# Evaluation approach for smart charging ecosystem – with focus on automated data collection and indicator calculations

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**Abstract.** Access to charging is a prerequisite for the transition to electric mobility. There are however challenges related to charging and charging infrastructures, e.g., charging availability, grid capacity during peak hours, and the CO2 intensity of the energy mix provided. This paper suggests measures to be taken in a smart charging ecosystem to mitigate the challenges. The impact of the measures must however be evaluated. The objective of the paper is to suggest an evaluation approach, with focus on quantitative aspects. The measures of relevance, the associated indicators for the impact evaluation, and an overview of the research data needed is provided. In addition, data content examples and calculation details are described for two indicators – the charging flexibility provided by the EV users and the peak to average ratio characterising the load balancing. Scenarios to be evaluated and how simulations are used to complement the evaluation of the demonstrators are addressed.

## 1 Introduction

The communication from the European Commission on "Sustainable and Smart Mobility Strategy – putting European transport on track for the future" [1] states that the uptake of zero emission vehicles must be boosted. However, citizens cannot be expected to replace their fossil cars with electric vehicles (EVs) unless they have easy and predictable access to charging. Thus, the strategy recognizes the need for charging infrastructures and the importance of the ongoing revisions of the alternative fuel directive (current version [2]) and the building directive (current version [3]). The revisions will address a smooth integration of charging infrastructures into the electricity grid as well as charge points in buildings.

The establishment of charging infrastructure must be sustainable from a societal, economic, and environmental point of view. The infrastructures themselves require investments, and with an electrified transport sector, the power demand will increase, and power grids may get overloaded. Thus, grid investments are required, and the energy provided must be as green as possible [4].

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The European Horizon 2020 project GreenCharge builds on previous work on energy smart neighbourhoods [5] and addresses the above challenges. In the GreenCharge concept, the charge management and smart local energy management work together to facilitate a transport system running on green energy. EV users get charging support, and peaks in the power grid and grid investments are reduced through load balancing. When many vehicles are plugged into the grid around the same time (e.g., on returning home from work), the energy management balances demand with available supplies, supplies from renewable energy sources included.

The concept aims for smart charging ecosystems where actors, devices, infrastructures, and software systems provide services to each other [6]. The ecosystems are cross sectorial, involving the building, charging, and energy sectors.

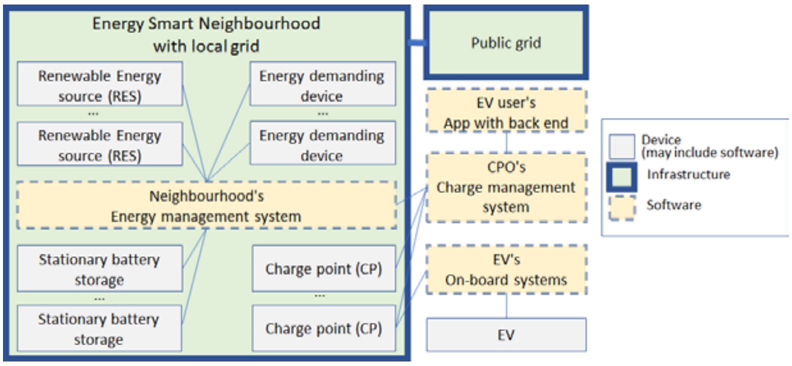

**Fig. 1.** Smart charging ecosystem components

Fig. 1 illustrates the ecosystem components. The building sector is within an energy smart neighbourhood (ESN) encompassing one or more buildings. It may have local renewable energy sources (RES) like solar plants, stationary batteries for energy storage, and devices like heating/cooling devices, washing machines and dishwashers.

The charging sector is represented by charge points (CP) in the premises of the ESN, the charge management system of the charge point operator (CPO), the EVs charging at the CPs, on-board systems for charging, and systems supporting the EV user regarding charging, e.g., an App used by the user or the navigation system.

The energy sector is represented by the power grids and associated systems. The local power grid has a local energy management system ensuring the best possible use of energy across the ESN. Devices and EV charging sessions are started and stopped, according to rules and the energy availability. The use of the energy from local RES is also managed, and if surplus, the energy may be stored in stationary batteries.

This paper describes a method for smart charging ecosystems evaluations. The quantitative aspects are emphasized since these are customized to the concept. Section 2 presents related work on evaluation frameworks. Section 3 defines relevant measures and an indicator framework for impact evaluations. Section 4 and 5 address the research data needed for indicator calculations, and calculation strategies for two indicators. Section 6 addresses how demonstrators and simulations will contribute to the evaluation and exemplifies the use of indicators. Finally, section 7 concludes and describes the remaining work.

## 2 Related Work on Evaluation Approach

According to Lervåg [7], impact studies in the transport sector traditionally are performed by ex post evaluations of implemented services, field operational tests, and simulations. They all may build on classic evaluation strategies involving a comparison of the before and after situations, or goal-oriented evaluation approaches where the results are compared with predefined criteria.

Several evaluation frameworks for the transport sector address impact assessments through the comparison of before and after situations. The FESTA methodology [8] provides guidelines for the evaluation of intelligent transport systems with focus on driver behaviour in field operational tests. The CIVITAS evaluation framework [9] defines an impact evaluation approach as well as guidelines for implementation process evaluations. The framework offers a common approach with pre-defined indicators to urban mobility projects funded by the European Commission, the GreenCharge project included. Electric mobility issues are however not addressed.

Lervåg [7] states that current evaluation strategies have shortcomings caused by the rapid development of technology and limited access to empirical knowledge due to the complexity of full scale implementations in real life situations. It may also be difficult to establish baseline data. To cope with the shortcomings, the use of program theory is suggested to find dependencies, and to support the development of policies.

## 3 Indicators Needed for Impact Evaluation

The impact evaluation approach described by this paper builds upon the CIVITAS evaluation framework [9] and supports the assessment of the impact of certain measures through use of indicators. The same indicators are established before and after the introduction of measures, and the differences are analysed.

**Table 1.** Measures in measure groups and related indicators

| Groups | Measure (S) or (B) | Description | Indicators (C) or (GC) |
|---|---|---|---|
| Charging | Public CP (S) | CP can be used by the public. | I1 Awareness level (C)<br>I2 Acceptance level (C)<br>I3 Perception level of physical accessibility (C)<br>I4 Operational barriers (C)<br>I5 Number of EVs (GC)<br>I6 Number of CPs (GC)<br>I7 Utilisation of CPs (GC)<br>I8 Charging availability(GC)<br>I9 Charging flexibility (GC) |
| | Private CP (S) | CP is owned and used by one EV user. | |
| | Shared CP (S) | CP is shared when not used by the owner. | |
| | Booking of CP (B) | Time slot for charging is booked in advance. | |
| | Flexible charging (B) | EV user allows charging at any time before a latest finish time. | |
| | Priority charging (B) | EV user requests charging as fast as possible with priority over non prioritised users if not enough energy for all. | |
| Smart energy management | Local RES (S) | Energy from local RES is exploited. | I10 Peak to average ratio (GC)<br>I11 Self-consumption (GC)<br>I12 Energy mix (GC)<br>I13 CO2 emissions (C)<br>I14 Share of battery capacity for V2G (GC) |
| | Stationary battery storage (S) | Energy is stored locally for later use when it is advantageous. | |
| | Exploiting V2G (Vehicle-to-Grid) (B) | Energy from connected EVs is used when it is advantageous. | |
| | Optimal and coordinated use of energy (B) | Energy use (charging included) is coordinated with energy availability and optimised to maximise the use of green energy and to reduce peak loads. | |

Table 1 lists and groups the measures to be implemented through the software systems in Fig. 1 to facilitate smart charging ecosystems. Some measures are state-of-the-art (S), while others go beyond state-of-the-art (B). Both types are included since the first facilitates the implementation of the second, and since combinations (e.g., shared CPs and booking of CPs) need to be evaluated. It may be difficult to assess the effect of individual measures. Thus, all measures in one group are evaluated as a whole, and Table 1 lists the indicators of relevance for each group. The indicators are either adopted from the CIVITAS framework (C) and adapted to the smart charging ecosystem, or they are defined by the GreenCharge project (GC).

### 3.1 Charging Measures

The objective of the charging measures is to provide better and more predictable access to charging services to the EV users. In addition, the measures should arrange for good utilisation of existing CPs to limit the need for additional CPs. It is also crucial that the charging services are designed to arrange for optimal use of energy.

The public/private/shared CP measures are about how EV users get access to charging, whether they have dedicated, private CPs, or must share CPs with others. A sharing of private CPs arranges for better availability and utilisation of the CPs. Bookings of CPs arrange for predictable access to charging services and may mitigate the so-called charging anxiety.

The priority and flexible charging measures are about when EVs are to be charged. With priority charging, the charging starts immediately and is accomplished as fast as possible. With flexible charging, the EV user accepts that the charging can be done at any time before a deadline. Flexible charging is most relevant when EVs are connected for a longer period. In such cases and when supported by the EV, the charging can be started and stopped several times according to what is optimal with respect to the grid capacity, other energy demands, the energy price, the availability of renewable energy, etc.

For all types of charging, a charging request should be provided. It defines the energy demand and the time slot in which the charging should take place. The latter may be hours or days ahead. Today, the EV user may have to provide the charging request manually, e.g., through an App. In the future, an integration with vehicle on-board systems (for access to the current state of charge), travel planners or navigation systems (for charge planning and scheduling support) and decision support systems (for adaption to habits, plans, etc.) may support the EV user and automatically make suggestions for the information needed.

The indicators selected for the charging measures cover several aspects. Indicator I1 – I4 (on awareness, acceptance, accessibility, and operational barriers) are evaluated by means of qualitative data collected from EV users on the awareness and perception of the charging services, as defined by the CIVITAS framework. These indicators are to a large extend about how successful the implementation of the measures is from the EV user's point of view and provide an important context for the analysis of the other indicators.

Indicator I5 and I6 are about the diffusion of eMobility by addressing the number of charge points and the number or share of EVs.

Indicator I7 – I9 (utilisation, availability, and flexibility) are about the charging behaviour and flexibility. The charge point utilisation addresses connection times, charging time, and use of energy. The charging availability is about the fulfilment of charging demands and about how booked time slots are used (e.g., delays in plug-in time and blocking after booked time slot). Charging flexibility addresses the flexibility of the EV user with respect to when the charging can take place.

Demonstrators and simulated scenarios will address sub-sets of the charging measures, and the measures will be evaluated as one package by means of a selection of the indicators. An indicator may also constitute a context for other indicators, and they may influence each other. A high number of charge points may for example give a higher number of EVs, and high awareness and acceptance about the need for flexibility may increase the charging flexibility provided by the EV users.

### 3.2 Smart Energy Management Measures

The smart energy management measures aim to fulfil individual energy demands while ensuring optimal use of energy to minimise both the CO2 emissions and the peaks in the electricity grid. The latter will reduce the need for costly grid investments and may also reduce the energy costs if the tariff rewards a reduction of peaks.

The local RES measure is about local production of green energy, e.g., by means of PV panels. The measures on stationary battery storage and exploiting Vehicle-to-Grid (V2G) arrange for flexibility with respect to when energy is used. In case of surplus or if it is not optimal to use the green energy from RES immediately (e.g., due to high availability of cheap energy from the distribution grid), the energy can be stored in the batteries of connected EVs or in stationary batteries. When energy costs are high, or when the energy demand exceeds availability, the stored energy can be used.

As mentioned, the aim is optimal use of energy, and the measures on optimal and coordinated use of energy do an optimisation across energy demands in the ecosystem through an integration and control of energy sources and energy demanding equipment (RES, stationary batteries, charging infrastructure, heating and cooling devices, washing machines, etc.). The optimisation should be based on the current situation as well as on prognosis on both future energy demands and energy production from RES (i.e., prediction-based energy optimisation). The input to the prognosis will be historical data, charging requests received ahead of the actual arrival of the EVs, and weather forecasts.

Indicator I10 is about the peaks in the energy use compared to the average value. Ideally, there should be no peaks in the energy use from the public grid, just a flat curve. The optimisation mentioned above aims to flatten the curve, and this is also supported using RES and stationary batteries.

I11 and I14 (self-consumption and V2G) is about the share of energy produced locally that is consumed locally and the share of the battery capacity in connected EVs that is available for use. In general, it is advantageous that both are high. Locally produced energy should be prioritised since prices for energy bought are higher than those for energy sold. Access to energy in EV batteries increases the flexibility.

I12 – I13 are about the energy mix and the CO2 emissions. The energy mix is the share of different energy sources in the energy provided, and the mix in the local grid improves if local RES is used. The CO2 emissions in eMobility depends on the energy mix in the energy which the EVs are charged with.

As for the charging measures, the smart energy management indicators are influenced by each other. Increased self-consumption due to local RES may for example give a greener energy mix and reduce CO2 emissions. There are also dependencies between the charging measures and the smart energy management measures. A high charging flexibility will arrange for a reduction of the peaks since the charging can be accomplished when energy is available. High flexibility may also increase the self-consumption and thereby decrease the CO2 emissions.

## 4 Research Data Needed to Calculate Indicators

Research data are collected in three ways: 1) Manually through surveys and interviews; 2) semi-automatically or automatically by means of the software systems running at demonstrators; and 3) through simulations. In the following, we focus on the quantitative data from 2) and 3). These datasets are designed in collaborations with experts on electric mobility and energy management to facilitate automated calculations of the quantitative indicators described in Section 3 (I5 – I14).

### 4.1 Dataset Entity Types

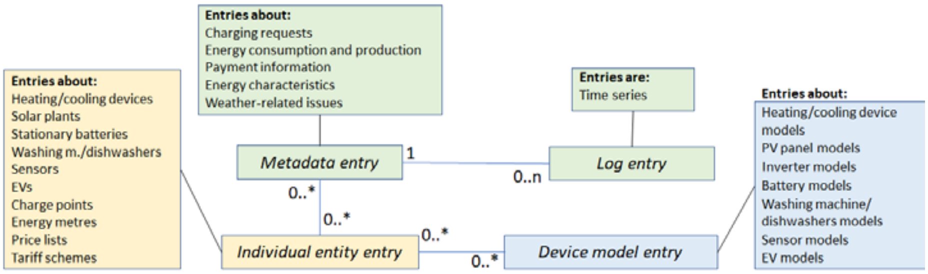

**Fig. 2.** Files with research data entries

The datasets with quantitative data are organized into the entity types in Fig. 2. Device model entries define among others EV models with properties like battery capacity, charging/discharging efficiency, maximum charging/discharging power, etc.

Individual entity entries define the physical entities involved in a demonstrator or simulation scenario - one entry for each EV, solar plant, stationary battery, etc. These will refer to their respective device model entries when this is relevant.

Metadata and log entries describe dynamic events or situations, such as charge requests, charge sessions, weather conditions, energy import/export and energy mix. A metadata entry provides overall information and refers to the individual entities involved as well as log entries that describe the situation over time by means of time series (i.e., timestamps with related values).

### 4.2 Research Data for Quantitative Analysis

Fig. 3 shows some of the classes in the research data information model. The orange classes are related to charging. The EV model class defines the properties of the EV being charged, among others the AC and DC charging efficency and the maximun power for AC and DC charging and discharging. For each charging session, a charging request defines the requested connector type, the location where charging is requested, and the charging constraints. The latter supports the charging measures in section 3.1. Earliest start and latest finish time (EST and LFT) define the booked time slot and the potential flexibility. Initial and target state-of-charge (SoC) define the energy demand. Priority can be requested, and a minimum energy content must be provided in case the energy availability is limited.

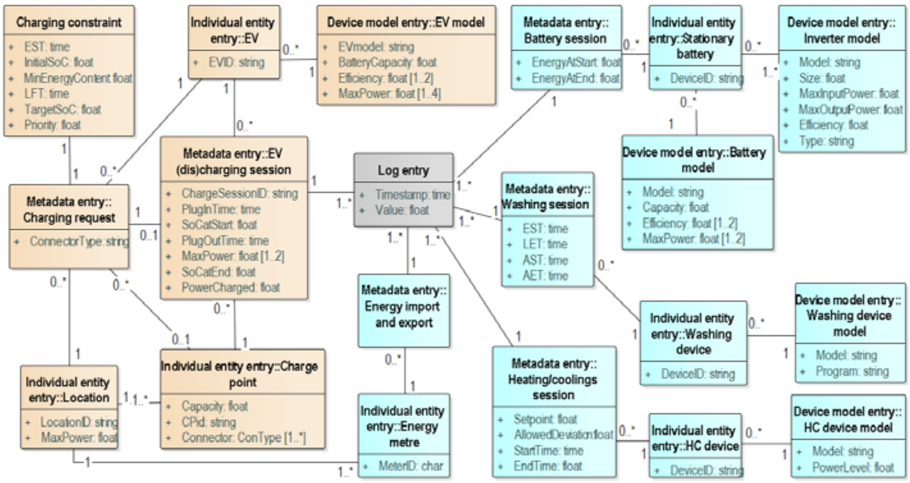

**Fig. 3.** A subset of the research data information model

An actual charging/discharging session is linked to its charging request and to a charge point (CP). The data of relevance are plug in and plug out time, SoC at start and end, the maximum power for charging/discharging, and the power charged. The accociated log entries provides the actual charging/discharging profile.

The blue classes are about other aspect affecting the load such as energy import/export, battery sessions, and other types of sessions. Metadata and log entries define the characteristics and the energy import/export/charging/discharging/use over time. Battery sessions have start and end time, and the battery model has charging/discharging efficiency and maximum power. Heating/cooling sessions also have start and end times, a setpoint and allowed deviations. Washing sessions are carried out within a timeslot defined by the EST and LFT and have actual start and end times (AST/AET). All sessions are linked to individual entities, and these are linked to the respective device models.

The research data on device models and individual entities are mainly created manually. The metadata and log entries are however established automatically by software systems (see Fig. 1). The implementation must be integrated in and followed up as a part of the software development. On-board systems in general do not provide data on EV battery's SoC (not supported by the current standards but might be so in the future). Thus, the EV user's App must collect the SoC from the user.

# 5 Calculation of Selected Indicators

In the following, we describe the calculation of two indicators – I9 Charging flexibility and I10 Peak to average ratio. These indicators are chosen since they are crucial to the understanding of the success of smart charging ecosystems. A high degree of charging flexibility facilitates load balancing, and the peak to average ratio is about the success of the load balancing. The data elements from the information model in Fig. 3 used in the calculations are listed in Table 2.

**Table 2**. Symbols used in calculations

| **Symbol** | **Description** | **Research data element (see Fig. 3)** |
|---|---|---|
| B_cap | Battery capacity | EV_model.BatteryCapacity |
| $EV_{max\_cp}$ | Max charging/discharging power for AC/DC | EV_model.MaxPower |
| $CP_{chrg\_cap}$ | Max charging/discharging power (if such a limit exists) | Charge_point.Capacity |
| $I_{soc}$ | Initial SoC | Charging_constraint.InitialSoC |
| $T_{soc}$ | Target SoC | Charging_constraint.Target_SoC |
| $Min_{ec}$ | Min. energy content the user can cope with | Charging_constraint.MinEnergyContent |
| $T_{dep}$ | Expected departure (latest finish time) | Charging_constraint.LFT |
| $T_{arv}$ | Expected arrival time (earliest start time) | Charging_constraint.EST |
| $T_{pin}$ | EV plugin time | EV_charging/discharging_session.PlugInTime |
| $T_{pout}$ | EV plugout time | EV_charging/discharging_session.PlugOutTime |

| **Symbol** | **Description** | **Symbol** | **Description** |
|---|---|---|---|
| $O_{eng}$ | Offered energy for V2G | $R_{eng}$ | Requested energy |
| $EV_{chrgp}$ | EV charging power | $A_{flexT}$ | Actual flexibility time |
| $EV_{dischrgp}$ | EV discharging power | $O_{flexT}$ | Offered flexibility time specified in the request |
| $P_{max}$ | Max power over a period T | $P_{avg}$ | Average power over a period T |

## 5.1 Charging Flexibility

A charging request specifies the charging constraints in terms of when the charging must be finalised and how much the EV must be charged. To allow for prediction-based energy optimisation, requests need to be received prior to arrival of the EVs.

EV charging is considered as flexible loads because the charging can be interrupted and the speed can be regulated, and a charge session may be spread in time as long as the charging constraints can be met. In general, the longer an EV is connected in portion to the needed time to charge to the desired energy level (depending on the energy required for charging and the charge speed), the more flexibility it provides.

If the EV is connected longer than the period specified in the request, the actual flexibility is higher than the flexibility provided by the user. If V2G is enabled, there is additional flexibility when the EV battery can be used as an energy source. Thus, there are three flexibility indicators. Each has a value within the range [0,1], where the value closer to 1 represents a better flexibility:

1. Offered flexibility: The flexibility the EV user provides with respect to when the charging can be accomplished as determined from the charging constraints.
2. Actual flexibility: The actual flexibility that the system could have utilised based on when the EVs are actually plugged in and out.
3. V2G flexibility: The flexibility the EV user is willing to provide through V2G.

The indicators are defined and calculated as following (see symbols in Table 2):

$$I_{offered\_flexibility} = 1 - \frac{R_{eng}}{EV_{chrgp}} \cdot \frac{1}{O_{flexT}} = 1 - \frac{B_{cap}(T_{soc} - I_{soc})}{EV_{chrgp}} \cdot \frac{1}{T_{dep} - T_{arv}}$$

$$I_{actual\_flexibility} = 1 - \frac{R_{eng}}{EV_{chrgp}} \cdot \frac{1}{A_{flexT}} = 1 - \frac{B_{cap}(T_{soc} - I_{soc})}{EV_{chrgp}} \cdot \frac{1}{T_{pout} - T_{pin}}$$

$$I_{V2G\_flexibility} = 1 - \frac{O_{eng}}{EV_{dischrgp}} \cdot \frac{1}{O_{flexT}} = 1 - \frac{B_{cap}(1 - Min_{ec})}{EV_{dischrgp}} \cdot \frac{1}{T_{dep} - T_{arv}}$$

where

$$EV_{chrgp} = \min(EV_{\max\_cp}, CP_{\mathrm{chrg\_cap}}),$$

$$EV_{dischrgp} = \min(EV_{\max\_cp}, CP_{\mathrm{chrg\_cap}})$$

### 5.2 Peak to Average Ratio

The peak to average ratio (PAR) indicator is meant to determine how flat the load curve is. It can be calculated as $P_{max}/P_{avg}$ (see Table 2) within a time period T, assuming: i) there are multiple power samples within this period; ii) all of them greater or equal to 0 (only one direction for electricity flow is considered, i.e.: consumption); and iii) PAR is 1 if $P_{max}$ equals 0. The minimum value for this ratio is 1, and it indicates the power in the installation or subsystem is constant, while bigger values indicate the power occasionally reaches high values and the rest of the time is much lower. It may be calculated for a CP, a charging infrastructure, a sub-network in the ESN or the feed-in line supplying the ESN. An objective of the ESN system is to keep it as close to 1 as possible to make the most use of the physical or logical (by contract) power capacity in the infrastructure.

## 6 Scenarios to be Evaluated

Scenarios are defined to investigate how the technology would work. Aspects such as charge planning and booking, charging in different types of neighbourhoods, and V2G are addressed in real life demonstrations and simulations.

### 6.1 Demonstrations and Simulations

Scenarios are adapted to local needs and contexts and implemented in real life ESN demos in Barcelona, Bremen, and Oslo by means of the measures in section 3. The demos address, among others, home charging in a housing cooperative with a common garage, charge at work for office buildings, and the sharing of CPs. Measures for smart energy management like optimal and coordinated use of energy, local RES, and stationary battery storage are combined with measures for charging to study the effects on the energy demand. EVs that are connected over a longer period, typically overnight or the whole working day, may offer flexible charging but may also request priority charging. The combination of shared CPs and booking of CPs may give predictable charging, but the frequency of blockings must be investigated.

In line with Lervåg [7], the traditional impact evaluation of the demos have shortcomings. Implemented instances of the measures are rather few and in small scale due to budgetary constraints and the limited duration of the project. To overcome these constraints and broaden the basis for the evaluation of future scenarios with much higher density of EVs than we see today, we apply simulations. Based on the collected data we can simulate the impact of the GreenCharge concept in a more diverse set of scenarios, both with respect to size of the ESN and diversity and dimensioning of included measures.

Three scenarios proposed for simulation corresponds to the implemented demos and may provide interesting feedback to demo owners about how the installations will behave in possible future scenarios. Other artificial scenarios are created by combining and/or replicating elements from the demonstrators and representing ESNs of varying size, complexity, and context, closer to the project vision than the implemented ones, and thus allowing to investigate the impact of more full-fledged deployment of the GreenCharge concept.

For each scenario we will run simulations varying systematically one characteristic of the scenario at a time and computing the indicators. In this way we will investigate to which extent and in which way the varying characteristics impact the indicators. The varying characteristics are listed in Table 4. Mostly they correspond to the presence and dimensioning of the measures implemented in the demonstrators. The dimensioning in some cases corresponds to the indicator framework in Table 1.

**Table 3.** Varying characteristics

| **Varying characteristic** | **Variation** |
|---|---|
| Local energy management | Optimisation method (centralised or distributed) and optimisation criteria (minimise energy cost or maximise energy greenness) |
| Number of EVs | EV penetration (e.g., 25%, 50%, … 100%) |
| Local RES | Percentage of total consumption, e.g., 0.25, 0.5, … |
| Stationary battery storage | Capacity as % of total consumption |
| Grid connection capacity | % of average consumption |
| Internal transfer capacity | With and without constraints, gradual removal of bottlenecks |
| Price model for the calculation and sharing of energy cost | E.g., energy only or mixed energy/power, fixed or Time of Use (ToU) or spot |
| Share of booking | Depends on available data |
| Share of battery capacity for V2G | Select EVs arbitrarily. Share of capacity drawn from distribution. |

## 6.2 Example on Use of Indicators

To demonstrate the impact of charge flexibility on loads, we use research data from the CoSSMic research project [10] and present three examples with charging at a charge station with a maximum capacity of 6 kW. The distribution of power among the CPs is controlled, and the charging of EVs is started and stopped accordingly.

Table 4 lists the indicators used. Each EV will request an amount of energy ($E_{req}$) and can charge at a maximum speed $P_{chg}$. Based on the optimisation of the charge station, each EV will get an amount of energy delivered ($E_{del}$). Assuming the EV charging constraints given in the charge requests correspond to the actual connection periods, the Energy Management Systems can charge the EVs from the arrival time ($T_{arv}$) to the departure time ($T_{dep}$). The actual time of charge completion ($T_{chc}$) depends on the optimisation policy.

The baseline example in Fig. 4a) includes a washing machine starting at 10:00, a dishwasher starting at 15:00, a freezer continuously running, and three EVs plugged in at 7:00, 10:00 and 9:30. The energy demand is in total 29.4 kWh. Fig. 4b) shows the time-series of the total demanded power. With no charging flexibility, the peak to average ratio (PAR) is 7.62, as $P_{max}$ equals 9.34 kW, and $P_{avg}$ is 1.2 kW. With a power limitation of 6 kW, the total power consumption exceeds the threshold from 10:00 to 12:12. In this interval, 3.4kWh cannot be delivered to charge the EVs.

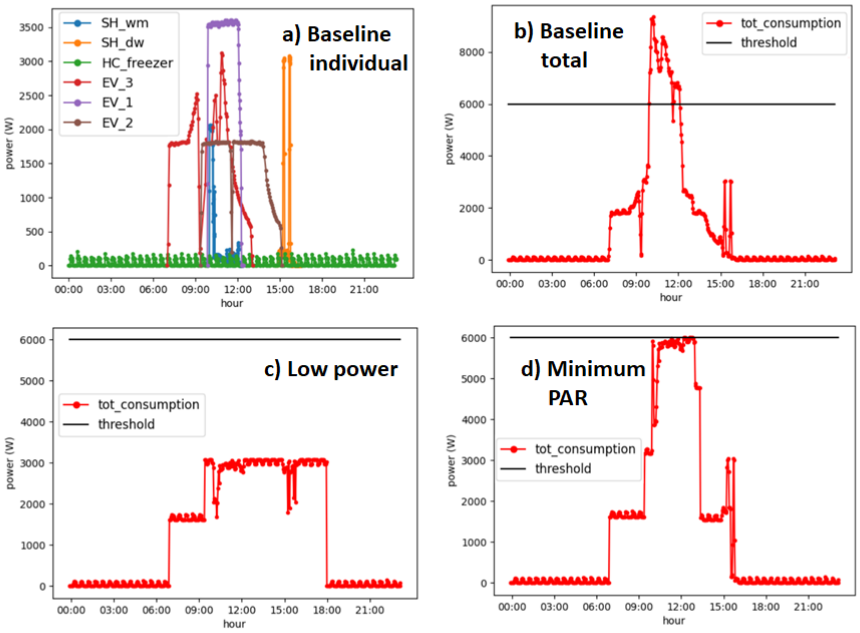

**Fig. 4.** Time-series examples – baseline, low power, minimum PAR

If the users driving the EVs will leave at 19:00, the charging flexibility can be exploited to reduce the peak demand. In Fig. 4c) and d), the optimisation aims to keep the power peak below 6kW, and to minimise the PAR, giving priority to the EVs that arrived earlier and satisfying all energy demands.

**Table 4.** Indicators for example scenario

| **EV** | **$P_{chg}$ kW** | **$E_{req}$ kWh** | **$T_{arv}$** | **Baseline** | | **Low Power** | | **Min PAR** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **$T_{chc}$** | **Flex** | **$T_{chc}$** | **Flex** | **$T_{chc}$** | **Flex** |
| EV1 | 3.6 | 8.2 | 07:00 | 12:33 | 0 | 13:30 | 0.86 | 18:05 | 0.86 |
| EV2 | 1.8 | 10 | 09:30 | 15:18 | 0 | 15:37 | 0.69 | 16:37 | 0.69 |
| EV3 | 3.1 | 9.8 | 10:00 | 13:13 | 0 | 13:05 | 0.68 | 13:20 | 0.68 |
| $SUM_{req\ eng}$ (kWh) | | | | 29.4 | | 29.4 | | 29.4 | |
| $SUM_{del\ eng}$ (kWh) | | | | 26 | | 29.4 | | 29.4 | |
| PAR | | | | 7.62 | | 5 | | 2.5 | |
| Charging Flexibility | | | | 0 | | 0.53 | | 0.53 | |

## 7 Conclusion and Further Work

This paper presents a method for evaluation of measures in a smart charging ecosystem. The measures, the indicator framework, the research data needed, and examples for indicator calculations have been described. The approach is hybrid, targeting both real life demos and simulation scenarios. Thus, we can also investigate scale ups and varying factors that could not be realised in real life due to limited demo size, capabilities and complexity, time, and budget. The approach covers a variety of aspects of relevance to cross sectorial smart charging ecosystems, as defined by the GreenCharge concept.

Further work is to be done in GreenCharge project regarding analysis of economic measures and its impact in the charging and smart energy management results. Among these measures, the impact of rewarding and penalising certain behaviours, such as incentivising charging flexibility or assigning penalties to users blocking booked CPs after expected departure time, will be investigated.

The evaluation process in the GreenCharge has already started by collecting research data from the demos, a process that will last about seven months. Baseline data will be further complemented through simulations, by disabling the smart energy management features.

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