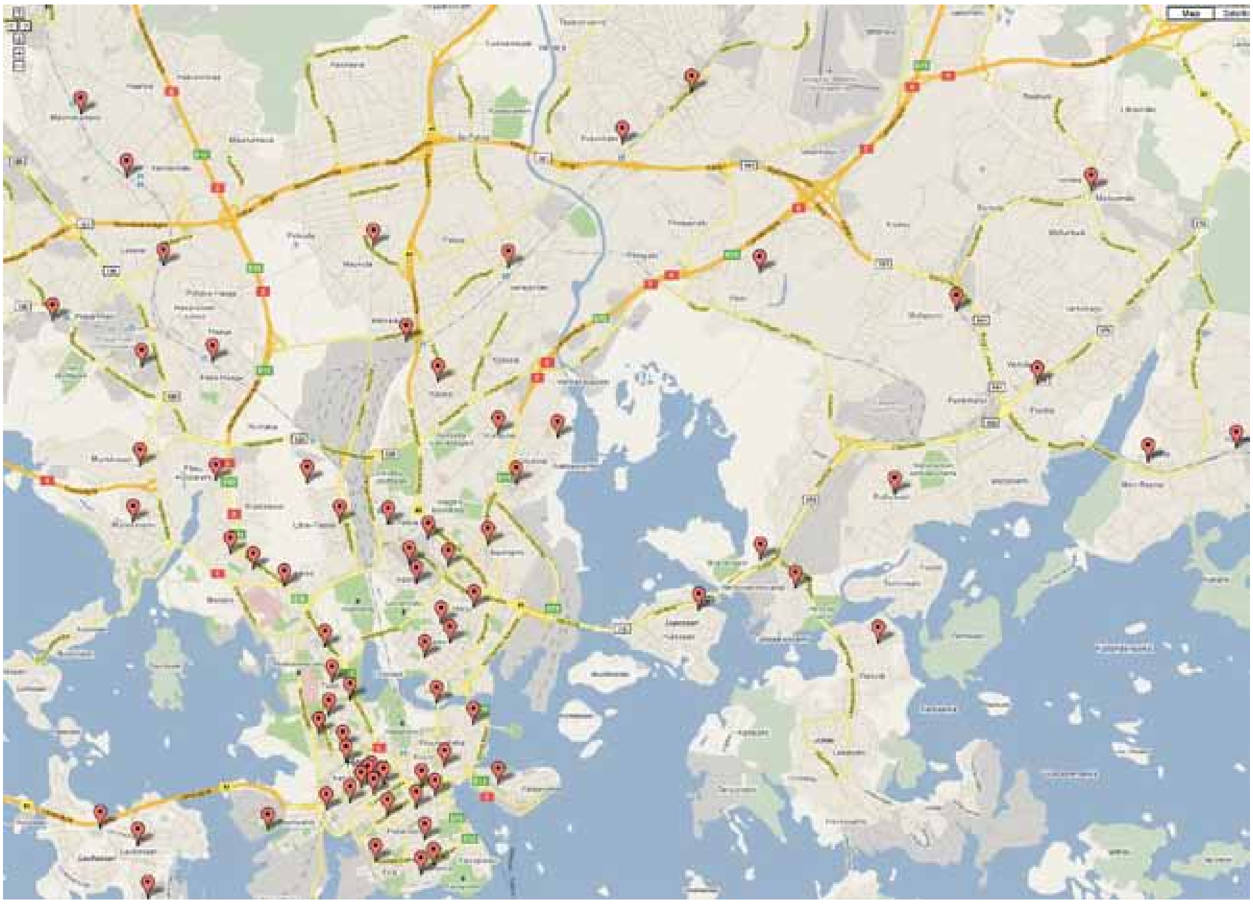

Figure 18. Car share slots. At present (spring 2011) the map includes slots reserved for City Car Club. For more information, please contact to City Car Club.

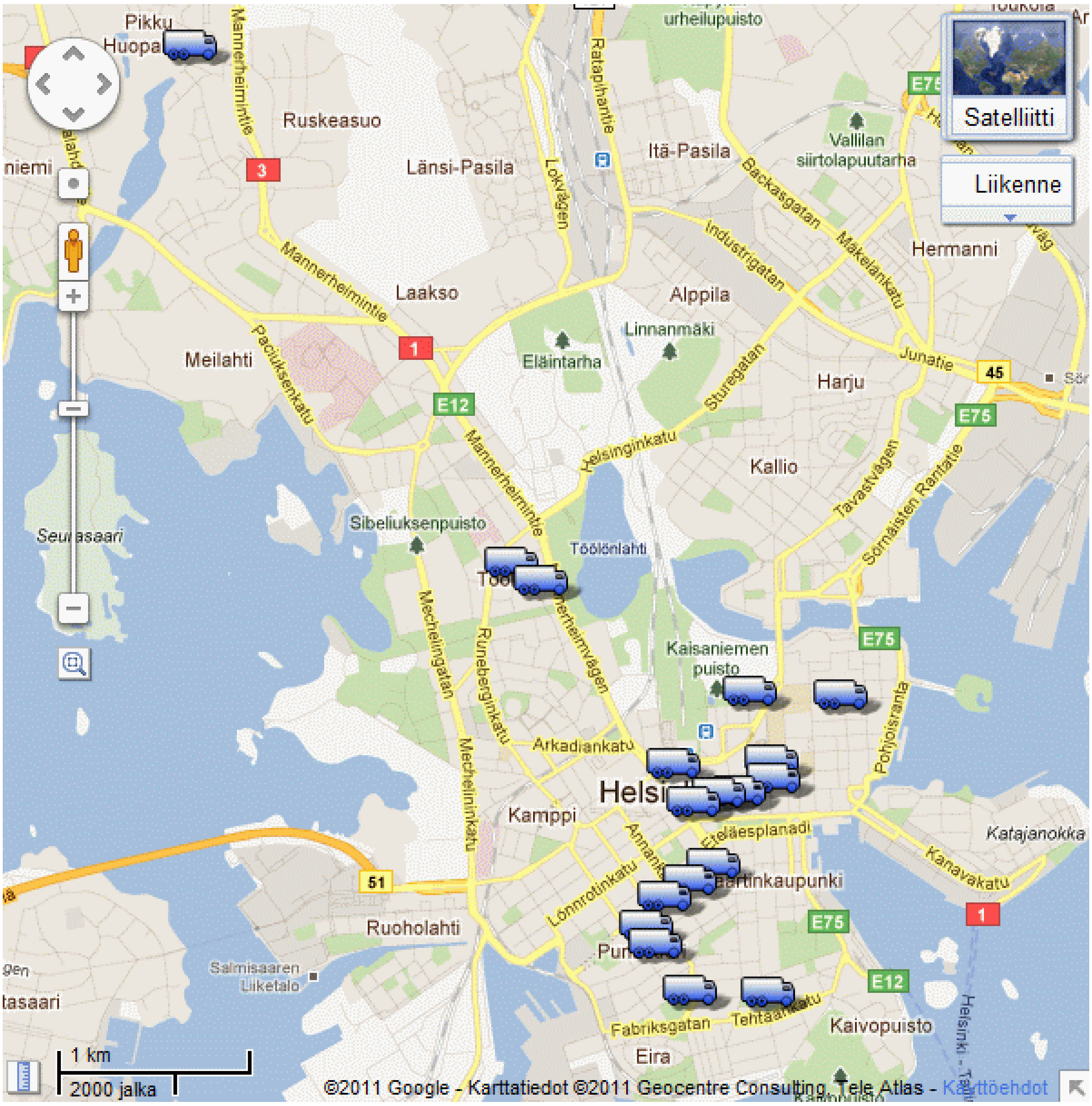

Figure 19. Delivery slot location map. Most of the curb side delivery slots are located in the city centre area. Locations are the status of 2011.

Map with street addresses is found in Google map service in address:

http://maps.google.fi/maps/ms?msa=0&msid=203875956496978019836.0004a379561f2e61098ec&ie=UTF8&z=13&vpsrc=0

4.4.4. High power charging

This includes the charging points with higher power than 22 kW and not taken into account their technology. At the early stage these are considered as experimental and bound to special purposes, like charging buses or delivery trucks. It is estimated in SIMBe scenario that there might be five (5) of these high power poles. The location of high power poles depends on the operators of the experiment projects.

4.5. The long term map of 2050

For long term SIMBe scenario it is estimated that EV:s that need charging represent 32 % of the number of cars. In the SIMBe scenario these are still considered to be similar to current combustion engine cars. Rest of the cars use some other propulsion technology, based on the picture displayed above (Figure 13). The target of the charging map is that charging is not the limiting factor for EV:s.

In practice, the list of charging poles for the one % phase in chapter 4.4.3 is to be multiplied to cover the demand based on the 32 % share of the vehicles to require charging.

- Shopping malls 10 700
- Public parking sites 2 500
- Airport parking 380
- Taxi stations (av.2,8 pcs/station) 405
- Car share slots (all) 97
- Delivery slots (all) 18
- Park and ride 3 700
- Private park sites 16 000

In the list above, the numbers for shopping malls, public parking sites and park and ride sites are simply a share of 32 % of the current capacity. In case the total number of parking slots and sites will grow, same share is to be followed.

For airport parking, the number of 22 kW poles is only 3 % of the total number of current capacity. This is due to the fact, that airport parking is not short time parking that requires high power poles.

For delivery and car share slots the order is to have them all with at least 22 kW pole. The numbers in the list are the current number of slots, but it is expected that especially the market share of car sharing will grow and then the number will be higher.

The pole number in private park sites is expected to grow according to the EV share growth, from 1 % to 32 %. It is not the responsibility of the authorities to equip these slots with the poles. But the requirement for the electric grid must be taken into account within the maintenance of the grid.

The list above makes 33 400 poles. Their total power when all in use at the same time is 735 MW which equals to the current maximum daily power value in Helsinki.

5. Discussion

5.1. Limitations

As mentioned in the chapters 4.1 and 4.4.1, there are plenty of factors that may influence to the need of the charging network and interact with the network.

Main factor is the development of the EV supply to the market. Based on the experience during the couple of recent years, car industry has not entered to the EV markets the way some analysts expected to happen. When car markets are quite saturated in Europe and USA and some companies are not running very well, it is understandable, that resources to invest to new product line are limited. On the other hand, EV’s might offer a change to find new growth. But that seems not to be the strategy of car industry. There is no successful plug-in EV on the market and the interest of car industry seems to be parallel hybrid solutions without plug-in option. This means that combustion engine, mechanical transmission and liquid fuel remain as base concept of a car. Minor EV-technology is just an add-on to this legacy structure.

As can be seen from the experience in car use behaviour in chapter 3.2, in the early phase of EV penetration charging network is not the critical condition to daily EV use. In single family houses there is no problem to charge the batteries during the night and have the EV available for use for the whole day. The use of engine heater poles is also easily possible as long as there are only few EVs to charge and the cabling of the poles do not require to be replaced.

It is pointed out often in this paper, that SIMBe scenario as a base of this work assumes the concept of a car to remain as it is today and the traffic system is assumed to develop the way it has developed in the past decades. The current traffic planning and estimating methods cannot estimate any future that is based on technologies from which there is no experience yet. This means, that even though the EV itself, also as a concept of current car, is a major change in the traffic system, there are no valid tools to estimate it's influence. Both the pricing scheme, operating range and the fuelling practice will change. The price of car use is a dominant factor in traffic volume and mode choice calculations, but it is uncertain to try to calculate estimates with practically zero fuel price but high vehicle price. Calculations may be considered reliable within small flexibility in the factors, but the difference in fuel and electricity price is not a small flexibility.

The above mentioned limitation may be disregarded by simply thinking, that let's assume that any other major changes than energy price per kilometre will not happen. But that is not the purpose for the EV development and not even possible with high battery cost. The electrification of the cars is based on the targets to reduce emissions generated from the traffic. The goals set are not possible to achieve without changes in car concepts and mobility behaviour. Therefore it is worth for to keep in mind, that however to proceed in building charging network, there must be certain flexibility included to be able to alter the plans according to the development to come true. And that to build the charging network is not the only task. The purpose of the network is to work for the growing penetration of the EVs. This means, that the network should stay in front of the penetration growth. But at the same time authorities must be active in reducing the need to use any kind of a car by means on urban structure, both in physical and social form.

5.2. Lack of battery swapping

At the beginning time of SIMBe, end 2009, battery swap technology seemed to be suitable solution to solve the problem of a short operating distance with one charge. At the time of writing, autumn 2011, battery swap seem not to be a popular idea. There are no concepts released that were based on battery swapping. It is understandable in situation, where markets generally seem to be slow to shift to EV. A swapping solution would require high level commitment from the whole car industry, which seems to be very unexpected in the current situation.

If available, battery swapping would change the whole structure of EV fuelling from what is described in this report. With battery swapping, high investments to charging facilities would not be necessary. Instead there would happen a shifting in fuel stations from distributing liquid fuels to battery swap stations. The number of battery swap stations should be 2 to 3 times the number of current fuelling stations, as swapping is required more often than liquid fuelling.

For grid loading battery swapping is also a different challenge. Electricity supply should be organized with high power to fewer locations compared to the overall charging solution that require some strengthening all over the grid.

5.1. Further Research

Winter conditions are a large question mark for the future of EV's. A simple solution of an EV to measure the temperature and to refuse not to start in a too cold condition is not a solution in Nordic countries. There is a clear need to research and development in battery technology to find out the battery behaviour in low temperatures. The results are important also to the grid structure. If EVs require continuous energy to temper the battery, electrification in the destinations and where ever an EV will stand still for several hours is necessary. In many cases like at the airports and public transport stations this is a responsibility of the authorities.

The next report will discuss about the environmental aspects of the use of EVs. In that work the concept of electric mobility is an important factor. One new phenomenon of the last years is the appearance of quadricycles (or microcar for teenagers not having a car driving licence, in Finnish *mopoauto*, a four-wheeled class L6e vehicle fulfilling the requirements defined in the EU directive 2002/24/EY). It is a kind of a development in the car concept, but also in the mobility behaviour. Quadricycle let a younger age class use a private car a year around. Depending on the living environment, these citizens have before been public transport users or travelled as passengers in a car driven by their parents or other elder person.

6. Conclusion

The current daily car use practice fits easily to start to switch over from combustion engine cars to electric vehicles that are used similarly like current cars. The operating range of current EV technology is large enough to cover the daily usage. At locations, where inhabitants mostly use car for their daily mobility, over night charging of EV batteries is easy to arrange. In single family houses, the owner of the house is responsible to arrange the plug or charging pole. In the parking sites of the multi family houses in suburbs, the engine heater poles may be used for charging with easy and cheap modification, as long as the share of EVs is very low.

Though there are no practical hinders to start to use EVs, it may be expressed, that if the home is the only opportunity to charge an EV, it will limit the interest to replace a combustion engine car with an EV. Therefore the role of a charging spot network is an important message from the authorities and the society, that EVs are taken seriously and there exist a will to have citizens to switch from combustion engines to electric mobility.

As the share of EVs will be very low in the beginning, the requirements to build a covering charging network are not difficult. In the first phase of one per cent share of EVs of the whole car fleet, the number of poles in parking sites is low and does not cause troubles for electric grid. But for the future development of the charging network, the load of the poles have to be taken into account. In that work this initial plan can be taken as a guideline where the load will grow.

The major difference in energy service between a combustion engine and an EV is with vehicles that are continuously used during a day. For them the daily usage is often more than the operating range of the current EV. And the charging speed requirement is also higher, as the charging time is lost vehicle usability. To have utility vehicles, rented cars or car share vehicles to use electricity as their energy is a kind of a way to promote EVs too. It also gives a change to lay audience to test an EV in real life. To make this possible there must be at least medium power charging poles available for utility purposes.

The charging pole locations represented in this paper are based on the current mobility behaviour. The precision is to serve as a guideline for actual implementation. Practical solutions of pole construction and charging slot layout is to be planned detailed later.

Summary of the statistics used

Battery capacity/weight -relation (Li-Ion) 0.202 kWh / 1 Kg (http://www.batteryuniversity.com/parttwo-55.htm)
Battery capacity/weight -relation (Li-Ion) 1 kWh / 10 Kg (Haakana 2008)
Battery capacity/volume -relation (Li-Ion) 0.514 kWh / 1 L (http://www.batteryuniversity.com/parttwo-55.htm)
Battery service life (lithium phosphate) 10 years (Battery manufacturer's specification)
Battery charge/discharge amount (lithium phosphate) 3000 (Battery manufacturer's specification)
Battery specific price for consumers 5.000-10.000 € / 10 kWh (European Batteries Oy)
Specific capacity of a solar panel, considering the efficiency coefficient of inverter and regulator, 100 W/m^2 (Savonia 2010)
The average capacity corresponding to the yearly yield of a solar panel in central Finland 15 W/m2 (Savonia 2010)
Length of a commute driven with a passenger car 15 km (average in the Helsinki area)
Average life cycle of a passenger car in Finland 19 years (HLT 2006)
The average usage of a passenger car in Finland 18.000 km/year (HLT 2006)
Average daily usage of a passenger car at 80 % probability at most 40 km (passenger car usage distribution in Henkilöliikennetutkimus (HLT 2006 6_31_tapa.xls))
Tax percentage in passenger car consumer price, about 40 %
Market price for coal in a port in Finland, price per thermal value, 8 €/MWh
Tax percentage in traffic fuel consumer price, about 60 %
(http://fi.wikipedia.org/wiki/Polttoainevero 8.4.2010 17:18)
Market price for traffic fuel, price per thermal value, 0,16 €/kWh
Density of wood chips 300 kg/m^3
Industry market price for wood, price per thermal value, 10–25 €/MWh
Density of wood logs when stacked 500 kg/m^3
Finnish passenger car stock 2.8 million cars (year statistics 2009)
The annual energy consumption of an electric car stock in Finland 9,2 TWh (Kronström 2009)
Practical battery capacity of an electric car 30 kWh (150 km range)
Nominal drive energy consumption of an electric car (tank-to-wheel) 0.2 kWh/km (Kronström 2009)
Consumer price of electricity 0.13 €/kWh
(http://www.sahkonhinta.fi/summariesandgraphs 8.4.2010 17:12)
Specific emission of electricity production in Finland 260 g/kWh (Energiateollisuus 2011)
The average effect corresponding to a wind power plant's yearly production, as share of nominal power 25 % (Holttinen ym. 1996, pp. 38–39)
The planned total wind power to be constructed in Finland 2000 MW (Matilainen 2008)

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Appendixes

Appendix 1, list of shopping malls in Helsinki region

Name	Address	Park slots	22 kW poles
Helsinki			
Arabia	Hämeentie 111	382	4
Citymarket Itäkeskus	Kauppakartanonkatu 3	900	8
Columbus, Vuosaari	Vuotie 45	970	8
Itäkeskus	Itäkatu 1-7	3 000	30
Lanterna	Varikkotie 2 B, Roihupelto	500	4
Nova Malmi	Malminkaari 13-19	1 100	10
Prisma Itäkeskus	Vanhanlinnantie 1	650	6
Prisma Kannelmäki	Kantelettarentie 1	1 250	12
Prisma Viikki	Viikintori 3	1 000	10
Ristikko	Ajomiehentie 1, Konala	262	2
Ruoholahti	Itämerenkatu 21	1 500	15
Helsinki altogether		11 514	109
Espoo			
Espoontori	Kamreerintie 3, Espoon keskus	400	4
Bauhaus	Rusthollarinkatu 6, Suomenoja	600	8
Entresse	Siltakatu 11, Espoon keskus	300	4
Galleria	Konstaapelinkatu 4, Leppävaara	415	6
Heikintori	Kauppamiehentie 1, Tapiola	258	4
Tapiola new (estimate)	Tapiola	1000	14
Ikea	Espoontie 21, Lommila	800	12
Iso Omena	Piispansilta 11, Matinkylä	2200	24
Kauniainen	Kauniaistentie 4	138	2
Lippulaiva	Espoonlahdenkatu 4, Espoonlahti	700	8
Martinsilta	Martinsillantie 10, Suomenoja	550	6
Merituuli	Isonniitynkuja 1, Suomenoja	485	4
Sello	Leppävaarantakut 3-9, Leppävaara asema	2900	30
Espoo altogether		10746	126
Vantaa			
Asko Porttipuisto	Porttipuistontie 1	140	2
Asko+Isku Varisto	Martinkyläntie 47, Varisto	100	2
Bauhaus	Valimotie 19, Tammisto	364	6
Flamingo	Tasetie 8, Vantaanportti	800	10
Ikea	Porttisuontie, Porttipuisto	1133	14
Isomyyri	Liesitori 1, Myyrmäen asema	500	6
Jumbo	Vantaanportinkatu 3, Vantanportti	4600	50
Myyrmanni	Iskoskuja 3 A, Myyrmäki	1100	12

Porttipuisto	Porttisuontie, Porttipuisto	460	6
Retail Park Tammiston	Antaksentie 4, Vantaanportti	1080	12
Ostospuisto	Sähkötie 2-6, Tammisto	363	6
Tammistontähti	Valimotie 2, Tammisto	128	4
Tikkuri	Asematie 4, Tikkurila	300	4
Vantaa altogether		11068	134
Malls altogether		33 328	369

Appendix 2, list of public parking sites in Helsinki region

Name	Address	Park slots	22 kW poles
Helsinki			
Arabian parkki	Arabianranta, halli, myös sopimus 75 €/kk (sis.alv)	467	2
Erottaja	Yrjönkatu 8–10 (Dianapuisto)	600	8
Forum	Simonkatu 7, Eteläinen Rautatiekatu 8	1 000	20
Kasarmitori	Fabianinkatu 17 (Kasarmitori)	420	4
Parlamentti Paikoitus	Nervanderinkatu 8–10		2
Posti	Elielinaukio, Postitalon edessä	40	0
P-City	Ruoholahdenkatu 3 (Lapinrinteen kulma)	500	10
P-Eliel	Asema-aukio 1 (Kaivokadun puolelta), Töölönlahdenkatu 1	480	10
P-Kamppi	Olavinkatu	250	4
P-Kluuvi	Puutarhakatu 1 / Kaisaniemenkatu 10, Fabianinkatu 27 / Pohjoisesplanadi 23	1 110	16
P-Presidentti	Olavinkatu 1 / Eteläinen Rautatiekatu 4	100	2
P-Ruoholahti	Porkkalankatu 20, Länsisatamankatu 2, Salmisaarenkatu 9 (Länsiväylältä)		4
P-Seaside	Kalevankatu 61 (Ruoholahdenrannan vierestä)		2
P-Tähtitorninvuori	Laivasillankatu 20		4
Stockmann	Lastenlehdonpuisto (Ruoholahdenkadun ja Lapinrinteen kulma), Kalevankatu 1 (Mannerheimintien kulma)	600	12
Vallila	Elimäenkatu 15	700	4
Nilsiänkatu, Vallila	Nilsiänkatu 5 (vain vuokrapaikkoja)	100	0
Aleksanterinteatteri	kenttä (määrä noin-arvo)	40	0
Bronda	Korkeavuorenkatu 36 sisäpiha		0
Elimäentkatu 15	kenttä		0
Heinon tukku	Vanha talvitie 2 kenttä+halli		2
Hiomotie 3	kenttä + halli	180	2
Hotelli Haaga	Nuijamiestentie 10 kenttä		2
Hotelli Katajanokka	Vyökatu 1 kenttä		2
Hotelli Linna	Lönnrotinkatu 21 halli		2
Hotelli Pasila	Maistraatinportti 3 halli		2
Kaarti	Kasarmikatu 19, halli, sopimuspaikoitus 295 €/kk (sis.alv)	32	0

Kaupunginteatteri	Eläintarhantie 5 kenttä		2
Kutomotie 9	Halli, myös sopimus 86,1 €/kk (sis.alv)		0
Malmin asema	kenttä		0
Malminkatu 30	sisäpiha		0
Tukkutori	Työpajankatu 2 kenttä		2
Työpajankatu 8	kenttä, myös sopimus 61,5 €/kk (sis.alv)		0
Valimotie 10	kenttä, myös sopimus 73,8 €/kk (sis.alv)		0
Valimotie 13	kenttä, myös sopimus 73,8 €/kk (sis.alv)		0
Valimotie 25-27	kenttä, myös sopimus 61,5 €/kk (sis.alv)		0
WTC	Keskuskatu 7 halli, myös sopimus 369 €/kk (sis.alv)		0
Helsinki altogether (public only)		6 619	120
Espoo altogether		0	0
Vantaa			
Säästötalo, Kielotie 20	kenttä	30	2
Vantaa altogether		30	2
Helsinki-Vantaa Airport		12400	12
Parking sites altogether		19 049	134
Parking sites altogether excluding airport		6 649	122

Appendix 3, list of delivery slots in Helsinki region

Address, length	22 kW poles
Fabianinkatu 33, 21m	1
Fabianinkatu 31, 26m	1
Fredrikinkatu 27, 12m	1
Mannerheimintie 5, 13m	1
Annankatu 5, 12m	1
Vuorikatu 18, 13m	1
Laivurinkatu 33, 15m	1
Mannerheimintie 8, 15m	1
Pohjoisesplanadi 37, 16m	1
Pohjoisesplanadi 33, 15m	1
Vironkatu 5, 20m	1
Albertinkatu 8, 12m	1
Yrjönkatu 6, 12m	1
Albertinkatu 15, 15m	1
Töölöntorinkatu 6, 14m	1

Pohjoinen Hesperiankatu 5, 15 m	1
Tilkankatu 20	1
Neitsytpolku 9, 11 m	1
Delivery slots altogether	18

Appendix 4, list of taxi stations in Helsinki region

Name	Address	Taxi slots	22 kW poles
Helsinki			
Annankatu	Annankatu 3, Iso Roobertinkadun kulma	1	2
Arabia	Intiankatu 2	1	2
Asema-aukio	Rautatieasema, postin puoli	1	7
Crowne Plaza hotelli	Mannerheimintie 50	1	4
Elielinaukio	Holiday Inn City Centre, Elielinaukio 5	1	4
Erottaja	Eteläesplanadi 9, Ruots. teatterin vieressä	1	4
Etelä-Haaga	Palokaivonaukio	1	4
Eteläranta	Eteläranta 10, Hotelli Palace	1	3
Grand Marina hotelli	Katajanokanlaituri 7	1	3
Hakaniemen tori	Hakaniemenranta 1, Metallitalon edessä	1	5
Hartwall Areena	Veturitie 13, Areenan ylätasanne	1	2
Helsinginkatu	Helsinginkatu 25, Brahen kenttä	1	5
Hernesaari	Hernematalankatu	1	0
Herttoniemen sairaala	Kettutie 8, Pääovi	1	1
Herttoniemi, Hiihtäjäntie	Hiihtäjäntie 2, K-Hertan edessä	1	3
Hietalahdentori	Abrahaminkatu 5, Lönnrotinkadun kulma	1	3
Hollolantie	Hollolantie 1, Mäkelänkadun kulma	1	2
Ilmala	Ilmalantori 1, MTV:n pääovea vastapäätä	1	3
Isokaari	Isokaari 30 -Viklankuja	1	0
Itäkeskus	Tallinnanaukio 1, Bohemian edessä, metroasema	1	4
Jakomäki	Jakomäenkuja 4, ostoskeskus	1	2
Jollas	ei taksiasemaa, alueellinen tilausnumero	1	0
Kalasatama	Työpajakatu 13	1	2
Kalastajatorppa	Ylhäällä Rantahotellin ovi	1	2
Kampin metroasema	Salomonkatu, metroaseman pääovi	1	5
Kanavaterminaali	Nordic Jet Line	1	2
Kannelmäki	Vanhaistentie 3, ostoskeskus	1	2
Kapteeninkatu	Kapteeninkatu 22, Tehtaankadun kulma	1	3
Karhupuisto	Fleminginkatu 1	1	3
Katajanokan terminaali	Viking-terminaali	1	3
Katajanokka hotelli	Merikasarminkatu 1 a	1	2
Klaus K hotelli	Bulevardi 2	1	5
Konala	Riihipellontie 1, Konalantien kulma	1	2
Kontula	Kontulantie 20, ostoskeskus	1	3
Koskela	Käpyläntie 8, apteekin edessä	1	3
Kulosaari	Relanderinaukio	1	2

Kämp	Pohjoisesplanadi 27, Kämpin vieressä	1	4
Laajasalo	Kuvernöörintie 2, Muurahaispolun kulma, ostoskeskus	1	2
Lapinlahdenkatu	Lapinlahdenkatu 2, Malminrinteen kulma	1	5
Lassila	Hopeatie 3, rautatieasema	1	2
Lauttasaarentie	Lauttasaarentie 23	1	3
Lehtisaari	Lehdesniityntie 2, ostoskeskus	1	1
Linja-autoasema	Salomonkatu 2, Rexin edessä	1	5
Linnanmäki	Tivolitie, Alppilan puoli	1	2
Länsisatama	Terminaalin edessä	1	3
Maistraatinportti	Maistraatinportti 4, Hotelli Pasilaa vastapäätä	1	3
Makasiiniterminaali	Terminaalin pääovi	1	2
Malmi	Kirkonkyläntie 1, bussiterminaali	1	3
Malminkartano	Luutnantintie 10, rautatieasema	1	1
Mariankatu	Mariankatu 23, Maneesikadun kulma	1	4
Marski hotelli	Mannerheimintie 10	1	4
Maunula	Suonotkontie 2, ostoskeskus	1	2
Mehiläinen	Pohjoinen Hesperiankatu 17	1	2
Meilahden sairaalat	Biomedicum, Haartmaninkatu 8	1	3
Mellunmäki	Mellunmäenraitio, metroasema	1	3
Messeniuksenkatu	Messeniuksenkatu 2	1	3
Messukeskus	Rautatieläisenkatu 3, Messukeskuksen ja hotellin vieressä	1	5
Munkkiniemi	Munkkiniemen puistotie 19, Laajalahdentien kulma	1	3
Munkkivuori	Raumantie 1, ostoskeskusta vastapäätä	1	3
Museokatu	Museokatu 12, puiston laidassa	1	5
Myllypuro	Kivensilmänkuja 3, ostoskeskus, Alepan edessä	1	3
Olympiaterminaali	Siljan Linen terminaali	1	3
Oulunkylä	Oulunkylän tori	1	3
Paloheinä	Paloheinäntie 22	1	1
Pasilan asema	Aseman pääoven edessä	1	5
Pihlajamäki	Graniittitie 4	1	2
Pitäjänmäki	Kutomotie 2, Pitäjänmäentien kulma	1	4
Pohjois-Haaga	Thalianaukio	1	3
Porvoonkatu	Porvoonkatu 19, Viipurinkadun kulma	1	3
Presidentti hotelli	Eteläinen rautatiekatu 4	1	2
Pukinmäki	Säterintie 2, apteekin edessä	1	2
Radisson Blu Plaza	Mikonkatu 23	1	2
Radisson Blu Royal	Runeberginkatu 2	1	3
Rautatiekatu	Eteläinen Rautatiekatu 10, Makuunin edessä	1	5
Rautatientori	Rautatientorin puoli	1	5
Roihuvuori	Roihuvuorentie 25, Tulisuontien kulma	1	2
Ruoholahti	Itämerenkatu 14, metroasema	1	3
Ruskeasuo	Koroistentie 17	1	2
Scandic Continental hotelli	Mannerheimintie 46	1	4
Seaside hotelli	Ruoholahdenranta 3	1	3
Senaatintori	Aleksanterinkatu 20 vastapäätä	1	5
Siltamäki	Jalopeurantie 2, ostoskeskus kääntöpaikka	1	1
Simonkenttä hotelli	Simonkatu 9	1	5
Sofianlehto	ei taksiasemaa, alueellinen tilausnumero	1	0
Sörnäisten metroasema	Helsinginkatu 3, Harjukadun kulma	1	3

Tapulikaupunki	Maatullinaukio 10, rautatieasemaa vastapäätä	1	2
Toivonkatu	Toivonkatu 2, Kisahallin pääty	1	2
Torni hotelli	Yrjönkatu 26	1	2
Tukholmankatu	Tukholmankatu 2	1	4
Töölöntori	Runeberginkatu, Tykistönkadun kulma	1	5
Vartiokylä	ei taksiasemaa, alueellinen tilausnumero	1	0
Viikki	Alempi talonpojantie 4, Tilanhoitajankaaren kulma	1	2
Viiskulma	Laivurinrinne 2, Fredrikinkadun kulma	1	5
Vuosaari	Valkopaadentie 4, Columbuksen ylätaso	1	3
Ylä-Malmi	Laulurastaantie 2, Kirkonkyläntien kulma	1	2
Ympyrätalo	Eläintarhantie 1, Rosson edessä	1	5
Östersundom	Kraputie 22	1	1
Helsinki altogether		97	282

Espoo

Bemböle, Jorvin sairaala		1	3
Espoon asema	Railway station	1	4
Espoonlahti, Ulappatori		1	2
Espoontori	Asemakuja	1	2
Haukilahti, ostoskeskus	Haukilahdentie	1	2
Juvanmalmi	Pieni Teollisuuskatu	1	2
Järvenperä	Auroranportti	1	2
Karamalmi	Karaportti	1	2
Kauklahti, asema	Railway station	1	2
Keilaniemi	Keilaniementie	1	6
Kilo	Kutojantie	1	2
Kivenlahti	Merivirta	1	2
Laajalahti	Kirvuntie	1	2
Lahnus	Lahnuksentie 2	1	1
Latokaski	Kaskenpää	1	2
Leppävaara, asema	Railway station	1	4
Leppävaara	Läkkisepänkuja	1	3
Länsikeskus	Piispanportti	1	2
Mankkaa, ostoskeskus	Vanha Mankkaantie	1	2
Matinkylä, Iso Omena		1	1
Nupuri, Brobackantie	Brobackantie	1	1
Olari	Kuunkehrä	1	3
Olarinluoma	Luomannotko	1	2
Otaniemi, Dipoli	Luolamiehentie	1	2
Soukka, ostoskeskus	Yläkartanontie	1	2
Suomenoja	Suomalaistentie 2	1	2
Tapiola, Pohjantori		1	4
Tapiola, Tapiontori		1	4
Viherlaakso, Turuntie		1	2
Westend, terminaali		1	2
Espoo altogether		30	72

Vantaa

Hakunila, Raudikkokuja	Raudikkokuja	1	4
Hki - Vantaan lentoasema		1	8
Hotelli Hilton lentoasema		1	2
Jumbo, Vantaanportti		1	4
Flamingo	Tasetie 8	1	2
Koivukylä, asema	Railway station	1	2
Korso, asema	Railway station	1	2
Länsimäki	Maalinauhantie	1	2
Martinlaakso, asema	Railway station	1	2
Myyrmäki, asema	Railway station	1	2
Pähkinärinne	Pähkinänsärkijä	1	2
Simonkallio, ostoskeskus	Maitikkakuja	1	2
Tikkurila, asema	Railway station	1	4
Tikkurila	Peltolantie 2	1	3
Vantaanpuisto, ostoskeskus	Vantaanrinne	1	2
Varisto	Martinkyläntie	1	2
Veromiehenkylä	Robert Huberin Tie, Vantaa	1	4
Voutila	Näpinkuja	1	1
Ylästö, Lehtikummunkuja	Lehtikummunkuja	1	1
Vantaa altogether		19	51
Taxi stations altogether		146	405