Integrating scheduling and control in an EV charging hub

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Electric Vehicle demand patterns

- EV charging demand patterns for residential areas, working locations and public charging points
- Agent-based approach that describes the charging probability of an EV based on its state-of-charge

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USING MOBILITY DATA AND AGENT-BASED MODELS TO GENERATE FUTURE E-MOBILITY CHARGING DEMAND PATTERNS

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https://ieeexplore.ieee.org/document/9841830

https://github.com/nijenhuisb/evcdgen

Today

- Introduction
- EV Charging Hub
- ENergy SCHEDuler
- User Interface
- System overview
- Demo of operation @ Living Lab

Introduction

- Energy and mobility transitions lead to challenges for the electricity grid
- Uncontrolled charging of EVs leads to grid congestion problems (but not only EVs..)
- Symbiosis between mobility (electric vehicles with users) and electricity (grid/market) system
- What is an EV Charging Hub and why do we need it?


University of Twente
9 chargepoints (11 kW)
27 kWp solar carport
30 kWh battery storage
3x125 A grid connection


Rijssen
24 chargepoints (22 kW)
74 kWp solar carport
3x630 A grid connection

EV Charging Hub

- Combines energy production, consumption, storage and a limited grid connection into one integral system *to approach better solutions*
  - Reduce grid congestion
  - Better use of (locally produced) renewable energy
  - Lower operational costs
  - Enhance end-user comfort

- Problem: this can only happen if we apply a form of control
- We need a system/concept/approach to *manage* this, *automagically*

Energy Management System: ENergySCHEDuler

(1) **Scheduler** to create *operational schedules* for all connected devices

(2) **Real-Time Control** to compensate for forecast errors, unexpected behavior, imbalance

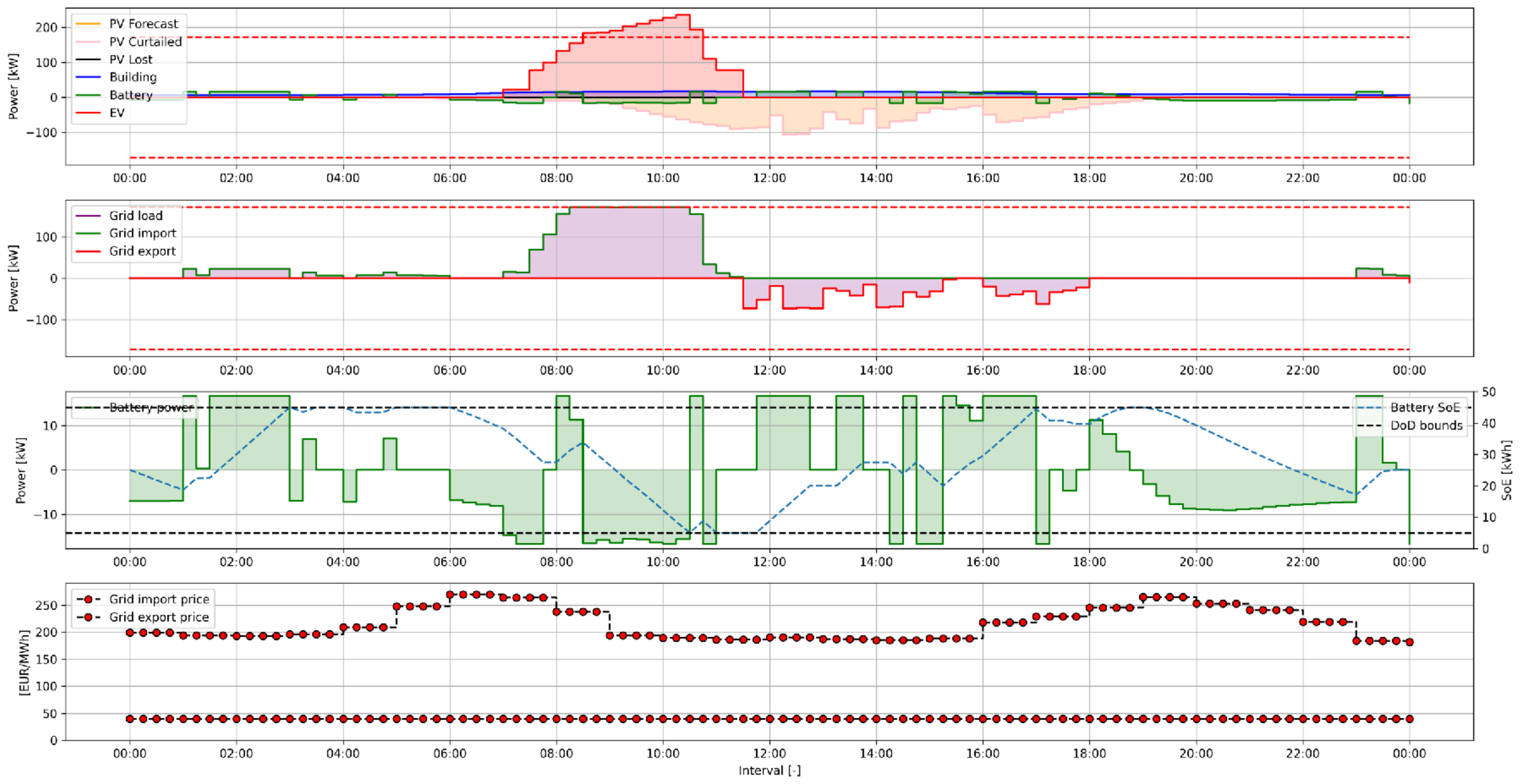
(3) **Interaction** with external systems (users, data, devices)

Scheduler

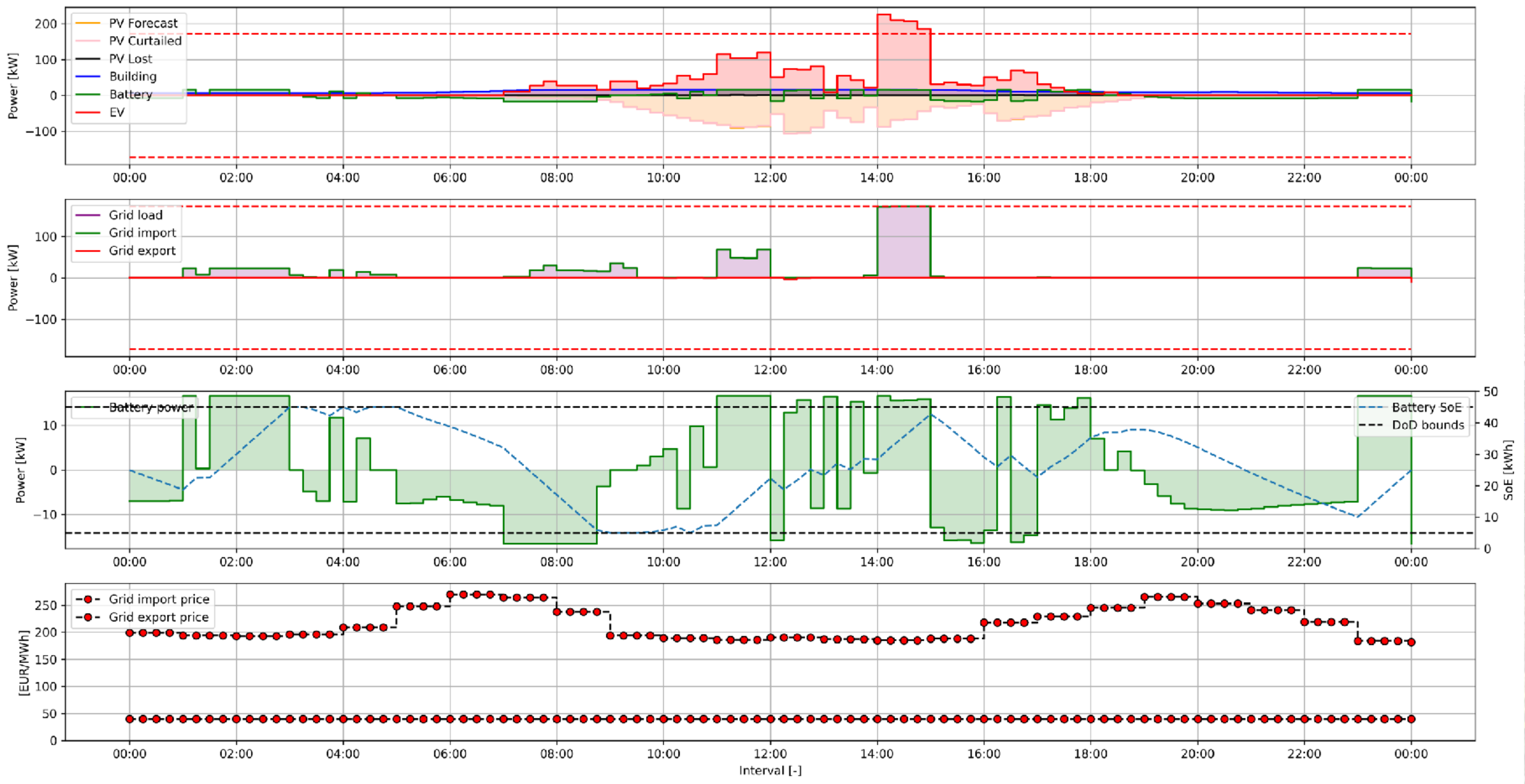
- Takes all available information and creates operational schedules for all connected devices to reach certain objectives:
  - *Load Balancing*
  - *Cost Optimization*
  - *Peak Shaving*

- Based on a Mixed Integer Non Linear Programming model built with Pyomo and solved with Gurobi (or another suitable solver)

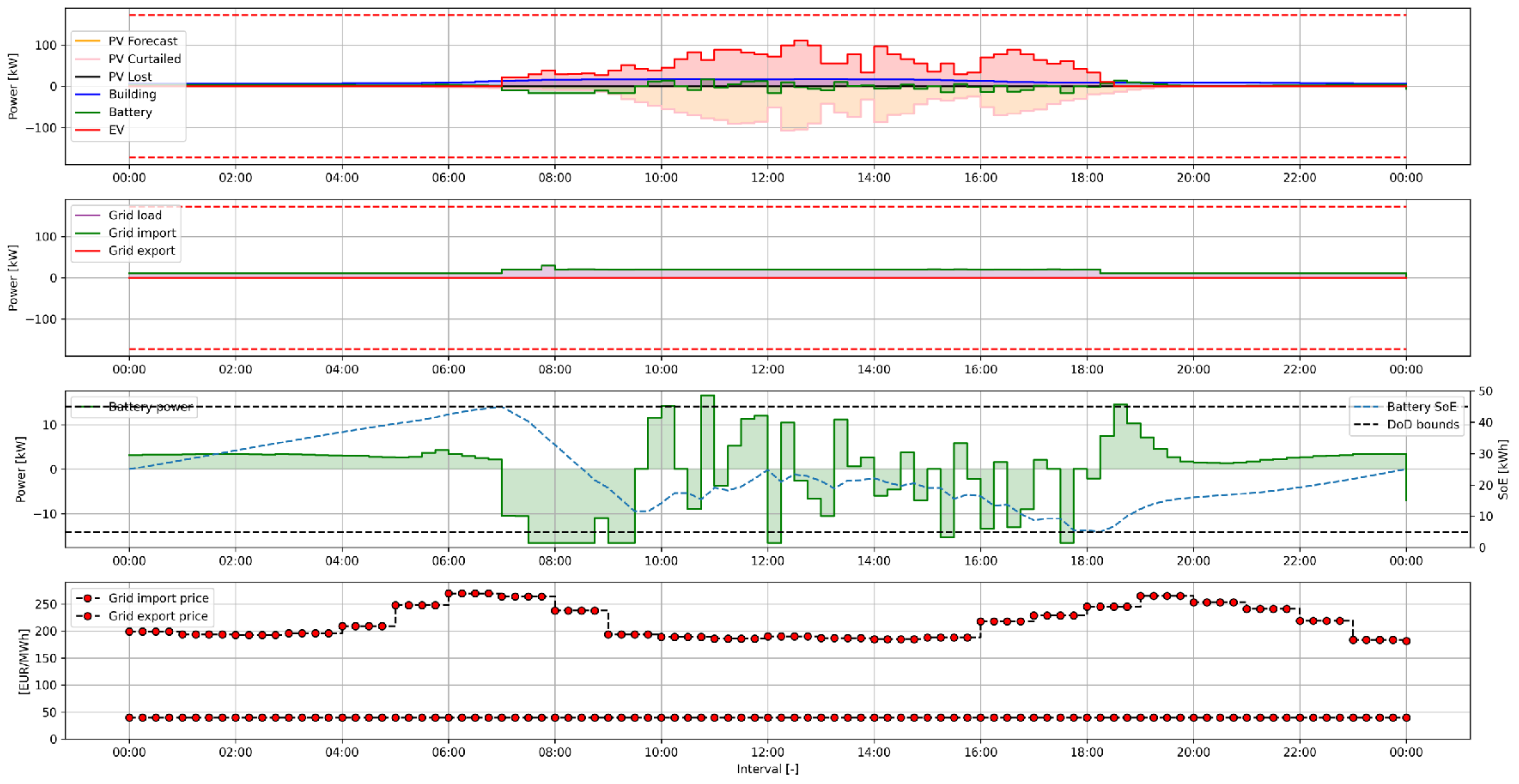
Scheduler - Load Balancing



Scheduler - Cost Optimization



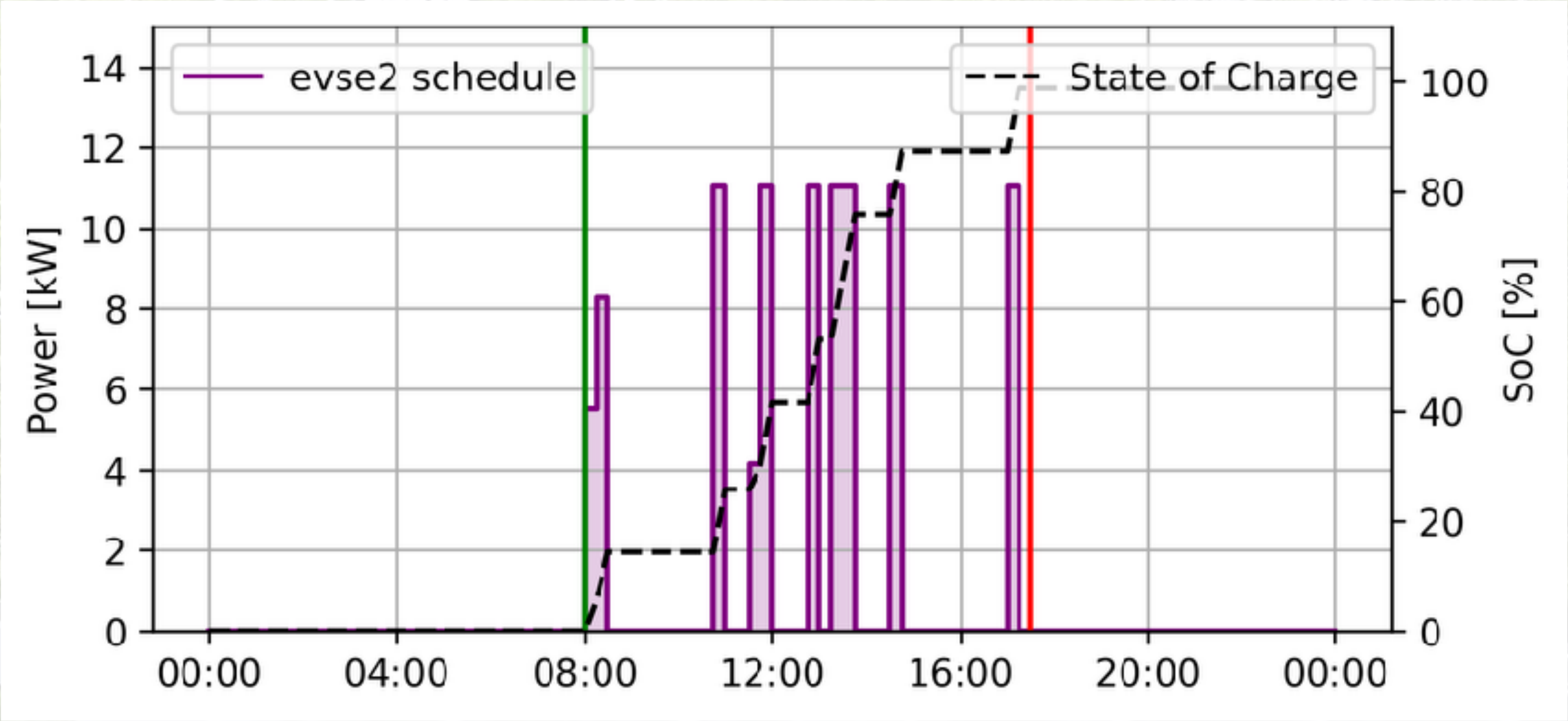
Scheduler - Peak Shaving

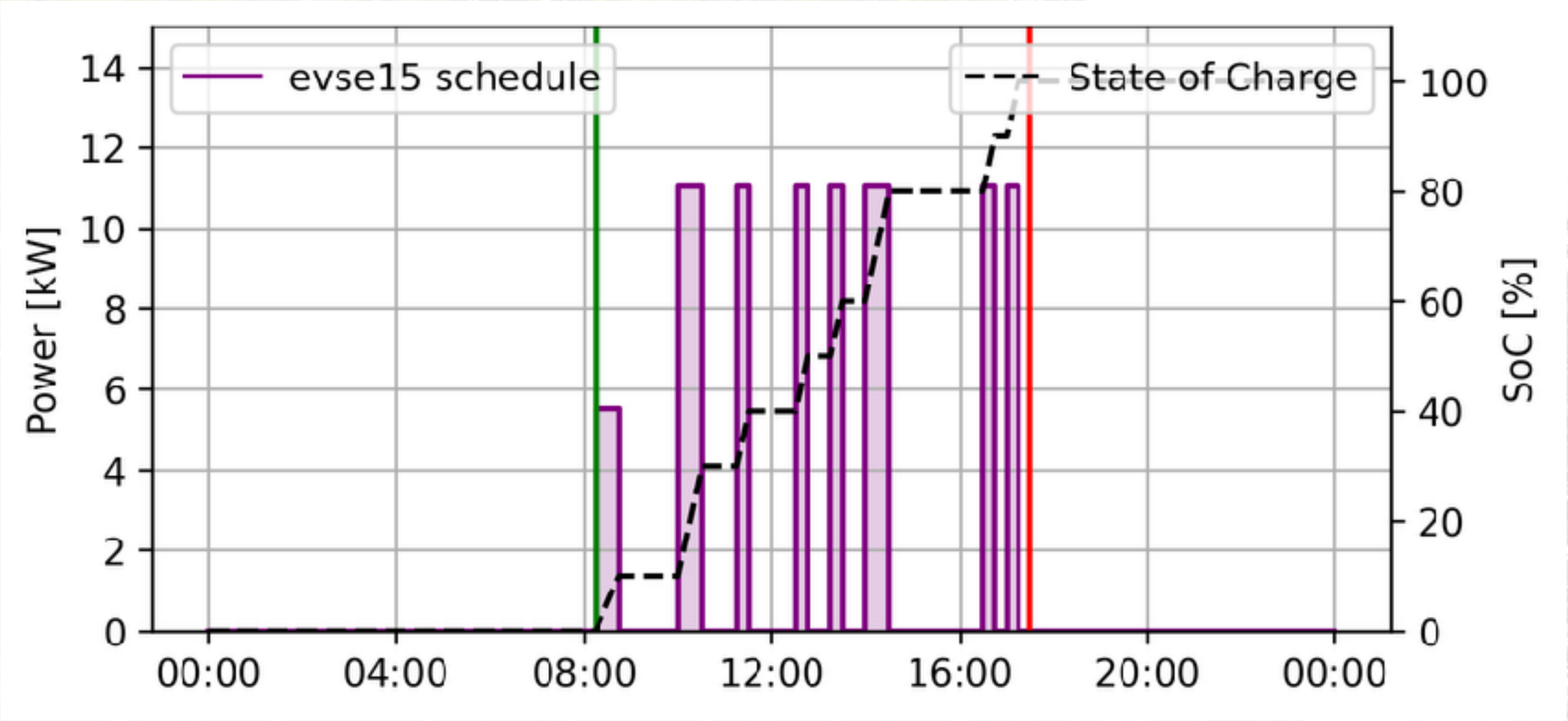


Scheduler - Peak Shaving - objective function

$$\min_{C} = \sum_{t=0}^{t_{\text{horizon}}} p_{\text{grid}_t}^{\text{imp}} E_{\text{grid}_t}^{\text{imp}} + p_{\text{grid}_t}^{\text{exp}} E_{\text{grid}_t}^{\text{exp}} + E_{\text{PV}_{t,p}}^{\text{curt}} p_{\text{PV}_t}^{\text{curt}} + p_{\text{BESS}}^{\text{cycle}} E_{\text{BESS}_{t,b}} + \sum_{\text{e}=0}^{\text{e}} f_{\text{ENS}(t_{\text{deadline}},e)}^{2} + E_{\text{grid}_t}^{2} \qquad (27)$$

$$f_{\text{ENS}_{t,e}} = \frac{E_{\text{EVSE}_{t,e}}^{\text{notserved}}}{E_{\text{EVSE}_{t,e}}^{\text{demand}}} \quad \forall\ t, e.$$


evse2 schedule
State of Charge
Power [kW]
SoC [%]
0
2
4
6
8
10
12
14
0
20
40
60
80
100
00:00
04:00
08:00
12:00
16:00
20:00
00:00


evse15 schedule
State of Charge
Power [kW]
SoC [%]
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4
6
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12:00
16:00
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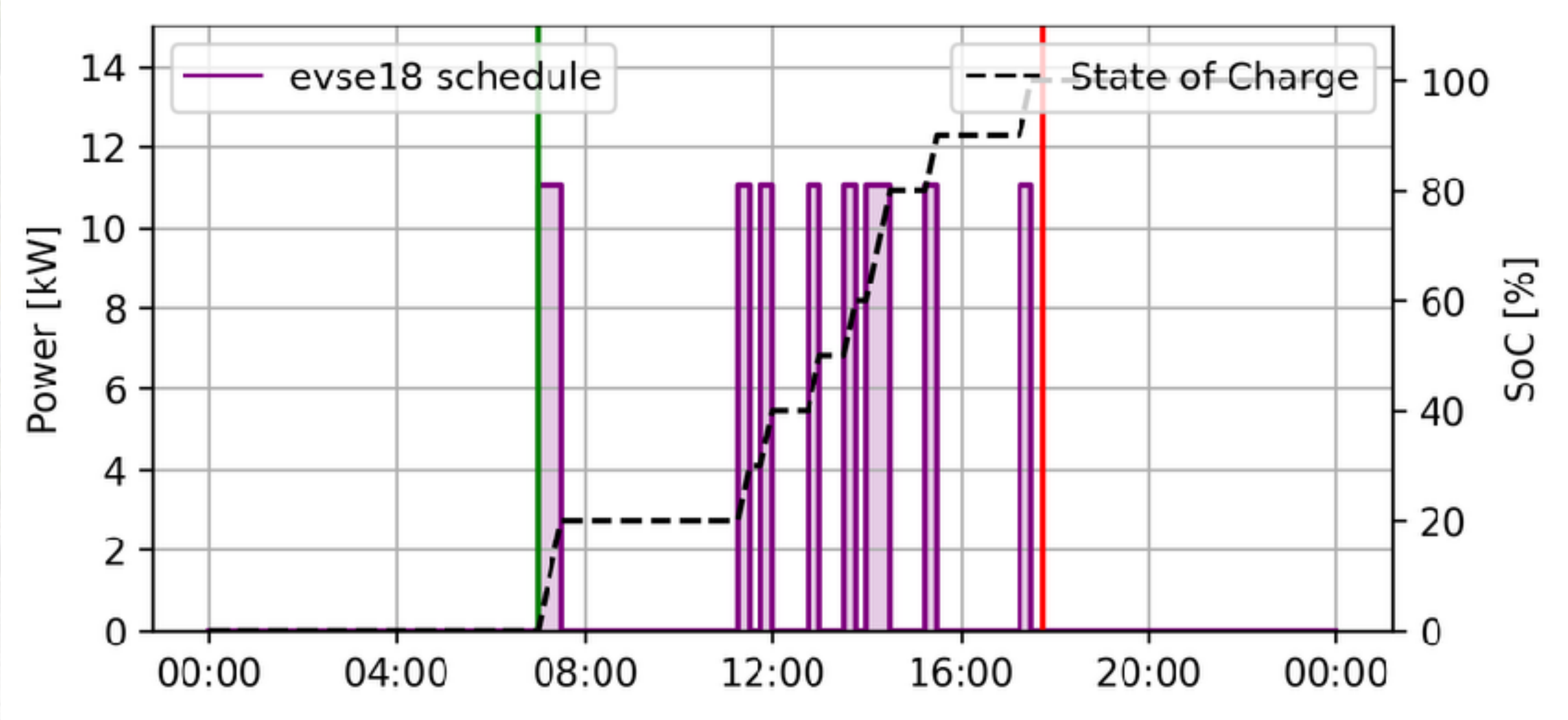
evse18 schedule
State of Charge
Power [kW]
SoC [%]
0
2
4
6
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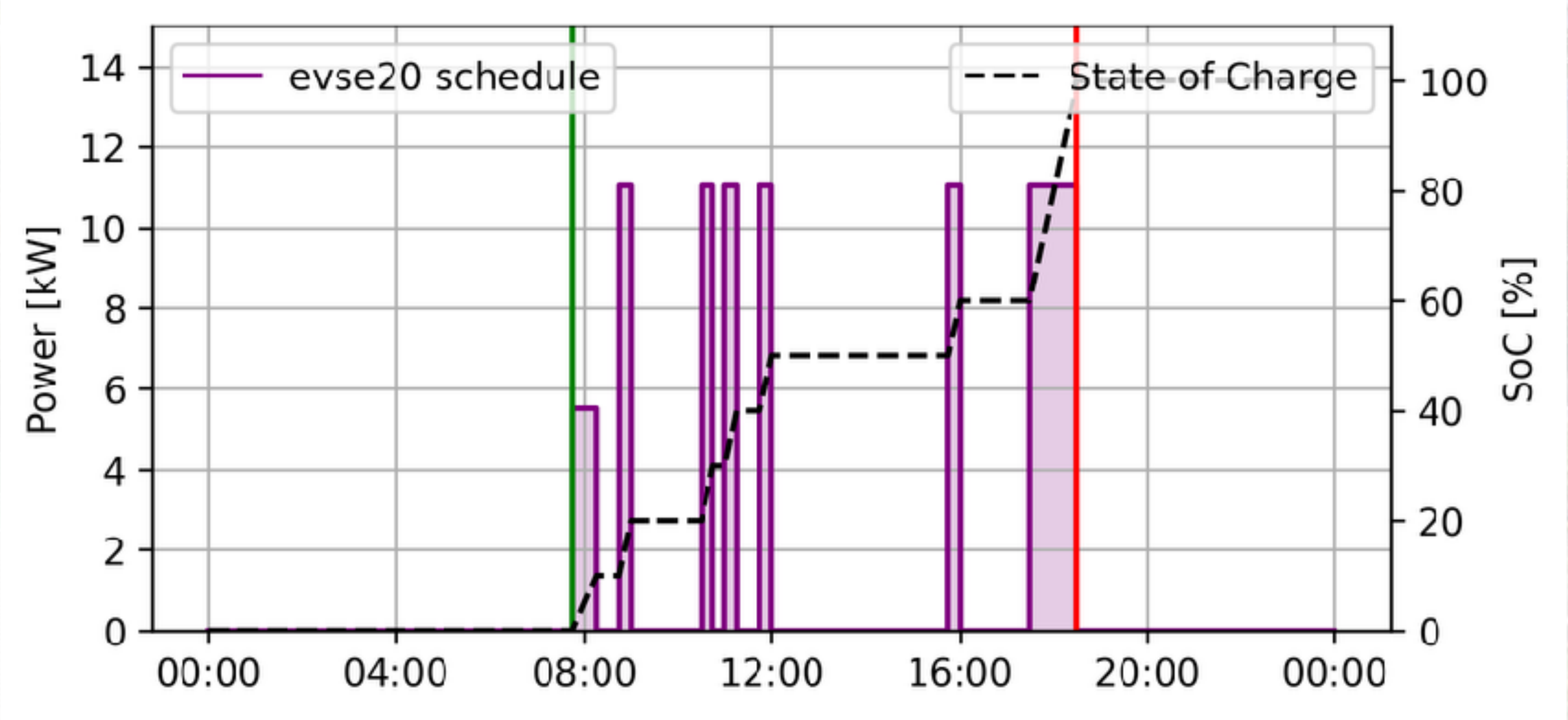
evse20 schedule
State of Charge
Power [kW]
SoC [%]
0
2
4
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60
80
100
00:00
04:00
08:00
12:00
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Real-Time Control

- Schedules are *optimal* but do not represent real-world circumstances
- Combine *predictive* control with *feedback* control
- Make decisions and track results to improve overall outcome

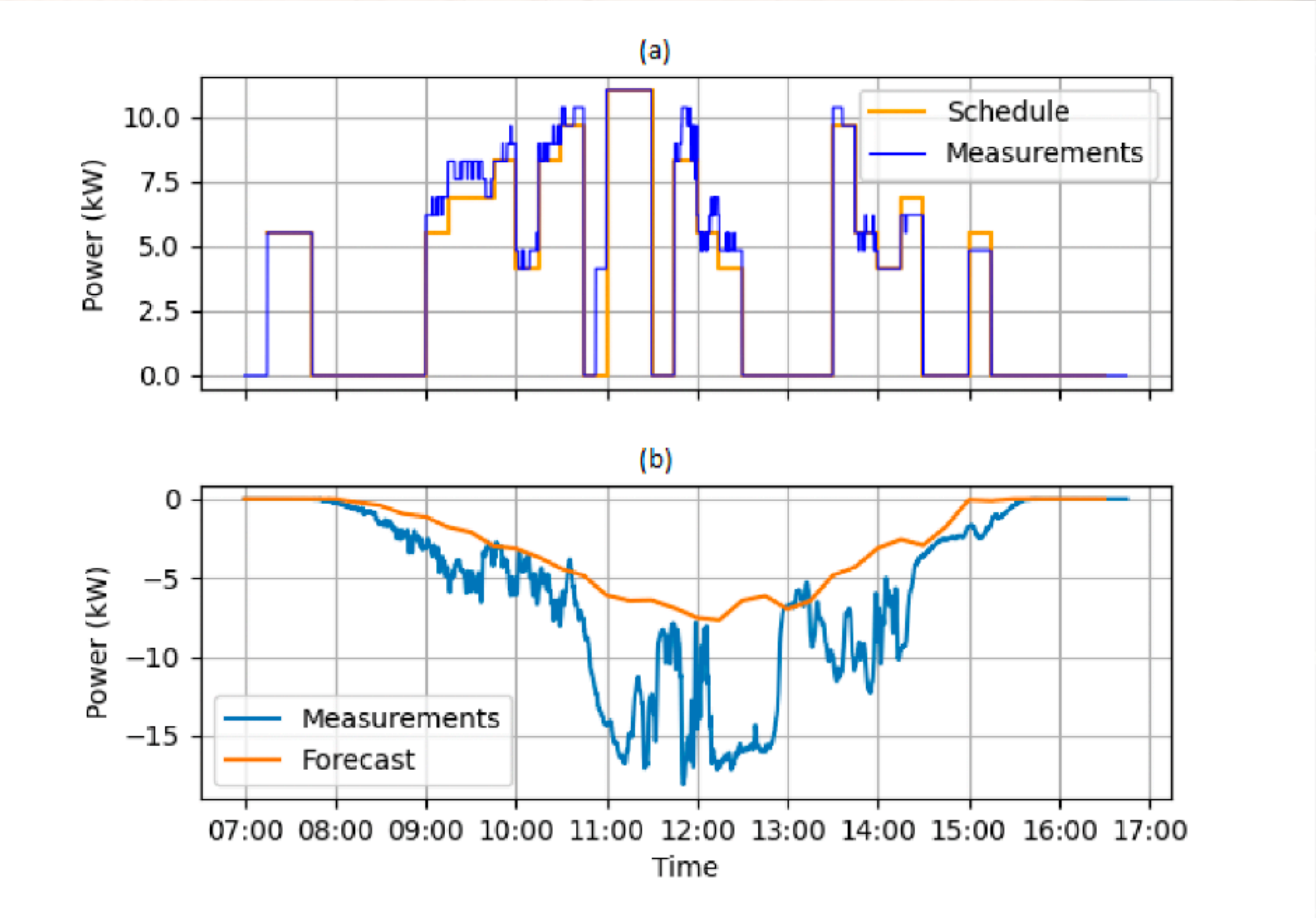
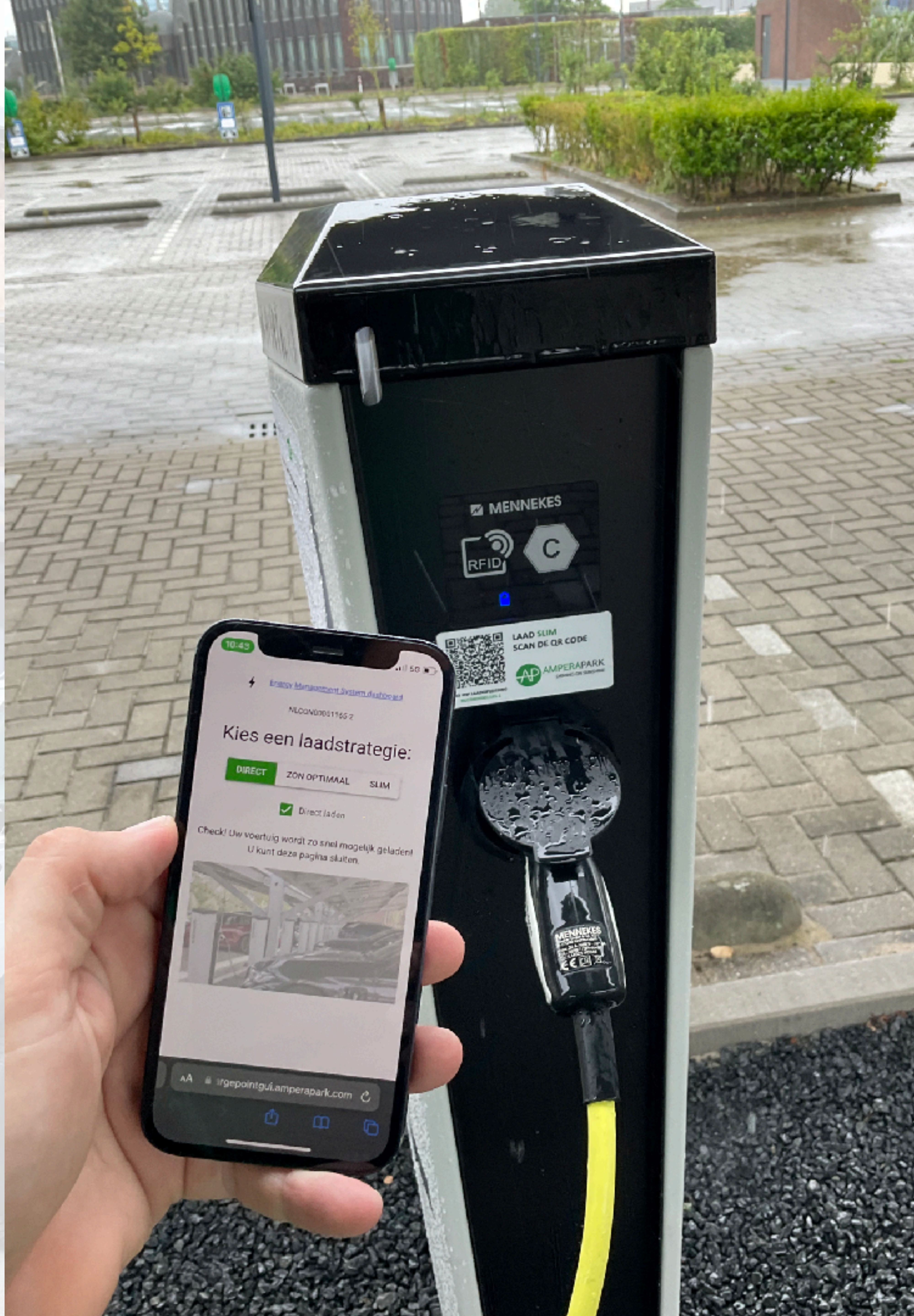


Image taken from “Robust Online Electric Vehicle Control at a Charging Hub” Master thesis from J. Reuling

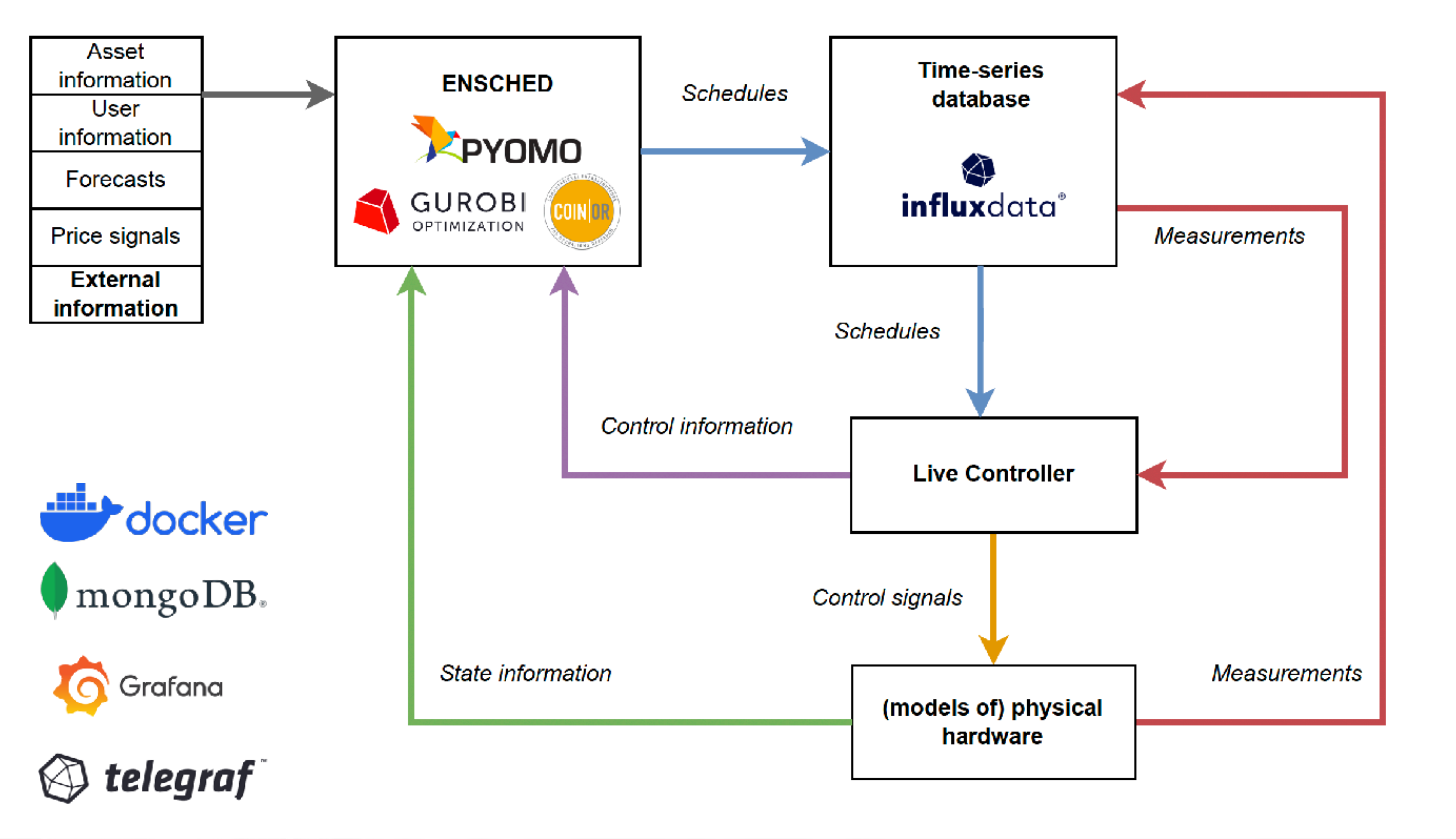
User Interface

- *Intelligent default:* use available historical data from a specific combination of location and user

- Give the user options to overrule:
  - Direct charging
  - Data input



System overview



System operational flow

- Continuously:
  - Measure
  - Apply Real-Time Control
  - Receive and store newly available external data (e.g. forecasts, prices)

- Trigger optimization (arrival, departure, updated forecast, other change of circumstances):
  1. Gather required data for scheduler
  2. Determine time horizon
  3. Execute & process

Demo