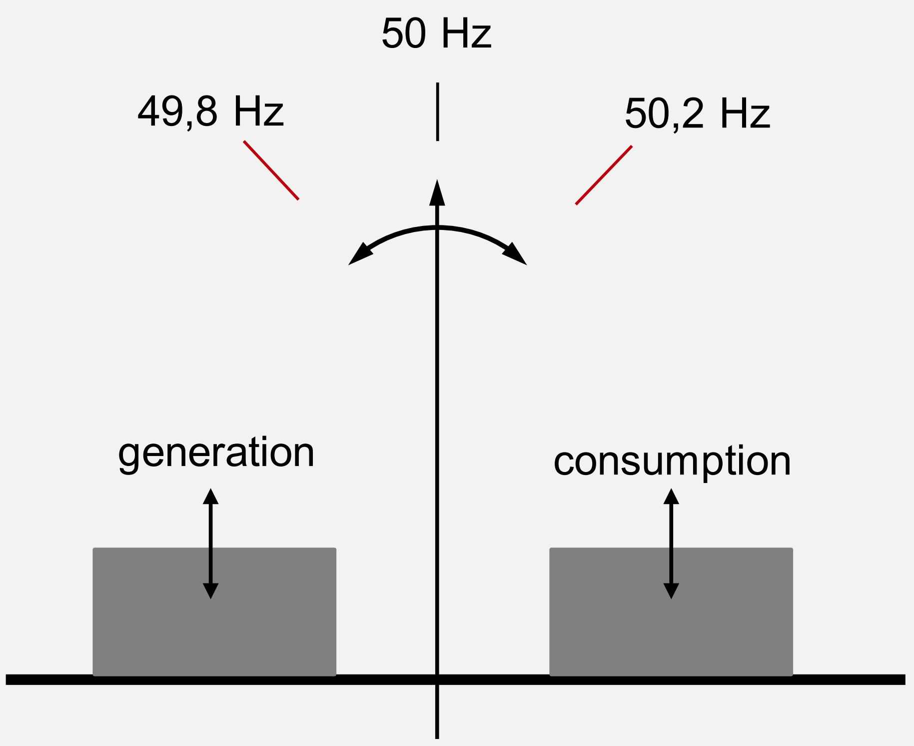


Technology
Arts Sciences
TH Köln

eman ta zabal zazu
Universidad del País Vasco
Euskal Herriko Unibertsitatea

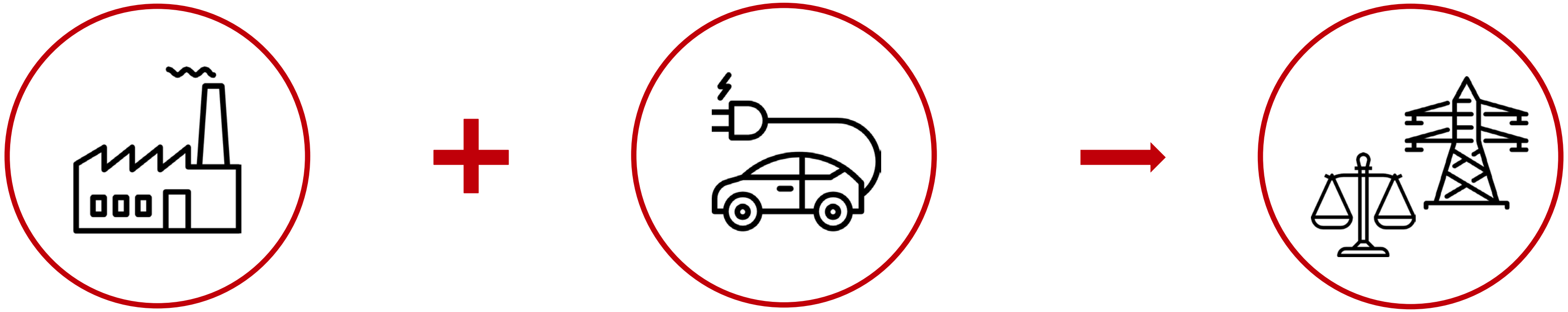
Integration of private electric vehicles into the balancing power market in the case of Germany

Master Thesis presentation Lea Kern

Table of contents

Introduction

Current development of the energy landscape in Germany



Decreasing number of fossil power pants

Increasing number of EVs

Potential of integrating EVs into ancillary services

[1, 2]

Introduction

Research Question

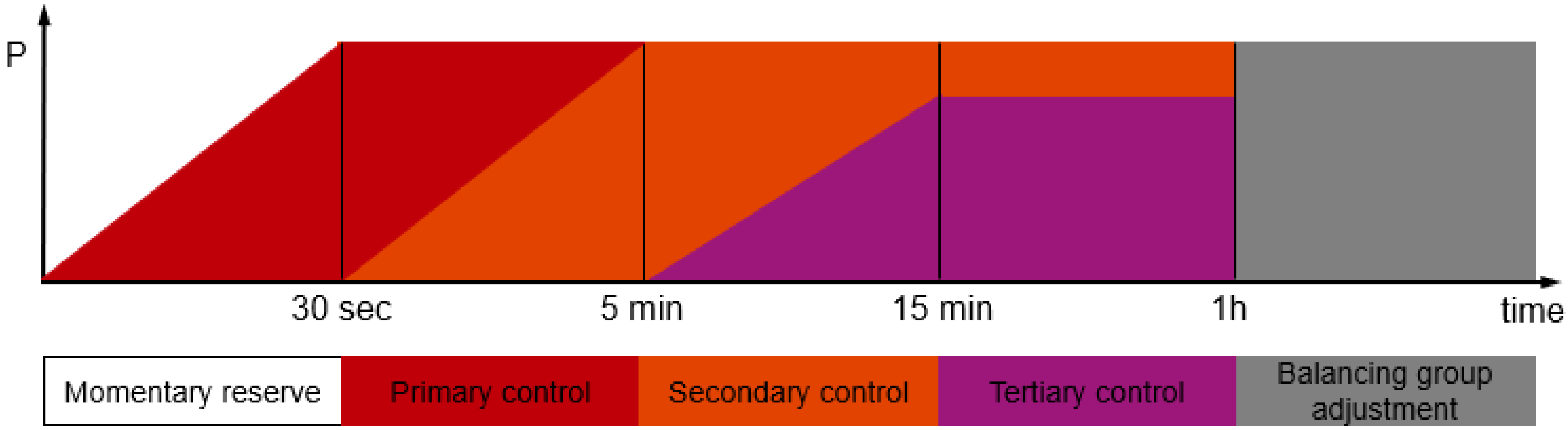
To what extent can private electric vehicles in Germany be used for the provision of Frequency Control Reserve (FCR)?

- To what extent is the implementation technically feasible in Germany at present and in the future?
- How economical is the implementation currently and in the future regarding the market design?
- What are the current legal and regulatory framework conditions, and which are necessary to provide FCR by private EVs in Germany?

Background

Frequency Control Reserve

- Balancing power: ancillary service to keep the balance in the grid at a frequency of 50Hz
- Currently: mostly hydropower and fossil generation plants
- Three different types of balancing power:

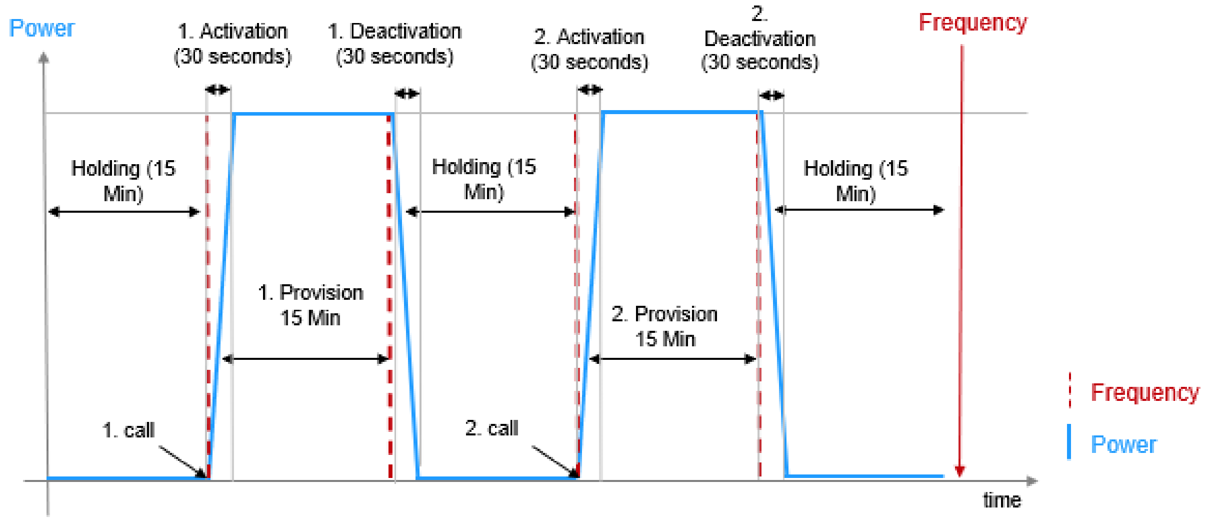


Schematic sequence of different types of balancing power [3].

[1, 2, 3]

Background
Market requirements and prequalification

- Daily bidding on a joint European Platform
- Daily tenders with 6x4 Time Slices
- Symmetrical offer
- “Pay-as-cleared” principle
- Prequalification at the TSO
- Limited storage systems have to provide 25% buffer of their offered power



Schedule to demonstrate the usable work capacity of a battery storage system to prequalify for providing FCR [4].

[4, 5]

Background
Stand of the art and research

Literature Review

- Several studies in the last years in the whole world
- Studies in recent years and in Europe particularly relevant for this work
- Several studies but with different results due to different framework conditions

→ FCR in Germany not studied for private EVs from different households

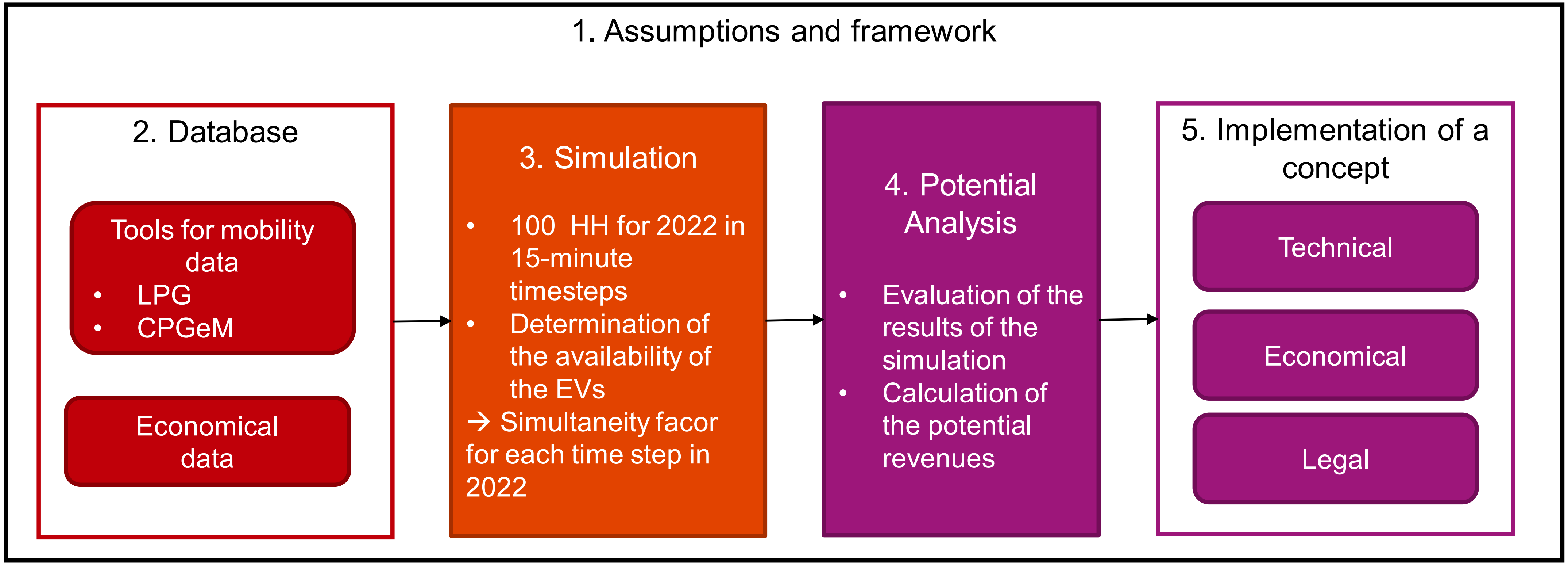
Pilot Projects

- Several projects with different TSO and manufacturer in Germany the last years
- Mostly with components, which are not yet publicly available in Germany
- Prequalification for FCR was successful

→ Technically possible, but mainly on a pilot scale

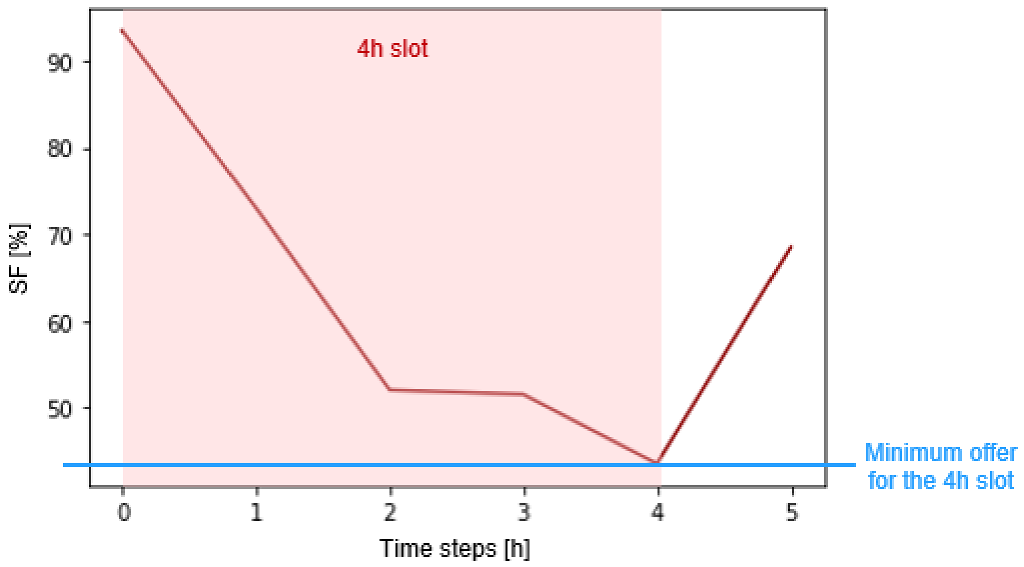
Methodology

Structure and approach



Methodology
Assumptions and framework

- Aggregator with a pool of vehicles under contract
- Communication and control of the vehicle, access when EV owner allows the use
- Minimal provision of 1.25 MW
- The aim is to offer the capacity with as few EVs as possible to increase the average payment per EV
- The minimum available capacity during each 4-hour time slice then determines the capacity that the aggregator can offer to the TSO as a reserve

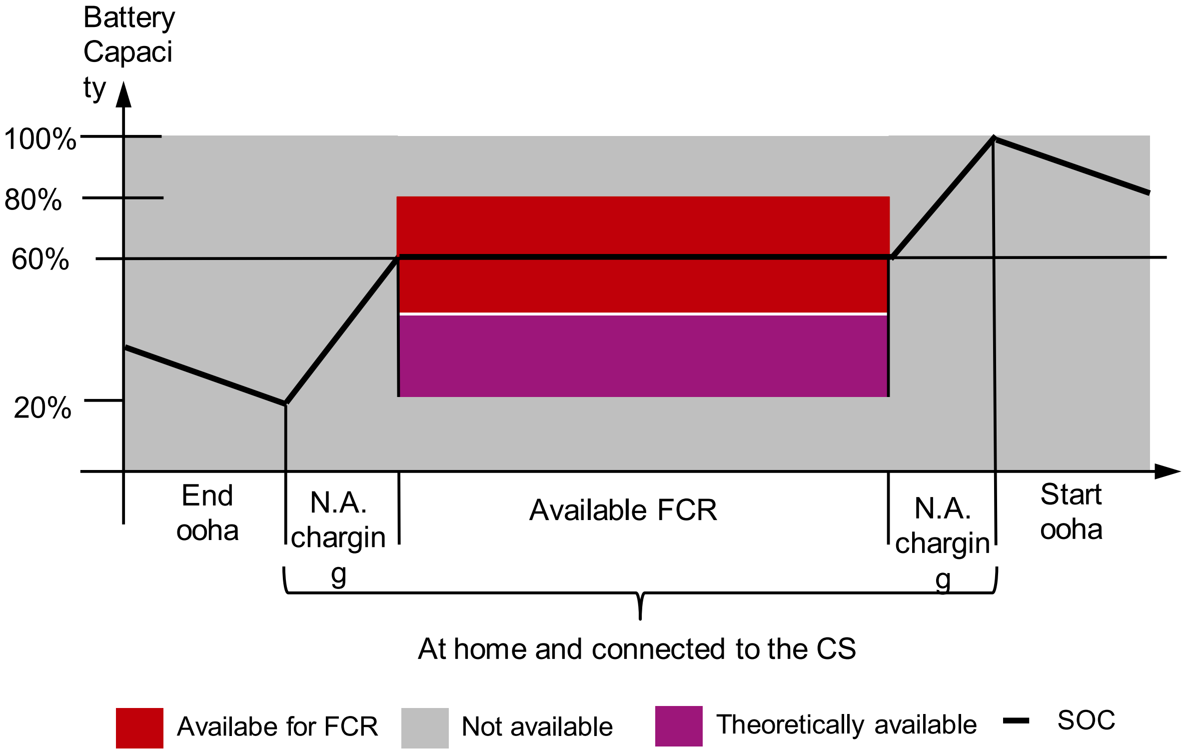


Presentation of the principle that the minimum availability determines the total availability for each 4h time slot [7].

[4,6]

Methodology
Assumptions and framework

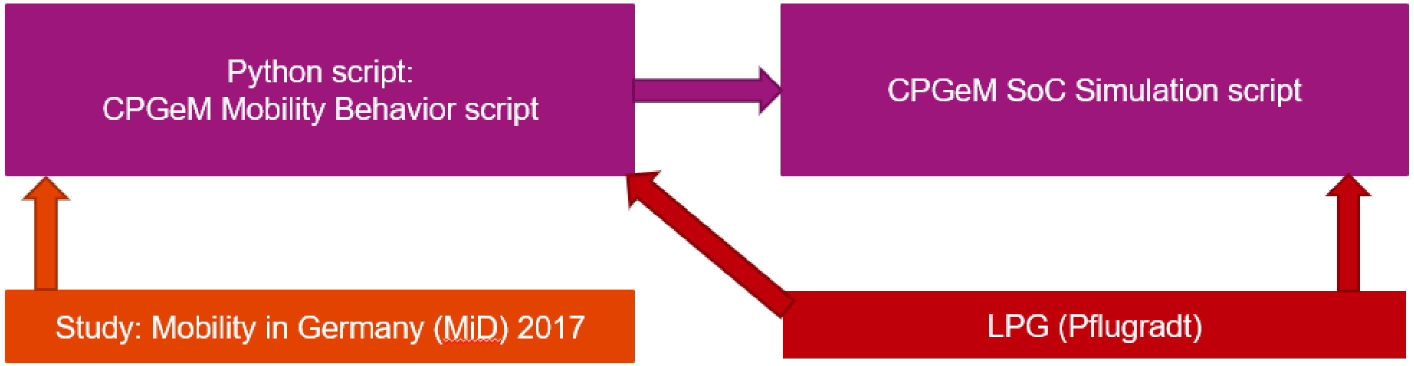
- Non-urban, village areas
- 11 kW bidirectional charging and discharging power
- 60 kWh capacity per EV
- Implementation of a charging Pattern
- charging power is limiting factor



Schematic representation of the charging pattern from arrival at home, through charging, provision of FCR and departure [8].

Methodology
Database

- Load Profile Generator by Pflugradt and Charge Profile Generator for e-Mobility by Sprünken are used
- Modification of the CPGeM, Charging only up to 60% SOC , generating new output files

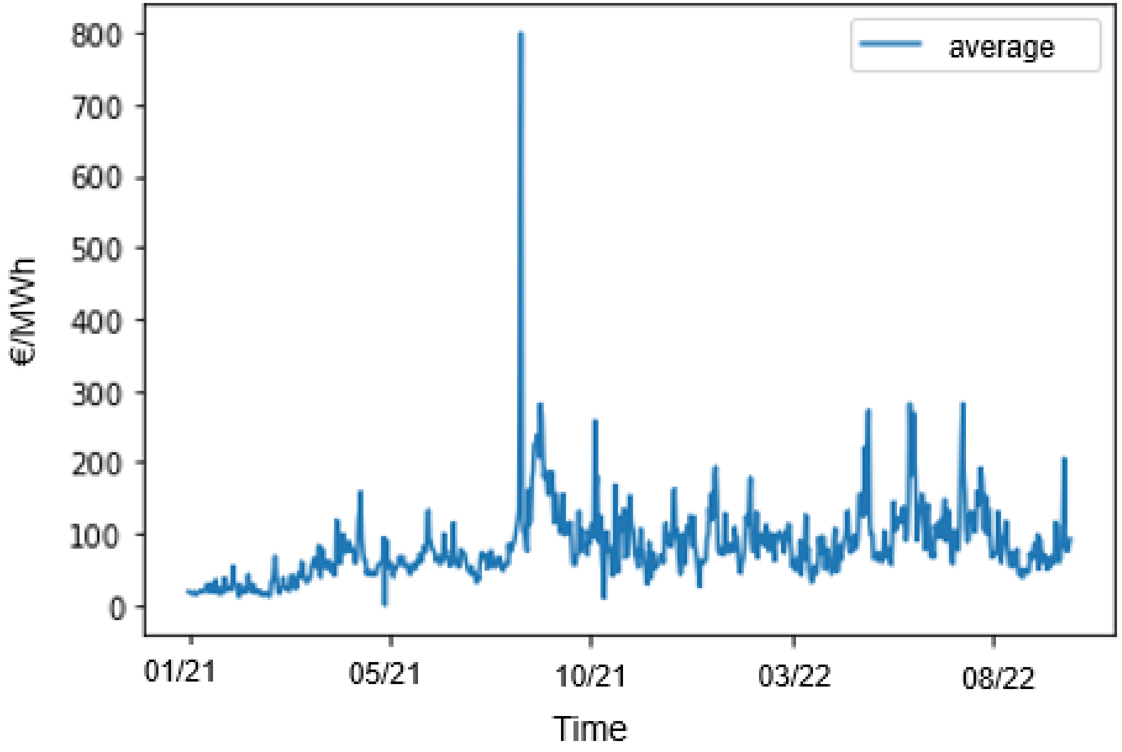


Overview of the CPGeM: Connection between CPGeM Mobility Bevavior, CPGeM SoC Simulation, MiD 2017 and LPG [10].

[9, 10]

Methodology
Database

- Economical data for the simulation to calculate the theoretical revenues is based on historical market prices
- TSO publishes the results on its tender platform *regelleistung.net*
- Use of the results of the tenders for FCR in Germany in 2022 for each 4-hour time slot.

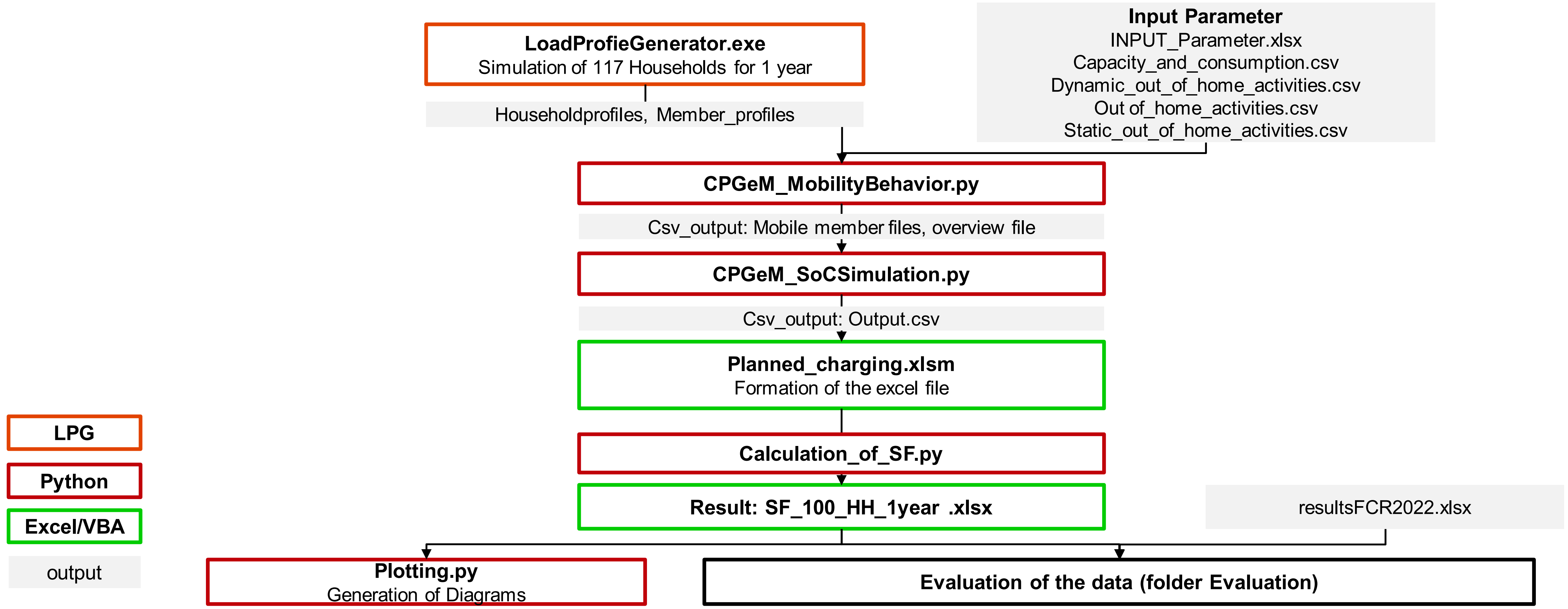


Average value of the results of the tenders for FCR in Germany in 2021 and 2022 [12].

[11]

Methodology

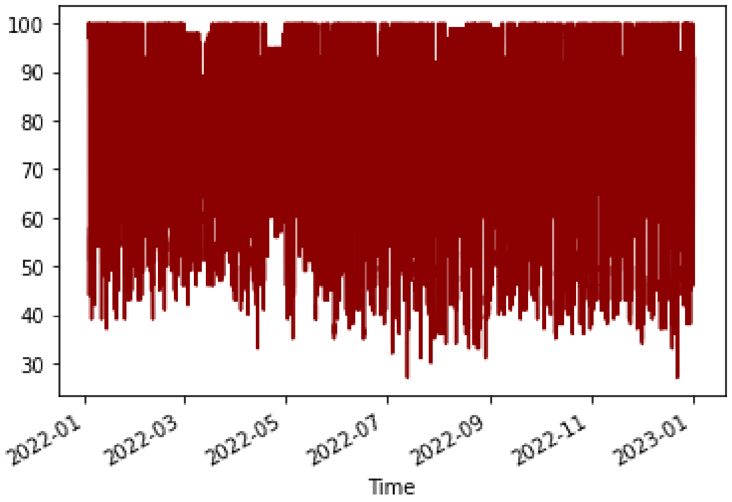
Overview of the Simulation



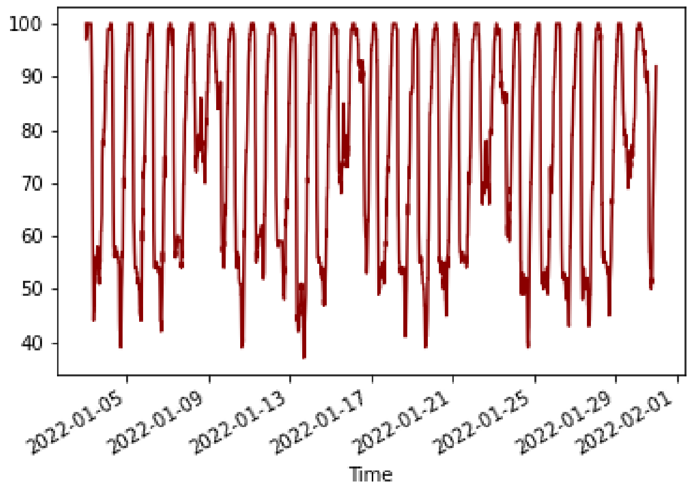
Results

Simultaneity factor for 1 year, month, week in 15-Minutes resolution

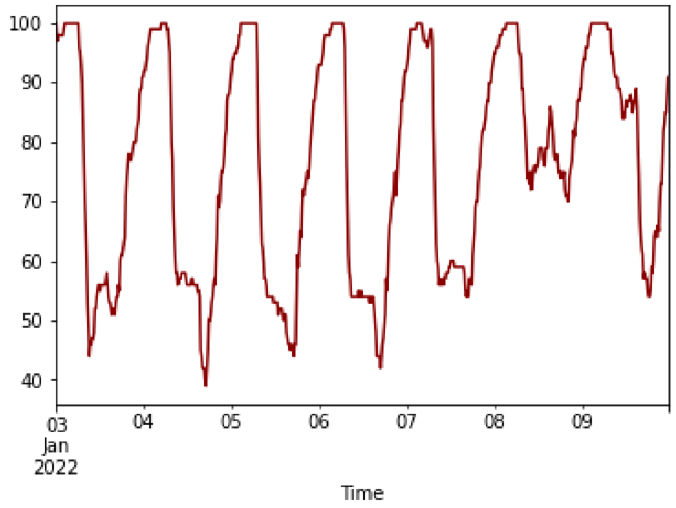
- Fluctuating simultaneity factor over time
- Difference between weekend and weekdays
- Difference between day and night



100 HH – 1 year



100 HH – 1 month

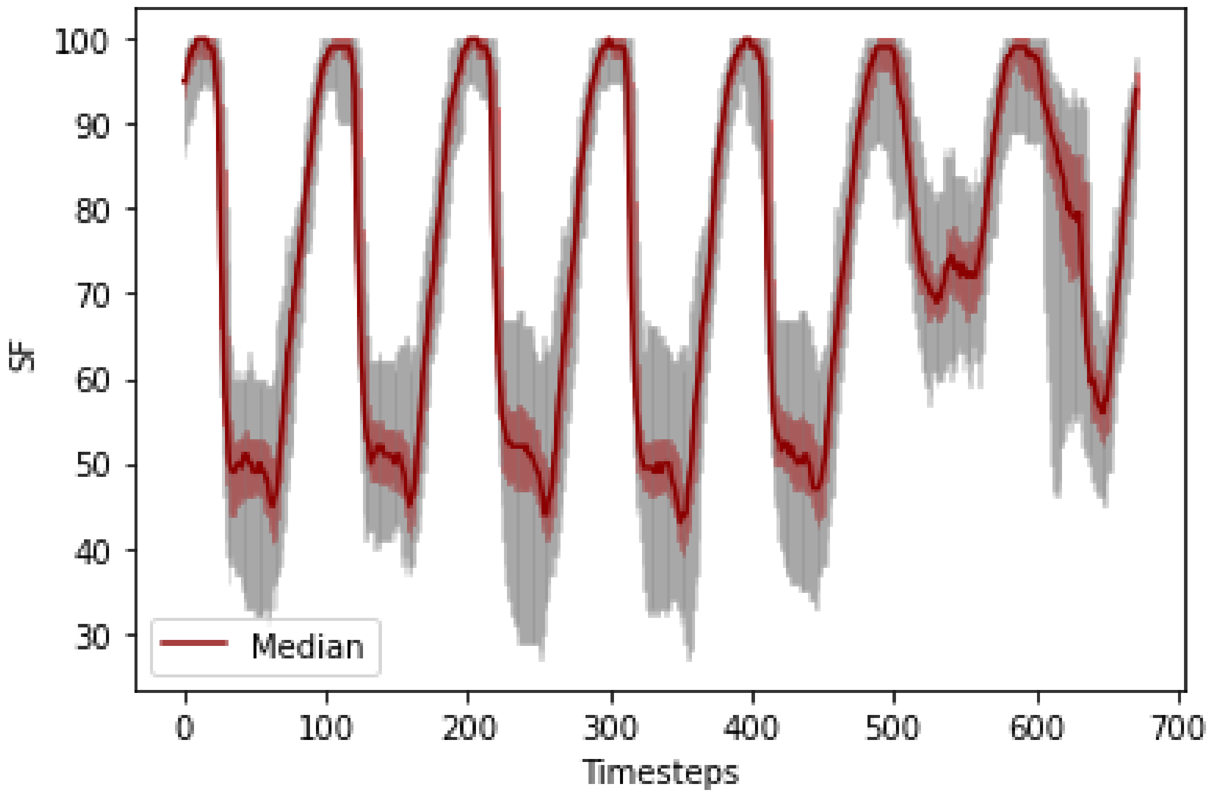


100 HH – 1 day

Results

Distribution and uncertainties

- Fluctuating availability throughout the year
- Median during the weekdays: around 50%
- Median during the weekends between 55 and 75%
- Median during the night: around 95%
- Higher uncertainty during the days compared to the nights



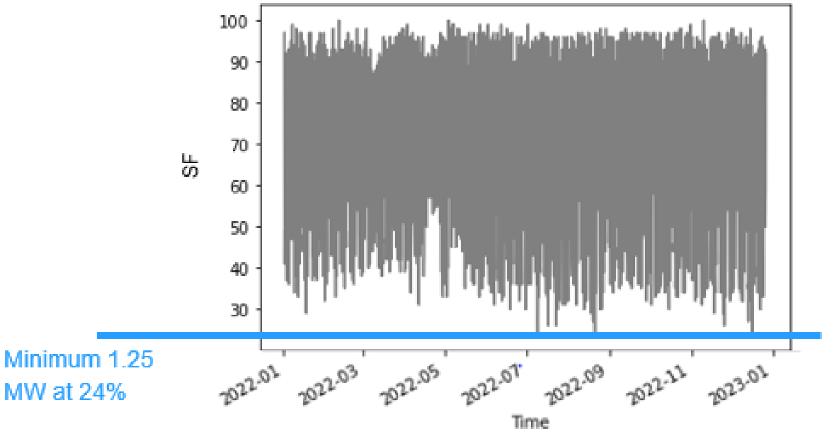
365 days of the year 2022 represented over a period of one week

Results

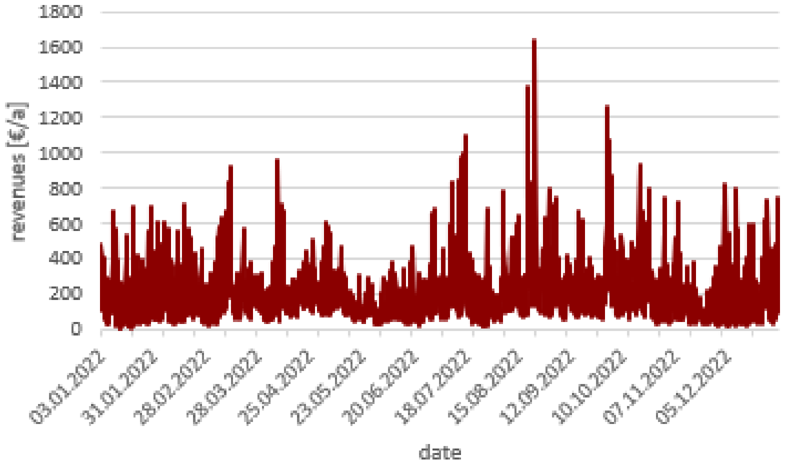
Minimum number of EVs required to provide FCR for one year

- Calculation, how many vehicles are required in a tool to reliably provide the minimum offer size of 1.25 MW
- 521 EVs required, including a 10% buffer

- Creation of a theoretical pool with 500 EVs by extrapolating the simulated 100 EVs.
- Around 900 € per EV could be achieved, assuming fair distribution on all EVs.



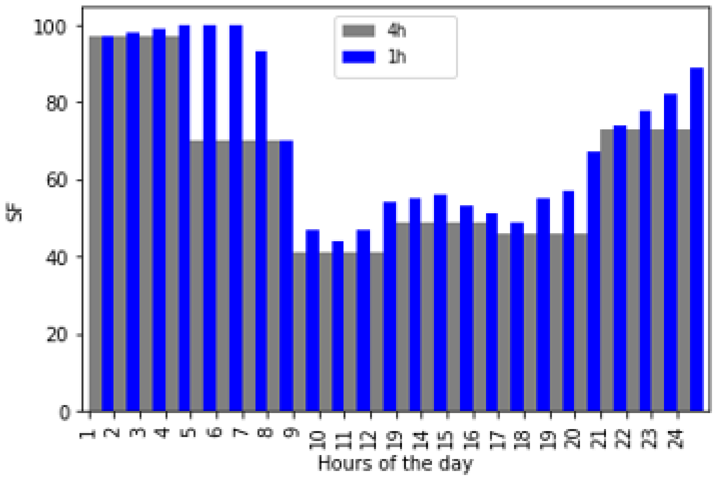
Minimum SF in the year 2022



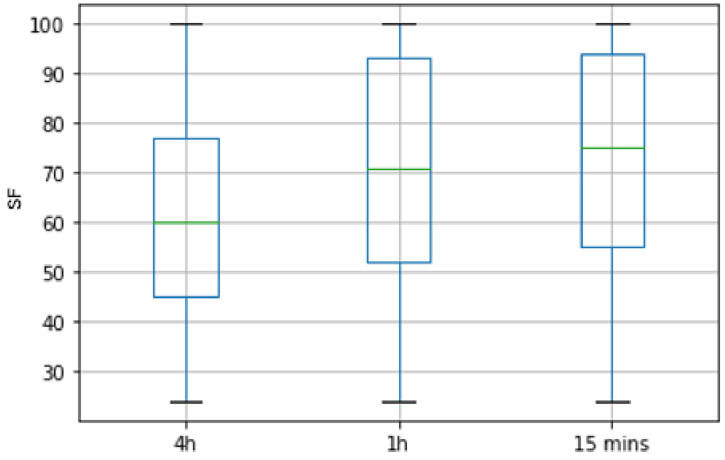
Theoretical revenues in 2022 for 500 EVs

Results
Analysis of the time slices

- Improvement of the average simultaneity factor and therefore the economic benefits through reduction of the time slices
- Minimum of 1h determines the minimum of 4h blocks
- Median increases from 60% (4h) to 71% (1h) to 73% (15mins)
- Revenues per EV per year can be increased to 1089 € (1h) and 1140 € (15 mins)



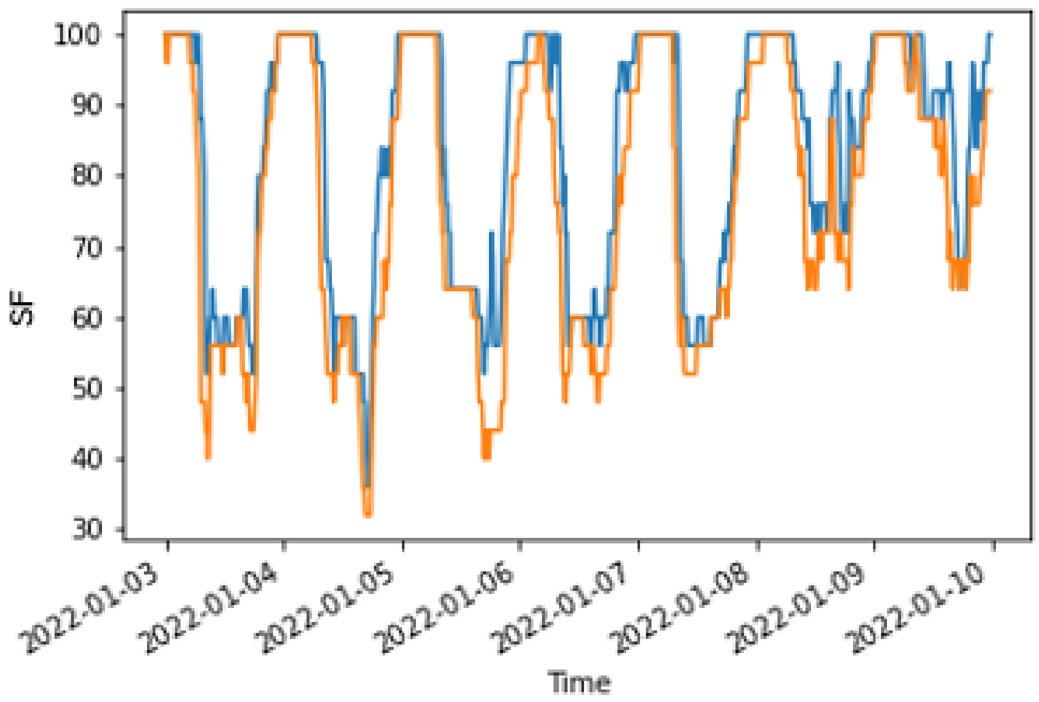
Influence of the reduction of time slices from 4h to 1h.



Boxplot of the different time slices

Results
Impact of the charging pattern

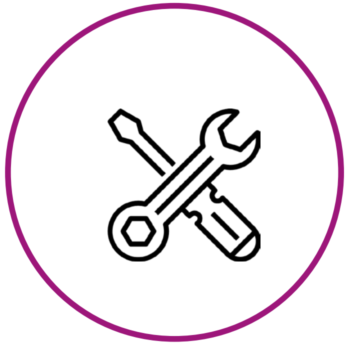
- Optimizing availability by changing the charging pattern.
- Previously, the EV could not be used for FCR when it was charging
- Now, intelligent charging allows this time to be used as well
- Improvement of availability
- Improvement of the average SF by 9%.



Influence of implementing an intelligent charging pattern

Results

Concept for implementation



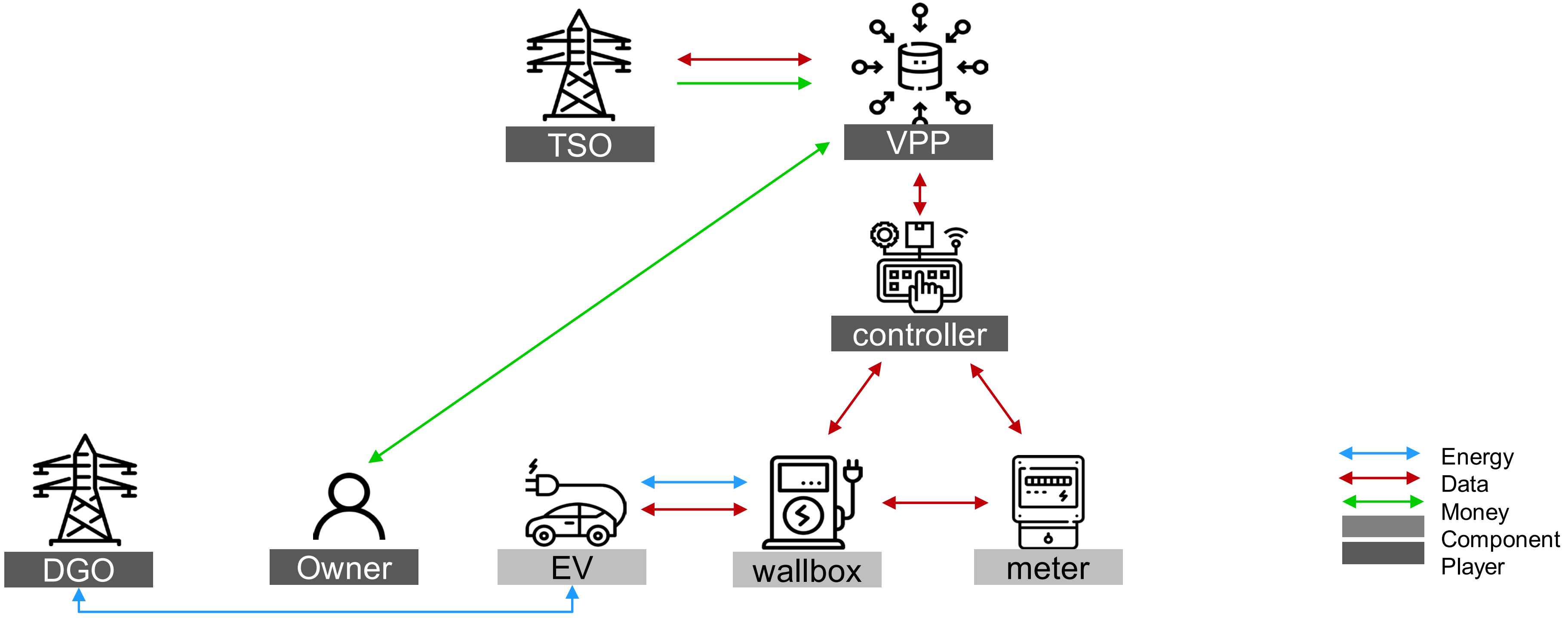
technical

economical

legal

Results

Concept for implementation



Overview of a concept for the implementation with consideration of technical components and players, payment flows and framework conditions.

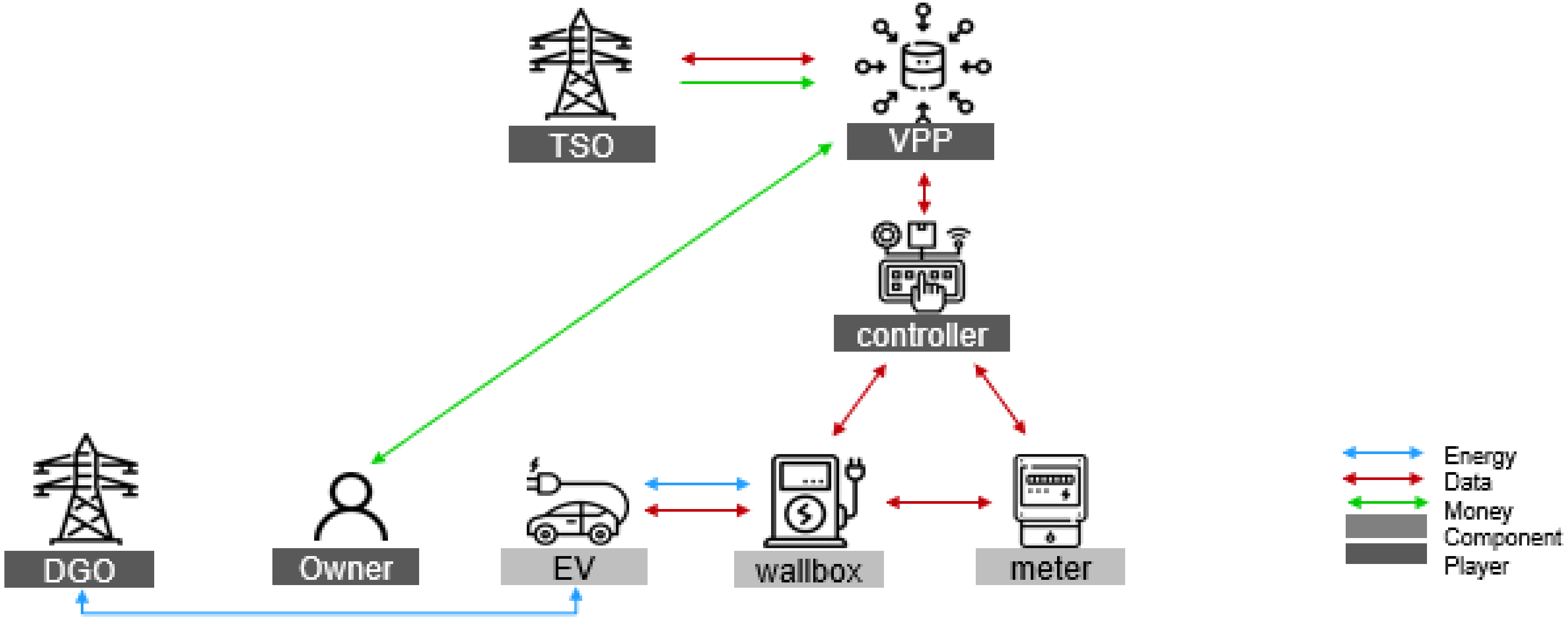
Results

Concept for implementation – technical

- Pilot projects have shown that provision of FCR through EVs is technically feasible
- Necessary technical components are available, and prequalification was successful in test cases
- Simulation confirms and expands literature results: a pool of 521 EVs was theoretically able to provide at least 1 MW throughout 2022
- SOC identified as a critical factor for offering (symmetrical) FCR
- Optimization of the potential by extending the connection time (e.g., also at work) or larger batteries
- Challenge: Requirement, that the pool can't be changed for 15 minutes
- Opportunity: connectivity with home storage systems
- Widespread deployment of bidirectional charging equipment and ensuring that the needs of EV owners and VPPs are met, are the most important prerequisites

Results

Concept for implementation – economical



Overview of a concept for the implementation with consideration of technical components and players, payment flows and framework conditions.

Results

Concept for implementation – legal

- Several legal and regulatory hurdles for V2G, which is necessary for EVs providing FCR
- Implementation of smart metering systems is crucial for effective integration of flexible consumers and generators into the grid → slow rollout so far
- Unequal treatment of stationary and mobile storage in energy apportionments, taxes and levies → economic disadvantage for mobile storage and challenge for EVs
- Current prequalification process is not well suited for EVs
- Federal government is working on the issue and wants to improve the prequisites for V2G

Conclusion

To what extent can private electric vehicles in Germany be used for the provision of Frequency control reserve (FCR)?

- Technically possible and already implemented in pilot projects, components available but not yet available for private individuals
- In the simulation, revenues of 900€ per EV were possible in 2022. Revenues depend on the development of the energy market and prequalification criteria.
- V2G, which is relevant for EVs providing FCR is still facing obstacles in Germany. It is likely that these will be resolved within the next years.

Sources

[1] Webseite der Bundesregierung, *Mehr Energie aus erneuerbaren Quellen.* [Online]. Available: https://www.bundesregierung.de/breg-de/themen/klimaschutz/energiewende-beschleunigen-2040310 (accessed: Feb. 15 2023).

[2] Webseite der Bundesregierung | Startseite, *Mehr E-Mobilität.* [Online]. Available: https://www.bundesregierung.de/breg-de/themen/klimaschutz/eenergie-und-mobilitaet/nachhaltige-mobilitaet-2044132 (accessed: Feb. 15 2023).

[3] K. F. Schäfer, *Systemführung: Betrieb elektrischer Energieübertragungsnetze*. Wiesbaden, Heidelberg: Springer Vieweg, 2022. Accessed: Oct. 12 2022,p.163. [Online]. Available: https://link.springer.com/content/pdf/10.1007/978-3-658-36199-0.pdf

[4] Präqualifikationsportal, *Prequalification Process for Balancing Service Providers (FCR, aFRR, mFRR) in Germany.* [Online]. Available: https://www.regelleistung.net/ext/download/PQ_Bedingungen_FCR_aFRR_mFRR_2022_en (accessed: Feb. 10 2023).

[5] Forschungsprojekt Bidirektionales Lademanagement, “Bereitstellung von Systemdienstleistungen aus Elektrofahrzeugen mit bidirektionalem Lademanagement Ein BDL-Positionspapier zu Vehicle-to-Grid-Anwendungen,” 2022. Accessed: Feb. 15 2023. [Online]. Available: https://www.ffe.de/veroeffentlichungen/positionspapier-zur-bereitstellung-von-systemdienstleistungen-aus-elektrofahrzeugen-mit-bidirektionalem-lademanagement/

[6] Tilman Huhne, Julian Schultheiß, Magnus Wobben, Patrick Wörner, and Oliver Wohak, “Optimale Erbringung von Systemdienstleistungen mittels Vehicle-to-Grid,” (in German), ET. Energiewirtschaftliche Tagesfragen, vol. 70, no. 10, pp. 59–62, 2020. [Online]. Available: https://www.researchgate.net/publication/346016926_Optimale_Erbringung_von_Systemdienstleistungen_mittels_Vehicle-to-Grid

Sources

[7] J. Jargstorf and M. Wickert, “Offer of secondary reserve with a pool of electric vehicles on the German market,” Energy Policy, vol. 62, pp. 185–195, 2013, doi: 10.1016/j.enpol.2013.06.088.

[8] J. Figgener et al., “The influence of frequency containment reserve flexibilization on the economics of electric vehicle fleet operation,” Journal of Energy Storage, vol. 53, p. 105138, 2022, doi: 10.1016/j.est.2022.105138.

[9] Dr. Noah Pflugradt, LoadProfileGenerator. [Online]. Available: https://www.loadprofilegenerator.de/ (accessed: Feb. 9 2023).

[10] Sprünken Marian, “Erzeugung synthetischer Ladeprofile für Elektrofahrzeuge synchron zu synthetischen Haushaltsprofilen,” (in German), vol. 2022. [Online]. Available: http://www.100pro-erneuerbare.com/publikationen/2022-01-Spruenken-Ladeprofilgenerator/Spruenken-Ladeprofile_fuer_Elektrofahrzeuge-MA2022.pdf

[11] consentec GmbH, “Beschreibung von Konzepten des Systemausgleichs und der Regelreservemärkte in Deutschland: Erläuterungsdokument im Rahmen der deutschen Übertragungsnetzbetreiber,” Aachen, 2022. [Online]. Available: https://www.regelleistung.net/ext/download/MARKTBESCHREIBUNG_CONS

[12] regelleistung.net, Datacenter FCR/aFRR/mFRR. [Online]. Available: https://www.regelleistung.net/apps/datacenter/tenders/?productTypes=PRL&markets=BALANCING_CAPACITY,BALANCING_ENERGY&date=2023-02-15&tenderTab=PRL$CAPACITY$1 (accessed: Feb. 15 2023).