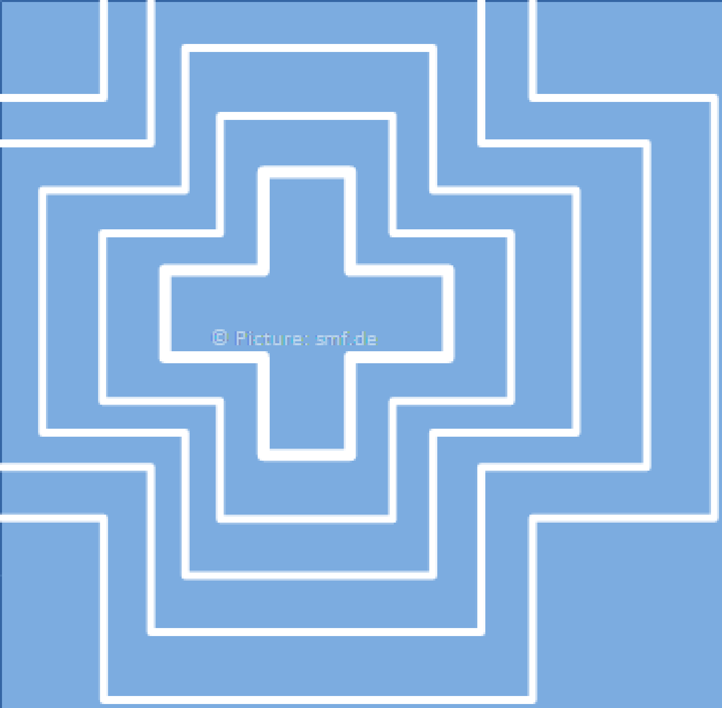
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simply positive

D4.3. Feasibility study on e-mobility support through local DERs with expected short, mid, & long-term impact on grid level

25th September 2024

Leader: LINKS Foundation

Dissemination Level

PU	Public	x
CO	Confidential	

History

Version	Description	Lead author	Date
V1	Table of content	LINKS	15th March 2024
V2	Main structure of the model and description of results	LINKS	30th March 2024
V3	Annex 2 by RINA	RINA	22nd July 2024
V4	Final draft	LINKS	12nd September 2024
V5	Final Review and approval	SON	23rd September 2024
V6	Final version	LINKS	25rd September 2024

Disclaimer

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Executive Summary

This deliverable aims to explain the tool developed to assess the energy demand of electric mobility and its application on three of the four Focus Districts defined in the project: Settimo Torinese, Resita, and Großschönau. The model does not apply to Amsterdam FD as it is in an area with a low car density and without public charging stations.

Using a parking-based model, the study uses vehicle travel patterns, parking behaviors, and public/private charging habits as well as environmental factors such as temperature for simulating and forecasting energy charging consumptions.

Each district was analyzed under a base scenario, reflecting present conditions, as well as two future scenarios for 2035, varying levels of EV penetration and charging point expansion.

In Settimo Torinese, despite significant growth in EV numbers, almost no disservice has been observed in the future simulations, indicating that the current charging infrastructure can handle increased demand, if charging points are strategically distributed. Resita has shown a moderate growth in energy demand, with additional charging points helping to alleviate potential congestion in the current and future states. In Großschönau, the charging infrastructure remains underutilized, suggesting it is more than capable of managing future growth.

Overall, it is possible to summarize that while the existing infrastructure appears sufficient, strategic distribution of charging points and demand management (such as pricing mechanisms to spread out charging times) are critical in areas with rapid EV adoption.

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List of Abbreviations and Acronyms

EV	Electric Vehicle
EE	Electric Energy
DER	Distributed Energy Resources
DevS	Standard deviation
FD	Focus District
PED	Positive Energy District
PV	Photovoltaic
WP	Work Package
SOC	State Of Charge

Table of Contents

1 Introduction

1.1 Purpose of the document

The aim of the document is to estimate the impact on local grid of e-mobility interesting the focus districts identified in the project.

Using a parking-based model, the study uses vehicle travel patterns, parking behaviors, and public/private charging habits as well as environmental factors such as temperature to simulate and forecast energy charging consumptions.

Each district is analyzed with reference to three different scenarios: the base scenario, reflecting present conditions, and two future scenarios for 2035 generally characterized by a higher number of EVs and charging points.

1.2 Relation to other project activities

In WP3 (Practical Operationalization of the PED Framework definition and criteria in the Focus Districts) UASTW developed a methodology to estimate the energy balance in the four Focus Districts. The method was described in D3.3 and here applied to 'PED Alpha', which focuses exclusively on operational energy.

To work on 'PED Beta', which incorporates private daily mobility, the results of the model described and applied in this deliverable can be used.

This idea will be resumed in D5.3 contents, that includes updates and stakeholder feedback coming with respect to usability and practicability of the UASTW methodology, as update to the methodology defined within WP3.

1.3 Structure of the document

The document is divided into two sections, the main sections to describe model and results of its application, the secondary section dedicated to annexes.

The core of the document includes the following chapters:

- Chapter 2: detailed description of the model developed to estimate the demand for electric energy by EVs travelling in FDs
- Chapter 3: application of the model to the FDs in the project.
- Chapter 4: conclusions.

2 The e-mobility model

To meet the goal of the Task a tool that forecasts the electricity consumption attributable to private electric mobility in a designated district has been developed.

It calculates the electric load with hourly precision throughout the year. This approach ensures accurate estimation of both the peak stress that the grid will endure, and the total annual energy needed to satisfy the demand.

2.1 The overall model

The model developed is based on a parking-based approach. It is not important to know the routes of the vehicles or where they start from and where they are going, but it is important to know when they park and how long they stay parked.

The model generates the circulating fleet of electric vehicles, assigns them travel and charging habits, makes them travel every day according to the average km assigned daily. If once parked, the SOC of the vehicle is below (or close to) the assigned threshold to activate charging, the vehicle starts charging. Each vehicle can park just once in each day, each vehicle has the same charging location preference each day.

2.2 Core Inputs and Assumptions

The model's inputs are divided into two categories:

- necessary data: they must be provided specifically for FDs
- non-necessary data: if the Focus District does not have specific data, the model's default ones can be used. Otherwise, they can be modified

Regarding the first group of data, the user must provide information related to the vehicles travelling in the district and the scenario charging infrastructure, as well as weather data.

The necessary data are:

- Number of electric vehicles travelling daily (average weekday) inside the district perimeter, divided as follows:
    - Urban: number of electric vehicles that travel within the Focus District (FD). Their trip origins and destinations are within the FD
    - Incoming: number of electric vehicles entering the FD. They have origin of the trip outside the FD and destination inside. These are the vehicles of people who daily travel to the FD for their activities
    - Outgoing: number of electric vehicles that leave the FD to reach an outside destination

- Average kilometers travelled daily by the three different group of cars (Urban, Incoming and Outgoing)
- Number and power of the charging points present in the district or forecasted, divided into:
  - Slow charge (with a charging power usually lower than 7 kW)
  - Fast charge (usually between 7 and 22 kW)
  - Ultrafast charge (more than 22 kW)
- Average Daily Temperatures as a 365-day array representing each day's average temperature over a year or an 8760 array with hourly data.

The second cluster of inputs regards the charging habits of the EVs' drivers, as well as the model segments of cars present in the district. These inputs rely on distributions at European level retrieved from peers' studies on the subjects (Figure 1). They can be used if the FD doesn't have more specific data. On the contrary they can be modified according to the specificities of the FDs.

The distributions present in this group refer to:

- Starting State of Charge (SOC) of the Vehicle [1]: this is the battery charge level below which the driver decides to plug in the electric vehicle. In other words, it is the "low battery" point where charging becomes necessary
- Final SOC of the Vehicle [2]: This represents the minimum battery charge level that meets the driver's needs, at which point they will disconnect the EV from the charging station. It's like setting a "goal" for how much charge they want before they stop charging. Not all vehicles charge to 100%
- Charging Location Preferences [3]: the preferred charging spot for the EV, chosen by the driver. Options include home, work, or another location. In addition, the charging points can be public or private. Distribution estimated by LINKS starting from different sources
- Parking Duration [4]: this is the duration of the parking state for each of the possible charging location (home, work and other)
- Parking Starting Time [1]: this is the percentage distribution of parking starting times during the day, in different locations (home, work, other)
- EV segments [6]: these are the percentage of car segments present in the European market. From derived also data about:
  - average energy consumption per kilometer [kWh/km]
  - average battery capacity [kWh]

“EV segments” and “Charging location preferences” have been considered as frequency distributions. The other distributions have been considered as probability distributions to give more variability to the charging behavior.

A-B	i.e. Fiat 500 elettrica / Renault Zoe
C-D	i.e. Volkswagen ID.3 / Tesla Model 3
E-F	i.e. Tesla Model Y / Porsche Taycan

Figure 1: Distribution used as default if FD doesn't have specific data

2.3 Model Operation Logic

The operational steps of the tool are detailed below.

Input Data Loading

As the first step the data about the district mobility, the car segments and the drivers' behaviors are uploaded in the model. This information is written in a .Yalm file which is read by the Phyton file.

Creation of Electric Vehicles

Depending on the vehicle inputs, the fleet of electric vehicles is created and divided into Incoming, Outgoing, and Urban categories. Behavior is then associated with each vehicle, in accordance with the frequency or probability distributions.

Each EV possesses the following details:

- SOC at simulation start (random between 10% and 100%)
- Starting SOC
- Final SOC
- Daily average distance traveled
- Favorite charging location
- Length of parking
- Parking starting time
- Market segment
- Kilometer consumption (from the EV segment)
- Battery size (from the EV segment)

Since at the beginning of the simulation the vehicle's SOC is randomly distributed between 10% and 100%, it may happen that in the first days there is an increase in charging sessions before reaching the expected pattern for the rest of the year, resulting in an increase of the energy demand for January, compared to other months.

Filtering of Generated EVs

The electric vehicles undergo a selection process, eliminating those that do not charge in the district. Specifically, Incoming vehicles that charge at home and Outgoing vehicles that charge at work. The objective of this step is to accurately isolate and analyze the subset of vehicles that utilize public or private charging infrastructure within the district.

Temperature Inefficiency Coefficient application

During the months characterized by low temperatures, a motor inefficiency coefficient calculated through a linearization process based on the results of the study [5] is used. It has been derived from the observation that energy consumption increases by 16% for every 5 degrees below 10°C. This often leads to a further increase in consumption in January, which, as already explained, may be higher due to the causal allocation of the initial SOC.

The additional increase related to the use of heating is not included, as it can be considered negligible for the modelled trips.

During the summer, any increase in energy consumption is only attributed to the use of air conditioning, which again can be considered negligible.

Charging Stations Implementation

The charging infrastructure is added to the simulation by following the inputs given by the user in terms of number of charging points and their maximum power outputs.

Charging Logic

With all elements and variables of the simulation established, the tool proceeds to generate the energy demands of the EVs on the grid, applying a distinct charging algorithm. This involves an hour-by-hour analysis for every day of the year, evaluating each vehicle's energy consumption based on:

- Its parking habits
- Its charging needs (Starting SOC)
- Availability of charging points in the district.

It is worth noticing that, as opposed to vehicles recharging at public infrastructures, private charging vehicles do not have to follow any constraint about charging points availability, so they can always recharge when needed. This can lead to higher power demand, especially in January, where the effect of temperatures and random assignment of the initial SOC, as explained above, are added together.

Following the detailed flow diagram of the developed model (Figure 2).

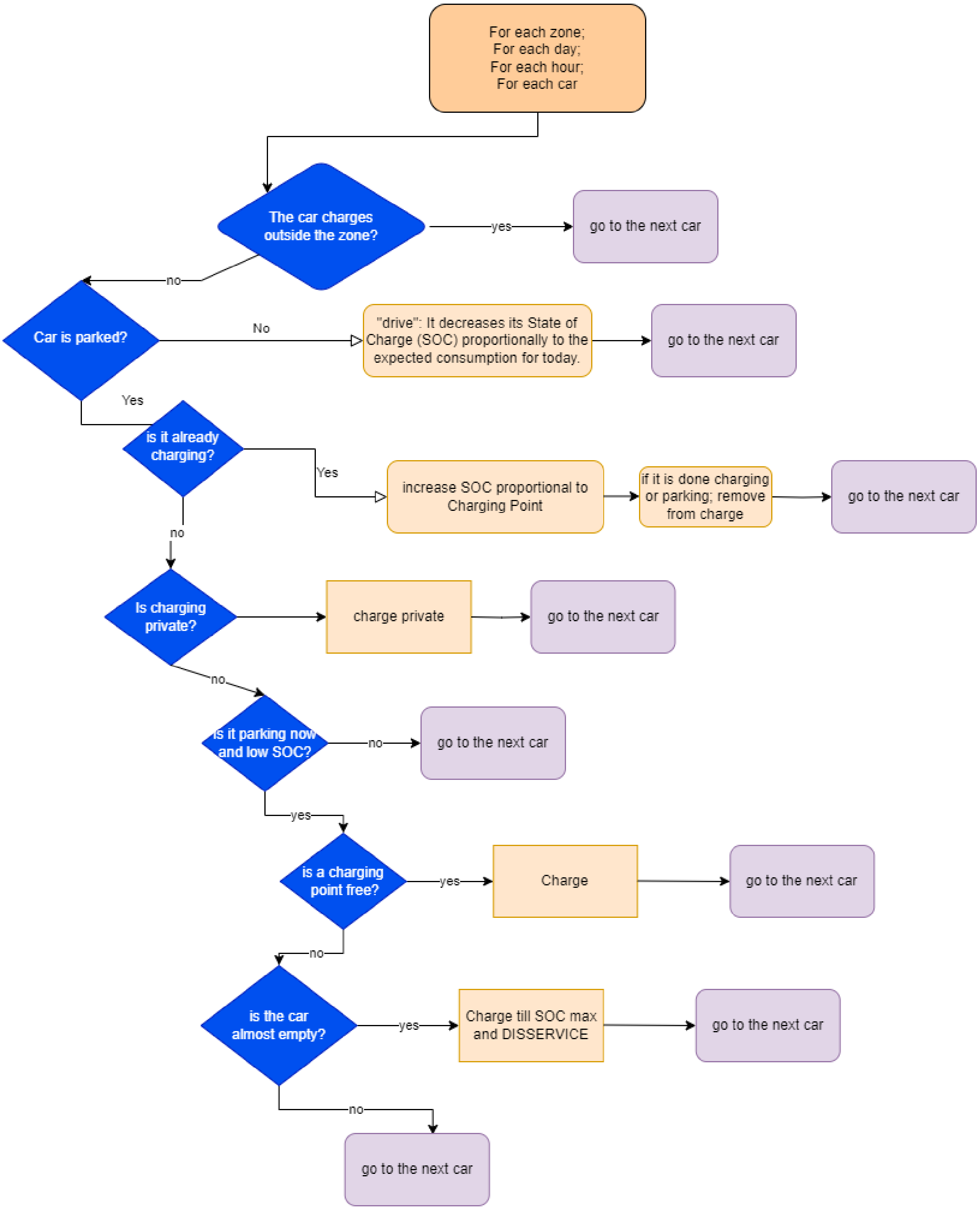


Figure 2: Model flow diagram

2.4 Outputs

As final outputs the tool provides different information about the energy need of the private electric mobility such as:

- The hourly electricity demand that comes from charging EVs for the whole year. This demand is divided between public and private.
- The electricity demand unmet by the charging infrastructure of the district. This quantity is named “disservice” and occurs when an EV necessitates charging to have enough energy for travelling the following day, but no available charging points are present.

Other mid-process outputs can be printed to check the correct execution of the model including the characteristics of the generated EVs or the total annual consumption.

The model is run 50 times for each scenario, to have a good variability on the results. With reference to the whole framework of the different iterations, the minimum, maximum, average and standard deviation values of the following outputs are presented:

- *Public consumption [kWh]*: it represents the total yearly amount of energy provided by the public charging infrastructure to the EVs.
- *Disservice [kWh]*: it represents the yearly mobility energy demand unmet by the infrastructures.
- *Number of charging sessions*: it represents the total number of charging during the year.

As a further step, some specific outputs coming from iteration with results closer to the mean values are shown.

A monthly evaluation is performed on data regarding charging, both on consumption and power sides. In particular, the visualizations focus on:

- *Public consumption [kWh]*: it represents the monthly total amount of energy provided by the public charging infrastructure to the EVs
- *Maximum public power [kW]*: it presents the maximum amount of power asked to the grid for each month. Such indication can be useful to understand if the charging infrastructures are overused or underused in some time periods, compared to others
- *Disservice [kWh]*: it represents the mobility energy demand unmet by the public charging infrastructures, with a monthly sensitivity. An above-zero value indicates an inadequate presence of charging points that forces the driver to charge in locations outside the district
- *Disservice maximum power [kW]*: it shows the maximum amount of power that is labelled as disservice during each month. This gives an additional inside about the disservice events at parity of monthly disservice value: if the disservice maximum power is low it means that many small disservice events occur during the month, and they affect many different people. On the other hand, if the value is higher, it means that the energy unmet is mostly created in few disservice events affecting less people but with higher values.

- *Charging points occupation [%]*: it is the average percentage of occupation on the charging points per each month. This helps us understand how much time per month the charging points are used. Such information is useful to comprehend if the infrastructure is underused or too redundant, compared to the EV fleet they serve in the district
- *Summary*: it presents the dimensions of the EV fleet in the district, the number of charging points, the total energy provided for the whole year
- *Private consumption [kWh]*: it represents the total amount of energy provided by the private charging infrastructure to the EVs
- *Maximum private power [kW]*: it presents the maximum amount of power asked to the grid for each month

3 Model implementation in Focus Districts

This chapter reports the results of simulations concerning the estimation of energy consumption by e-mobility in the project FDs.

Three FDs have been analyzed, excluding Amsterdam: Settimo, Resita and Großschönau. Amsterdam FD is in an area with a low car density, without public charging stations (they are not planned for the future either) and with a high share of 'external mobility' difficult to be characterized. For these reasons, it was deemed impossible to apply the proposed model. It might be interesting to address the problem with a different model developed as part of new projects.

For each FD the base scenario is simulated, but also two possible scenarios for the year 2035.

Generally, future scenarios are set up for an increased number of electric vehicles and charging infrastructures. They have all been simulated with the same technologies to consider the worst-case scenario, in fact in the future both vehicles and charging stations could be more efficient, the first for consumption, the latter for the kW offered.

Note that, as already pointed out, January consumption and maximum power could be higher than average, driven by the effect of random SOC initialization (which leads to more charges event in the first days of the simulation) and losses of battery efficiency due to colder temperatures.

Input data for the model has been gathered using the template in Annex 1 – A guide to collect necessary data for e-mobility model.

3.1 Settimo Torinese

Following the input data for base scenario in Settimo Torinese are summarised (Table 1 and Table 2).

Table 1: Settimo Torinese FD – basic scenario input data (1/2)

Settimo

Basic scenario - input data

Focus District specific data: Number of electric vehicles; Average km travelled per working day; Charging points; Temperature

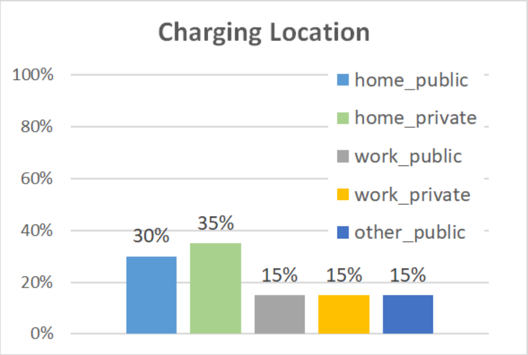
EVs and charging points

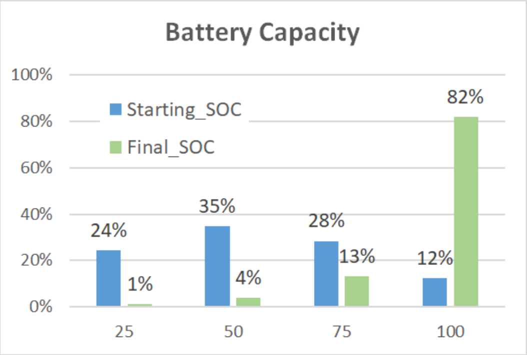
Number of electric vehicles	
Urban	0
Outgoing	4
Incoming	7

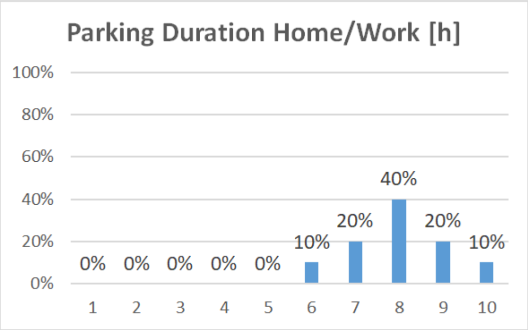
Average km travelled per working day	
Urban	4
Outgoing	34
Incoming	33

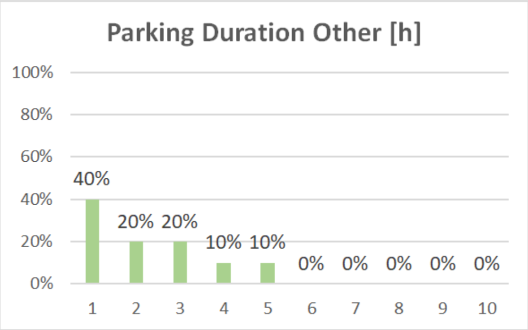
Charging points	Quantity	Power [kW]
Slow	0	0
Fast	2	22
Ultrafast	0	0

HABITS









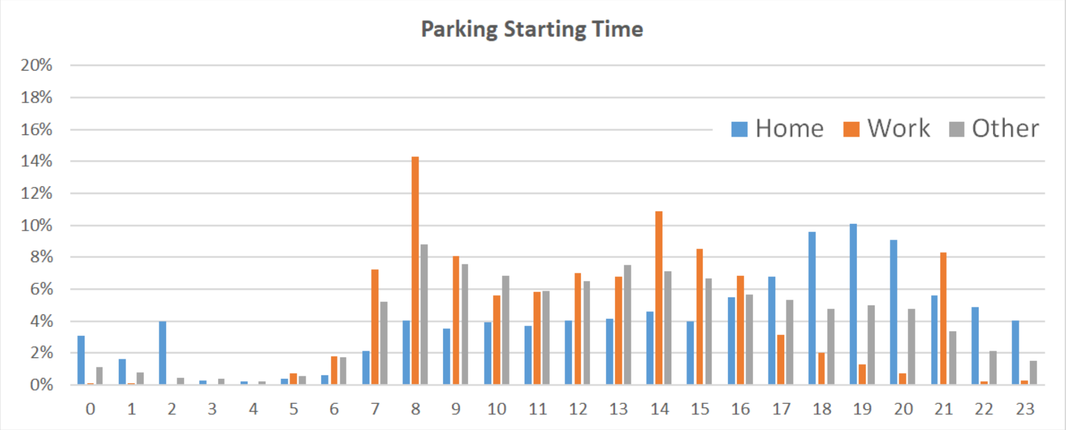
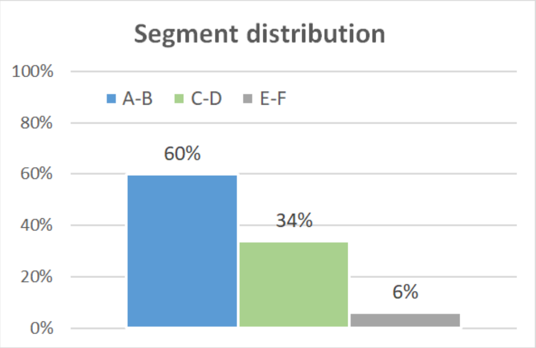


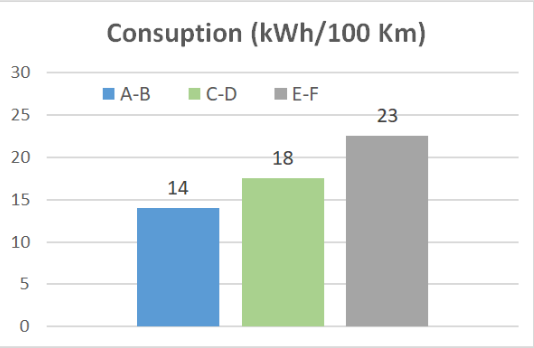
Table 2: Settimo Torinese FD – basic scenario input data (2/2)

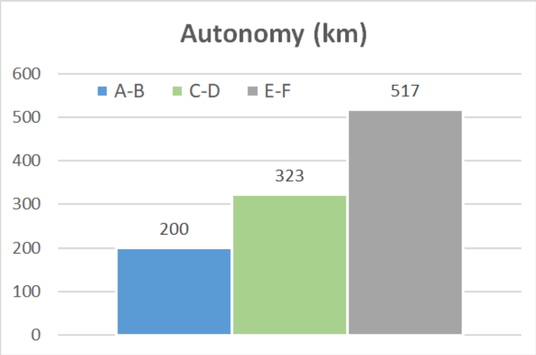
Settimo

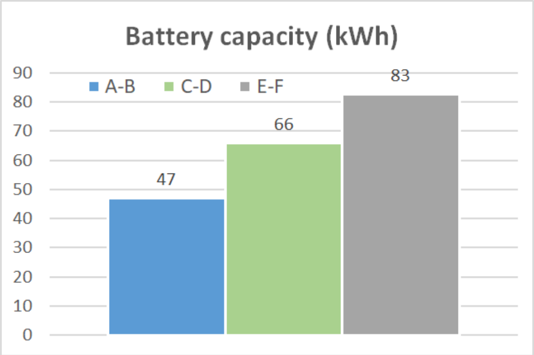
Basic scenario - input data

VEHICLES

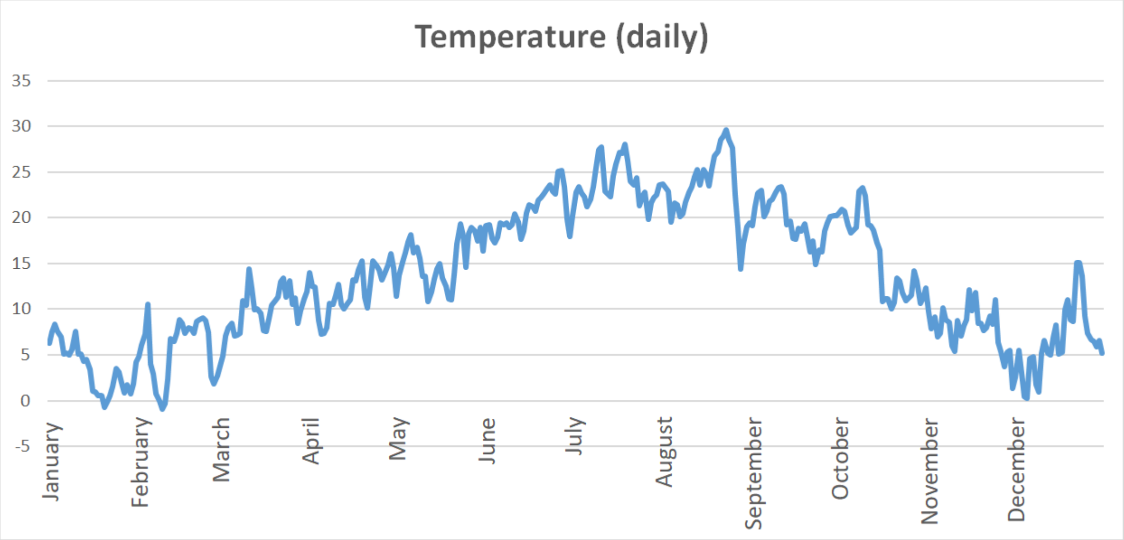








ENVIRONMENT



Compared to this scenario, the two scenarios to 2035 take in consideration un increase of electric vehicles and charging infrastructures as detailed in Table 3, driving and parking habits remained unchanged.

The two scenarios were defined with reference to the Smart Mobility Report 2023 (SMR23) of the Milan Polytechnic, which estimates the number of electric vehicles and charging points at a national level for the years 2025 and 2030, according to different policies adopted. Two scenarios, Business as Usual and Policy Driven, were considered for the Settimo FD. Through a linear regression based on the report estimates, extended to 2035, the increase of electric vehicles and charging points in the Focus District was estimated.

Table 3: Settimo Torinese FD - differences in input data between the different scenarios

Electric vehicles	*Base*	*2035 – v1*	*2035 – v2*	***Charging points***	*Quantity*			*Power (kW)*		
					Base	*2035 – v1*	*2035 – v2*	*Base*	*2035 – v1*	*2035 – v2*
Urban	0	0	0	**Slow**	0	0	0	0	0	0
Outgoing	4	56	100	**Fast**	2	11	11	22	22	22
Incoming	7	98	175	**UltraFast**	0	7	11	0	50	50

In Table 4 are presented some statistics related to public charging demand in base scenario, and the two different 2035 scenarios.

Table 4: Settimo Torinese FD – statistics from scenarios

Settimo Torinese FD	***Total yearly energy (KWh public)***				***Disservice (KWh public)***				***Yearly n. of charging sessions***			
	Min	***Max***	***Average***	***DevS***	***Min***	***Max***	***Average***	***DevS***	***Min***	***Max***	***Average***	***DevS***
Base scenario	3605	5378	4315	538	0	0	0	0	230	731	384	125
2035 – v1	77442	84080	80550	1783	0	0	0	0	3795	7014	5207	683
2035 – v2	139096	147568	142413	2258	0	0	0	0	7855	10805	9335	870

As can be seen:

- The indices of variations (DevS/Average) for both energy and charging sessions are always below 0,5 meaning that the variability of the data is small and therefore the average can be considered a good value.
- None of the three scenarios presents disservices, because of a charging points/EVs ratio appropriate to driving habits (not more than 13 electric vehicles per charging point).
- The increase in energy consumption between the scenarios is not linear with the increase in EVs. This is because, although the expected percentage of EVs charging within the PED remains consistent across all scenarios, in situations where the number of vehicles is low (like base scenario), rounding to the nearest whole number results in fewer EVs charging in the PED than what would be expected.

The results of the scenarios closest to the average values of the 50 iterations are presented in the following diagrams (Table 5, Table 6, Table 7).

As previously noted, the base scenario (Table 5) involves a limited number of EVs charging within the PED, regarding public charging. As a result, the annual public charging consumption remains modest at 4,2 MWh, which is roughly equivalent to the annual energy consumption of two average households[1]. This additional demand at the district level is not expected to pose any challenges for energy supply.

The absence of disservice highlights that the current availability of public charging points is adequate to meet demand in this scenario.

As expected, winter months show higher consumption due to lower average temperatures and, for January, also due to the random assignment of initial SOC.

The maximum power delivered reaches 22 kW, a value easily handled by the existing distribution network within the district. Lastly, the average annual charging station occupancy stands at 5,6%, meaning that each station operates for approximately 490 hours per year.

It is important to note that in the simulation, each EV follows a consistent pattern in terms of parking and, consequently, charging times. The only factor that disrupts this regularity is the increased energy consumption caused by low temperatures, which may prompt the vehicles to charge a day earlier than usual. Analyzing the simulation results for maximum power demand, it is evident that during the warmer months (from May to September) no reduction in efficiency occurs, the charging patterns remain uniform, and the maximum power demand stays consistent across these months.

Private yearly consumption is equal to 3,3 MWh and follows the same pattern of public charging due to lower temperatures in winter months.

It is also important to note that maximum private power is lower than the public counterpart due to lack of charging availability constraints and so EVs are less likely to overlap during charging.

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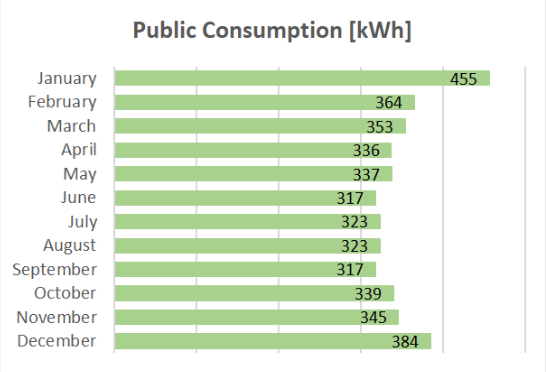
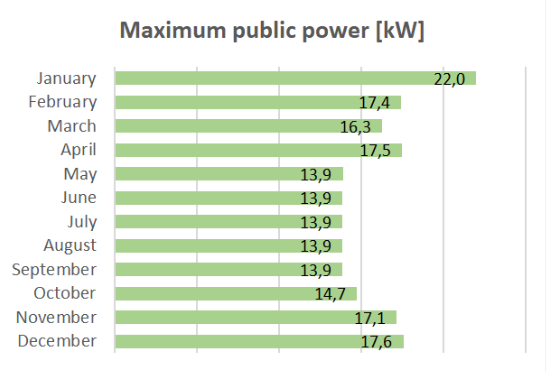
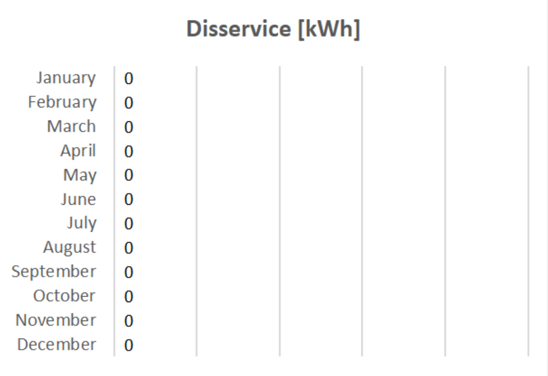
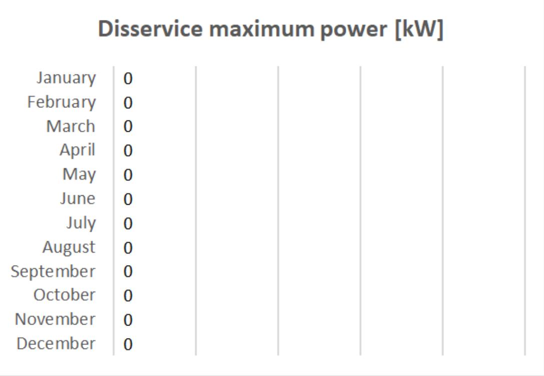
[1] ARERA (Italian regulatory authority for energy, networks and environment). Foot note [1] in www.arera.it/comunicati-stampa/dettaglio/elettricita-bollette-in-calo-del-198-nel-secondo-trimestre-2024#:~:text=%5B1%5D%20La%20famiglia%20tipo%20ha,consumo%20associato%20ad%20ogni%20trimestre.

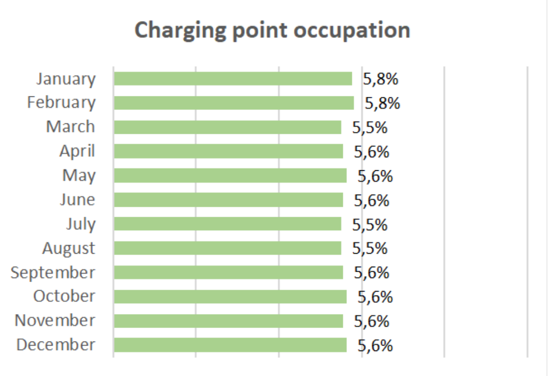
Table 5: Settimo Torinese FD – basic scenario results


Public Consumption [kWh]

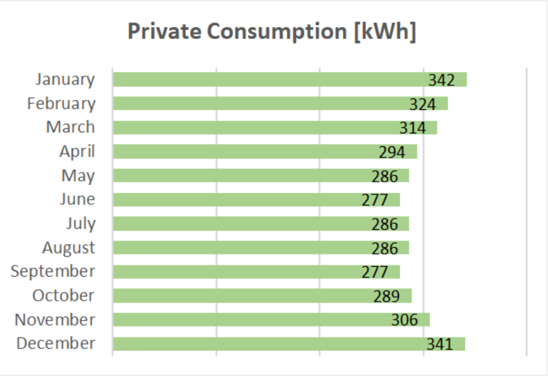

Maximum public power [kW]

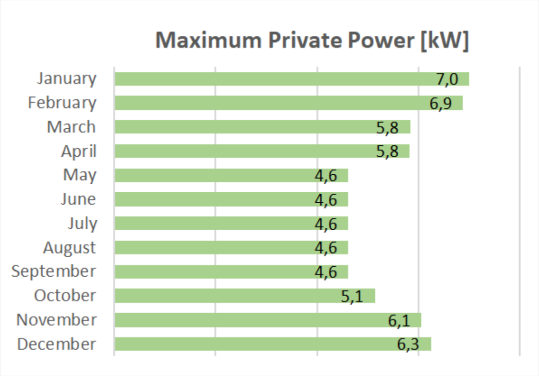

Disservice [kWh]


Disservice maximum power [kW]


Charging point occupation

Summary table	
EVs travelling	11
Charging Points	2
Total Energy Provided Public (kWh)	4193
Average Montly Energy Provided Public (kWh)	349


Private Consumption [kWh]


Maximum Private Power [kW]

In Scenario 2035-v1 (Table 6) public charging demand rises significantly because of the great increase in the number of EVs. The total annual energy consumed for public charging reaches 8,6 MWh, a substantial rise compared to the base scenario. Despite this higher demand, no service disruptions are observed, indicating that the 18 public charging points in the district are sufficient to meet the requirements.

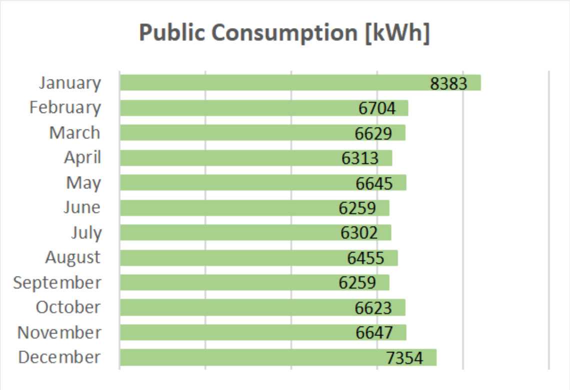
Winter months once again show the highest energy consumption due to lower temperatures, which reduce battery efficiency and lead to increased energy usage. For instance, January records the highest public average consumption at 8,4 MWh.

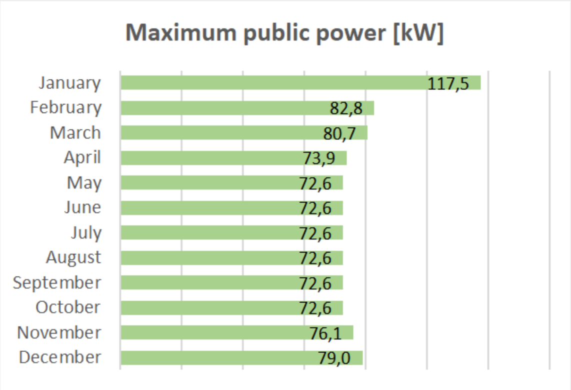
The maximum power drawn for public charging in January reaches 117,5 kW, which could become a burden if all the charging points were concentrated in a single area. However, if they are distributed more evenly throughout the district, this demand should not place significant strain on the electric distribution grid.

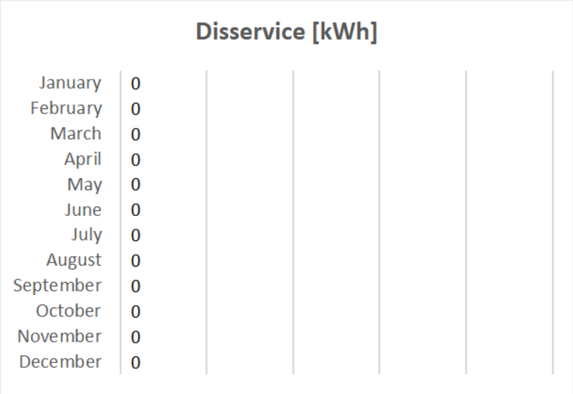
The average charging point occupation ranges between 4,4% and 4,6%, meaning that each charging point is in use for approximately 390 hours annually, as a light decrease compared to the current scenario.

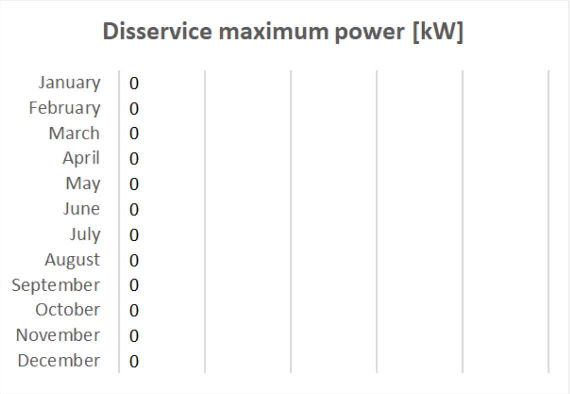
In this scenario also private consumption and power are lower compared to public and spike in January, for the reasons already explained.

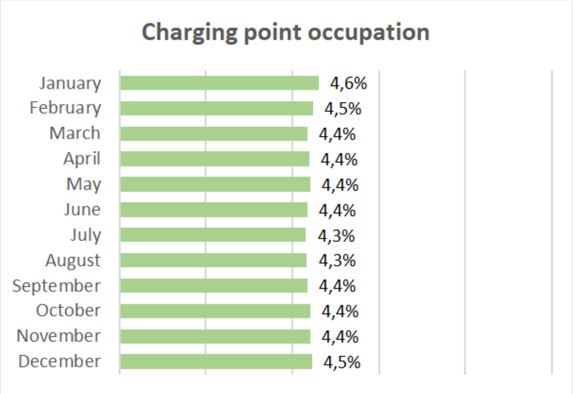
Table 6: Settimo Torinese FD – 2035-v1 scenario results



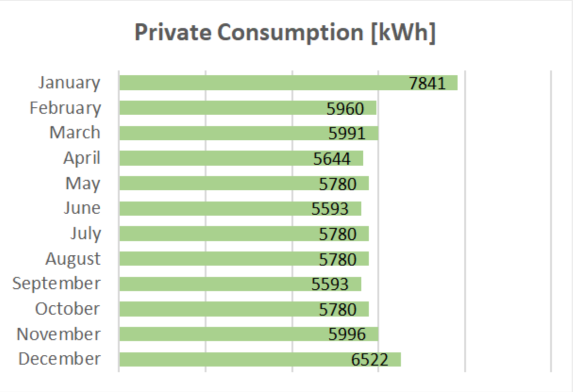


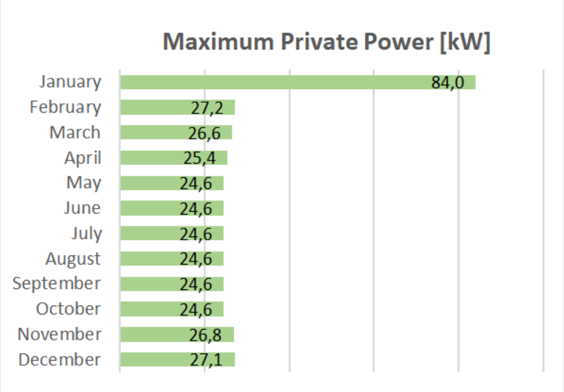






Summary table	
EVs travelling	154
Charging Points	18
Total Energy Provided Public (kWh)	80573
Average Montly Energy Provided Public (kWh)	6714





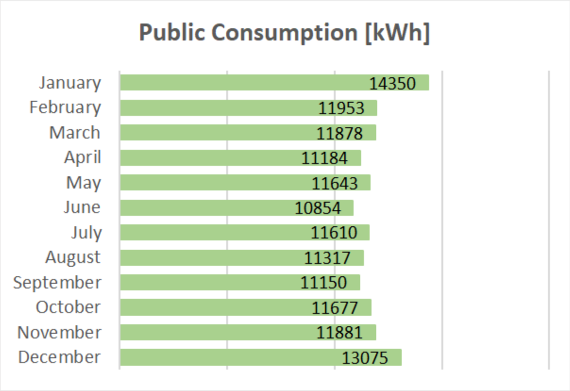
In the second scenario at 2035 (Table 7) scenario, the number of electric vehicles increases further, resulting in a notable rise in public charging demand. The total energy consumed for public charging reaches 142,6 MWh, nearly double the amount observed in previous scenarios and equal to more than 6% of all the district electricity consumption (Annex 2), so a non-negligible amount. Despite this increase, no disservice or supply issues were recorded, demonstrating that the 22 public charging points are currently sufficient to handle the demand of the district.

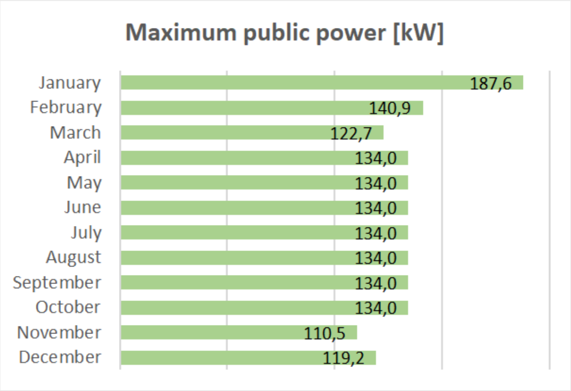
As in previous scenarios, winter months show the highest levels of consumption, driven primarily by lower temperatures. January stands out with the highest public consumption, at 14.4 MWh, which is the result of both the temperature impact and the random initial state of charge (SOC) assigned to each EV at the start of the simulation.

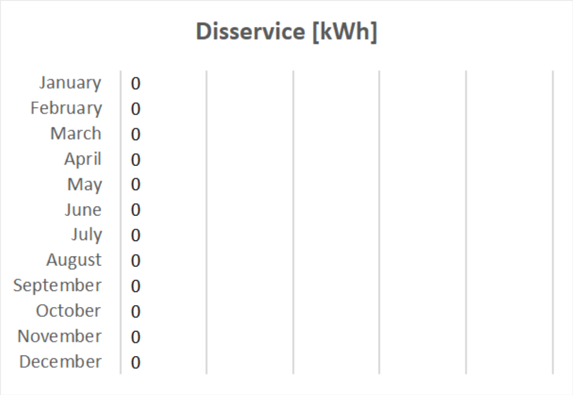
The maximum power delivered for public charging in January reaches 187,6 kW. While this peak power demand could strain the grid if charging points were clustered too closely together, distributing the charging points more evenly throughout the district should alleviate any significant pressure on the distribution network.

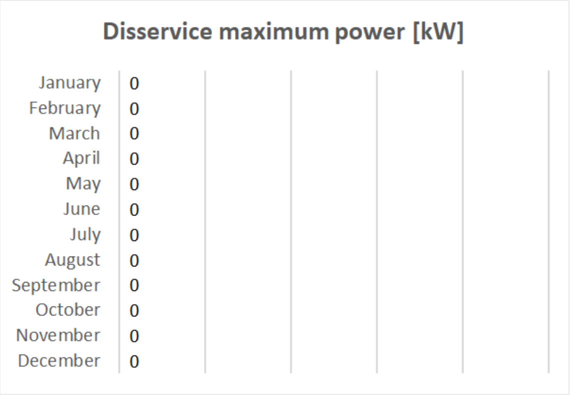
The average charging point occupancy varies between 4,2% and 4,7% throughout the year, meaning each charging point operates for approximately 410 hours annually.

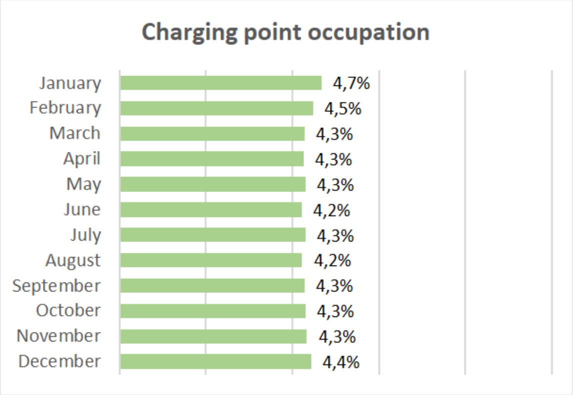
Table 7: Settimo Torinese FD – 2035-v2 scenario results



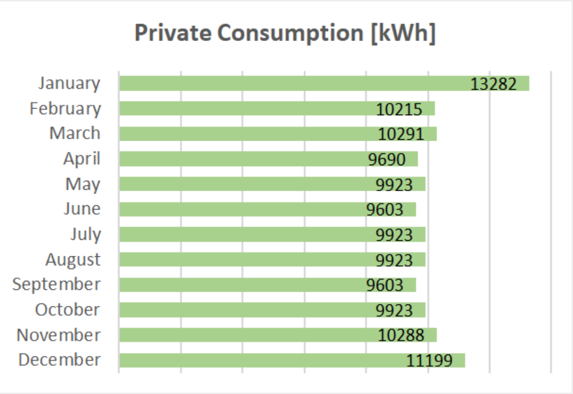


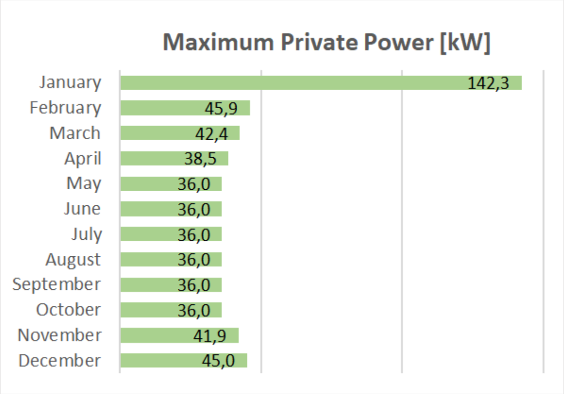






Summary table	
EVs travelling	275
Charging Points	22
Total Energy Provided Public (kWh)	142573
Average Montly Energy Provided Public (kWh)	11881





Some sensitivity tests were carried out, varying the average kilometers travelled by vehicles. Results are presented in Annex 3 – Sensitivity test per Settimo Torinese FD.

Finally, the modelling estimations has been to demonstrate the potential for transforming the Settimo Torinese Focus District into a Positive Energy District (PED) through the implementation of a 1.88 MW photovoltaic plant, installed both on the roofs and in the green areas. The specific study is presented in Annex 2 – Transformation of Settimo FD into a PED.

3.2 Resita

With reference to Resita simulations, following the input data for base scenario are summarised (Table 8 and Table 9).

Table 8: Resita FD – basic scenario input data (1/2)

Resita

Basic scenario - input data

Focus District specific data: Number of electric vehicles; Charging points; Temperature

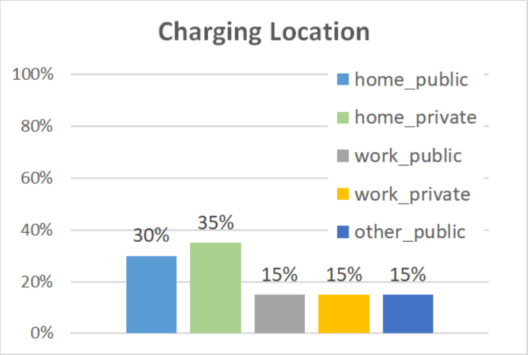
EVs and charging points

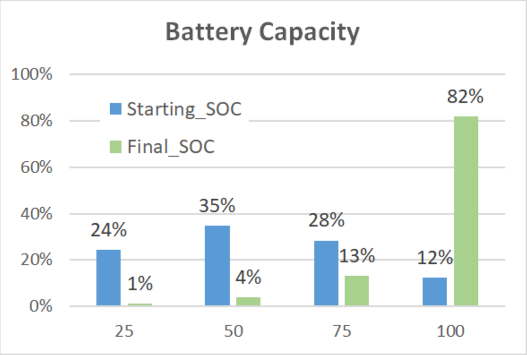
Number of electric vehicles	
Urban	3
Outgoing	25
Incoming	20

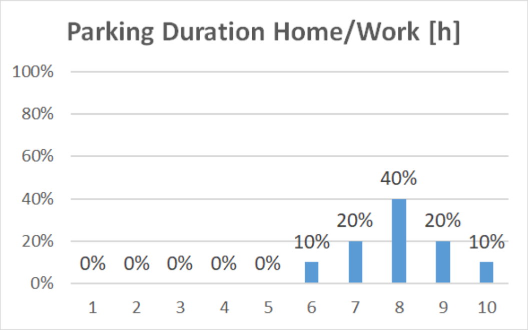
Average km travelled per working day	
Urban	4
Outgoing	34
Incoming	33

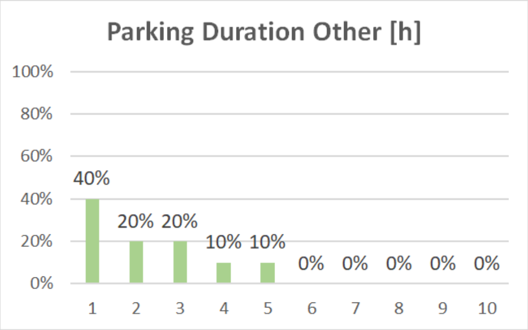
Charging points	Quantity	Power [kW]
Slow	0	0
Fast	1	22
Ultrafast	1	60

HABITS









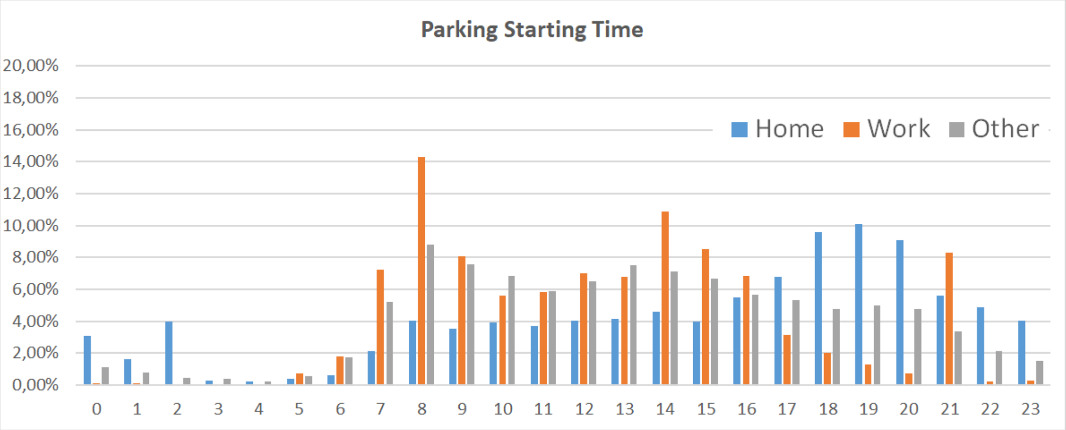
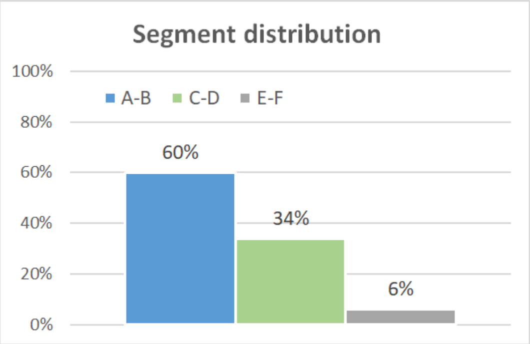


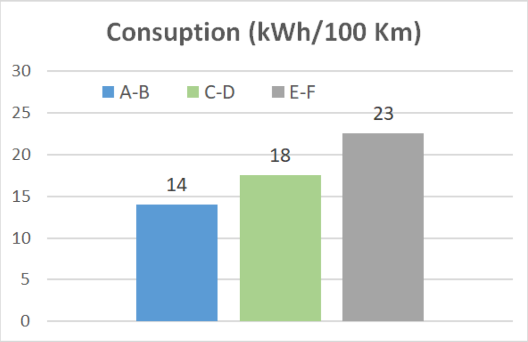
Table 9: Resita FD – basic scenario input data (2/2)

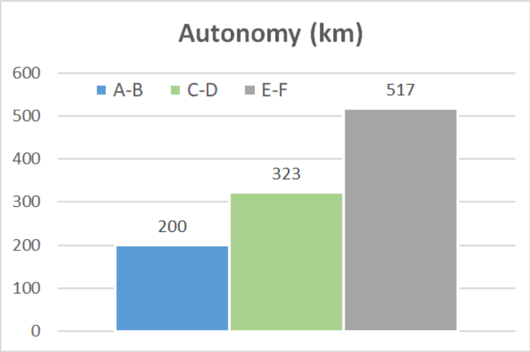
Resita

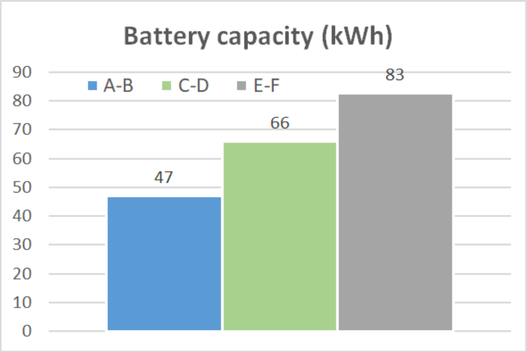
Basic scenario - input data

VEHICLES

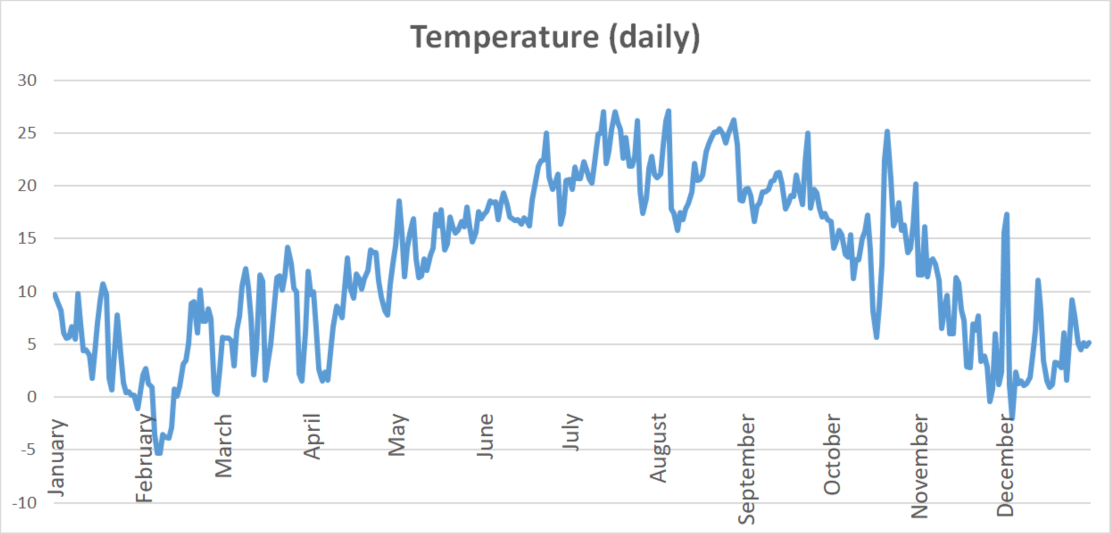

Segment distribution


Consuption (kWh/100 Km)


Autonomy (km)


Battery capacity (kWh)

ENVIRONMENT


Temperature (daily)

Data used for the base scenario and the two future scenarios are summarized in Table 10.

Table 10: Resita FD - differences in input data between the different scenarios

Electric vehicles	*Base*	*2035 – v1*	*2035 – v2*	***Charging points***	*Quantity*			*Power (kW)*		
					Base	*2035 – v1*	*2035 – v2*	*Base*	*2035 – v1*	*2035 – v2*
Urban	3	4	6	**Slow**	0	0	0	0	0	0
Outgoing	25	33	50	**Fast**	1	2	3	22	22	22
Incoming	20	27	40	**UltraFast**	1	2	3	60	60	60

Compared to other FDs, in addition to an increase in vehicles and charging infrastructures, Ricita also considers an increase in the average kilometres travelled by cars, estimated on the current trend of electric cars and the Resita goal to become a green city, as detailed in Table 11.

Table 11: Resita FD - differences in average kms between the different scenarios

Average kms	*Base*	*2035 – v1*	*2035 – v2*
Urban	4	5	8
Outgoing	34	45	64
Incoming	33	44	66

In Table 12 are presented some statistics related to public charging demand in Resita scenarios.

Table 12: Resita FD – statistics from scenarios

Settimo Torinese FD	***Total yearly energy (KWh public)***				***Disservice (KWh public)***				***Yearly n. of charging sessions***			
	Min	***Max***	***Average***	***DevS***	***Min***	***Max***	***Average***	***DevS***	***Min***	***Max***	***Average***	***DevS***
Base scenario	23565	29119	25976	1043	0	2305	827	323	828	2965	1688	437
Scena 2035 – v1	45134	52559	48082	1456	0	0	0	0	1845	4471	2828	491
Scena 2035 – v2	91806	104546	98651	2973	0	0	0	0	3570	5845	4523	472

As can be seen:

- The indices of variations (DevS/Average) for both energy and charging sessions are always widely below 0,5 meaning that the variability of the data is small, and the average can be considered a good value.
- The Base scenario shows the presence of some amount of disservice, due to few charging points in the district compared to number of EVs travelling.
- Disservice is present only in some of the 50 simulations we conducted for the base scenario, when drivers' charging habits overlap, resulting in an insufficient supply of charging points. The maximum disservice recorded is 2,3 MWh, equivalent to approximately 9% of the total average public energy supplied. In the years in which a

disservice was estimated this averaged out to 827 kWh, calculated as the average of the disservice values excluding zeros.

The results of the scenarios closest to the average values of the 50 iterations are presented in the following diagrams (Table 13, Table 14, Table 15).

In the base scenario (Table 13) no disservice was recorded throughout the year. This is primarily because the charging times for vehicles did not overlap significantly, with charging sessions being more evenly distributed throughout the day. This spread of demand helped prevent congestion at the public charging points, ensuring that the two charging stations were sufficient to meet the needs of the electric vehicles in circulation.

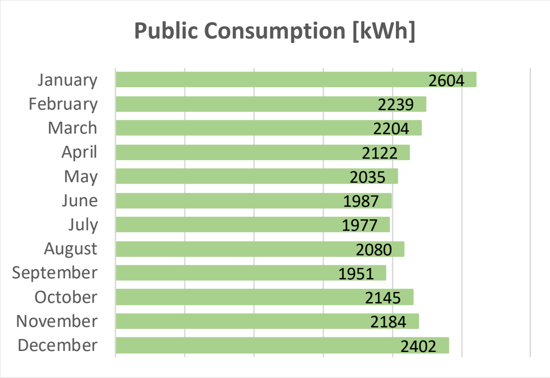
The public annual energy consumption remains moderate, totaling about 26 MWh annually, with the highest consumption recorded in January (2,6 MWh). This seasonal peak is likely due to colder temperatures, which typically increase energy consumption for electric vehicles by reducing battery efficiency. Private consumption follows a similar pattern, with the highest consumption also in January (2,7 MWh).

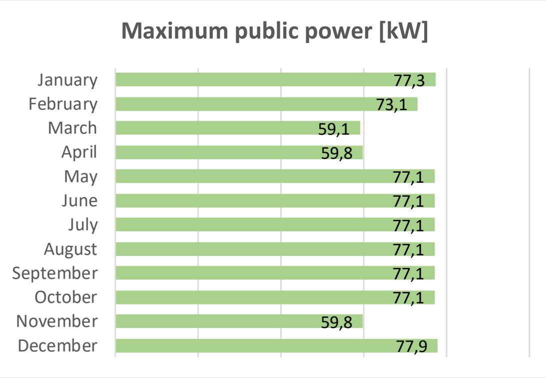
The charging point occupation throughout the year is relatively high, particularly in January and February, where it peaks at about 12%. These values suggest that the charging points are used for approximately 1045 hours per year. Although this indicates a good level of utilization, it also implies that, should the number of electric vehicles increase in the future, additional charging infrastructure might be required to prevent potential bottlenecks.

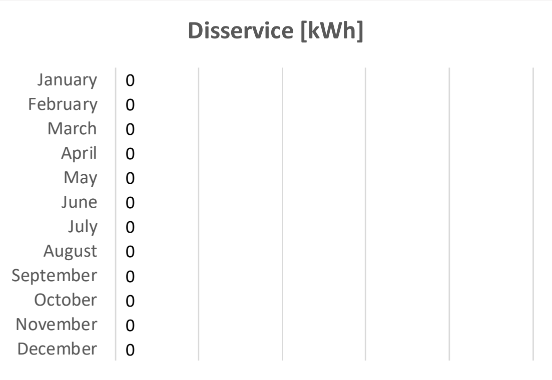
The maximum power demand for public charging occurs in January, reaching 77,3 kW, a manageable level for the district’s grid.

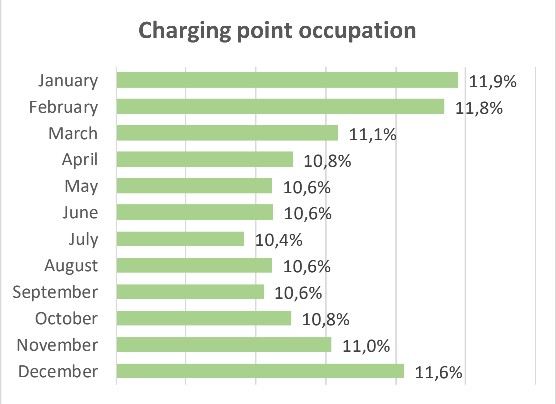
In Resita, as in Settimo, the maximum power remains stable throughout the summer months, unaffected by cold-related inefficiencies. However, in this case, power consumption is higher during the summer compared to winter, which is attributed to the timing of the BEVs' recharging cycles.

Table 13: Resita FD – Base scenario results

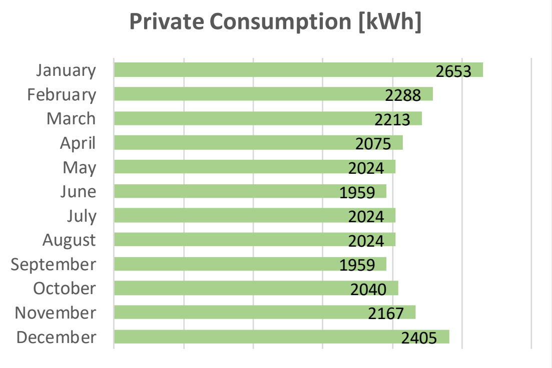


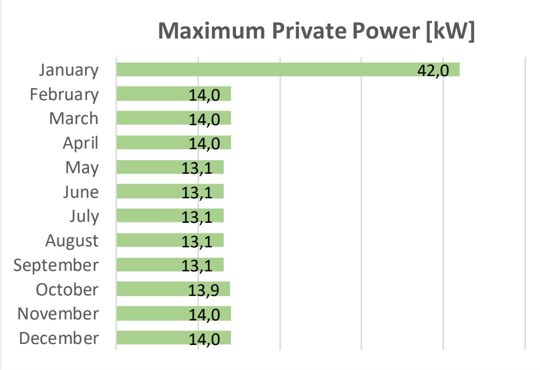






Summary table	
EVs travelling	48
Charging Points	2
Total Energy Provided Public (kWh)	25930
Average Montly Energy Provided Public (kWh)	2161





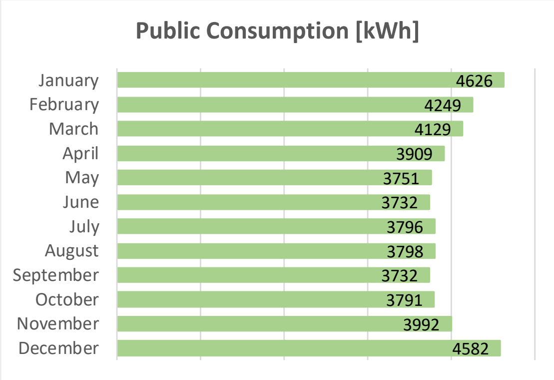
In the first 2035 scenario (Table 14) the total energy consumed for public charging reaches about 48 MWh annually. The addition of more charging points (now totaling four) plays a key role in reducing the overall charging point occupation. While the highest occupation peaks at 9,7% in February, it remains lower than the base case throughout the year, with values between 8,6% and 9,6%. This reduction in occupation suggests that the infrastructure is becoming more balanced, ensuring a better distribution of demand across the charging points.

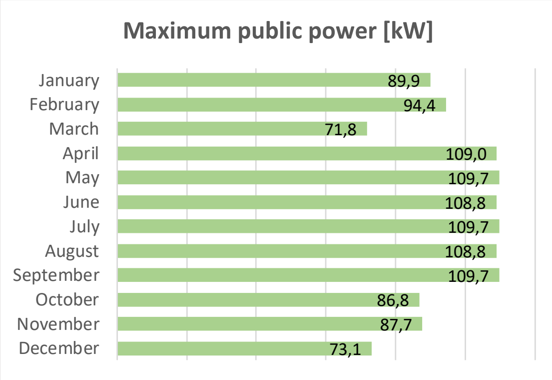
As a result of this lower charging point occupation, no disservices are recorded in any of the simulations.

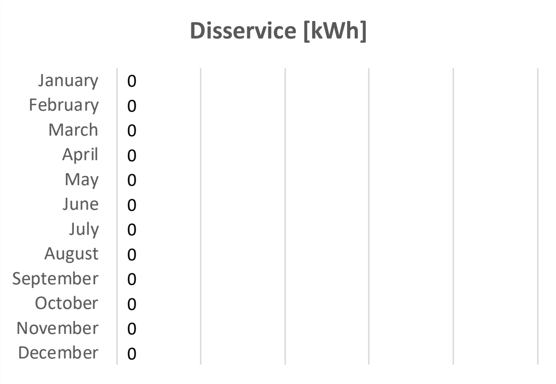
The maximum public power demand peaks at 109,7 kW in May and September, which should be easily manageable by the existing grid infrastructure in a district as wide as Resita.

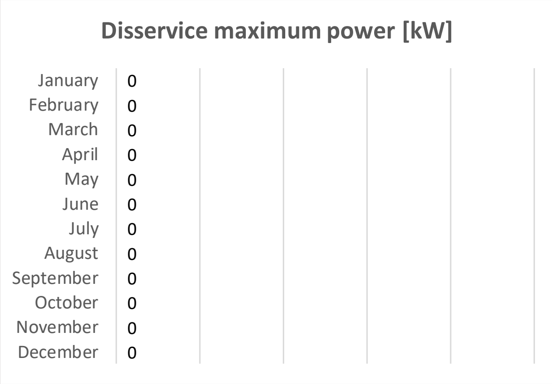
Private consumption is slightly lower than the public one, and the monthly trends in similar.

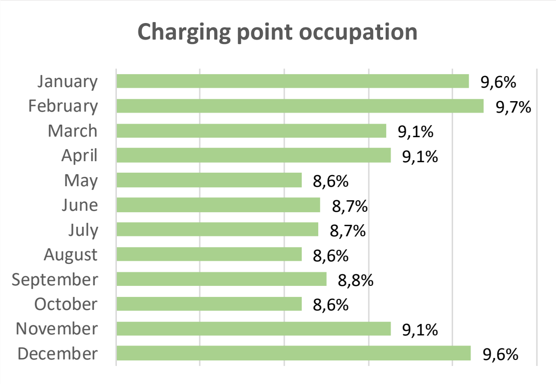
Table 14: Resita FD – 2035-v1 scenario results



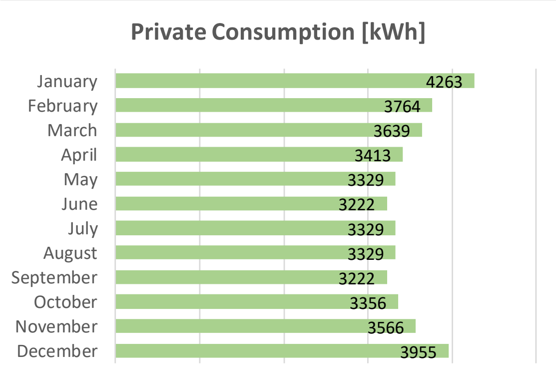


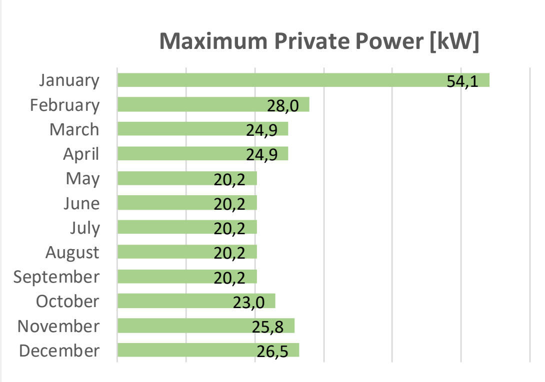






Summary table	
EVs travelling	64
Charging Points	4
Total Energy Provided Public (kWh)	48088
Average Montly Energy Provided Public (kWh)	4007





In the last scenario both the increase in the number of electric vehicles and the rise in the average distance traveled by drivers significantly contribute to higher energy consumption. As a result, the annual demand for public charging reaches 97,9 MWh, which is nearly double the amount seen in the previous scenario.

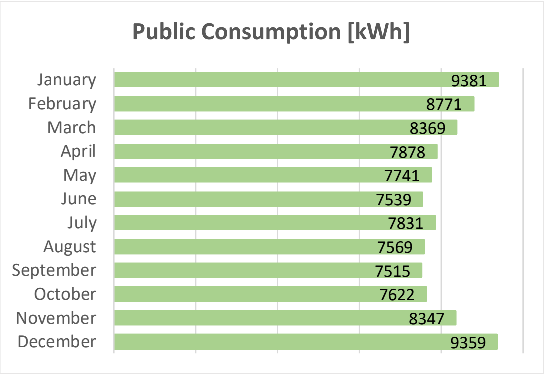
The public energy consumption peaks in January at 9,4 MWh, closely followed by December at 9,4 MWh. This pattern reflects the increased energy demand during colder months, which typically reduces battery efficiency and leads to higher consumption.

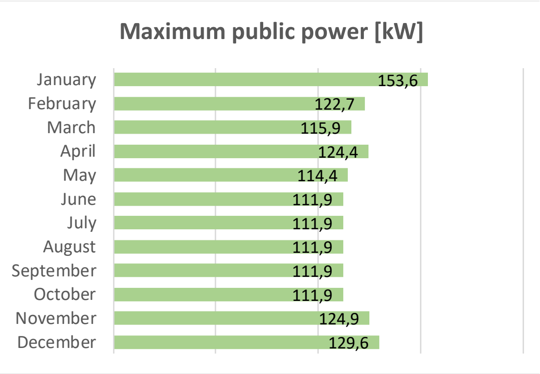
Despite the increased energy demand, the charging point occupation remains relatively low, especially due to the addition of 6 charging points in the district. While February shows the highest occupation at 9%, the occupation levels fluctuate between 7,6% and 9% throughout the year. This suggests that the expanded infrastructure is successfully distributing the load, reducing the pressure on individual charging points.

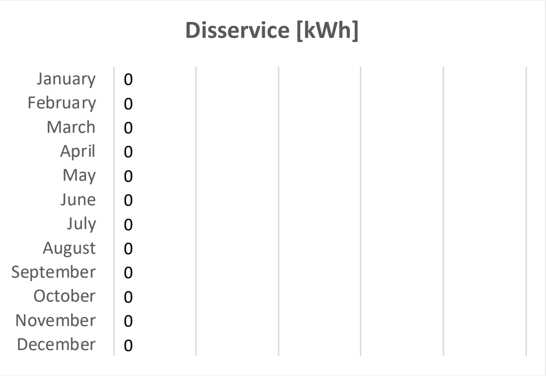
The maximum public power demand reaches 153,6 kW in January, reflecting the peak in consumption during this month. However, the grid should be able to accommodate this demand given the overall distribution of charging points.

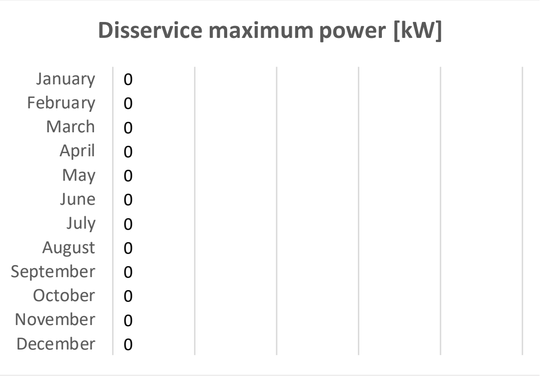
Private consumption is again slightly lower than public consumption.

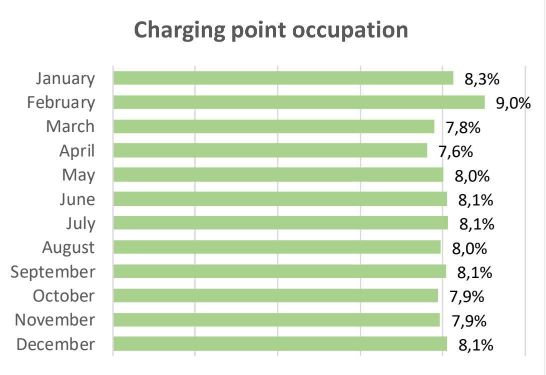
Table 15: Resita FD – 2035-v2 scenario results



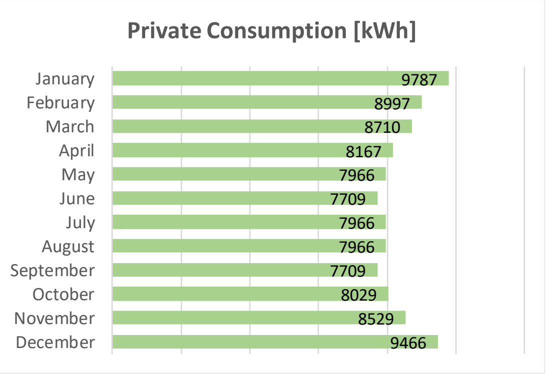


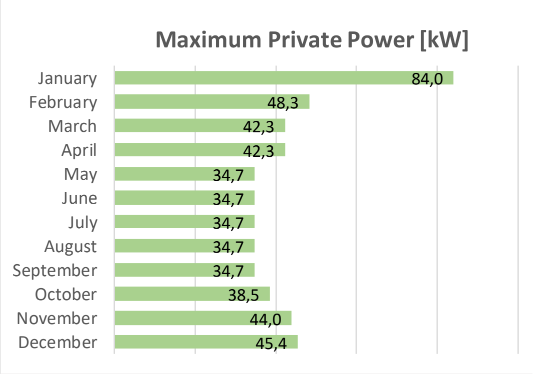






Summary table	
EVs travelling	96
Charging Points	6
Total Energy Provided Public (kWh)	97923
Average Montly Energy Provided Public (kWh)	8160





Finally, some sensitivity tests were carried out, varying the average kilometers travelled by vehicles. Results are presented in Annex 4 – Sensitivity test per Resita FD.

3.3 Großschönau

Following the input data for the Großschönau base scenario are summarised.

Table 16: Großschönau FD – basic scenario input data (1/2)

Großschönau

Basic scenario - input data

Focus District specific data: Number of electric vehicles; Average km travelled per working day; Charging points; Charging Location; Parking Starting Time; EV segment; Temperatures

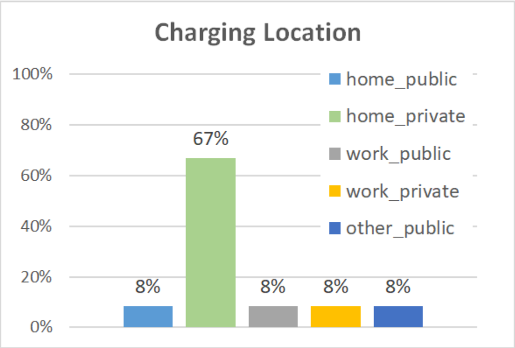
EVs and charging points

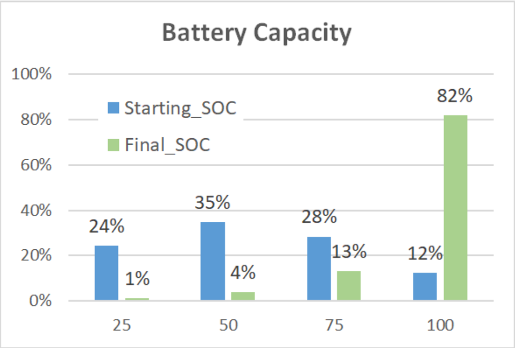
Number of electric davehicles	
Urban	0
Outgoing	9
Incoming	24

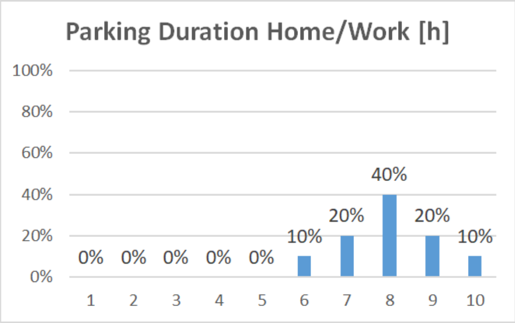
Average km travelled per working day	
Urban	0
Outgoing	33
Incoming	33

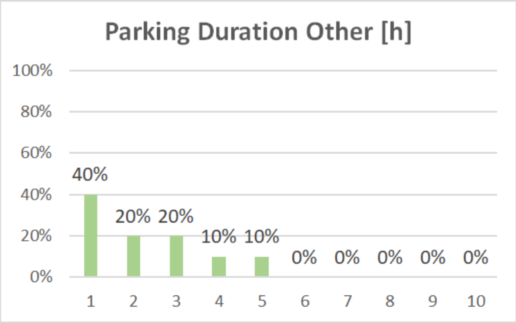
Charging points	Quantity	Power [kW]
Slow	3	11
Fast	4	22
Ultrafast	0	0

HABITS









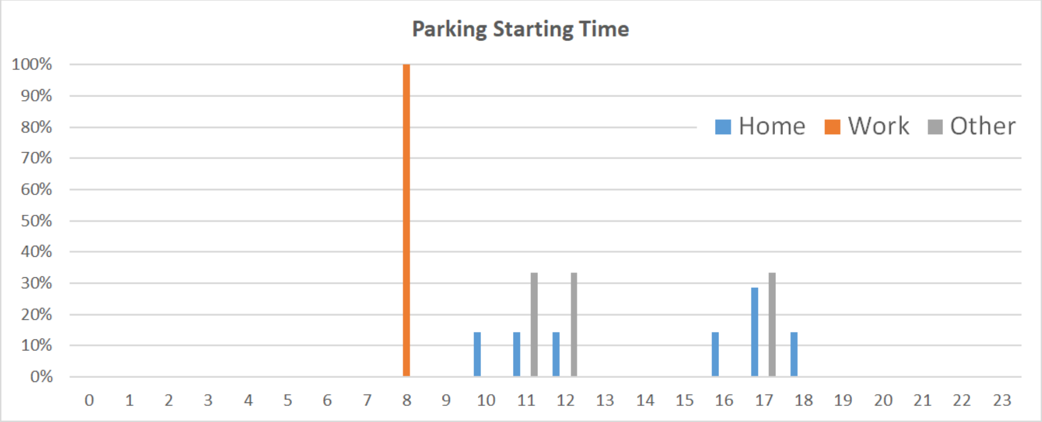
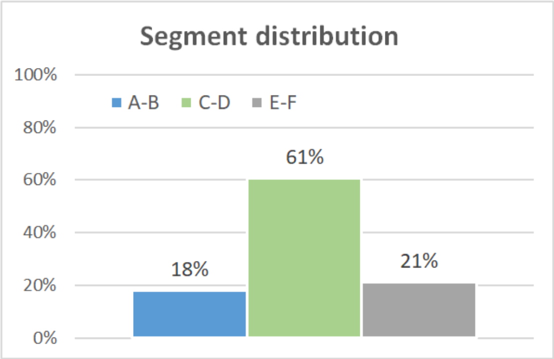


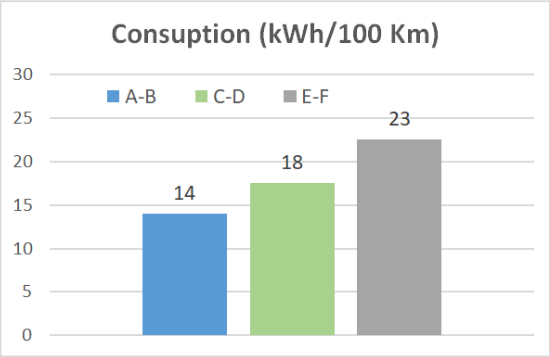
Table 17: Großschönau FD – basic scenario input data (2/2)

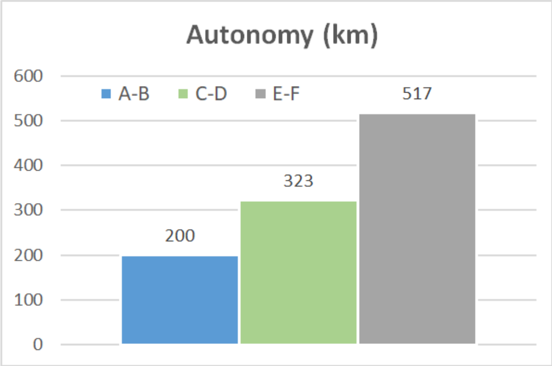
Großschönau

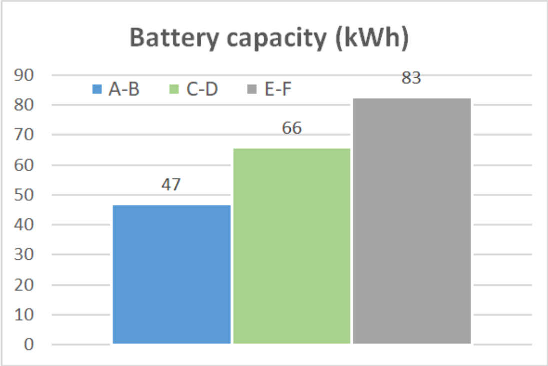
Basic scenario - input data

VEHICLES

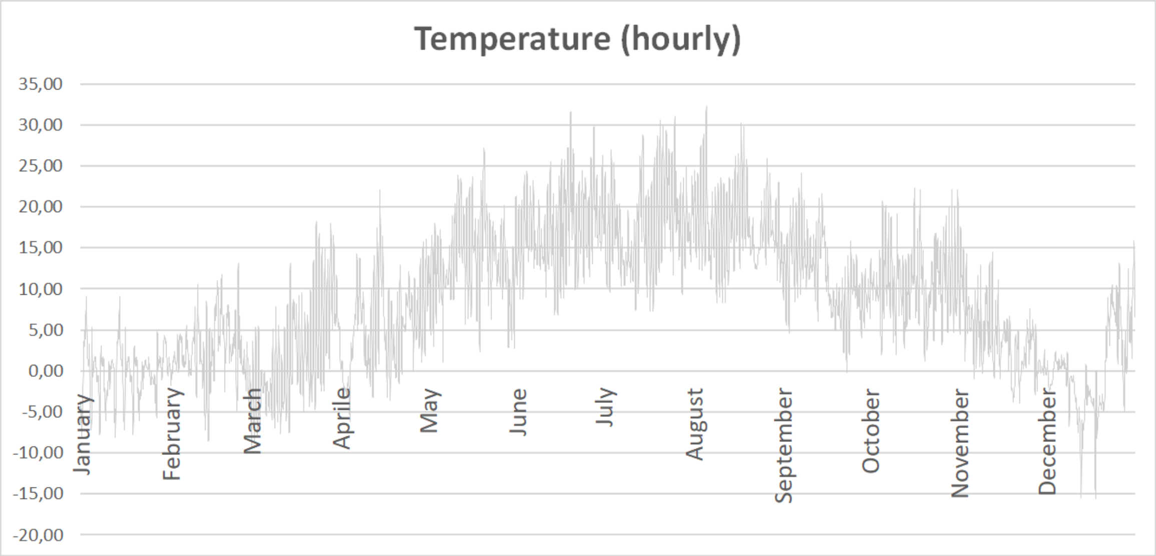

Segment distribution


Consuption (kWh/100 Km)


Autonomy (km)


Battery capacity (kWh)

ENVIRONMENT


Temperature (hourly)

Compared to the base scenario, the two 2035 scenarios take in consideration an increase in the number of electric vehicles interesting the FD and the addition of a single 250 kW charging point, as detailed in Table 18.

Table 18: Großschönau FD - differences in input data between the different scenarios

Electric vehicles	***Base***	***2035 – v1***	***2035 – v2***	***Charging points***	***Quantity***			***Power (kW)***		
					Base	***2035 – v1***	***2035 – v2***	***Base***	***2035 – v1***	***2035 – v2***
Urban	0	1	5	***Slow***	3	3	3	11	11	11
Outgoing	9	40	70	***Fast***	4	4	4	22	22	22
Incoming	24	35	50	***UltraFast***	0	1	1	0	250	250

In Table 19 are presented some statistics related to public charging demand in Resita scenarios.

Table 19: Großschönau FD – statistics from scenarios

Settimo Torinese FD	***Total yearly energy (KWh public)***				***Disservice (KWh public)***				***Yearly n. of charging sessions***			
	Min	***Max***	***Average***	***DevS***	***Min***	***Max***	***Average***	***DevS***	***Min***	***Max***	***Average***	***DevS***
Base scenario	12636	16667	14302	874	0	0	0	0	706	1606	1022	228
Scena 2035 – v1	27670	32820	30160	1188	0	0	0	0	976	3020	1689	422
Scena 2035 – v2	47863	55819	50836	1563	0	0	0	0	2224	4363	3280	520

As can be seen:

- the indices of variations (DevS/Average) for both energy and charging sessions are always below 0,5 meaning that the variability of the data is small and therefore the average can be considered a good value.
- none of the three scenarios presents inefficiencies, because of a charging points/EVs ratio appropriate to driving habits (not more than 16 electric vehicles per charging point).
- The increase in energy consumption grows linearly with the increase in EVs: if EVs double, consumption also doubles.

The results of the basic scenario closest to the average values of the 50 iterations are presented in the following diagrams (Table 20, Table 21, Table 22).

In basic scenario simulation the total energy consumption and power demand are well within the capacity of the current electrical distribution system. The maximum public power demand peaks at 60,1 kW in April, a value that can be easily managed by the grid infrastructure currently in place. Additionally, the maximum private power demand occurs in January at 32 kW, which also represents a manageable level for the existing infrastructure.

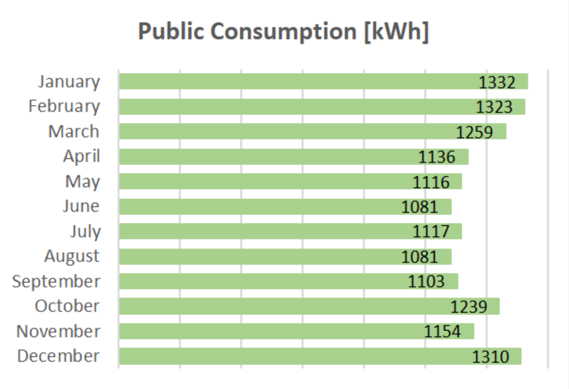
The annual public energy consumption remains relatively low, totaling 14,3 MWh for the year. This modest energy requirement should not pose any significant strain on the energy supply to the district, and the infrastructure is more than capable of supporting these levels of demand.

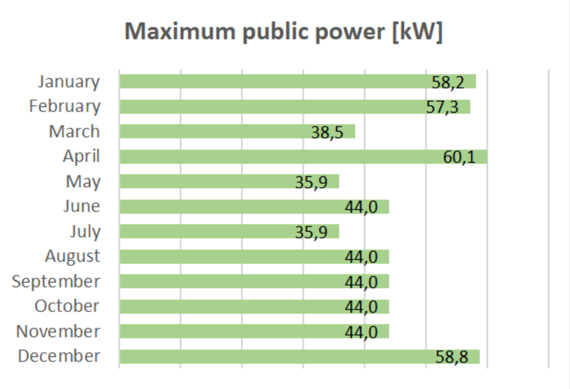
One of the most notable aspects of this scenario is the charging point occupation, which remains extremely low throughout the year. Even in the busiest months of February and January, the occupation levels only reach 1,6% and 1,4%, respectively. These figures indicate that the seven charging points in the district are more than sufficient for the 33 electric vehicles circulating. The low occupation rates show that the charging infrastructure is underutilized, meaning there is no immediate need for expansion or concern about bottlenecks in charging capacity.

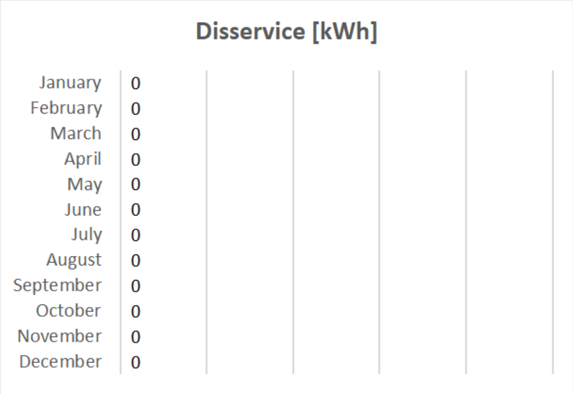
Table 20: Großschönau FD – basic scenario results

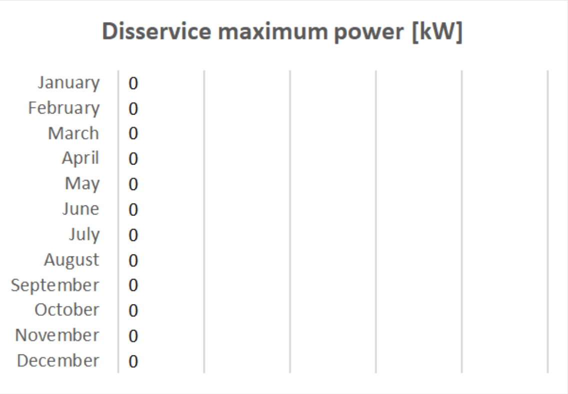
Großschönau

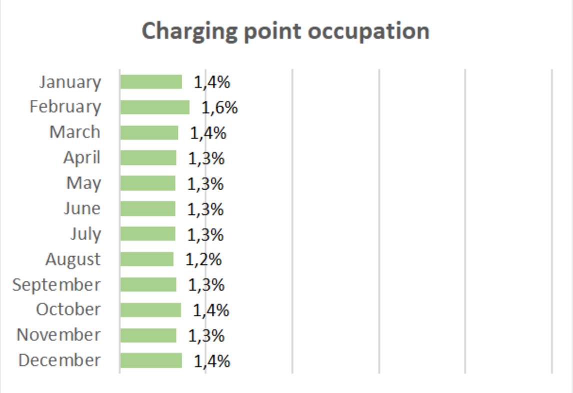
Basic scenario - input data - Results



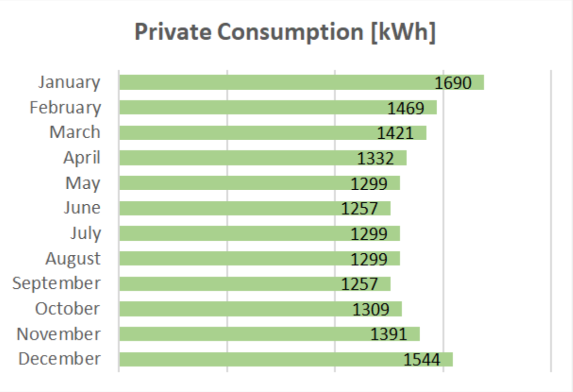


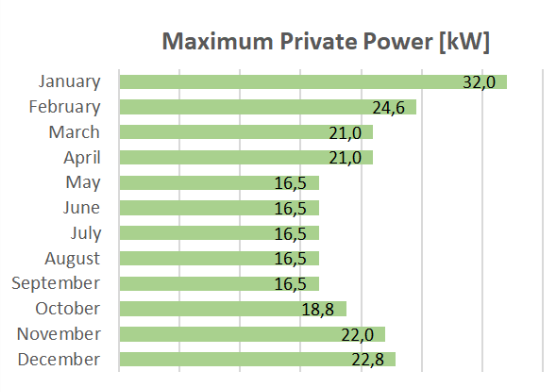






Summary table	
EVs travelling	33
Charging Points	7
Total Energy Provided Public (kWh)	14250
Average Montly Energy Provided Public (kWh)	1187



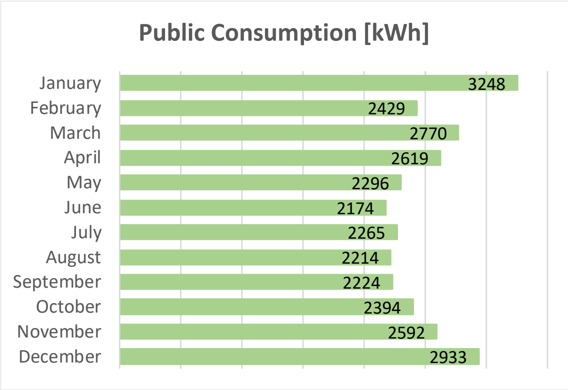


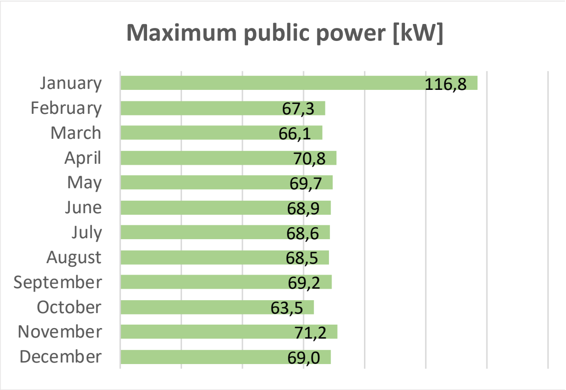
In 2035-v1 scenario (Table 21) the projected increase in electric vehicles remains modest and the total energy demand and the number of EVs (76 vehicles) do not show a drastic rise.

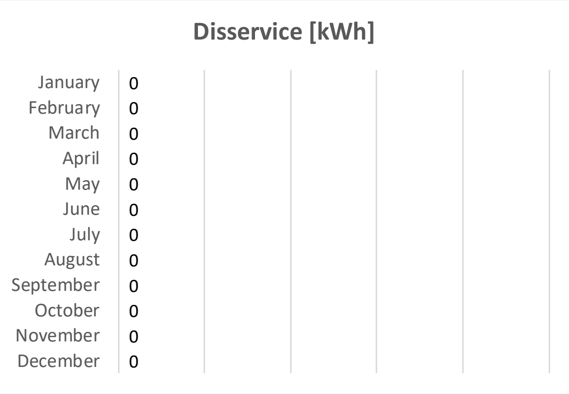
Public energy consumption reaches 30.2 MWh annually, which is still manageable for the existing infrastructure. The difference in energy consumption between December and August is notable, with December showing 2,933 kWh, about 700 kWh more than in August (2,211 kWh). This difference clearly illustrates the impact of colder winter months on energy usage due to decreased battery efficiency and the need for additional energy to maintain vehicle performance in lower temperatures.

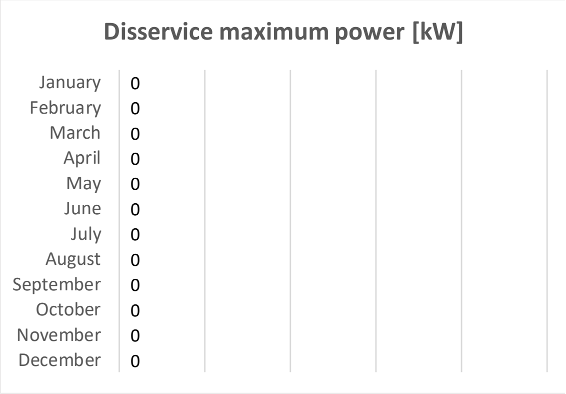
Another aspect worth highlighting is the charging point occupation, which remains quite low throughout the year. Even in January, which sees the highest occupation rate, the value is only 2.8%, while the lowest is in May at 2.0%. These figures show that the eight charging points in the district are more than sufficient to meet demand, and no significant stress is expected on the grid.

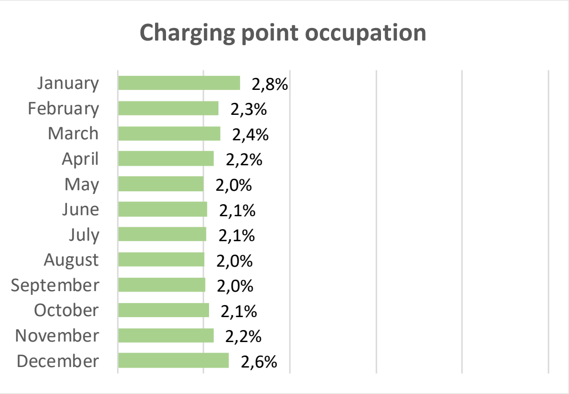
Table 21: Großschönau FD – 2035-v1 scenario results


Public Consumption [kWh]

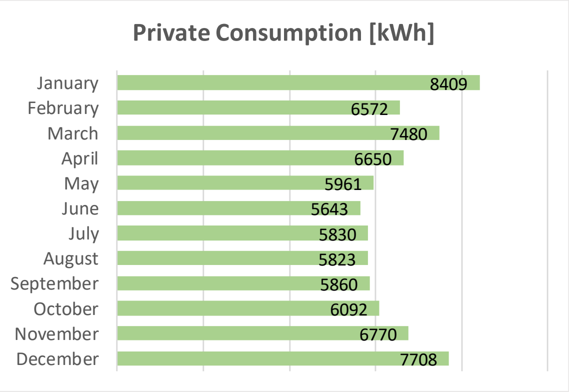

Maximum public power [kW]

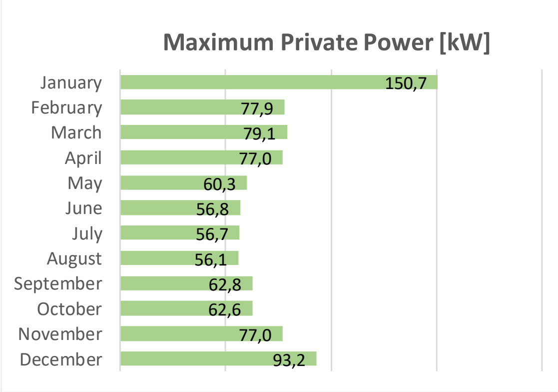

Disservice [kWh]


Disservice maximum power [kW]


Charging point occupation

Summary table	
EVs travelling	76
Charging Points	8
Total Energy Provided Public (kWh)	30159
Average Montly Energy Provided Public (kWh)	2513


Private Consumption [kWh]


Maximum Private Power [kW]

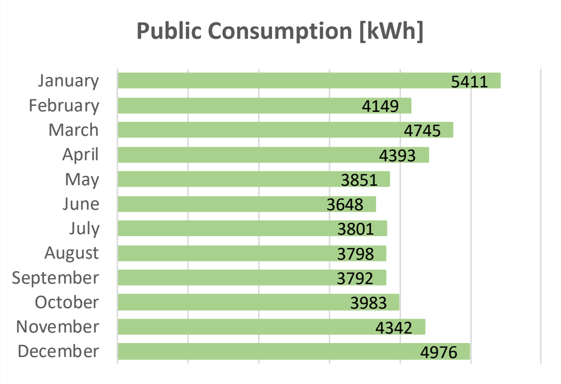
In 2035-v2 (Table 22) there is a more significant increase in the number of electric vehicles compared to the previous simulation. However, the number of charging points remains the same, which is enough to accommodate the increased demand, as evidenced by the relatively low charging point occupation rates. In fact, even with the higher number of EVs, the charging point occupation remains modest, peaking at 5,8% in January and staying around 4,6-4,9% for most of the year. This suggests that the infrastructure is sufficient to handle the additional EVs without any major strain or need for expansion in the immediate future.

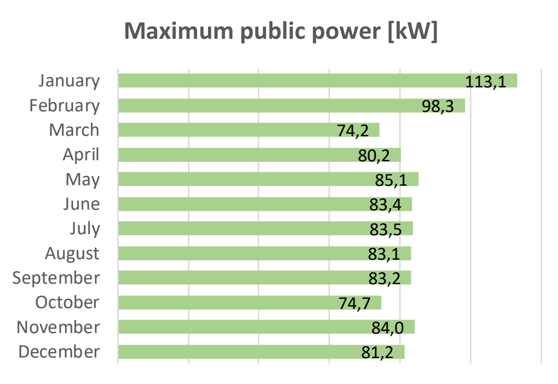
The total public energy consumption rises to 50,9 MWh annually, a substantial increase compared to the previous scenario, but still within the limits of what the district can manage. Similarly, maximum public power demand reaches 113,1 kW in January, a manageable figure for the current distribution system.

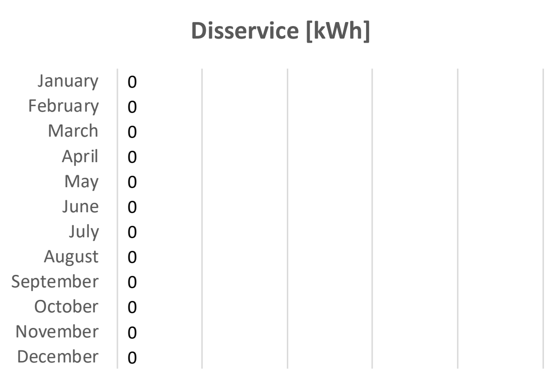
Despite the increased number of EVs, the charging infrastructure is more than adequate, as the occupation rates remain consistently low across all months.

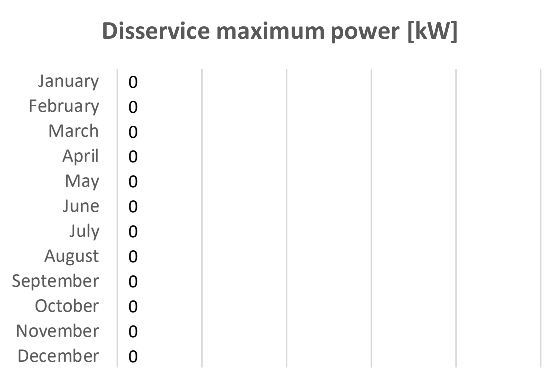
Additionally, monthly energy consumption varies notably between the colder winter months and the warmer periods. This reflects the harsher winters typical of Großschönau, where lower temperatures drive up energy needs for charging. However, peak power demand seems to be influenced more by the location and concentration of the charging points, rather than simply by the seasonal differences. The infrastructure can easily handle the power required, but localized stress could occur if many charging events overlap in a short period in specific areas.

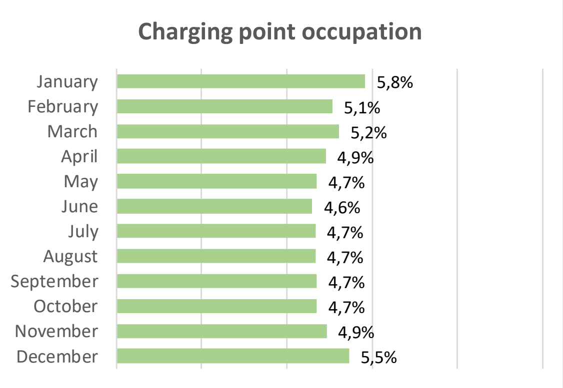
Table 22: Großschönau FD – 2035-v2 scenario results



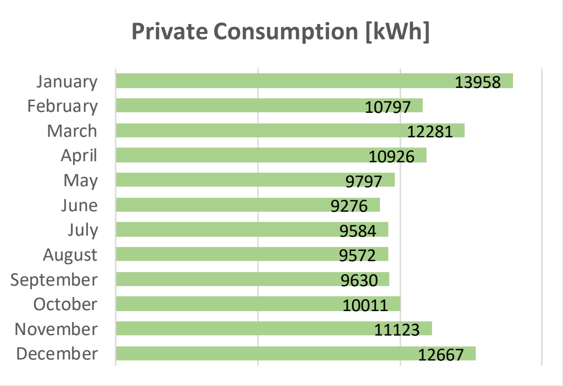


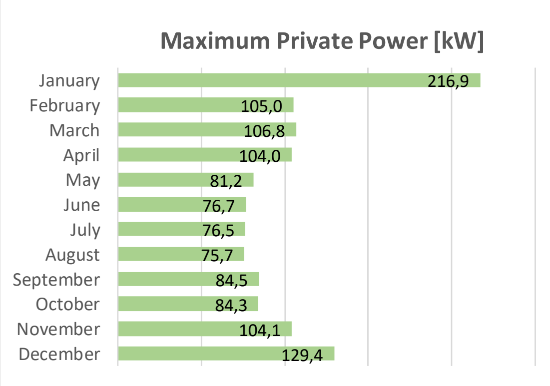






Summary table	
EVs travelling	125
Charging Points	8
Total Energy Provided Public (kWh)	50890
Average Montly Energy Provided Public (kWh)	4241





In the context of private charging, total demand is somewhat lower compared to public charging. Maximum power output is also reduced, thanks to the flexibility of charging times, which are not constrained by a limited number of stations. Nonetheless, the general trend remains unchanged, with higher demand in colder months and a peak in January.

Having available for the Großschönau FD some data on existing charging infrastructure use, simulation results have been compared with real data and sensitivity tests have been conducted. The results of these in-depth analysis are presented, respectively, in Annex 5 – Measures and simulations in Großschönau FD and in Annex 6 – Sensitivity test for Großschönau FD.

4 Conclusions

In this study a series of simulations across the three districts of Settimo Torinese, Resita, and Großschönau has been conducted to assess the energy demand of electric mobility and the load on the distribution network at the current state and in two future scenarios in 2035.

The number of electric vehicles expected on the road in 2035 varies significantly among the districts: some, like Settimo Torinese, predict a substantial increase in the EVs, while others, like Großschönau, expect more moderate growth.

A key aspect that emerges is the need for an adequate charging infrastructure to meet the growing energy demand. It is crucial that the expansion of infrastructure keeps pace with the increasing number of vehicles, especially in districts where rapid growth in electric mobility is expected.

Another critical factor is the distribution of charging points throughout the territory to avoid excessive concentrations in specific areas, which could overload the distribution network at those points.

Finally, energy consumption increases in the winter months due to lower temperatures, but this does not always translate into an increase in peak power demand. In fact, it is more closely related to the simultaneous use of charging points, to limit which demand management policies can be considered, such as economic incentives or pricing systems that encourage a more distribution of charging throughout the day.

Annex 1 – A guide to collect necessary data for e-mobility model

To facilitate the collection of useful data for the e-mobility model, the following document explains in more detail what is needed and has been shared with partners.

Data required

- some data are "necessary" (INPUT data)
- other data are non-necessary ("HABITS", "VEHICLES", “ENVIRONMENT”). This means that if the Focus District does not have specific data, the model’s default ones can be used. Otherwise, they can be modified (retaining the indicated structure)

INPUT DATA

These data are all necessary and must be found for each Focus District

	N. of Electric Vehicles	Explanation
Urban	XXX	number of electric vehicles that, on an average weekday, travel within the Focus District (FD). Their trip origins and destinations are within the FD
Incoming	XXX	number of electric vehicles entering the FD, on an average weekday. They have the origin of the trip outside the FD and destination inside the FD. These are the vehicles of the people who daily travel to the FD for their activities
Outgoing	XXX	number of electric vehicles that, on an average weekday, leave the FD to reach a destination outside the FD
• For these three groups, electric vehicles are needed (an estimate) • Data are non-depended on the city in which vehicles area registered • Note that also if a vehicle that starts in the FD will probably return the same day, it has not to be counted twice (incoming and outgoing) but only ones (as outgoing). The same for vehicles incoming		

	Average km travelled per working day	Explanation
Urban	XXX	average km travelled per day by an electric vehicle that stay inside the FD
Incoming	XXX	average km travelled per day by an incoming electric vehicle
Outgoing	XXX	average km travelled per day by an incoming electric vehicle
It doesn’t matter where vehicles travel their kms. Data refer to how many kms the vehicles travel on average, every day, for each group. So, for example, if a vehicle only makes two journeys in a day, one of 10 km to enter the FD and one of 10 km to return home, both journeys must be considered, so the vehicle travels an average of 20 km each day		

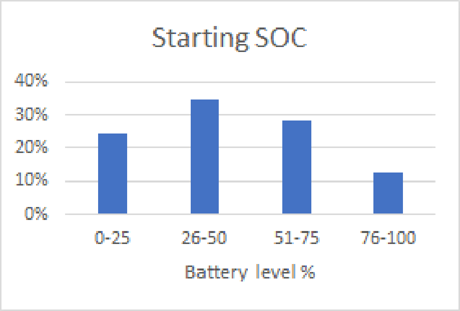
	N. of charging points	**Power [kW]**	**Explanation**
Slow (< 7 kW)	XXX	XXX	

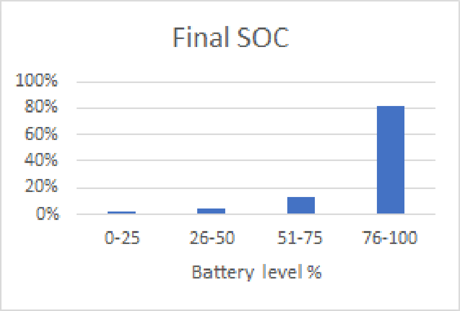
Fast (7-22 kW)	XXX	XXX	
Ultrafast (22 kW)	XXX	XXX	
Points = points where cars are plugged in. So, if in the FD there are 3 columns with 2 sockets each, Points = 6			

HABITS

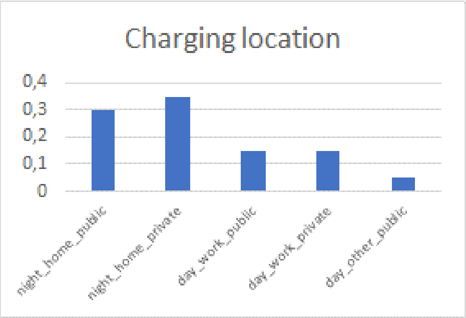
This data isn’t necessary. If the Focus District has data they can be used (retaining the indicated structure), if not, European average data derived from the literature and already included in the tables can be used.

Battery capacity %	**Starting_SOC (0-1)**	**Final_SOC (0-1)**	How to read the table, an example: 0,2443 means that 24,43% of vehicles desire to charge when their battery is below 25% of charge. 34,7% of vehicles desire to charge when their battery is between 25-50% of charge. *These data represent European averages and can be used in the absence of specific FD data.*
	It is the battery level of the vehicles when it plugs to start charging	It is the battery level of the vehicles when it has finished charging. Not all vehicles charge to 100%	
25	0,2443	0,0109	
50	0,3473	0,0388	
75	0,2838	0,1316	
100	0,1246	0,8187	





Charging location	**Percentage (0-1)**	This table contains the percentage distribution of charging preferences for electric vehicles. We need to know the % of vehicles that in general charge at home (private or public along the road), at work (private or public along the road) and in other locations, without distinguish if the charging operations happen at night or during the day. The words "night" and "day" are only used to give an idea of the peak frequency of charging. The model assumes that if a vehicle must recharge, the recharge occurs when it starts parking, all along the day, but maybe with a peak in specific hours (for example, home charging occurs with a peak at 7-8-9 pm, but it also occurs in other hours of the day). *These data represent European averages and can be used in the absence of specific FD data.*
night_home_public	0,30	
night_home_private	0,35	
day_work_public	0,15	
day_work_private	0,15	
day_other_public	0,05	

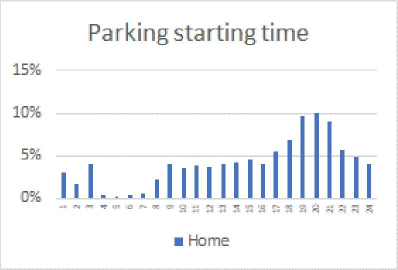


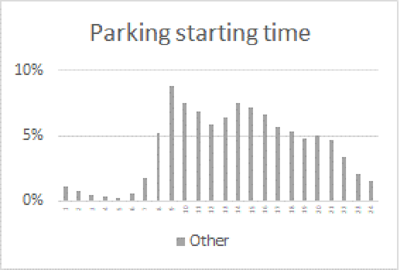
parking_starting_time	Home (0-1)	Work (0-1)	Other (0-1)
0	0,0311	0,0014	0,0115
1	0,0165	0,0012	0,0081
2	0,0397	0	0,0047
3	0,003	0	0,0039
4	0,0025	0	0,0025
5	0,0041	0,0076	0,0058
6	0,006	0,018	0,0174
7	0,0212	0,0723	0,0519
8	0,0404	0,1431	0,0878
9	0,0354	0,0808	0,0755
10	0,0392	0,0562	0,0685
11	0,0371	0,0585	0,059
12	0,0403	0,0699	0,0648
13	0,0416	0,0681	0,0751
14	0,046	0,1085	0,0714
15	0,04	0,0853	0,0668
16	0,055	0,0686	0,0567
17	0,0677	0,0315	0,0532
18	0,0961	0,0203	0,0478
19	0,1009	0,0131	0,05
20	0,0907	0,0074	0,0475
21	0,0563	0,0828	0,0337
22	0,0487	0,0025	0,0211
23	0,0405	0,0029	0,0153

This table contains the percentage distribution of parking starting times during the day, in different locations.

For instance, 10% of vehicles that park at home start parking at 7 pm.

These data represent European averages and can be used in the absence of specific FD data.





parking_duration_hours	Home/work (0-1)		parking_duration_hours	Other (0-1)
6	0,1		1	0,4
7	0,2		2	0,2
8	0,4		3	0,2
9	0,2		4	0,1
10	0,1		5	0,1

This table contains the percentage distribution of parking duration. For instance, 40% of stops at home or work last 8 hours.

These data represent European averages and can be used in the absence of specific FD data.

VEHICLES

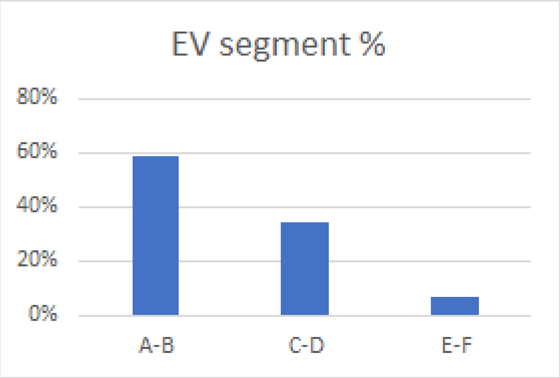
This data isn't necessary. If the Focus District has data they can be used (retaining the indicated structure), if not European average data derived from the literature and already included in the tables can be used.

	EV segment	**% Segment**	**Consumption (kWh/100 Km)**	**Autonomy (km)**	**Battery capacity (kWh)**
	Passenger car classification	% of electric vehicles belonging to segment	Average consumption of vehicles, per segment	Average autonomy of vehicles, per segment	Average battery capacity of vehicles, per segment
i.e. Fiat 500 elettrica / Renault Zoe	A-B	0,59	14	200	47
i.e. Volkswagen ID.3 / Tesla Model 3	C-D	0,34	18	323	66
i.e. Tesla Model Y / Porsche Taycan	E-F	0,06	23	517	83

This table contains some information related to electric vehicles fleet circulating in the Positive District.

For segment definition refer to "Passenger car classification" as defined by European Commission (https://alternative-fuels-observatory.ec.europa.eu/general-information/vehicle-types)

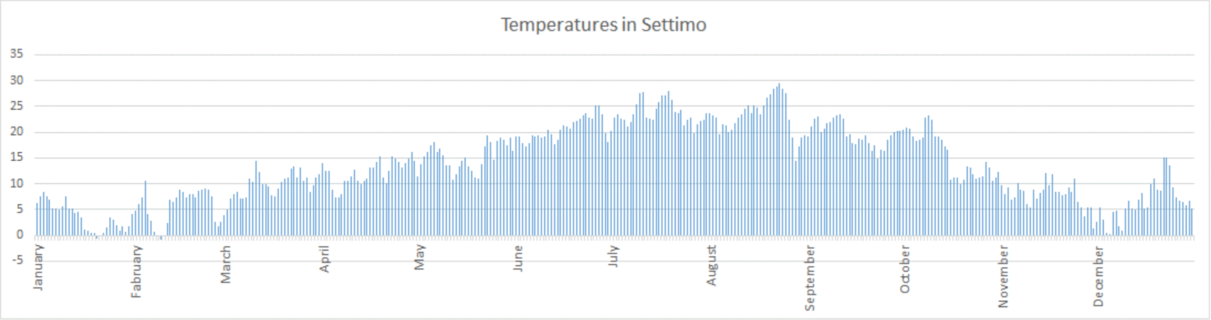
These data represent European averages and can be used in the absence of specific FD data.



ENVIRONMENT

An algorithm that considers the air temperatures of the Focus District to vary vehicle consumption has been developed. It can be used if specific temperature data are available for the Focus District. Otherwise, the model is run without the "temperature" effect.

The histogram represents the average daily temperatures of Settimo, as an example. Data can also be provided at hourly level (hourly temperatures, for all hours of the year).



Annex 2 – Transformation of Settimo FD into a PED

This Annex outlines the methodology and key steps used by RINA to demonstrate the potential of transforming the Focus District in Settimo Torinese, in its current state, into a PED (Positive Energy District) through the implementation of a photovoltaic system of 1.88 MW, installed both on rooftops and in green areas.

4.1 Methodology

To achieve the objective, the work has been divided into the following tasks.

Table 23: Task, Topics, and Methodological Approach

	TASK DESCRIPTION	
Task	**Topic**	**Methodological Approach**
1	Characterization of Buildings	• Analysis of material shared by the Municipality of Settimo Torinese. • Online research for technical information.
2	Identification of typical annual energy consumption indicators	• Online research for technical information.
3	Annual energy consumption profiles	• Online research for technical information. • Online research for demographic information useful for determining the lifestyle of the inhabitants.
4	Hourly energy consumption profiles	• Online research for technical information. • Online research for demographic information useful for determining the lifestyle of the inhabitants.
5	Hourly energy consumption profiles for e-vehicles charging	• According to model estimations, object of this deliverable
6	Quantification of available spaces for installation of photovoltaic plants	• Analysis of material shared by the Municipality of Settimo Torinese. • Evaluation of the space available for the installation of the PV system using online tools (google earth)
7	PV Plant hourly power generation profiles	• Orientation of the identified surfaces chosen for installation of PV panels. • Assumptions about roof/surface inclinations. • Extraction of hourly power data generated by the single photovoltaic module using online tools: 1. https://www.renewables.ninja/ 2. https://re.jrc.ec.europa.eu/pvg_tools/en/
8	Sizing of PV Plant to be installed	• Definition of PV Plant size according to data elaboration. • Maximization of self-consumption rate. • Meet the “positive energy district” requirements.

4.2 Quantification of Building Electricity Demand (Task 1, 2, 3, 4)

The use of shared technical materials and targeted online searches have allowed us to classify and quantify the number of residential buildings.

The number of residents of the village is estimated by assuming an average value of 3 inhabitants per accommodation. This hypothesis is obtained considering that 71% of the population is of working age with at least one dependent child and the remaining 29%[2] can be considered as a retired population.

In the following pages the images of the different typology of buildings that are part of the Settimo FD ("FIAT village") are shown.

Type C Type D Type E

Type F Type G

Figure 3: Building typology

In Table 24 the number of residential buildings, classified according to the different typology, and the overall volume of inhabitant of the village is reported.

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[2] These data were obtained by considering the ISTAT evaluations of the entire retired population of Piemonte, equal to 1.250.867 inhabitant, 29% of population.

http://dati.istat.it/viewhtml.aspx?il=blank&vh=0000&vf=0&vcq=1100&graph=0&view-metadata=1&lang=it&QueryId=21587

Table 24: Building Characterization

	BUILDING CHARACTERIZATION					
Building Tipology	**N° Buildings**	**Floors for buildings**	**Accomodation for each floor**	**Total Accomodation for building typology**	**N° inhabitant for Accomodation**	**Total Inhabitan for building Typology**
C	26	4	4	408[3]	3	1,224
D	4	4	6	90[4]	3	270
E	21	8	4	672	3	2,016
F	10	4	4	160	3	480
G	2	4	4	32	3	96
Total				**1,362**		**4,086**

Through online research it has been possible to identify an average value of electricity consumption for inhabited nucleus related to the population of Italian region of Piemonte, equal to 1.697 MWh/year[5]. This value has been deemed reliable and used as a guideline for the elaboration of the seasonal and annual daily consumption curves.

For the realization of the seasonal consumption curves, the following electrical absorptions are considered:

- Electrical devices (always on): 0.06 kWh for 24h per day.
- other consumption of electrical appliances (white-goods, TV, PC etc...): 0.27 kWh for 10h per day.
- Air conditioning (only for Summer): 0.21 kWh for 6h per day.
- Electric heating (only for Winter): 0.10 kWh for 4h per day.

The consumption curves are estimated considering the different social habits of people of working age and pensioners.

Below, the power consumption curves (Electric Energy) for the four different seasons are reported (Figure 4, Figure 5, Figure 6, Figure 7).

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[3] 2 buildings of type C have commercial activities on the ground floor; therefore, the floors are not considered as residential and excluded from counting the inhabitants of the village.

[4] 1 building of type D have commercial activities on the ground floor; therefore, the floor is not considered as residential and excluded from counting the inhabitants of the village.

[5] https://www.sorgenia.it/guida-energia/consumi-luce-e-gas-piemonte#:~:text=Il%20consumo%20medio%20unitario%20di,733%20tra%20i%20clienti%20Sorgenia.

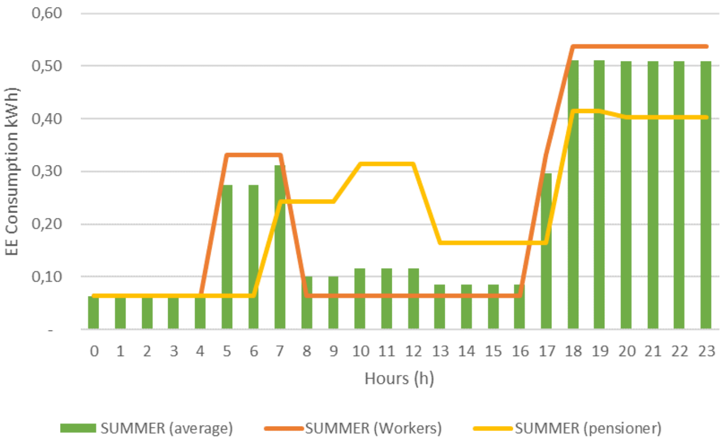

Figure 4: Average daily EE consumption (kWh) per accommodation in Summer

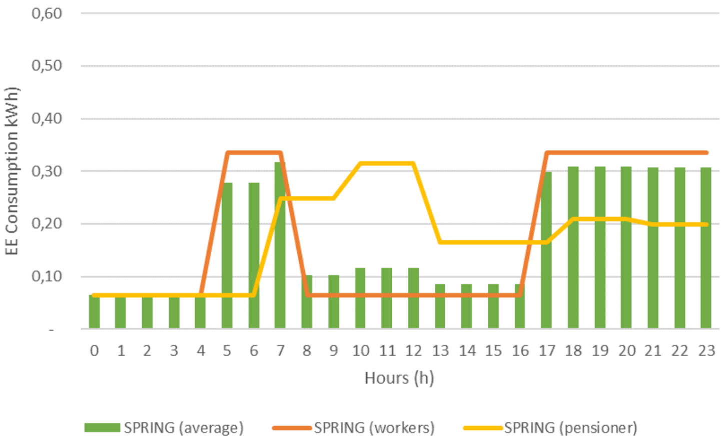

Figure 5: Average daily EE consumption (kWh) per accommodation in Spring

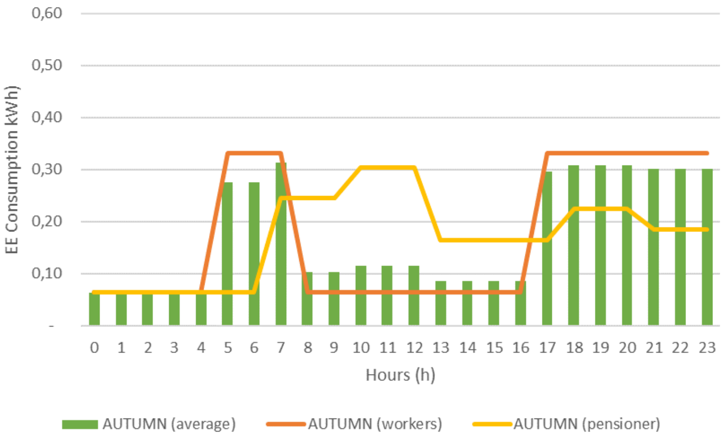

Figure 6: Average daily EE consumption (kWh) per accommodation in Autumn

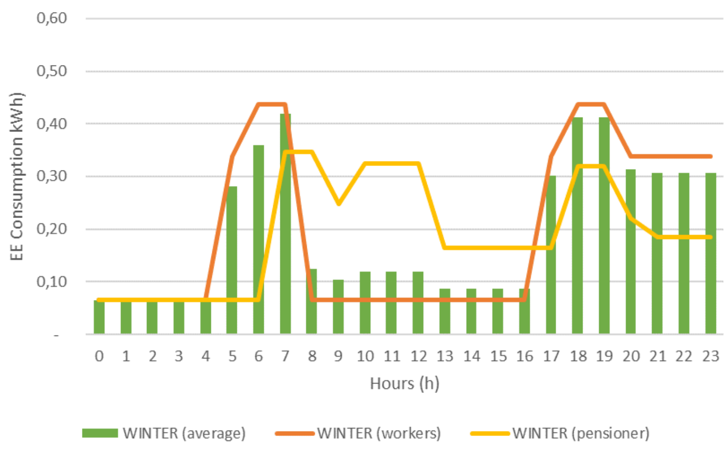

Figure 7: Average daily EE consumption (kWh) per accommodation in Winter

In Table 25, a recap of the electric energy consumption for each season and for the typical year is reported.

Table 25: Seasonal and annual EE consumption for inhabited nucleus

	EE CONSUMPTION FOR INHABITED NUCLEUS				EE CONSUMPTION
Season	**EE consumption per day (kWh/day)**		**Day per each season (day)**	**Total EE consumption per season (kWh/year)**	**Total EE consumption per season (kWh/year)**
	Working Day	**Weekend**	**Days/year**	**Year**	**Year**
Summer	5.43	5.38	92	498.0	678,321.22
Spring	4.20	4.16	92	385.2	524,667.63
Autumn	4.23	4.16	91	383.3	522,002.00
Winter	4.68	4.61	90	419.3	571,121.24
Year			**395**	**1,686**	**2,296,112.09**

The energy consumption per residential unit, previously noted as 1.697 MWh/year, has been exclusively used as a reference for developing daily and seasonal consumption curves for the municipality of Settimo Torinese.

The total calculated electricity consumption, amounting to 1.686 MWh/year per residential unit, shows a discrepancy compared to the referenced value. This difference arises from assumptions made regarding the distribution of the population between working-age individuals and retirees, as well as daily variations in routines.

An approach incorporating various consumption curves has therefore been adopted, considering the type of day (weekday or weekend) and the proportion of the population that is active versus retired.

Considering the developed Electric Energy consumption curves, the overall energy consumption for the FD is estimated to be equal to 2,296 MWh/year.

4.3 Quantification of E-Mobility Electricity Demand (Task 5)

See Chapter 3.1 - Settimo Torinese, base scenario

4.4 Sizing of PV Plants (Task 6, 7, 8)

The dimensioning of the photovoltaic system has been evaluated starting from the identification of the free surfaces on which the photovoltaic panels can be optimally laid.

The considered surfaces used to develop the project can be classified as:

- Existing surfaces:
    - Roofs of all the residential Buildings with South-West, South-East, South, East and West orientation, assuming an average slope of 30°. To maximize the cost-effective of the PV Plant, the surfaces North oriented are not taken into account.
    - Roofs of Industrial Buildings, assuming roofs with an average slope of 30°.
    - Roofs of municipal school, assuming a roof with an average slope of 30°.
- Available Areas:
    - A fraction of the green area in the South-East of the FD.
    - Shelters and new covered car parks between residential buildings.

The area of the recreation zone (green area in Figure 8) used for the purposes of the project is such as to allow the achievement of the balance between electricity consumed by the village for residential activities and the amount of electricity produced by PV Plant. The green areas adjacent to the village offer an exceptionally large surface. However, it must be also considering the social effect that the intervention could have on the population of the neighborhood.

In Table 26 all surfaces identified for the installation of PV Panels, according to optimal orientation, are represented.

The area investigated is marked red in Figure 8. In orange are indicated the existing surfaces that can accommodate the panels of the plant while in green the surfaces that should be made for the completion of the plant.

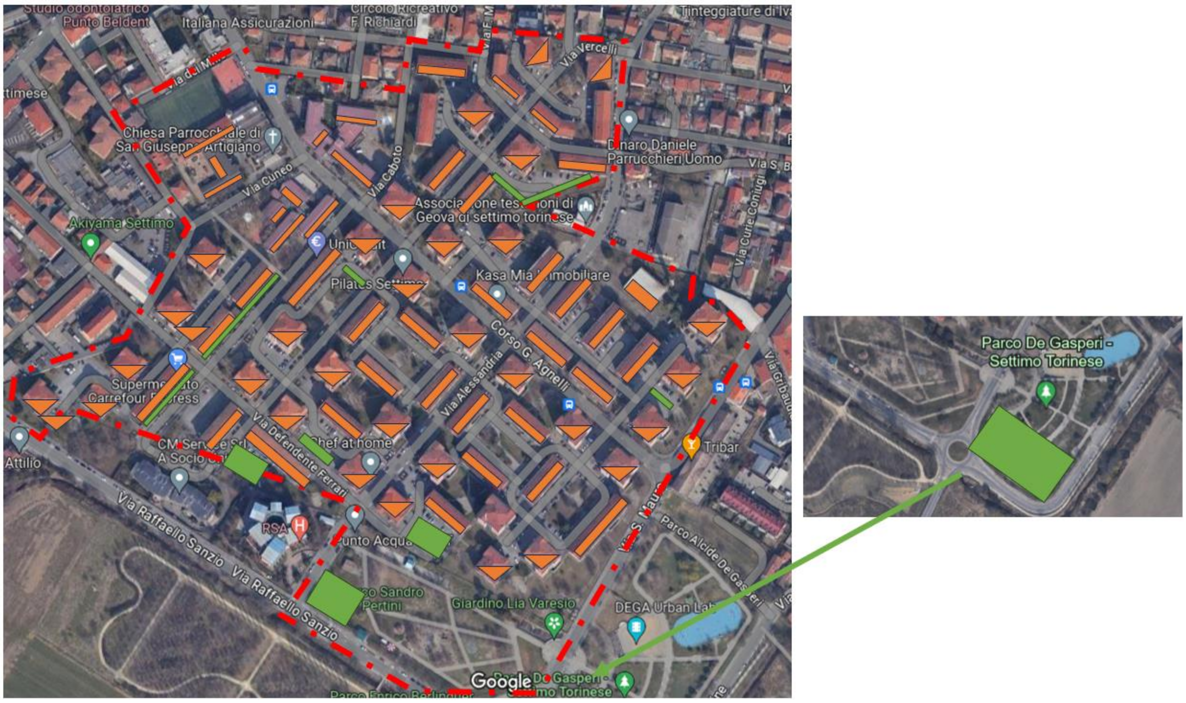

Figure 8: Surfaces for positioning PV panels

Table 26: Available areas and orientation

	Available areas and orientation				
Surfaces	South-West	South-East	South	East	West
Azimuth (°)	45	-45	0	90	-90
Existing Surfaces (m²)	5,033	5,990	375	375	375
Available Surfaces (m²)	2,551	945	5,073	-	-
Total Surfaces per orientations (m²)	7,584	6,936	5,449	375	375
Total surface (m²)	20,719				

Once the surfaces and their own orientation has been defined, the Electric Energy generated by the PV Plant can be computed thanks to the online tools https://re.jrc.ec.europa.eu/pvg_tools/en/ and https://www.renewables.ninja/ which allow, once fixed the peak power of the single PV Model, the system losses and the azimuth angle, the extrapolation of monthly/hourly EE production data.

The proposed PV module technology is Crystalline Silicon and has been chosen, to be cautionary, a ratio of 1kW/11m^2.

The identified areas and the PV technology adopted make possible the installation of a PV Plant of 1.88 MW of power. The value of Electric Energy production is in line with the estimated energy consumption of the residential building and e-mobility.

In Figure 9, shows the monthly trend of the electricity production of the entire photovoltaic system according to the orientations of the analyzed surfaces. Since only a few areas facing east and west have been developed, the electricity produced is marginal compared with the other orientations.

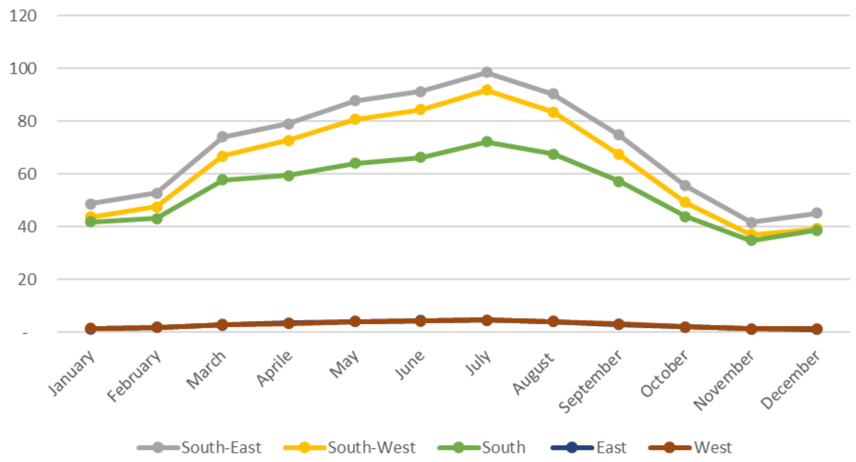

Figure 9: Monthly trend of EE Production according to the orientation of PV panels

Table 27 shows the monthly breakdown of the village's electricity consumption, comprehensive of residential energy consumption and electric mobility consumption, the plant's energy production and the electric energy fed into the local grid. As reported in the last row of the table, the annual energy production is in line with the electric consumption for the residential buildings analyzed.

Table 27: EE Produced by PV Plant vs EE Consumed

	EE Produced by PV Plant vs EE Consumed			
Month	**EE from PV plant**	**EE Consumption**	**EE Injected in the Grid**	**Hours with Energy Surplus**
	(MWh)	**(MWh)**	**(MWh)**	**(h)**
January	138	198	92	195
February	120	178	76	166
March	197	190	138	229
Aprile	239	172	169	278
May	234	177	160	296
June	260	188	181	310
July	281	229	198	321
August	233	229	163	278
September	187	205	126	255
October	140	178	87	211
November	158	172	109	212
December	132	185	87	200
Total	**2.319**	**2.304**	**1.587**	**2.951**

Overall, the hours of the year in which the village behaves like a Positive Energy District correspond to 2,951, that is 34% of the entire year. The amount of electric energy injected in the grid corresponds to 1,587,214 kWh, which is 68% of the electric generation.

The behavior of the PV Plant and FD total energy consumption can be observed in Figure 10.

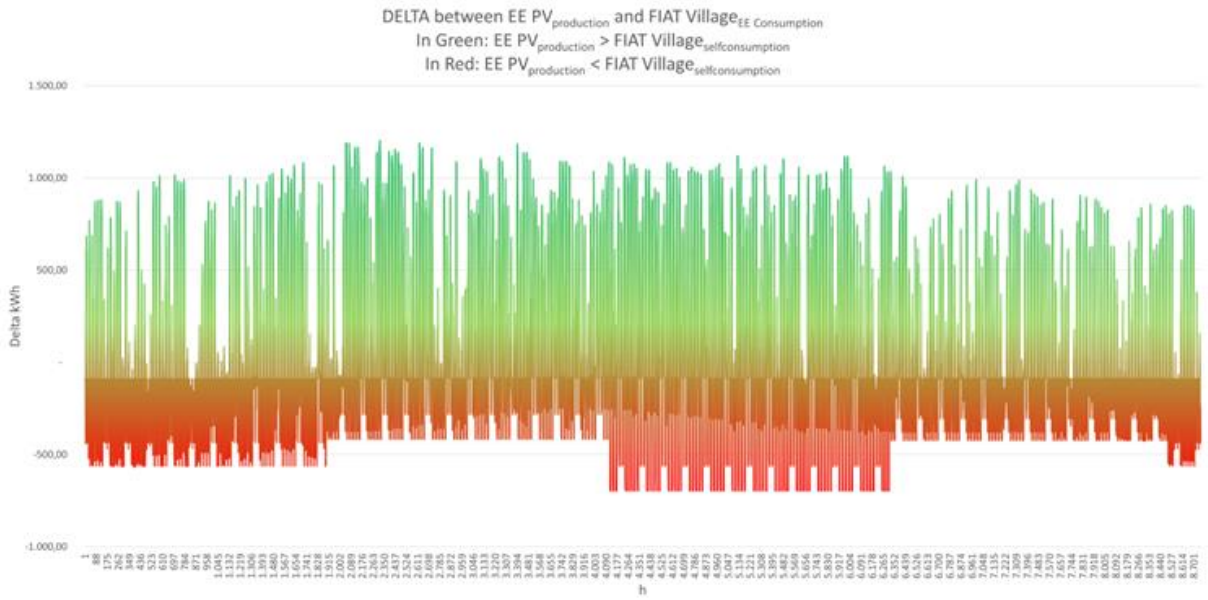

Figure 10: Net EE production/consumption in Settimo FD

Annex 3 – Sensitivity test per Settimo Torinese FD

Some sensitivity tests were conducted for the Focus District in Settimo Torinese to assess how the kilometers travelled by electric vehicles in the baseline scenario may affect the total yearly energy required for public recharging. The kilometers travelled were varied with two levels of increase and two levels of decrease. The results of the tests are shown in full in Table 28.

Table 28: Settimo Torinese FD – Sensitivity tests

Settimo Torinese FD	***Total yearly energy (KWh public)***			***Disservice (KWh public)***		
	MIN	***MAX***	***Average***	***MIN***	***MAX***	***Average***
50 km	*5.343*	*7.920*	*6.246*	*0*	*0*	*0*
40 km	*4.236*	*6.370*	*4.954*	*0*	*0*	*0*
33-34 km	*3.605*	*5.378*	*4.315*	*0*	*0*	*0*
26 km	*2.824*	*4.209*	*3.294*	*0*	*0*	*0*
20 km	*2.203*	*3.282*	*2.634*	*0*	*0*	*0*

If electric vehicles travel an average of 50 km daily, the (average) energy consumption increases by 45%, from approximately 4.300 kWh to 6250 kWh. The recharging infrastructure is still adequate for the energy demand as there are no disservices.

Reducing the number of kilometers travelled to 20 km, the total energy required decreases by almost 40%, with an annual average of 2600 kWh.

Annex 4 – Sensitivity test per Resita FD

Some sensitivity tests were conducted for the Focus District in Resita to evaluate how the kilometers traveled by EVs in the baseline scenario might impact the total annual energy required for public recharging. The kilometers traveled were adjusted with two levels of increase and two levels of decrease. The full results of the tests are presented in Table 29.

Table 29: Resita FD – Sensitivity tests

Resita FD	***Total yearly energy (KWh public)***			***Disservice (KWh public)***		
	MIN	***MAX***	***Average***	***MIN***	***MAX***	***Average***
50 km	*35654*	*42666*	*37957*	*0*	*1128*	*157*
40 km	*26885*	*33784*	*30330*	*0*	*2217*	*1133*
33-34 km	*23565*	*29119*	*25976*	*0*	*2305*	*827*
26 km	*17258*	*22026*	*19806*	*0*	*1870*	*1550*
20 km	*14182*	*16938*	*15550*	*0*	*1092*	*1092*

To give a clearer sense of the scale of the problem when it happens, the average disservice is computed by including only the scenarios with disservice. These are scenarios in which the timing of drivers' charging habits sometimes overlap, resulting in an insufficient supply of charging points or alternatively.

Tests show that increasing the daily travelled kilometers to 50 km, the energy consumption increases by an average of about 50%, from approximately 26.000 kWh to 38.000 kWh. Reducing the number of kilometers travelled to 20 km, the total energy required decreases by almost 40%, with an annual average of about 15.500 kWh.

Each scenario highlights some disservices. Over the 50 runs of each scenario, years without disservices and years with disservices are estimated, i.e. with vehicles that need to recharge in the FD but fail because they find the charging points occupied. Table 29 shows the maximum annual disservices, which in principle remain within 10% of the annual consumption (max and average) and which do not show a linear trend with respect to the increases in km travelled as they are highly dependent on the initial assignment of vehicle behavior.

Annex 5 – Measures and simulations in Großschönau FD

This chapter presents a comprehensive comparison of electric vehicle charging data collected on-site against the outputs from simulation model. Measured data are related to recorded charging events at seven specific charging points in three charging stations in Großschönau FD, over one year (April 2023 – Marzo 2024).

In the following table the summary of comparison is shown. As can be seen the model estimates well the total number of Charging Sessions during the year, but overestimates the Total Energy Consumption, the Average Energy Consumption per Session and the Average Energy Provided per Charging Point.

	Measured Data	**Simulated Data**
Number of Charging Sessions (#/year)	450	582
Total Energy (kWh/year)	8.658	14.250
Average Energy per Session (kWh)	19	24
Average Energy per charging point (kWh)	1.236	2036

Looking at the average data for the charging points of the three charging stations the overestimates are confirmed.

	Average charging sessions per charging point (#/year)	Average Total Energy per charging point (kWh/year)	Average Energy per charging session (kWh)
Sonnenplatz	55	910	16
Municipality	36	862	24
School	76	1.494	18

To fully understand the model results it is important to consider that in general, the model estimates the maximum energy that can potentially be required by the e-mobility that insists on the Focus District In fact, the model:

- Treats all charging points (stations) as interchangeable, making it less likely for an electric vehicle to find no available charging point nearby. This makes it difficult for a vehicle not to find a place to recharge when it needs to. On the contrary charging stations in Großschönau FD are in different areas, each with specific users depending on their locations. So, it may happen that if a charging station is fully occupied, the vehicle has to be recharged either on another day (perhaps at the same station, but not necessarily) or at home (home charging) or outside the FD. The latter two cases could be the cause of less energy being used in the year.

I. Assumes repetitive habits that are the same every day throughout the year, without accounting for variations due to weekends and holidays, periods that could be affected by different mobility needs (and thus electric recharging), which could also be met outside the Focus District. To confirm this, if we divide the estimated total energy required in a year (14.250 kWh/year) by the number of days in a year (365) and multiply by 250 (average number of working days) we obtain 9.760 kWh/year, a value very close to the measured total energy (9.760 vs 8.658; +13%). This shows that the energy required in a year by the FD for e-mobility varies between a minimum of about 9.700 kWh/year and a maximum of about 14.300 kWh/year.

Annex 6 – Sensitivity test for Großschönau FD

Sensitivity tests were performed for the Focus District in Großschönau to evaluate the impact of changes in the kilometers driven by electric vehicles in the baseline scenario on the annual energy demand for public recharging. The distances driven were adjusted with two levels of increase and two levels of decrease. Detailed results in Table 30.

Table 30: Großschönau FD – Sensitivity tests

Großschönau FD	***Total yearly energy (KWh public)***			***Disservice (KWh public)***		
	MIN	***MAX***	***Average***	***MIN***	***MAX***	***Average***
50 km	*20.037*	*26.005*	*23.298*	*0*	*0*	*0*
40 km	*16.719*	*20.638*	*18.277*	*0*	*0*	*0*
33-34 km	*12.636*	*16.667*	*14.302*	*0*	*0*	*0*
26 km	*10.216*	*12.731*	*11.343*	*0*	*0*	*0*
20 km	*7.987*	*10.064*	*8.795*	*0*	*0*	*0*

If electric vehicles travel an average of 50 km daily, the (average) energy consumption increases by about 63%, from approximately 14.000 kWh to 23.000 kWh. The recharging infrastructure is still adequate for the energy demand as there are no disservices.

Reducing the number of kilometers to 20 km, the total energy required decreases by almost 40%, with an annual average of about 8.800 kWh which, moreover, represents the value measured for the FD charging points, as described in Annex 5 – Measures and simulations in Großschönau FD.

Sources

ID	Paper	Sources for
[1]	C. Corchero, S. González-Villafranca and M. Sanmartí, *"European electric vehicle fleet: driving and charging data analysis",* 2014 IEEE International Electric Vehicle Conference (IEVC), Florence, Italy, 2014, https://core.ac.uk/download/pdf/41778899.pdf	Starting SOC and Parking starting time
[2]	Oliver Frendo, Jérôme Graf, Nadine Gaertner, Heiner Stuckenschmidt, "*Data-driven smart charging for heterogeneous electric vehicle fleets*", Energy and AI, Volume 1, 2020, 100007, ISSN 2666-5468, https://madoc.bib.uni-mannheim.de/55378/1/1-s2.0-S2666546820300070-main.pdf	Final SOC
[3]	Scott Hardman, Alan Jenn, Gil Tal, Jonn Axsen, George Beard, Nicolo Daina, Erik Figenbaum, Niklas Jakobsson, Patrick Jochem, Neale Kinnear, Patrick Plötz, Jose Pontes, Nazir Refa, Frances Sprei, Tom Turrentine, Bert Witkamp, *"A review of consumer preferences of and interactions with electric vehicle charging infrastructure"*, Transportation Research Part D: Transport and Environment, Volume 62, 2018, ISSN 1361-9209, https://www.sciencedirect.com/science/article/pii/S1361920918301330 Markus Hagenmaier, Christian Wagener, Julien Bert, Jennifer Carrasco, Nathan Niese, and Aman Wang; *"What Electric Vehicle Owners Really Want from Charging Networks";* - Center for mobility https://web-assets.bcg.com/18/4f/edb337e546b4b2897ef61efdcef5/bcg-what-electric-vehicle-owners-really-want-from-charging-networks-jan-2023.pdf CTEK E-MOBILITY CENTER. *Electric vehicle survey – Electrical vehicle ownership and take up in Europe*. https://www.ctek.com/storage/A81A53BEA83A11C5B5C58D97C24AED0C170469072D5A34224DACD72F0D88A0B8/dda6f99c6ad1490d9c6642bc693a7759/pdf/media/c3350d34847b45e2af13b8e5f6f4745f/CTEK%20-%20Electric%20Vehicle%20Survey.pdf	Charging location preferences
[4]	Pasaoglu Kilanc G, Fiorello D, Martino A, Scarcella G, Alemanno A, Zubaryeva A, Thiel C, "*Driving and parking patterns of European car drivers – a mobility survey*". EUR 25627 EN. Luxembourg (Luxembourg): European Commission, 2012. JRC77079. https://publications.jrc.ec.europa.eu/repository/handle/JRC77079	Parking duration
[5]	Xu Hao, Hewu Wang, Zhenhong Lin, Minggao Ouyang, *"Seasonal effects on electric vehicle energy consumption and driving range: A case study on personal, taxi, and ridesharing vehicles"*. Journal of Cleaner Production, Volume 249, 2020, 119403, ISSN 0959-6526, https://www.sciencedirect.com/science/article/pii/S0959652619342738	Seasonal effects on EVS
[6]	European Alternative Fuels Observatory Alternative-fuels-observatory.ec.europa.eu	EV segments

simply positive