Innovation Action

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D2.7 - Electric vehicles and charging stations roll-out strategy and analysis in Oulu

WP 2, Task 2.6

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Table of content

List of figures

List of tables

Abbreviations and acronyms

Acronym	Description
CHP	Combined Heat and Power
DH	District Heating
EV	Electric Vehicle
HP	Heat Pump
OUK	City of Oulu (Oulun kaupunki)
PED	Positive Energy District
RES	Renewable Energy Source

Executive Summary

This deliverable, which objective is to report about the impact on the grid of the e-vehicles and charging stations on different scenarios at a longer term, will serve as study about electric vehicle possibilities in Oulu, especially concerning the energy infrastructure.

The design, monitoring and controlling strategies for the roll-out of charging stations in the district and the rest of the city will be outlined. This will be achieved by considering the production and load profiles of PED and its surroundings, including EV chargers. Information about the charging profiles will be gained from the measurements in the charging places inside the project and from the other studies about the issue. The essential point and impact to be measured in reporting is handling the hourly power balance as well as the practical solutions in the field.

The aim is thus to assess the real-world potential of e. g. different charging strategy scenarios. The scenarios are the following:

- reference (no timing intervention)
- coordinated charging (a sum of charging current from the bunch of neighbouring charging places is limited, in practice by changing the timing of the charging)
- bi-directional charging scenario (EV battery can also supply power to the grid)
- coordinated loads scenario (charging is suited to the balance situation in the local grid including other large loads like heat pumps etc. or in the whole electricity grid).

In subtask 2.6.1, which handles the issue of this deliverable, the impact analysis of the electrical vehicles and charging infrastructure in Oulu is done. The City of Oulu is promoting the decarbonisation of the urban mobility. One part of it is a roll-out of electrical vehicles, in addition to promoting walking and cycling. This subtask will analyse the impact of the eVehicles deployed in the city during the project timeline and will estimate a future impact based on these results and the future plans of the city.

As a preliminary result, there will be no significant problems, if the electric car use is not more than car use now. Especially nighttime charging is an easy way to handle even quite large charging loads without problems. If the car use increases, there are also other drawbacks than energy consumption and they are easily cumulative. Thus, the intention of the city is to promote walking, cycling and public transport, and also the compact urban structure to keep the distances tolerable.

The decrease of the use of the internal combustion engine cars is the main target, with EVs and the other mentioned measures. The role of the city is however limited concerning EVs, due to the fact that the highest barrier is for the moment very limited availability of the affordable EVs themselves. The needed energy infrastructure improvements seem to be minor compared to that.

Keywords

Electric Vehicle, EV, Electric bike, Electric car, Electric bus, Charging, Electricity, Transmission, Flexibility, Transportation system, Renewable energy

1 Introduction

1.1 Purpose and target group

The electric vehicle impact on the electricity production and delivery is studied. These are studied concerning different parts of the electricity supply chain. As the penetration is still low and our possibilities to demonstrate a large number of charging places thus very limited, we use also other sources for estimations to have an idea for the larger context. However, the target in Finland is to have a high share of EVs and thus the issue is very important in the future. The study is also connected to the general transportation planning, which aims to high share of walking, cycling and public transport.

1.2 Contribution partners

In this section the contributing partners to this report and their responsibilities are explained.

Table 1: Contribution of partners

Partner nº and short name	Contribution
13 – OUK	Writing the report, based on the earlier reports on the issue and new combination of data when we get it. The author is Samuli Rinne.
15 – OEN	Background information regarding electricity network dimensioning
16 - SIV	Investing in the shared EV on one of the rental housing blocks (B2)
19 – ARI	Providing chargers in the parking lot of the grocery store (B5)
20 – VTT	Recording and visualising consumption measurements

1.3 Relation to other activities in the project

The following table depicts the main relationship of this deliverable to other activities (mainly deliverables) developed within the MAKING-CITY Project and that should be considered along with this document for further understanding of its contents.

Table 2: Relation to other activities in the project

Deliverable / Task nº	Relation
Task 1.3	Background information on the city
Task 1.26	Development of a City Vision 2050. Transportation is one crucial part of it. EV impacts on the grid and on the traffic emissions are studied.
Task 2.4.	Smart energy systems in PED. This task is going to demonstrate technical integration of RES and storages in the different grids of PED, so charging infrastructure will be also considered.
Task 2.5.	District Energy flows. The estimated charging profile of EVs is used to assess the PED realization possibilities and the needed solutions to get towards it. In estimation, the measurements from the upcoming charging places are used if possible, in addition to the knowledge about charging profiles in other studies.

Deliverable / Task nº	Relation
Task 2.6.	The design, monitoring and controlling strategies for the roll-out of charging stations will be outlined. The impact on the grid based on different scenarios at a longer term is analysed. We put emphasis on the predicted large-scale future impacts.
Task 4.4.3.	Replication and upscaling plans development. The results are upscaled to cover the whole city, acting at least partly as a one large PED, in addition to "sub-PEDs" inside it.

2 Actions implemented in Oulu PED on electric vehicle charging points

2.1 PED descriptions

The Oulu PED located in Kaukovainio district has in its demonstration actions some ones linked to electric vehicles in order to analyse the impact that their charging points would have in the power grid. These actions driven by the Task 2.6 named as E-mobility roll-out: impact on the grid, were originally described in the MAKING-CITY project DoA and have been suffered some changes during the project execution that are also described in the following sections.

2.1.1 EV actions proposed in the DoA

Task 2.6 E-mobility roll-out: impact on the grid [OUK] (OEN, VTT)

In this task, the design, monitoring and controlling strategies for the roll-out of 15 charging stations in the district and the rest of the city will be outlined. This task will be in charge of analysing the impact on the grid based on different scenarios at a longer term.

Subtask 2.6.1: Impact analysis of the electrical vehicles and charging infrastructure in Oulu. The city of Oulu is promoting the decarbonisation of the urban mobility towards an extensive roll-out of electrical vehicles in the city. This subtask will analyse the impact of the eVehicles deployed in the city during the project timeline and will estimate a future impact based on these results and the future plans of the city.

2 new eCar parkings are going to be place in the area (building 1 and Arina). In this concept, the building costs are divided between city and the companies. Part of the parking/charging facility is reserved for private use and part is meant for car sharing. The charging energy management is implemented to the energy management of the area. Therefore, this way is helping in balancing the loads and production. Thus, the amount of parking area in the site will be reduced due to the car sharing.

Action 6: eCar parking in building 1. Leader: SIV

In building 1 (Action 1) the eCar parking area is having 10 charging stations for eCars. The facility will be located in the close walking distance from SIV and YIT buildings. Half of these are reserved for public use (car sharing and eCar charging) others can be rented for eCar private owners who need a parking facility. SIV will be responsible to build the parking facility and OEN to build the charging stations and taking care of the facility and management. The facility will be part of the local energy system. Local electricity will be used to charge when possible.

Action 27: 5 charging points for ECars in Arina. Leader: ARI

5 (->3) eChargers for public cars will be deployed in the Arina (Action 19). The charging points are mid speed, which means that a normal eCar having 30 kWh battery capacity can be charged in 3-4 hours.

Action 44: Business model for charging stations. Leader: OEN

Grid bottlenecks that will become a challenge in urban areas can be reduced or even avoided via the integration of charging stations into the PED (Actions 6 and 27). Storage batteries can assist in improved load management of supplier and possibly improve economics of charged electricity by making use of time periods with excess supply and/or without local grid bottlenecks. Charging station can also be used as flexible components for demand/response control of electricity in the local grid.

2.1.2 Changes during the project

The future of EVs depend very much on the decisions done by other actors that the city. This is not a problem for the issue in general, but from the project point of view it means that our possibilities to impact on the development are very limited. The most limiting factor this far has been the price of EVs. The larger share of EVs require markets for pre-owned EVs and that will take some time.

The charging places planned in the parking lot of housing blocks must in reality wait for cheaper EV prices, so the intended places in B1 are not feasible to be realized due to no users. Instead, they are to be replaced by a shared EV in B2.2 and 5 charging places of type 2 in B3 (YIT).

So, there will be a shared EV charging place for the rental housing block B2, which may allow us to have a bit more charging data than would have been possible to gather from single-user charging and parking lots. This data will be shown in WP5 deliverables.

As concerning the organizational patterns, during the project the electricity-selling part of Oulu Energy is detached from the parent company. A new joint company is formulated, owned by several electricity retail companies, of which Oulu Energy is one. EV charging businesses are also transferred to the new company, so Oulu Energy cannot be developing the solutions as was intended and getting the new company as a replacement would need totally new negotiations with them.

The city itself is neither the right organization to establish charging places, in the Finnish context it is not a kind of duty that a city should do. However, the grid impact is still considered in this and further deliverables in WP1 and/or WP5. The charging station operators are many and it seems most probable that this will not be a limiting factor.

2.2 Projections

The final solutions that would be implemented are the following:

Task 2.6 E-mobility roll-out: impact on the grid [OUK] (OEN, VTT)

To have a generalisable idea of EV impact on grids, we use for abovementioned reasons additional data to evaluate the issue, in addition to the information that we will collect from the upcoming charging places in Oulu PED area. The design, monitoring and controlling strategies are studied as intended as much as possible. This applies also for analysing the impact on the grid based on different scenarios at a longer term. The future scenarios are made using the national ones as a background, since the possible subsidies and taxes as well as targets are set on national level.

Action 6: eCar parking in building 1. Leader: SIV

In building 2, there will be an eCar sharing and charging service. SIV will be responsible to build the parking facility and having the car ownership, maintenance and charging as a service from a third party (Omago). The facility will be part of the local energy system. Local electricity will be used to charge when possible. The charger (Virta Global) has an ability to adapt to the required maximum effect at certain time etc.

Action 27: 3 charging points for ECars in Arina. Leader: ARI

3 eChargers for public cars will be deployed in the Arina (Action 19). The charging points are mid speed, which means that a normal eCar having 30 kW battery capacity can be charged in 3-4 hours. However, the charger speed may still be subject to changes, depending on the forecasted exact needs.

Action 44: Business model for charging stations. Leader: OEN

Grid bottlenecks that may in certain cases become a challenge in urban areas can be reduced or even avoided via the integration of charging stations into the PED (Actions 6 and 27). This is first studied in theory, using the knowledge of OEN about the electricity networks, data collected from the local charging stations as well as that from other studies. If possible and feasible, charging stations can also be used as flexible components for demand/response control of electricity in the local grid.

3 Methodology for the impact analysis

3.1 Data measurements

Data from measurements will be ready when the results from the charging plots and other electricity consumption in the buildings are gained. They will be used for evaluation in deliverable D5.11. Nevertheless, for analysing the impact of these interventions data from other sources is utilized.

3.2 Models

The need for different modes for charging can be studied by for example two methods. First, a simpler approach presented here is an hourly Excel model, created by OUK/SR. The basic idea is to study the hourly consumptions in one winter day. Wintertime sets the dimensions for the electricity and heat networks and is therefore a feasible time to study the issue. The very core of the problem (if there is any) is here in a nutshell. Also, considering the production-consumption balance the winter day is general the most challenging, even if it is not handled that much in this deliverable but rather in those of WP1 and WP5.

The other approach is to use for example EnergyPLAN model. It is a deterministic energy simulation model, which aims to have electricity and heat balances also hourly, as the before mentioned Excel model. The model includes a possibility to use EV batteries in many ways, which is beneficial for this task. The aim of that is to have the heat and electricity production and consumption in Finland balanced hourly, without using a lot of electricity imports or exports. EnergyPLAN model is developed in Aalborg University. It is a freeware.

For this report EnergyPLAN is not used due to the schedule and lacking data, but for the other ones concerning the whole system and EVs as a part of it, it can be used. If needed, the studies can also be done in smaller area (e. g. PED area) and with limited set of electricity and heat production methods. However, in practice the limits are set by the larger entities than for example only those inside a certain neighbourhood.

One very important feature in the Finnish energy system is the use of hydropower to balance the production-consumption fluctuations and this is one of the issues to be solved, when future energy scenarios are created. For this purpose, energy simulation models are very useful.

When there is more basic data, euros can be also added to the studies. Even if the electricity prices, especially their fluctuation in the future is very probably not the same than now, by monetary values some idea of the feasibility of different scenarios can be estimated. From more general and technical point of view, the feasibility can be estimated also just using the resulting total load curves during the day, as is done here.

3.3 Scenarios

The scenarios are studied at daily level, during winter day, which is the most difficult situation in the Finnish conditions. The dimensioning of the networks must be done for loads occurring then and therefore especially this situation is important. The first scope is that for building-level and it is applied in this phase, following the first step of PED idea.

The estimates are now done using Excel and data from existing examples mainly other than those from PED area. When data from PED buildings is gained, it will be used for further studies in other deliverables. Impact on the larger network (Finland-wide) is later to be created by EnegyPLAN software especially concerning City Vision 2050 in WP1.

3.3.1 Reference scenario

The reference scenario would describe how EV charging will impact the grid if there is no intervention. But in practice studying this in detail is not feasible at least to deep extent, since already now most of the chargers have a feature of limiting the charging current when the total current intake for all electricity under a certain fuse is reaching the limit. It can be estimated with high probability that in the future the proportion of smart chargers is remarkably high.

Thus, the “dumb” charging option must not be given too much weight. The hourly estimation for it is given in the alternatives, however, for comparison.

3.3.2 Coordinated charging scenario

The coordinated charging scenario describes how EV charging will impact the grid if charging stations can communicate with one another to limit the total EV charging load. This is the way the recommended chargers work now. The Finnish government also sets this kind of target: ”In the future, the construction of the charging infrastructure should be steered more towards intelligent systems that can also take into account the state of the electrical system in controlling the charging power.” (VN 2021)

The technology is ready, and it is not expensive. This smart type of charger (type 2, 22 kW) has a cost of 1000…1500 euros + installation. More, for housing cooperatives there is 35% subsidy available (ARA 2022).

3.3.3 Bi-directional charging scenario

The bi-directional charging scenario describes how EV charging will impact the grid if the EV battery is accessible to the grid operator. This scenario allows the grid operator to control the charging or discharging of EV batteries, within certain constraints.

This is a big step from “coordinated charging scenario”, since in bi-directionality an external actor can have a significant impact on the functionality of the EV, in the form of charging level. Thus, the issue gets far more complex and requires proper agreements. The advantages must be big enough to offset this possible nuisance.

In figure 1 there is one official Finland-wide scenario about this possibility. It shows the “weather independent production capacity available during a consumption peak and the demand-side response capacity in the different scenarios.” More, “the calculation of flexibility in consumption has been compared to a situation where consumption is not flexible at all.” (Fingrid 2020, 53)

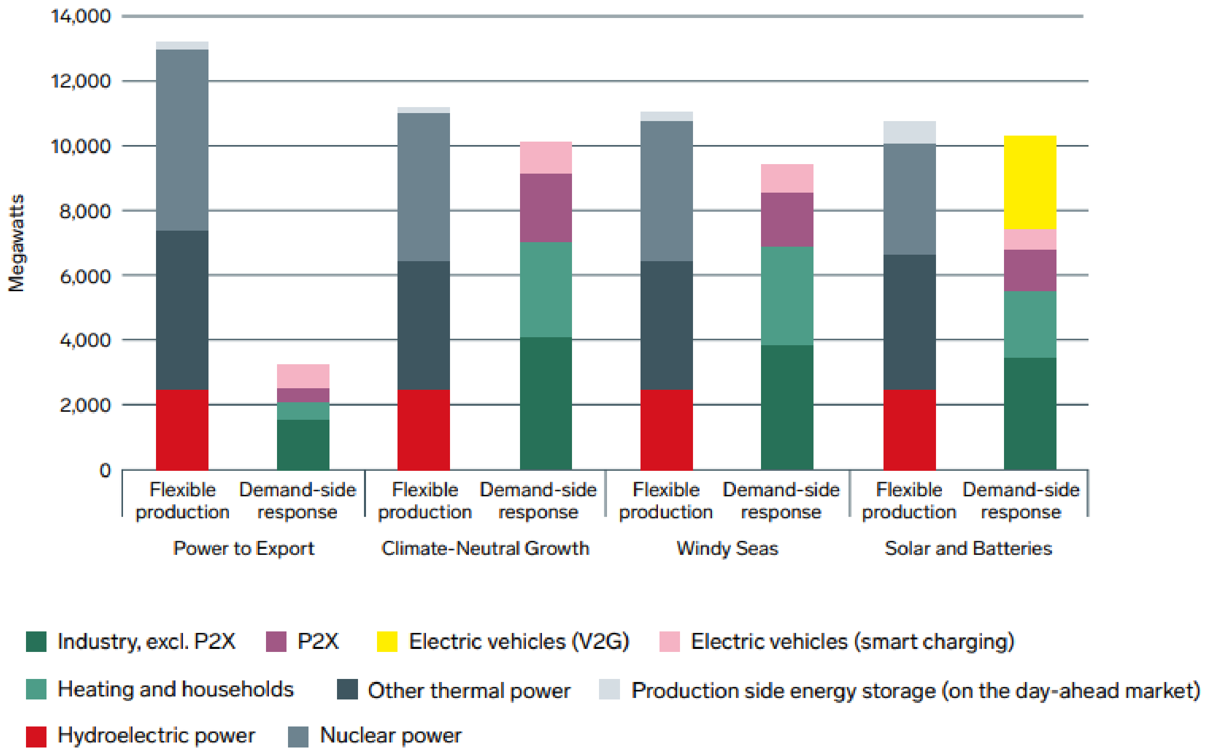

Figure 1: Future electricity scenarios by the Finnish electricity transmission system operator Fingrid.

In the Finnish system, the need for bi-directional charging could be for example as seen in figure 2. This is based on Excel model (made by OUK/SR) and high wind power share (about 30%), low imports/exports share and no condensing power. From this and the properties of the energy system as a whole can be in principle calculated, what could be the maximum investment cost per bi-way charging point and thus the feasibility of the option. An easier way is to use current costs for the effect (max. kW needed) and the energy part (price per kWh, hourly), but that is (too much?) bound to the current prices and will possibly not be valid in the future.

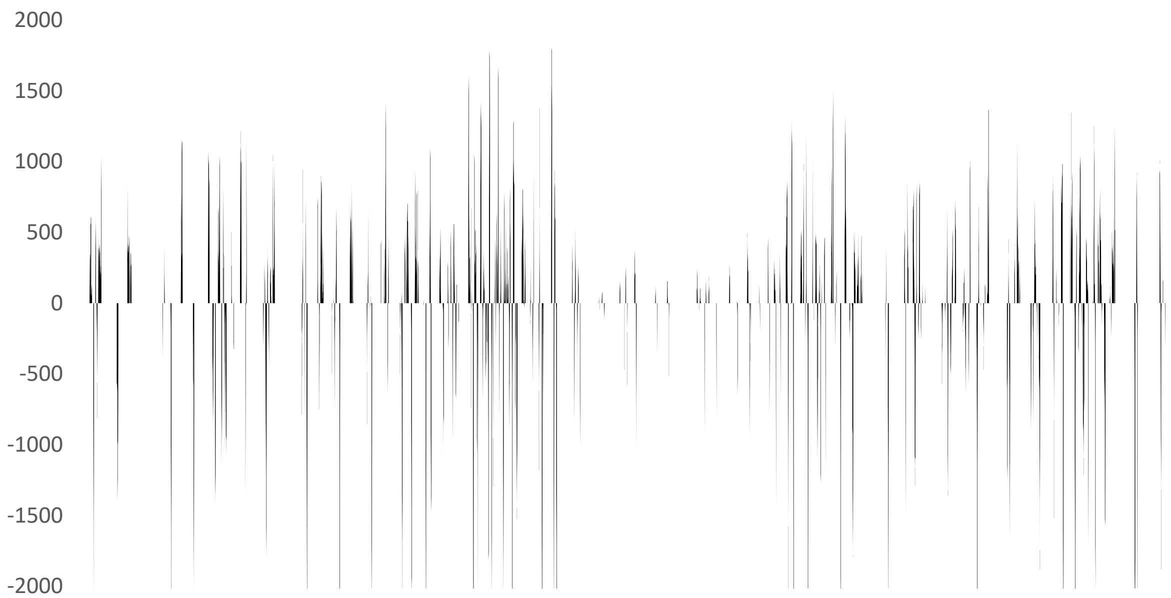

Figure 2: A possible charging and de-charging pattern over one year in the future in Finland. Simulation made by S. Rinne.

In Figure 2 "+" means feeding to the grid, i. e. de-charging and "–" means charging the EV battery. The "normal" charging cycle is not included, only the one caused by the balancing of the grid. For comparison, the maximum consumption in this scenario would be about 16,000 MW. The amount of full cycle equivalents is about 50/year. The typical duration of one cycle is some days, which is in turn related to wind energy production profile shape.

3.3.4 Coordinated loads scenario

This scenario describes how EV charging will impact the grid if the charge cycle is coordinated with other large grid loads, such HPs in an apartment block. It is close to "Coordinated charging scenario" and in many cases the same smart chargers can be used. The question is only about the settings in the charger. To limit the amount of varieties, it is assumed here that in this scenario bi-directionality is not used

3.4 Common assumptions for the scenarios

The limiting factors in the maximum electricity consumption, concerning a certain moment can be divided in e. g. four categories, namely

1. Production-consumption balance in Finland, concerning also imports and exports and hydropower in regulating the balance.
2. Transmission capacity of the high- and mid-voltage network.
3. Transmission capacity of the low-voltage network.
4. Maximum load per user set by the electricity transmission contract and fuse size of the building.

Here we take a look in #4 of these. According to other simulations, if peaks especially in the daytime can be avoided, it is easier for the rest of the energy system to cope with the loads. The key is to avoid to drive the system "on the edge" so that no flexibilities or alternative production methods, storages etc would be possible to use. If there is some "free capacity" left in different phases of the chain, the optimizing is far easier and even possible.

The low-voltage network capacity should be studied case by case and requires exact place-specific data, so that is excluded. The method is considering the hourly values and their predicted development.

3.4.1 Electricity and heat production

For proper scenarios, it is essential to have an idea of the future energy production. It is already now known that there are changes to come, so it would be wise to use "possible" background scenarios when assessing the future solutions like EVs. Figure 3 shows one possible hourly future scenario. The current plants and also the future plan concerning wind and nuclear power have been considered. The scenario is created by OUK/SR.

As can be seen, the production may be quite peaky due to large wind power share. Locally PV causes the same effect. This returns to the earlier issue that peaks in consumption are to be avoided. Thus it is more probable that the peak consumption does not hit the possible simultaneous production "valley" that heavily. If the touch is smoother, it can be handled with storages and flexibilities. Currently in Finland hydropower takes a lot of regulation in daily basis, but also a bit for longer spans. Combined heat and power (CHP) in turn handles seasonal variation well.

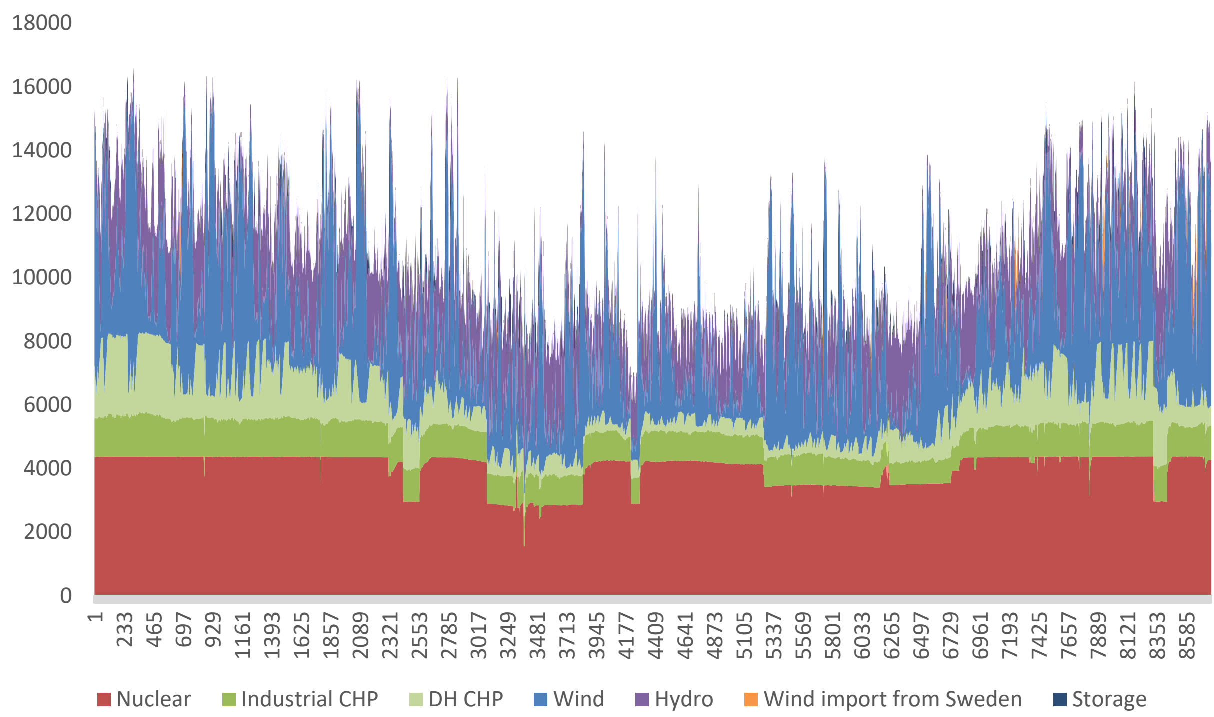

Figure 3: A possible hourly electricity production in Finland in the future. The high peaks are from wind power production, which in this case represents about 30% of the total electricity production.

3.4.2 Transmission grid and building load profiles

The transmission grid can be divided to high-, mid- and low-voltage ones. The relative investment cost of those are highest in low-voltage grid, since it has smaller connection density (i. e. more line per transferred energy amount) and a very large share of it is underground, which is a far more expensive solution than aerial lines.

The high-voltage transmission has currently a cost of 3-9 euros/MWh or perhaps better said roughly 50 euros/peak-kW/a, or less (Fingid 2021, 63). For lower voltage transmission, the cost per kW is a bit higher or about double that, but per kWh much more, for example 5 times that high, due to the much lower peak load hours.

In electricity transmission, the use-dependent share of the cost is practically zero, so the peak capacity defines the total cost completely in practice. And, the weak usage percentage of the low-voltage transmission (weak essentially in energy terms) is also an opportunity, since there is consequently a lot of unused capacity then, of course. This concerns also the internal wirings in the buildings or building groups, if we take a step closer to PED idea. The key question about EVs or other additional consumption is if they can fill in the gaps in capacity, or do they need additional peak capacity? To find this out we must assess the load profiles of different uses.

Figure 4 shows an example of the electricity transformer substation (110/20 kV) load in one day (Tikka 2010, 76). The area consists mainly of detached houses, which may explain the higher load in the night, due to the electricity heating and heat storage in the structures for the following day, which is a common solution in Finland.

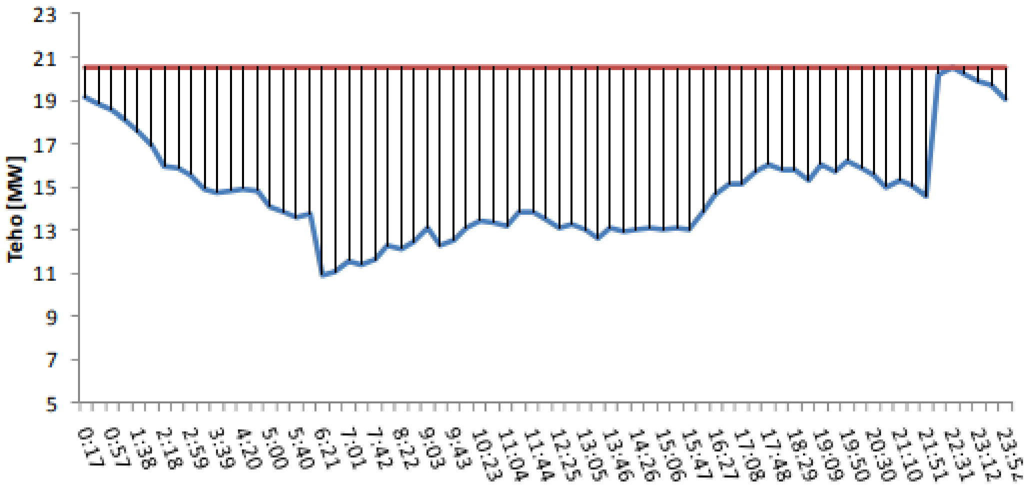

Figure 4: An example of electricity substation load in Finland in one day.

The consumption of block of flats, which is interesting in our case, looks different. There is usually no electrical heating, or at least of that kind which would be concentrated into the night-time. Until we get long-term enough results from buildings in MAKING-CITY project, results from other studies are used to estimate the impact of EVs. In figure 5 there is an example of one study, concerning typical single-person household (Rouhiainen&Heiskanen 2015, 5).

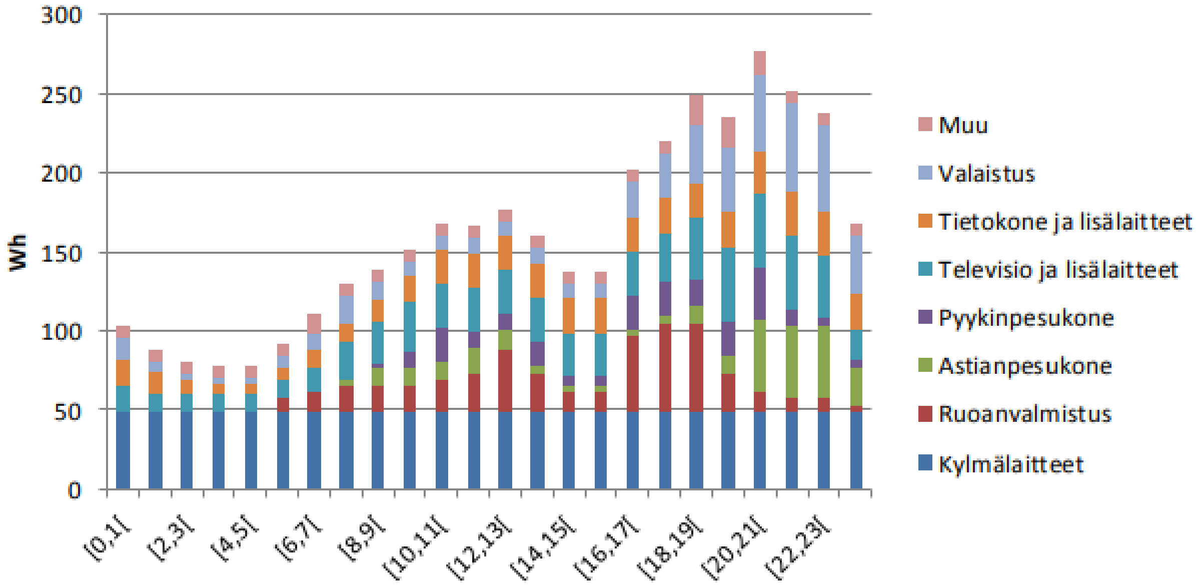

Figure 5: An example of average electricity use in one day in single-person household.

The pattern is logical related to common sense, having peaks in the morning and more strongly so in the evening. It must be noted that in this case there is no apartment-wise sauna, which has been common in Finland also in the blocks of flats from 1980's onwards. If there would be, the evening peak would be even higher.

In fig. 5 there is only apartment-wise consumption shown. In fig. 6 there is the common consumption of the block of flats kind of building, respectively (Viljakainen 2015, 10). "Common" here means mostly ventilation, lighting of public spaces and as largest use point in wintertime, car heating.

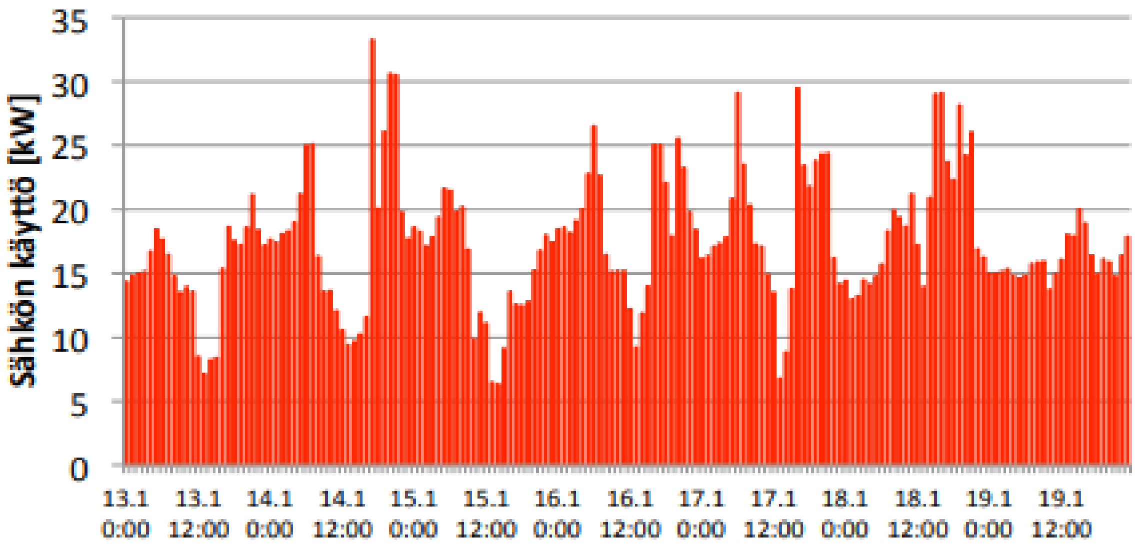

Figure 6: Electricity use for public spaces, lighting, car heating and a common sauna in apartment building in January 2014, Mo-Su.

Please note that the unit here is kW (for the whole building), while it in fig. 5 was W (for the single apartment). The size of the building is roughly the same than those of Kaukovainio PED area. In summertime the consumption is significantly lower, about half of that presented in fig. 6.

Since in Kaukovainio there are electricity-driven heat pumps in the buildings, they must be remembered also to be taken into the sum of the consumptions. In fig. 7 there is the measurement data of two Sivakka buildings (B1,renovated and B2.1, new) and YIT building (B3). For each it is chosen the day when the electricity consumption for HP has been highest this far.

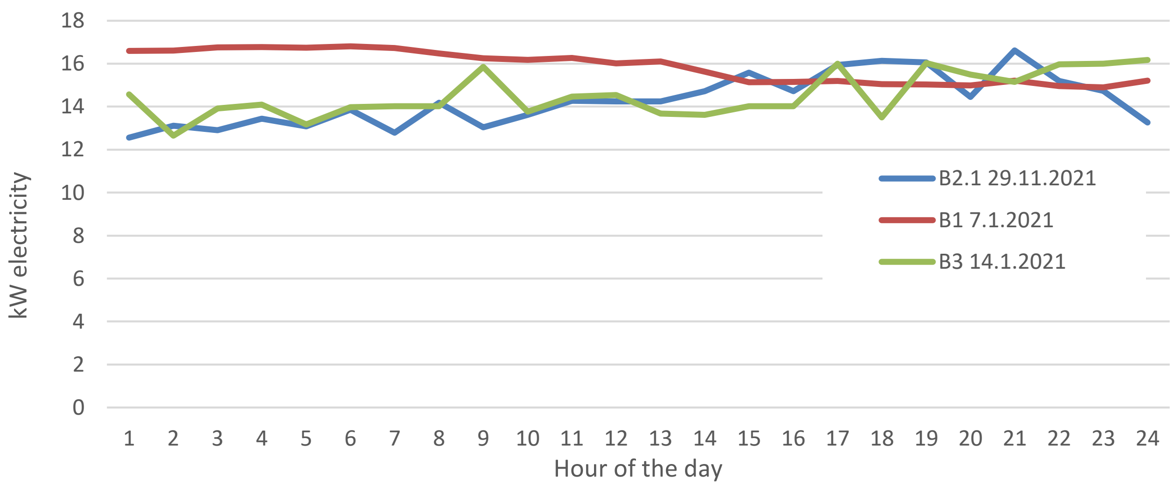

Figure 7: Hourly electricity consumptions for HPs in peak days in Oulu PED area.

As can be seen, the consumptions are nearly the same. The HPs are nearly of the same type and they are running in practice in full power in those days in question. In these cases, HPs produce mostly energy for space heating, not very much for DHW. B1 has partly a different heat source (exhaust air instead or in addition to DH return water in B2&3), but it does not seem to have significant effect on the consumption, possibly the effect concerning ore the heat production i. e the COP value. Slight fluctuation in power intake may arise from altering temperatures in source and sink sides.

To have an idea of all electricity consumption in the whole apartment block, the values presented in figures 5-7 must be counted altogether. Further, it is assumed that for an average household the consumption is doubled from that expressed in fig. 5 (more people in one apartment than just one like in fig. 5). This kind of coarse estimate is likely to be accurate enough for this kind of estimation here. In addition, this doubled one-apartment use must be multiplied by 50, which is the number of apartments in one block in our example.

So, after these, a reference consumption for further estimations can be summed up. This is shown in fig. 8. The size of the building is here about 50 mid-sized apartments, the same than in Kaukovainio PED.

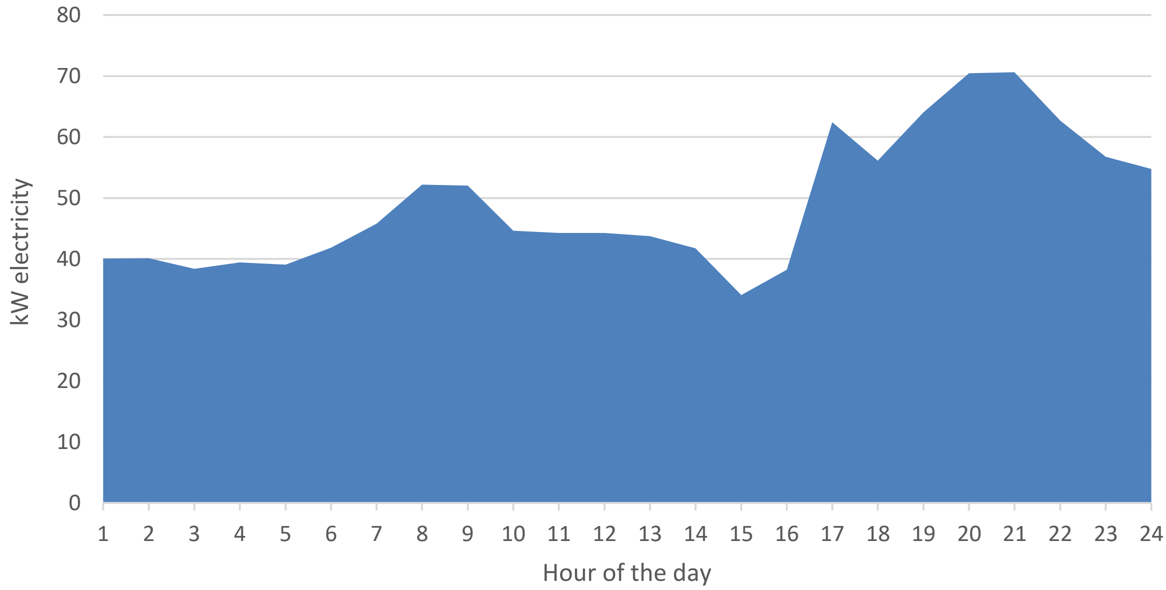

Figure 8: Total hourly electricity consumption in apartment block in winter day. Includes apartments, common spaces, ventilation and part of heating.

The evening peak stands out clearly. It is mostly due to the increased use in apartments when people come home. One part of the phenomena is also car heating at the same time.

The result is now a combination of different buildings, but it can be used as a basis for now. When more experience and data from specific real buildings are gained, that data can be used. In the following chapters it is estimated, how the EV charging is related to these loads.

3.4.3 An estimate of the EV amount in the future

The impact of different amounts of EVs in Oulu and in Finland is first estimated. The prediction of the EV amounts is difficult, with many unknown variables. Thus, it makes more sense to assess, what would be the impact if the target set by the Finnish government would be met.

In the calculations, which are presented in the "Results"-chapters, we use different levels of EV number and use per building. How much they may be realized and when could be estimated from the official documents presented in this chapter.

The Ministry of Traffic and Communications has made a projection of the traffic emission reductions (LVM 2021). The predicted base scenario of the following carbon dioxide emissions is shown in figure 9.

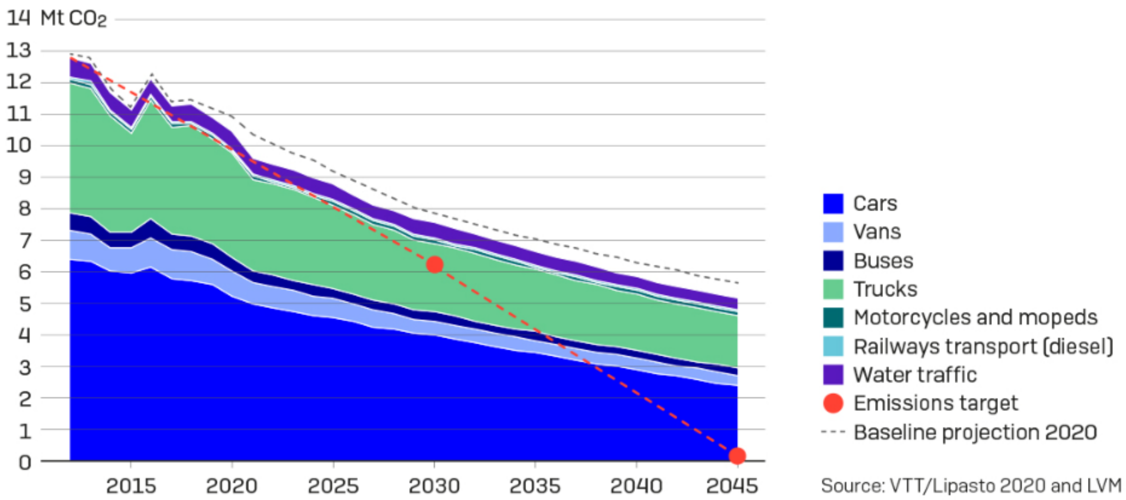

Figure 9: CO2 emissions from domestic transport, Mt, baseline projection 2021

Please note that the legend is in "reverse order", so cars are the widest dark blue area on the bottom. This estimate can be said to be quite conservative, since even in 2045 there is still remarkable emissions left from fossil fuels in cars and trucks.

Citing the ministry, the following forecast is done: "The share of electric and gas cars is increasing and the share of petrol and diesel cars decreasing. According to the forecast, there will be some 600,000 electric passenger cars in Finland in 2030. Last year, it was still predicted that there would be 350,000 electric cars." and "In June 2021, there were around 82,000 electricity-powered cars and 15,000 gas-powered cars. ". More, "The size of the subsidy has been based on approximately 120,000 full-electric cars by 2025.". The subsidy here means that for installing charging points. It is about 35% of the total cost, depending on the case. (VN 2021)

It is estimated that around 11 000 new charging points annually would be needed to be hand in hand with the increasing number of EVs. If it is scaled down to Oulu in relation to the number of persons, this would mean 400 points annually for Oulu. If compared to the possible EV number increase, this looks like a slow rate of EV penetration increase. Namely, annually about 120 000 new cars are purchased in Finland (VN 2021, 22).

If car use is not decreased, it would require about 2 million EVs in Finland by 2045 to eliminate the emissions from cars. In addition, there should be 500 000 biogas-powered cars. The problem may be that the average value of a car in Finland is now €6,800 (VN 2021, 23). Using much more money for the car than currently, is not an environmentally sound choice, even if the purchase would be an EV. So, first there should be a well-functioning second-hand EV market before the real breakthrough of EVs could be waited for.

It is also estimated that without significant subsidies or limitations the transition to electric/biogas cars will happen only not before 2040. And again, subsidising material consumption does not represent a sustainable solution despite the advantages. Alas, for these and some other reasons the aim is at least to stop car traffic from increasing and direct the possible transport growth to the sustainable traffic modes, i. e. walking, cycling and public transport.

3.4.4 Local EV electricity consumption

Car use in different kind of areas has very big differences. This in turn affects the predicted EV electricity use in the area, respectively. Figure 10 shows the situation in different areas in Oulu, expressed in carbon dioxide emissions per person per day. This is based on gasoline- or diesel cars.

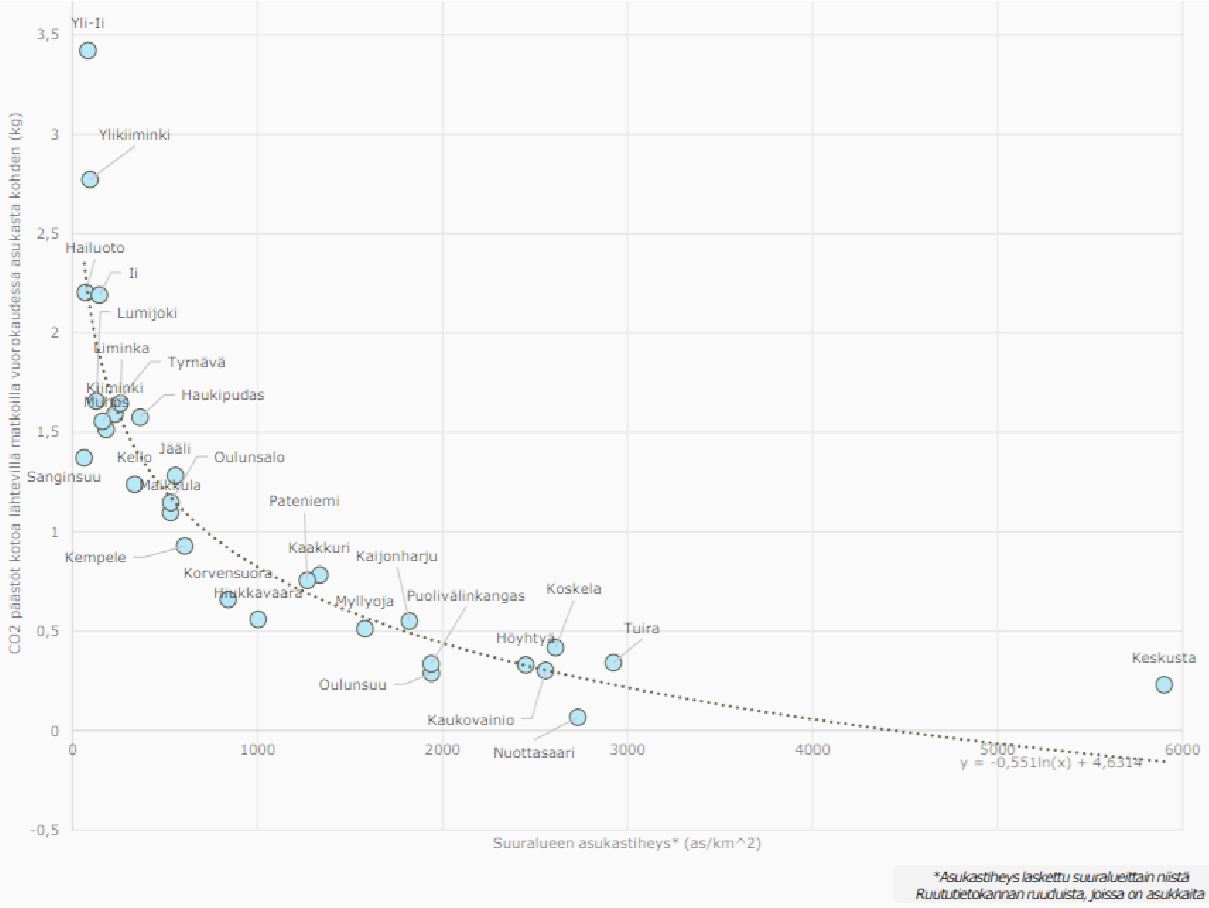

Figure 10: The CO_2 emissions/person/day in trips starting from home in different suburbs of Oulu (Nissinen 2021).

In sparsely populated areas car share of trips is larger than in areas with more services, due to the longer distances. This added to the longer distances as such in remote areas lead to the exponential shape of the curve.

What is especially interesting in our MAKING-CITY case is the "low-emission" position of our PED area, Kaukovainio. Even if in some surveys from the area it has been noticed that people there use quite a lot car, according fig. 10 the total use in absolute terms is however relatively low, possibly thanks to the handy location concerning the different kind of services etc.

And what is very useful for this study, is the estimate of CO_2 emissions per person from traffic in Kaukovainio. For simplicity's sake we can assume that the indicated 0,3 kg/person/day is all from private cars. This emission comes from about 1 kWh of oil, which in turn converts to 0,1 litres/person/day, or in another unit 1,5 car-km/person/day. This looks like very low, but it must be remembered that a part of the population uses no car at all and for many they are also others in the same trips. Also, there are only those trips that start from home. In Finland the average use of car fuels per person is 9-fold compared to the one calculated here, but it includes also more rural areas and all trips.

This value 1,5 car-km/person/day may be very useful in estimating how much cars some population uses. More, the trips starting from home are of special interest when we try to estimate how much electricity is charged to EVs.

If an electric car uses 20 kWh/100 km, this 1,5 km means 0,3 kWh/day. And if we have a block of flats with 100 inhabitants (which is roughly the case in Kaukovainio buildings), the daily electricity use for EVs in that block would 30 kWh/day as a total sum if all cars would be EVs. In this estimate we could double that if it is thought that EV is not charged in the destination, but rather driven home with the same charge.

So, the sum would be 60 kWh/whole building/day. Let's compare it with other electricity consumption in buildings like those of Sivakka or YIT in Kaukovainio:

- heat pump 0…500 kWh/day, depending on the weather
- building electricity (lights in public spaces, ventilation, elevator etc) 100 kWh/day
- apartment electricity (all 50 in a block altogether)in average 400 kWh/day, in wintertime a bit more

Even if this estimate is very approximate, it can be seen that EV charging in this case is only a small part of the whole consumption and causes therefore very probably no problems. In Finland the electricity networks are strong, which underlines this.

However, as stated earlier, the average car use in Finland is much higher than in this example. The other issue to be considered is the timing of charging. If electricity consumption is too much concentrated in certain hours of a day, it may cause a problem with electricity networks in different scales (inside building or outside it). This is elaborated in the following chapter.

3.4.5 EV charging pattern

An important issue about charging is the possible timing of it. Fig. 11 shows the average departure time from home (left) and arrival back to the home (right) times of the car user in Finland (Tikka 2010, 30). Fig. 12 in turn shows the average car trip departure time in Oulu region (WSP 2018).

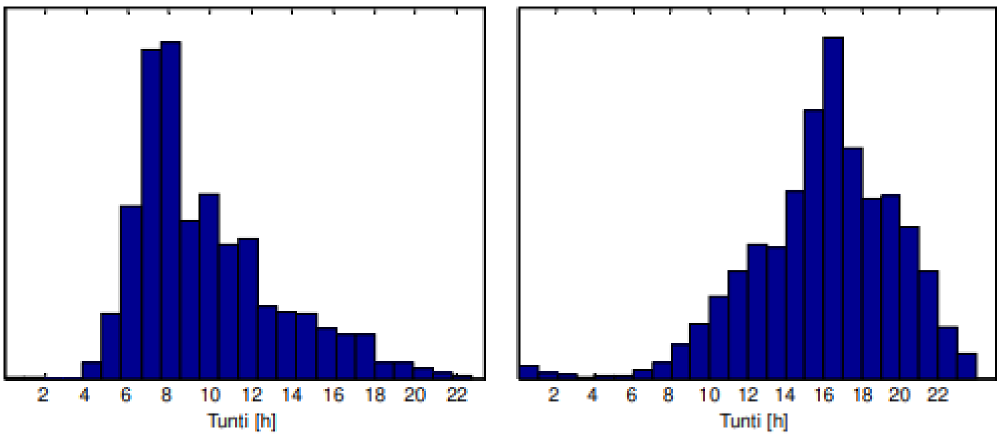

Figure 11: Average Finnish car users' departure and arrival time from/to home.

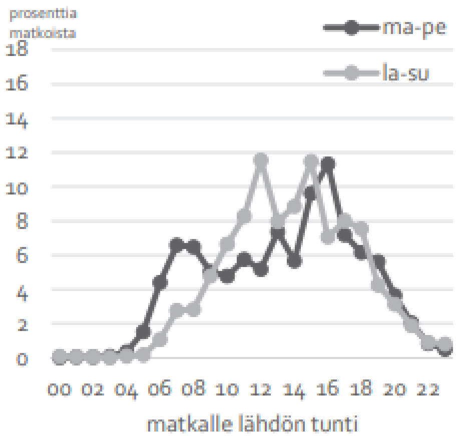

Figure 12: The starting time of the car trip in Oulu region, concerning the driver of the car.

Hourly percentages. Darker line = Mo - Fr, lighter line = Sa - Su. The y-scale is % of trip starts at certain hour.

According to these car use patterns, the charging can be estimated to be timed on the evening, especially if the charging for return trip is supposed to be performed also at home. Figure 1313 shows one modelling result of the charging timing.

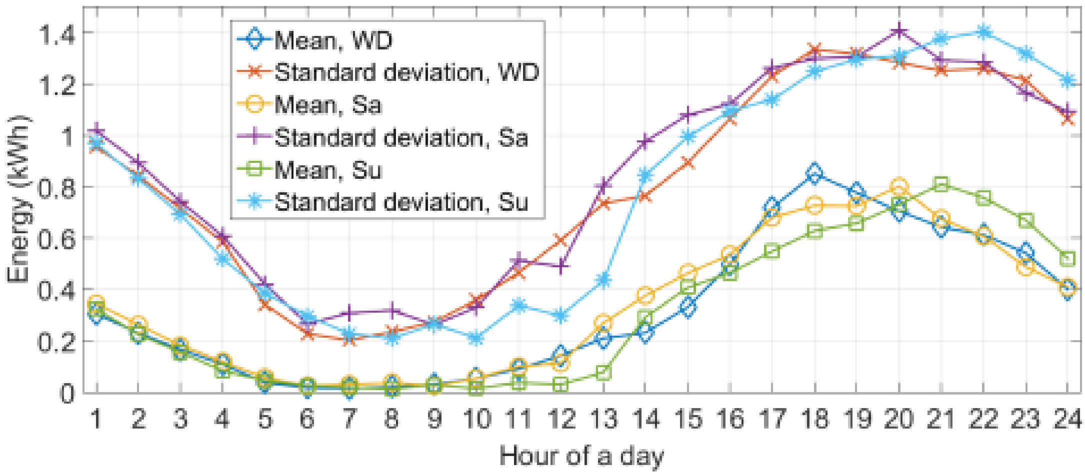

Figure 13: A simulated EV charging pattern, according to Rautiainen (2015).

The charging seems to be strongly concentrated on afternoon and evening hours, which sounds natural remembering the probable pattern of use. If there would be problem with networks, it probably arises in the evening after 17 o'clock. Another point of concern may be after 22 o'clock, since in Finland the so-called "night electricity" pricing starts then, and electrical heating wit heat storage ability starts to heat up then. If there is simultaneously a lot of EV charging, the load may be too high.

One essential question is if the very common Schuko sockets can be used for charging in large scale. If yes, the whole issue may be easily solved even nearly without investments in charging infrastructure. In Finland these sockets exist in nearly all permanent parking places in apartment yards.

An ordinary Schuko socket can handle 8 A current continuously, while fuses are usually 10 A or 16 A. In power output these mean 1.8, 2.3 and 3.7 kWs. In the charging adapters, it is often possible to set the charging current for example between these 8 and 17 amperes. According to the standard SFS-EN 62572, the current must be limited to 8 A for long-time use. This kind of charging is called "Mode 2", i.e. slow charging. The common load currently for them is usually, as an usual example, 600 W engine block heater + 1400 W car indoor heater, i. e 2000 W or 9 A as a total. But these are usually used for only a couple of hours before start. So, for longer-time loads the dimensions of e. g. the feeding cables to the posts must be checked case by case.

The lightest charging is Mode 1, which is intended to be used with electric bikes, scooters etc. The requirement is that the Schuko-socket used for that is in proper order and there is a residual current circuit breaker installed permanently. The charging current in Mode 1 is so small that it very probably does not cause any problems in the network or production-consumption balance. As a very rough estimate, it can be e. g. 1/40 of that of an electric car. The e-bike consumption may be round 1 kWh/100 km, i.e. 1/20 compared to the electric car and if the trip length is for example ½ of the car trips, then we end up with the mentioned 1/40 ratio.

As the consumption and an ordinary socket goes well, there will probably be no problems from electricity supply side if e-bikes are to be promoted. Oulu is well known for the quality of the cycling lanes and especially winter cycling, with proper maintenance also then. The largest obstacles of cycling in general are possibly too large grain size of affordances, i. e. too large unit size of "everything" and the following large distances, social reasons to use car (it is "normal" etc) and as a detail not too good cycle parking facilities in many places. Also, lane quality is not always reasonable, even in Oulu, not to speak about other cities. That's a personal view by the author, but in many occasions and discussions with laypeople, authorities and researchers these have been up strongly and thus can be seen valid.

The Finnish average daily car use is 47 km. The approximate average electricity consumption in turn is 20 kWh/100 km, so the daily consumption in average would be about 10 kWh. Considering the losses in the charging cycle, it would theoretically take about 7 hours to charge this amount of electricity with Mode 2 slow charger. As stated in earlier chapter, in Kaukovainio the average daily charging per person could be significantly lower, which eases up the situation further.

As seen in fig. 12, 95% of the car trips begin between 5.00 and 21.00. If this is assumed to be valid also for an individual, "normal" electric car user, there is 8 hours for charging at home, i. e. enough. The slowdown of the charging towards the end of the cycle may lengthen this theoretical time.

The marginal is not very large, however. On the other hand, we may ask, if the system should be tuned for high car kms or rather so that it is best suited for the moderate car use? From environmental point of view, the aim should be the moderate use. It would not be sustainable "development" if the car use as a whole is increased because of the EVs. More, if the car need is higher, then it is possible to buy a dedicated, quicker charger, Model 3 type. The price of that kind is around 1000 euros, which is not much compared to the price of an electric car.

One better solution in terms of sustainability is a shared EV. It is in MC project demonstrated in Sivakka rental building. In addition, it can be mentioned, that City of Oulu has both EVs, e-bikes and conventional bikes for shared uses for work-related trips.

3.4.6 The current EV charging places

For longer trips there should be intermediate quick charging possibilities if electric cars are used for those trips, but they would be located outside city areas, in the parking lots of roadside service stations.

About the current situation, Google Maps shows the current public charging stations, Figure 14.

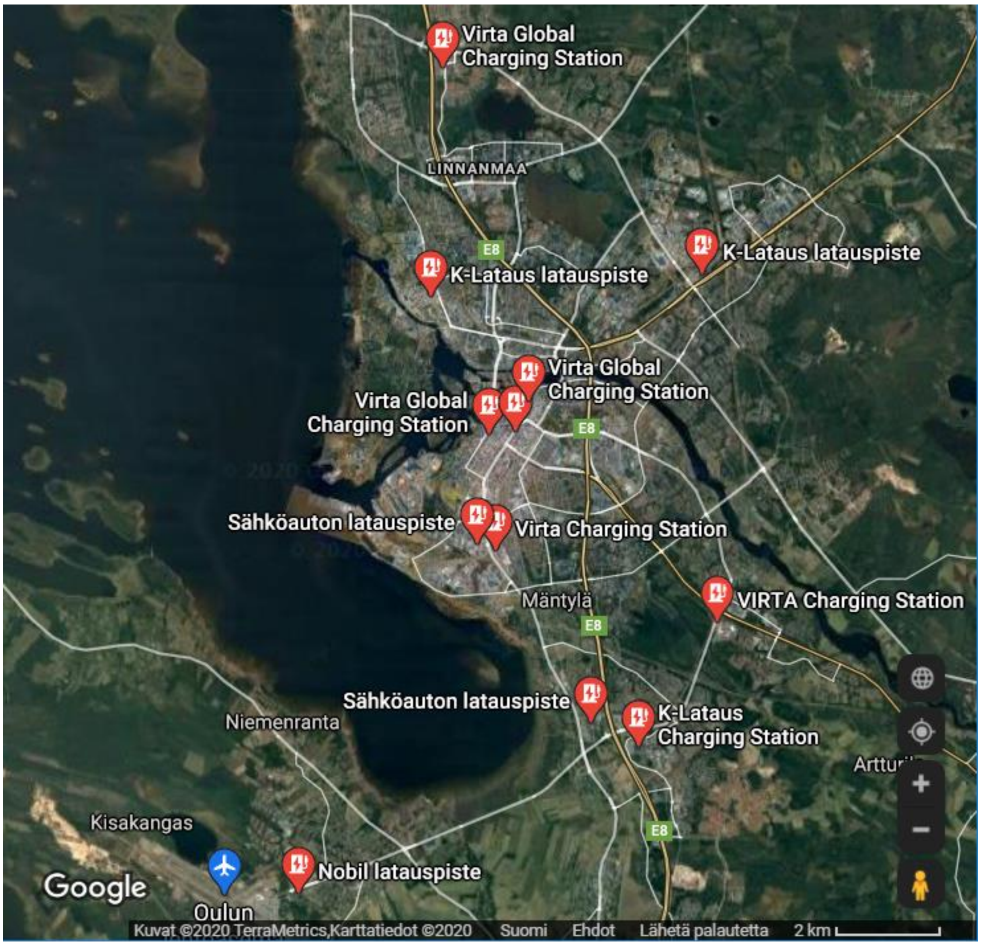

Figure 14: The public EV charging points in Oulu in 2/2021, according to Google Maps.

Figure 14 shows only those equipped with special EV chargers. In addition, there is a very large number of car heating posts (can be used with max. 8A current for longer time) and sockets in bike sheds etc. for e-bikes.

Most of the chargers have output of 22 or 50 kW (see list in table 3), so the charging for the fully empty battery takes 1…3 hrs. In practice batteries are rarely uncharged that empty, so a much short time is enough. It must be noticed that the more these quick chargers are used, the higher are the peaks in the grid and also in the production side.

Table 3: The properties of the charging points, according to Google.

Owner	Address	Charger type	kW	Amount
Fortum	Kallisensuora 6	CHAdeMO	50	1
		CCS	50	1
		Type 2	43	1
K-Lataus	Satamatie 26	CCS	50	2
		Type 2	22	4
Virta	Kasarmintie 6	CHAdeMO	50	1
		CCS	50	1

		Type 2	22	1
Virta	Lentokatu 2	Type 2	22	2
Virta	Saaristonkatu 4	Type 2	11	3
Virta	Hallituskatu 1	Type 2 Wall socket	22 22	3 3
Liikennevirta Oy	Poutalantie 1	Type 2	22	2
Virta	Voudintie 3	Type 2	22	2
Finavia	Lentokentäntie 720	Wall socket	3.6	99
Nobil	Lentokatu 2	Type 2 Wall socket	3.6 3.6	1 1
Virta	Karintie 6	Type 2	22	2
Virta	Kunnakuja 2	Type 2	22	2
Sum, subclasses		CHAdeMO CCS Type 2 Wall socket	100 150 476 426	2 3 23 103
Sum, total			**1152**	**131**

There is also a plan concerning the placement of the future charging points. Fig. 15. shows an example of that, concerning the city centre (Karjalainen&Koukkula 2016). When compared to the figure 14, it can be seen that there are many to be established in the future. Please note again that these are only the charging points for public use, those for private purpose either by dedicated charger or a by using an existing heating socket post are omitted here. The number of the latest mentioned in the map area is in hundreds, since the heating post is very common in permanent parking lots.

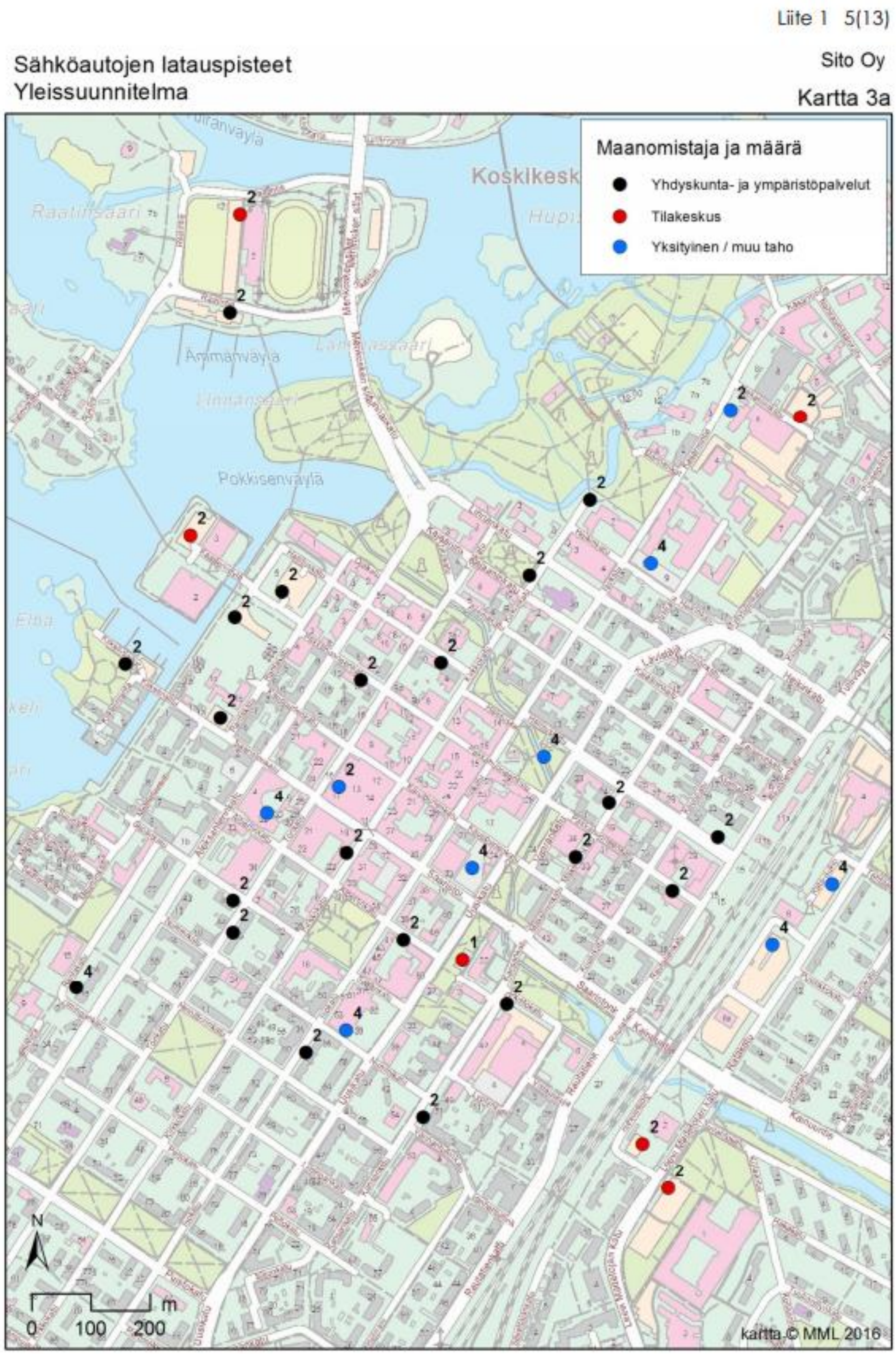

Figure 15: Planned EV charging places in the central city area.

Black & red = city-based, blue = private.

To have the charging places and biogas fuelling infrastructure realized, the Finnish state (not the Finnish cities) give subsidies for that. In 2018-2019 the sum was 3 M€/a. In 2020 the sum was 3,5 M€ and the need for the subsidy is increasing. In 2022…2025 the sum may be 8,5 M€/a, according to the estimate by the ministry of transport and communication. Of the total 34 M€ 22 is for high-capacity chargers

(=1400 chargers) and 12 M€ for heavy vehicle chargers. In the estimate it is assumed that there are 170 000 EVs in 2025 in Finland. However, the estimates are moving quickly.

In addition to cars, heavier vehicles are also turning to use electricity instead of liquid fuels. For the first wave, delivery trucks and local buses are the ones to use electricity. In Oulu the target is that 15% of the city buses run on electricity in 2030 (WSP 2019).

But, considering the news from the city bus sector in Finland in general, that may be an underestimate and the change may happen also in quicker pace after the experiences are gained from other cities. For example, the transportation organizer HSL in the largest public transport city area in Finland, i. e. that of capital Helsinki and the surrounding cities, has a target of having 1/3 of all buses electrical in 2025. Now the share is already about 15%. (HSL 2022)

However, there is a certain slowness in getting electric buses or other vehicles different from the current. The main share of the agreements with the bus companies in Oulu region is valid until 2025 and the new tendering round takes about 2 years, with the needed time for the operators to prepare the practical operation. Thus, no extremely quick changes must not be waited for.

Buses can be charged in the depot over the night, or in the end stops. The later alternative allows smaller batteries and thus cheaper investment. The price of the (large) batteries is about half of the total bus price, so the battery capacity has a significant impact on the investment.

On the other hand, the charging device, stretching over the pantograph installed in the bus, has a cost of 250,000 euros and is not feasible to be installed everywhere. The charging effect is for example 300 kW, which in the same size class than the fuse size of quite large block of flats (in Finnish scale). However, as buses are energy-efficient as such, the relative total impact is smaller than that of private cars. (WSP 2019).

It seems to be at least now that the large batteries (e. g. 300 kWh, enough for about 250 km drive) and depot charging-alternative may be the most popular choice. As a total it is generally a bit cheaper than the alternative based on quick chargers and smaller batteries (e. g. 100 kWh) in the end stops. What is interesting in the scope of this deliverable, is that the depot charging is naturally done mainly by night, which is advantageous from network point of view.

4 Results and discussion

The results presented here are this far based on the other studies, to get some estimate on the issue in general. When we get more real data from PED buildings, these can be updated.

4.1 Reference scenario

In chapter 3.4. the basic assumptions about EV and other electricity consumption profiles in an apartment building were discussed. They are used as a basis here. Figure 16 shows the estimated EV charging and other loads in winter day, with different amount of EVs.

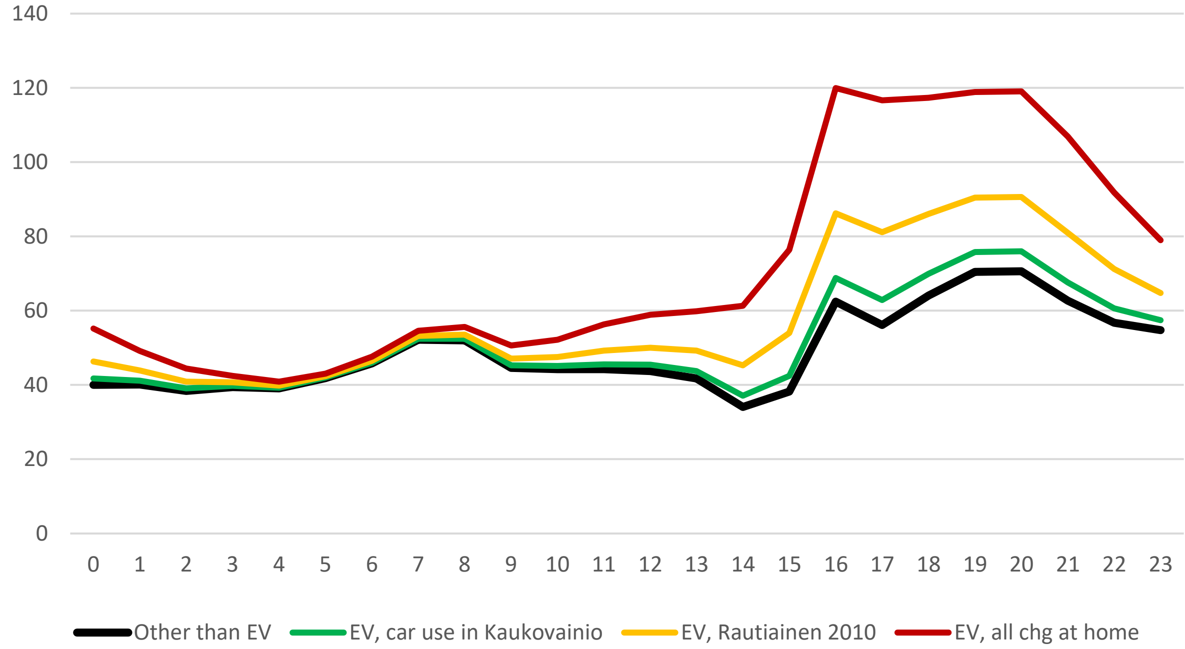

Figure 16: Hourly electricity consumption (kW) in an apartment building in winter day, added with different amount of EV charging. Timely unadjusted charging.

The black line in the bottom shows the consumption in the building without EV charging. It includes the consumption in apartments, as well as that for common spaces and a part of heating. The consumption profile is otherwise quite flat, but in the evening, there is a peak when people get back to home and start using electricity there.

The green line above that includes EV charging, assuming that the car use per person is on the level that it is currently in Kaukovainio. Only the (short) return trips from home are considered and therefore the driven km's and also energy consumption are low. The good location of Kaukovainio, close to the services, schools, workplaces etc., has a big impact on the very moderate car use.

The yellow line above the green represents the situation presented by Rautiainen (2010) in his study and an estimated "general" average of EV use in Finland. The car use is about fourfold compared to the average car use in Kaukovainio.

The red line in turn shows what would the consumption be, if all the electricity needed to run the EV would be charged at home and the car use is of average level in Finland. It is ninefold compared to the first "local trips only, Kaukovainio average"-scenario.

The reality may be closer to the lowest consumption scenario here, since the local conditions have a large impact on the use. On the other hand, if EV is invested in, the low variable cost may lead to the increased use. However, any car use increase is not a target, so this could be a drawback, but it is another story.

Most of the charging seem at least now happen somewhere else than in workplace, like in home charger. Now only 1/5 of the EV users charge their vehicle in workplace (LVM 2021, 20). This observation in turn enforces the relatively high amount of home charging.

In this reference scenario it is assumed that the charging timing is just up to the immediate need. When the EV trip has been finished, EV is connected to the charger. In figure 16 this charging pattern is shown.

This kind of charging timing maximises the availability of the vehicle in full charge, but on the other hand it may be sub-optimal if the electricity network or production is considered. As can be seen, this unwanted situation seems to be the case. The strong evening peak is made even peakier with EV charging, even if in the lowest car use scenario, the relative impact is nearly neglible.

Another approach is to compare these values to the common dimensioning of the electricity connection, i. e. in practice the fuse size. In apartment blocks larger than 2500 m^2, the formula to calculate the maximum needed power is P_{max} = 65 + sq. m. * 17/1000. This must be added with the car heating post needs, for which the formula is P_{max} = 10 + 0.5 * number of parking lots. These guide values are used for apartments, which do not have apartment-wise sauna. If there are separate saunas, the values are much higher, but as the extra can be thought to be reserved for saunas only and the saunas are used mostly in the evening (=peak time), we can leave those out from this estimate. (Luomanen 2019, 19)

In Kaukovainio case we have about 3000 m^2 and 30 heating post places/building. As a sum this means a fuse size corresponding the peak power of 141 kW. If we look fig. 16, there seems to be some room for additional consumption even if the “worst” EV charging scenario would realize. However, occasionally the other loads can rise above the averages used here. So, the “free” capacity of about 20 kW/14% is in practice too small.

4.2 Coordinated charging scenario

To prevent the evening consumption peak, EV charging should be at nighttime. Interpreting fig. 16, it could be also claimed that morning or midday would be good as well. However, as electricity price and environmental impacts (marginal emissions of electricity) are at highest in the daytime, it is advisable to use nighttime for charging. See fig. 17 for the average hourly prices. And from immediate user point of view, EVs are simply in place to be charged in the nighttime.

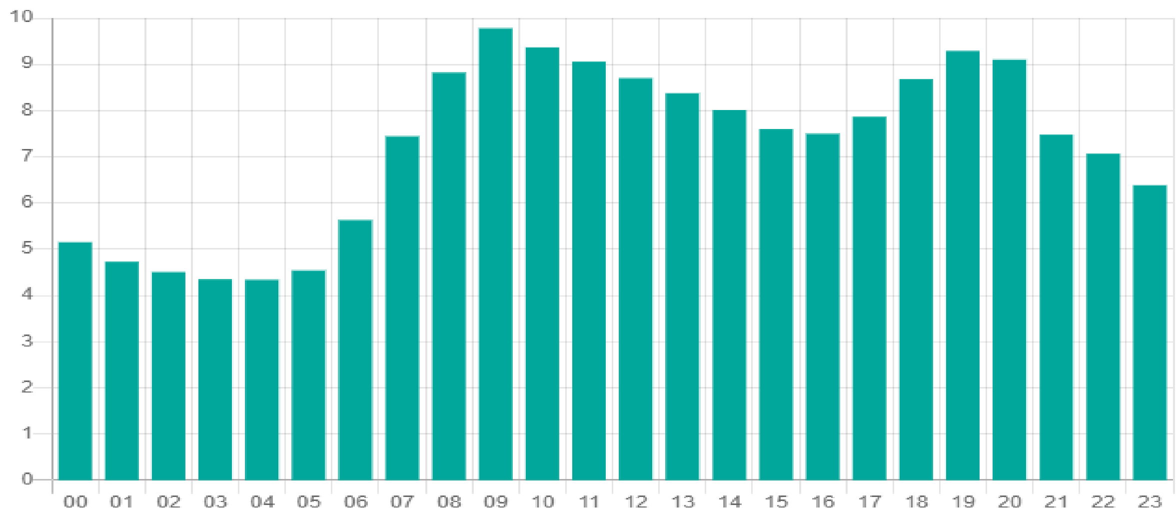

Figure 17: The average hourly electricity prices in Finland in 2021, in cents/kWh (Väre 2022).

In fig. 17 there is only electricity market price, so the transmission fee (1,5-6 c/kWh) and taxes (2,9 c/kWh) are not included. In average, the price in the nighttime is 5,1 c/kWh and in the daytime 8,3 c/kWh. The best time to charge is therefore from about midnight to 6 o'clock in the morning. In fig. 18 this assumption has been used.

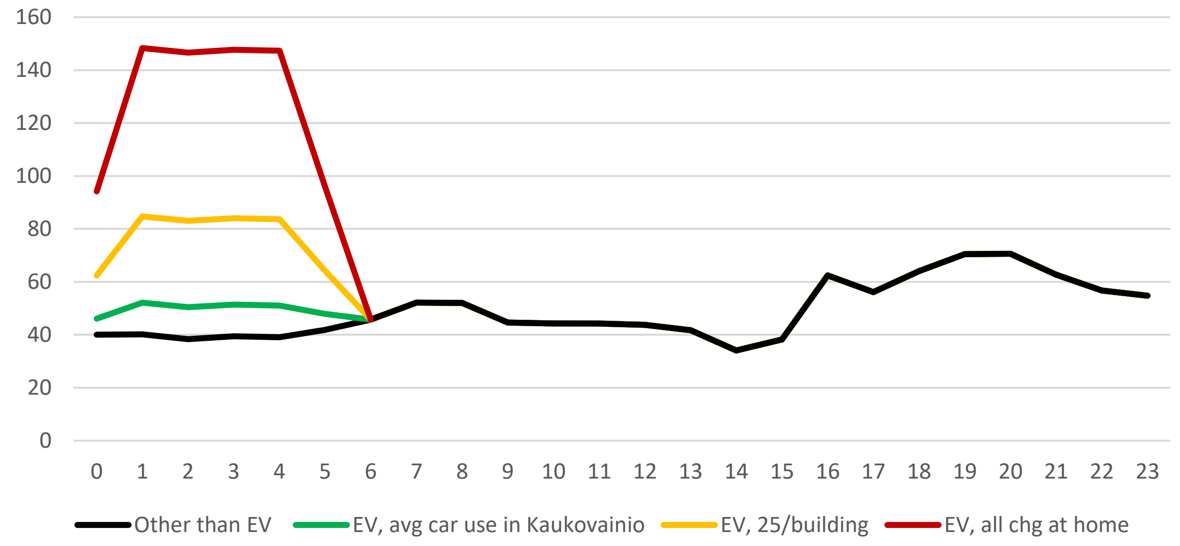

Figure 18: Hourly electricity consumption (kW) in an apartment building in winter day, added with different amounts of EV charging. Charging only in nighttime.

The different EV use scenarios are the same than in fig. 16. In this scheme, the beginning and the end of charging are smoothed a bit, to limit the sudden impact to the network. Now the lowest car use scenario seems to lead to a good result, but the others not that much. Especially the maximum scenario shoots out of tolerable area. So, in the following phase the charging is stretched out from the pure 0-6 nighttime charging. Figure 19 shows the result.

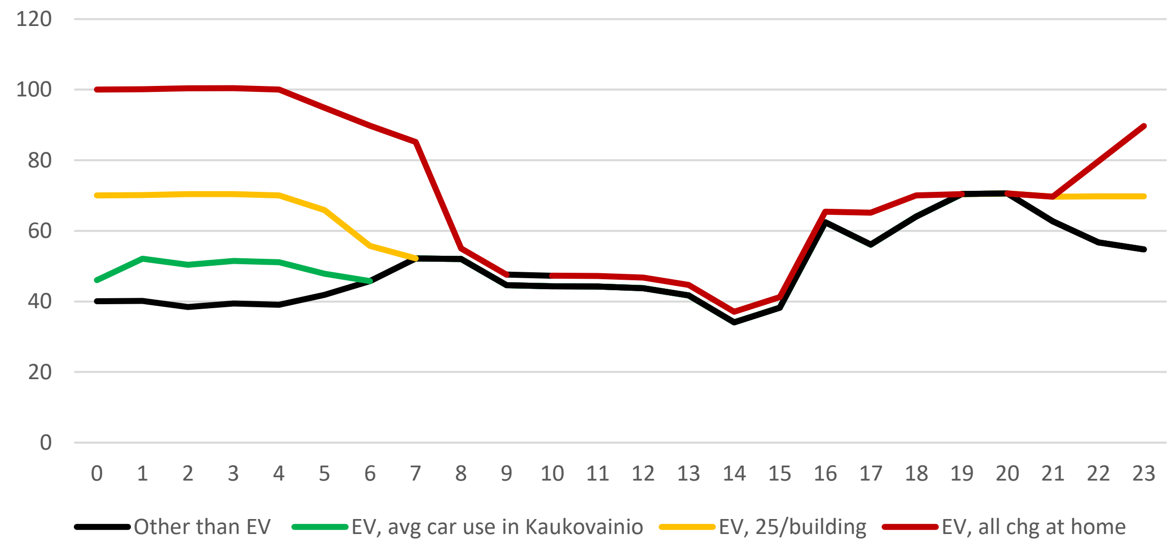

Figure 19: Hourly electricity consumption (kW) in an apartment building in winter day, added with different amount of EV charging. Charging spread to the lowest hours, in addition to nighttime.

The biggest difference to the previous one pattern is that in the most consuming scenario also other not-peak hours than nighttime are utilized. The critical evening time is kept in around 70 kW, i. e in the level of non-EV-charging case. Remembering that the basic dimensioning of the electrical system in this example allows 140 kW and in the nighttime it is not that probable that there occasional are big loads other than EV, this scenario can be said to be on safe side, even if now the nighttime load is quite high, 100 kW. In other than max. scenario the situation is even easier. The basic idea of nighttime charging is supported by e. g. in the report made for the Finnish Climate Change Panel, by Kopsakangas-Savolainen and Meriläinen (2018).

One more practical issue, which can make even the straight-forward night charging like in fig. 18 feasible, is considering the impact of saunas to the network dimensioning. The older buildings usually do not have apartment-wise, saunas, but newer do. The amount varies. For example, B2.2 has sauna in all the apartments, while in B3 about 1/3 have.

For buildings with sauna in every apartment the formula for maximum electrical effect is P_{max} = 90 + sq. m. * 24/1000 (Luomanen 2019, 19). This must be again added with the effect needed for the car heating posts. Altogether we get a dimensioning effect of 187 kW. In fig. 18 it was estimated that charging only in the nighttime would lead to the peak effect of about 150 kW, including other loads too. Saunas are not usually heated up by the middle of the night, nor other big extra loads are to be waited then. It can thus be concluded that if the electrical system in the building is dimensioned bearing the saunas in mind, EVs can be charged in the nighttime without any probable problems.

In the example above it was assumed that all the apartments have sauna. If only a part has, then the charging pattern should be shifted towards more timely spread one, like in fig. 19. This need for shifting occurs only if there are a lot of EVs and they are also used a lot. Smaller charging outputs can be handled still with simple timing strictly to nighttime.

The chargers that are sold in Finland seem to have smart charging function mostly by default. This means that the simple nighttime charging (fig. 18) or a bit more elaborated version, timely scattered one (fig. 19), can be handled automatically.

From the whole energy system point of view, also a more complex charging pattern could be advantageous. The production-consumption balance of electricity fluctuates. Hourly spot price can be used a handy indicator for that. The phenomena is visible in day-night-cycle, but also for example in weekly or monthly level. In December this was especially pronounce. Electricity market prices in Nordpool spot market sky-rocketed, being even 10-fold compared to the ordinary level (about 400 e/MWh as maximum vs. 40 e/MWh as a normal level). Depending on the contract with supplier, the users won't notice that immediately, but after a while the companies must pass the increase to the consumer prices also.

Alas, the timespans for that kind of larger optimization are easily so long that EV batteries are not very practical in that. The storing need could be for example one week, so in optimal state the batteries are in minimum average charge when the electricity price is high. Or in the best case EV is not used at all. When the price goes down, the full charging takes place.

The inconvenience, or perhaps more accurately uncertainty, of being "on the edge" of the charge in the low point may be too much for many. Therefore, the potential of other than nighttime smart charging can be limited.

4.3 Bi-directional charging scenario

This kind of solution for the whole Finland-level was presented for example in Fingrid's scenario,fig. 1. A further estimate, what kind of impact would this have in hourly level in the large energy system, is presented in fig. 2.

As stated in earlier chapter, it is not self-clear that the EV users would accept this solution at least used in large extent, using a large part of the capacity of the batteries. It may have a negative impact on the availability of EV, or as an alternative the extensive use of capacity must be limited into the nighttime only or into the moments, when EV is not needed anyway.

But, for exploring the impact of 2-way charging, let's assume that there are no such limitations. If a scheme presented in fig. 16-19 is used as a basis, we get for example a charging-decharging pattern presented in fig. 20. It is also assumed that the useful capacity of EV battery is 40 kWh and there are 20 EVs at the same time, that can be used as electricity storages.

In daily level, there are in principle at least two different strategies in which way the bi-directional charging can be useful. The first one is to minimize the hourly peak consumption, i. e. in practice to minimize the fuse size.

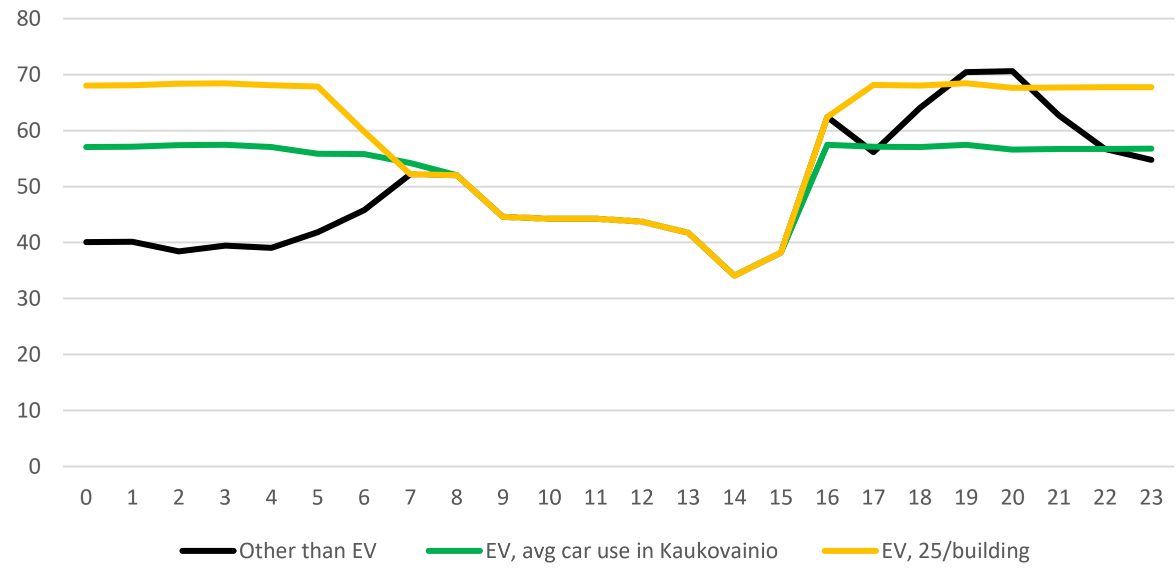

Figure 20: Hourly electricity consumption (kW) in an apartment building in winter day, added with different amount of EV charging.

Bi-directional charging: in the evening electricity is fed from EV batteries to the building.

Especially the evening peak can be flattened, when EV battery is used for peak shaving. Of course, there must be enough battery capacity, but this seems to be no problem in these estimates.

The impact is the bigger the less there is need for electricity for EVs themselves. The highest car use scenario is lacking here, since bi-directionality gives no advantage in that case. The energy needed to charge the batteries in relation to the other electricity use in the building is so high, that it sets the fuse size also in the nighttime. So, there is no energy left after the day to be used to shave the evening peak.

Another way of using bi-directionality is to concentrate the grid electricity consumption strongly into the nighttime (or e. g. into the moments of high wind/PV production in longer timespan) and de-charge the batteries in the evening (or low win/PV moments). This to cut the grid electricity use then to the minimum in the "bad", expensive and more polluting hours. This requires larger fuse size, which may offset the economic advantage. It is complicated and may require changes in the transmission pricing principles, but also potentially perhaps the most interesting one.

4.4 Coordinated loads scenario

This option is needed especially if there should be a continuous possibility of charging a large number of EVs simultaneously. In the classification of the amounts of EV use here, the largest one (EV, 25/building) seems obviously the most interesting.

The other flexible loads than those for EV charging could mostly be the ones for heating, i. e. for HP compressors. The problem could be that the HPs should be dimensioned for part-load in this case. They run in full power in wintertime, from some minus degrees onwards. See figure 7.

There are also other loads that in principle could be used for flexibility, but the coordination of those is much more difficult since they have mostly a direct impact on the everyday life of the inhabitants. On the other hand, in MAKING-CITY project the inhabitants are given information about their real-time consumption and thus it is hopefully easier to change the timing of electricity or heat use. The inclusion of other than HP electricity consumption in coordinated loads can be derived e. g. from the results of those trials in the future.

Back in the first-phase scenario with coordinated loads, if HP output is limited to limit the electricity load, the HP share of total heat production is decreased. Depending on the total load in DH network, it may still be a good idea, when the electricity price is high, and the marginal emissions of electricity are at highest. In Oulu the rest (and currently nearly all) of the DH production comes from CHP plants. Thus, in situations where there is free capacity in CHP plants, it is feasible to use them more and HPs less when electricity price is high.

The basic assumption here is that HPs are temporarily run down to shave the evening peak and respectively the gap in heat production is filled in by supply-side DH. In all PED area apartment buildings the electricity input for HPs in peak effect situation is about 15 kW, fluctuating only a little. So, the shaving of this magnitude is placed in the eveningtime in this scenario, fig. 21. EV charging pattern is the same than in Coordinated charging scenario, and the version where the charging is done mostly in nighttime, but also a bity in the evening.

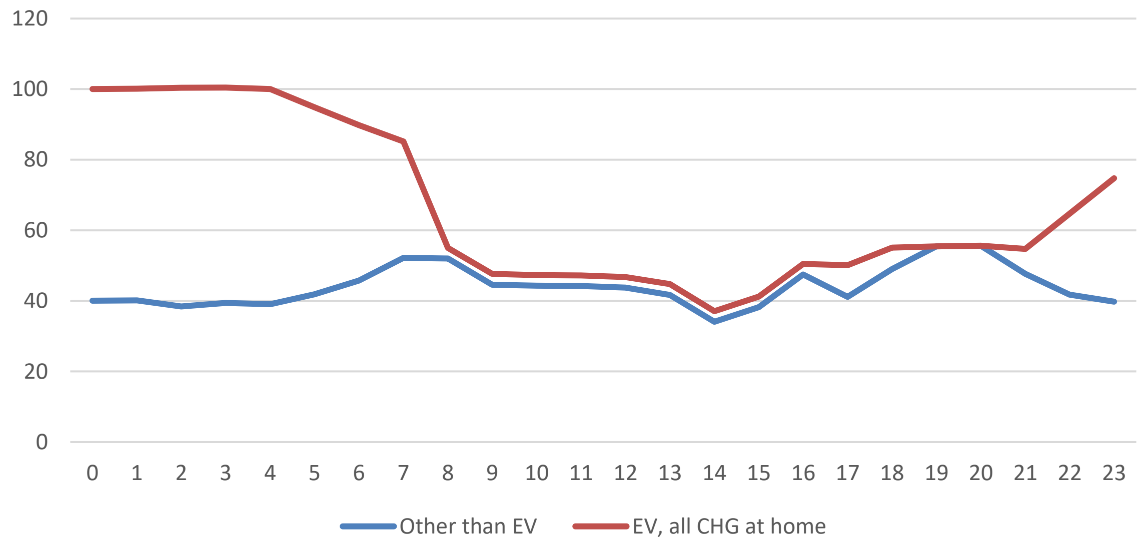

Figure 21: Hourly electricity consumption (kW) in an apartment building in winter day, added with different amount of EV charging.

Electricity consumption in the evening is limited by turning the HP off for some hours and replacing the heat by DH then.

Now the electricity consumption profile from morning to evening is quite flat. In the night there is a strong peak, but from the system point of view that is ok.

5 Applicability of results for other cities

The electricity production portfolio, grid strength and standards of in-building electricity are different in different countries. Thus, the results cannot be generalized as such. However, the methodology and the procedure of estimation presented here can be utilized. The studies should be done case by case, but of course some basic data and methodology can be used. The EV properties are practically the same in all countries, so that can be seen as a generalisable issue. However, the use pattern of EVs may differ country by country and especially the infrastructure properties.

In Finland one important characteristic is strong electricity network due to the quite high share of electrical heating and the high amount of electricity-consuming industry. The wintertime load is the dimensioning one, only in exceptional cases the summertime cooling. In the future the production portfolio consists mainly of nuclear power, wind power, CHP and hydropower.

These preconditions set quite favourable starting point for EVs. In the Nordic countries in general the starting point is good, due to the high share of hydropower with dams and thus ability to use it in regulating purposes.

6 Follow-up work

This study may be used in estimating the EV possibilities from the energy infrastructure point of view in Finland and more locally in Oulu. It is also strongly connected to the general transportation planning. When real data about EV charging in PED area is obtained, the estimates made in this report can be adjusted in D5.11. Then also we have more data about the other electricity consumption in the buildings, which helps the evaluation still more.

In MAKING-CITY WP1 City Vision 2050 we outline, in addition to this document, some possible developments concerning transportation. It is an aim of the city to decrease the amount of fossil-fuel cars and replace them by more walking, cycling, public transport, EVs and biogas. These measures are decided in e.g. the environmental program of the city. MAKING-CITY-project does its part in strengthening these developments and adding information needed to have the good decisions done.

Conclusions

With the other transport sector targets and measures, it seems to be possible to integrate EVs in the current grid smoothly, without large additional investments. The strong networks in Finland make this possible, in addition to the smart charging as a default.

However, if charging is not coordinated in any way, there may be electricity network congestion problems in the evening when the consumption in apartment buildings is at highest. If the already then peaking consumption is added with EV charging when people get home after working day, there may be problems. The simplest and likely an effective enough solution is to time the charging in the nighttime. It is feasible from points of view of transmission network, electricity production and car use comfort.

The most important barrier in improving the share is the high investment cost of the EVs. The charging infrastructure in the Finnish conditions is only a minor issue and presumably not a bottleneck. It seems probable that the high share of EVs will be there only when the market of the second-hand EVs has been realized enough, which takes some time.

On the other hand, we'd like to remind that the most environmental car is the one which is not used nor owned, even if it were an EV. Thus, for example in Oulu, walking, cycling and public transport are promoted. One practical target could first be for example to prevent the increase of motorized traffic amount. And, in addition to this, to encourage people change to EVs when new or second-hand car is to be purchased.

An interesting alternative to private car ownership is also being tested in MAKING-CITY project, namely a shared EV. With that solution the high investment cost is not a barrier, and in the best case it also nudges the behaviour towards nearly car-free lifestyle. Car is available when really needed, but otherwise the infrastructure supports other transportation modes.

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