DAI-Labor
TU Berlin

Smart Energy System Management

A case study of an Autonomous Car

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Smart Energy Management System for Future Mobility Concepts

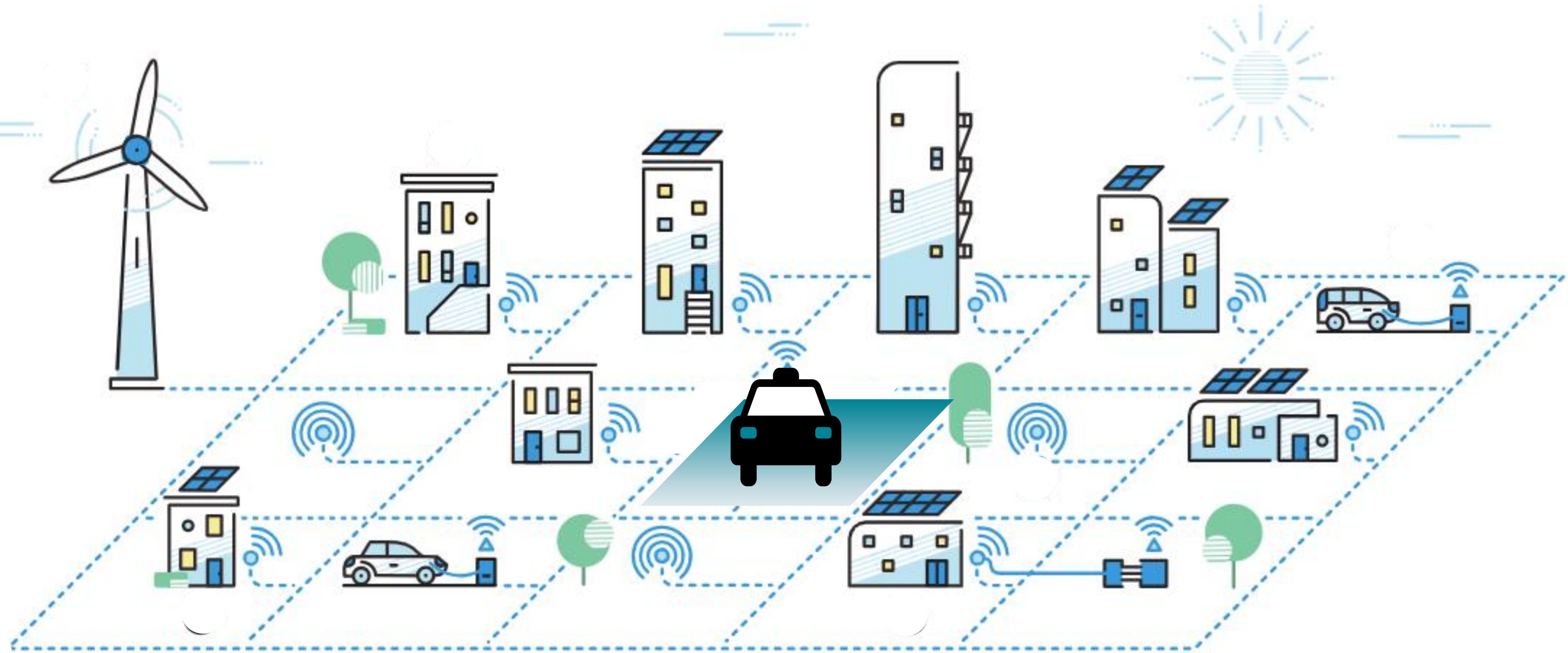


Illustration based on [1]

Project Stages

Stage 1

SOC < 20%

-> Charge now according to the following objectives: most economic, least time consuming

- All grids have same parameters

Stage 2

SOC = random value

-> Charge if needed (i.e. SOC <40%) according to the following objectives: most economic, least time consuming

Varying Grid parameters i.e. different prosumers (office, supermarket, house, autonomous car etc.)

Stage 3

SOC over time

-> Charge if needed according to the following objectives: most economic, least time consuming

- $SOC(t_n)=f(SOC(t_{n-1})$

Stage 4

Additionally consider autonomous car's own consumption and scheduled routes etc.

- Forecasting energy requirements and decide when to charge
- Integrate driving profiles

User Story Stage 1

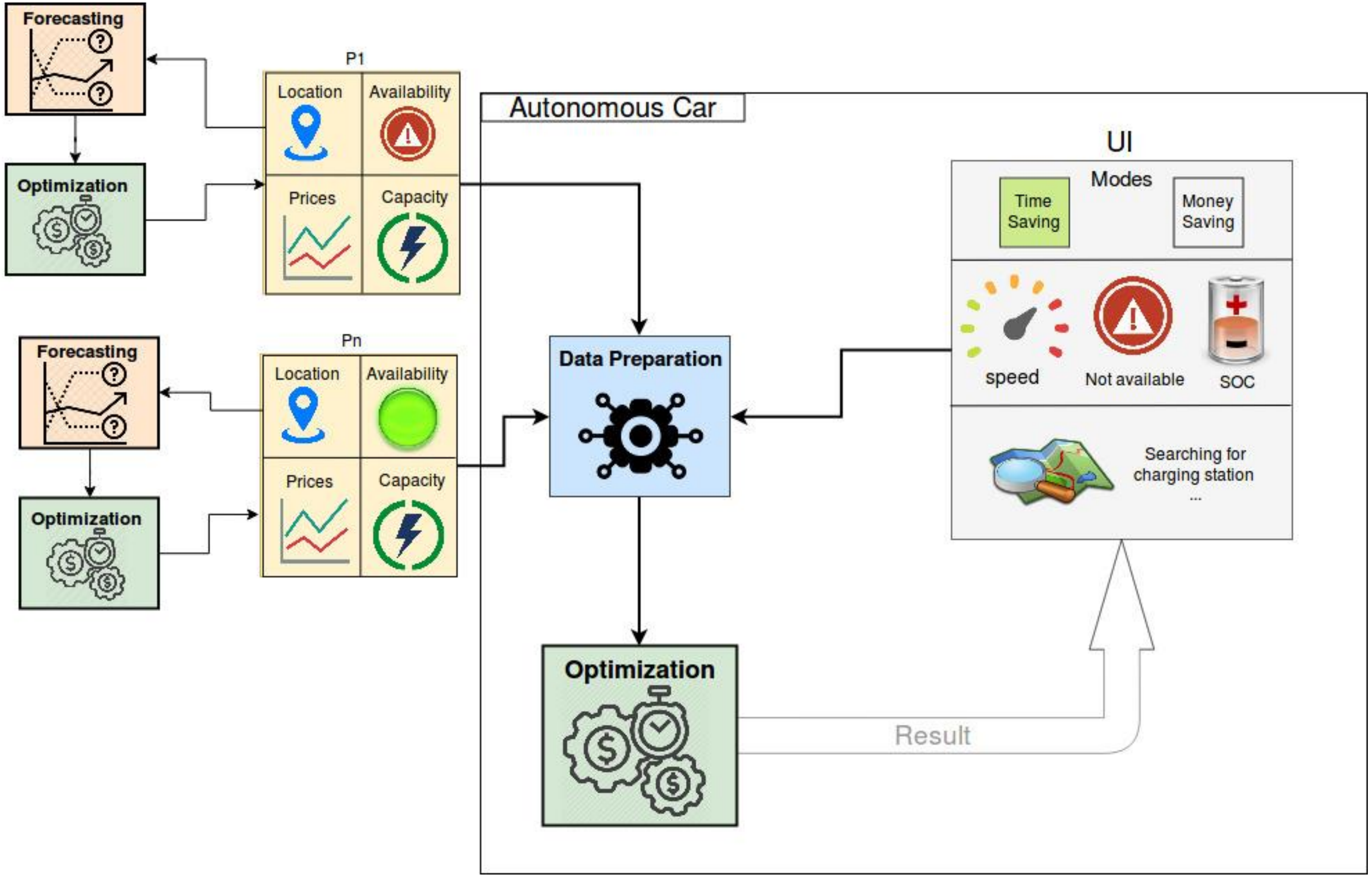
SOC < 20 % -> I have to charge myself now but where?

- Charge according to the following objectives: most economic, least time consuming
- Asking for location, price, availability and capacity of charging station

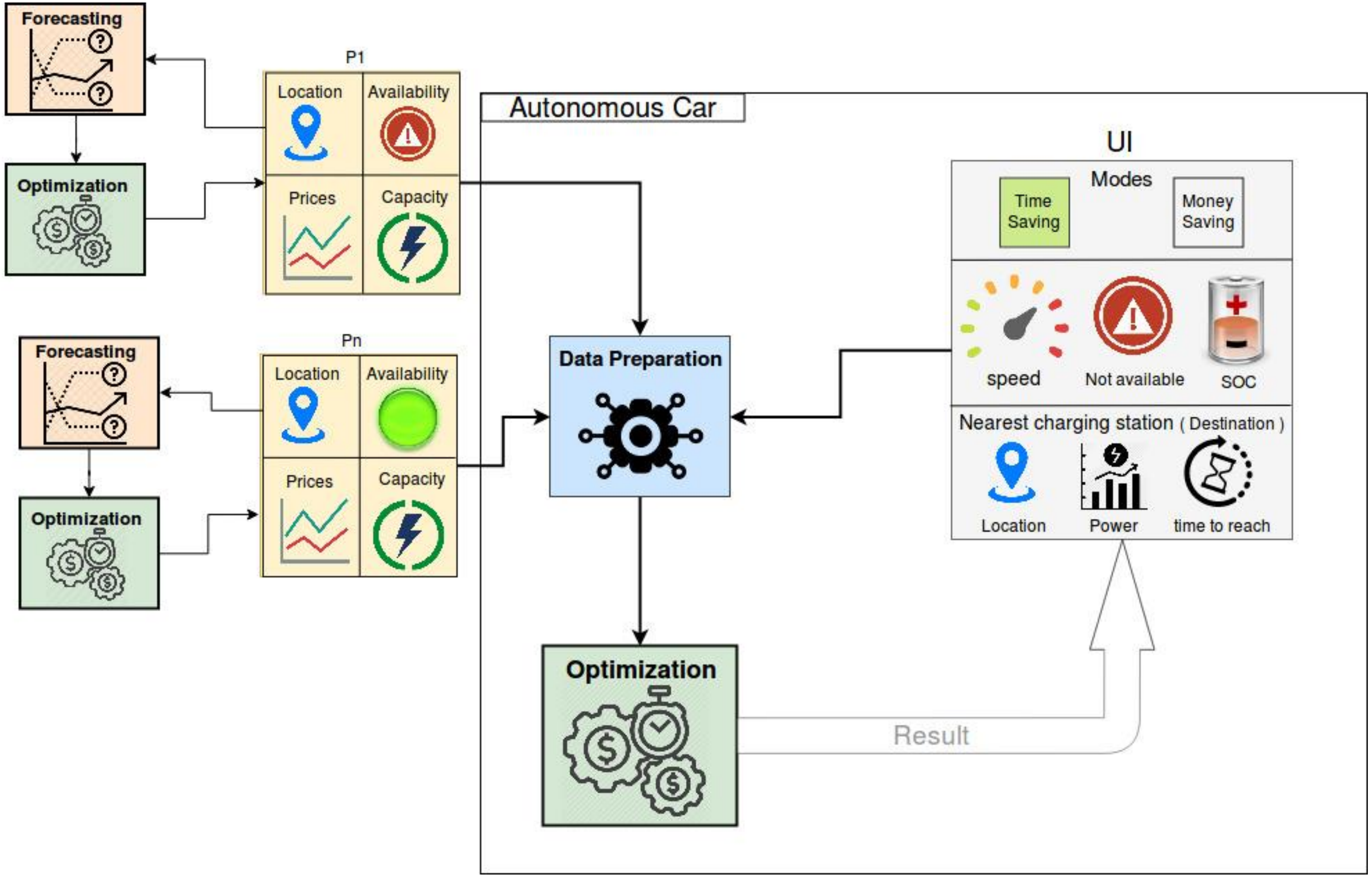
Type	Capacity	Energy need for 100 km
Tesla S [2]	75 kWh	17 kWh
Smart [3]	17.6 kWh	14 kWh
BMW [4]	37,9 kWh	14 kWh

Battery parameters for different car models

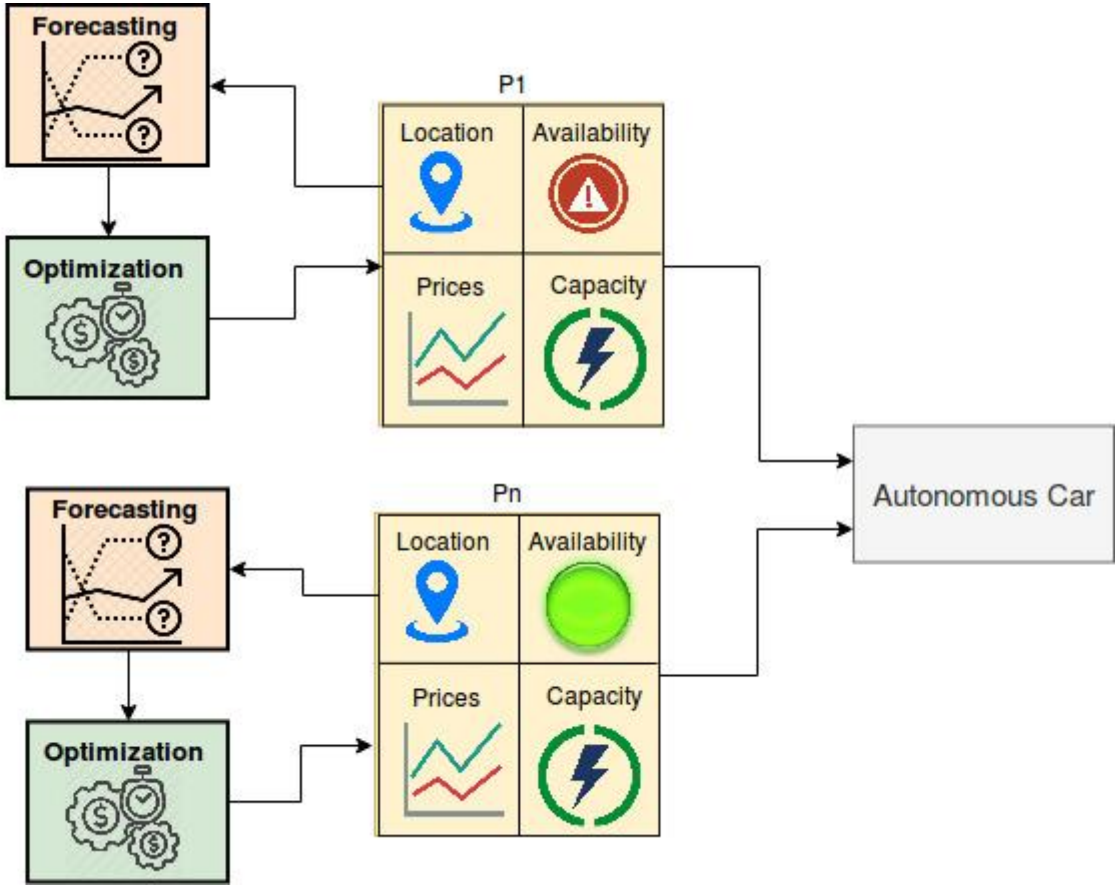
Conceptual Overview



Conceptual Overview

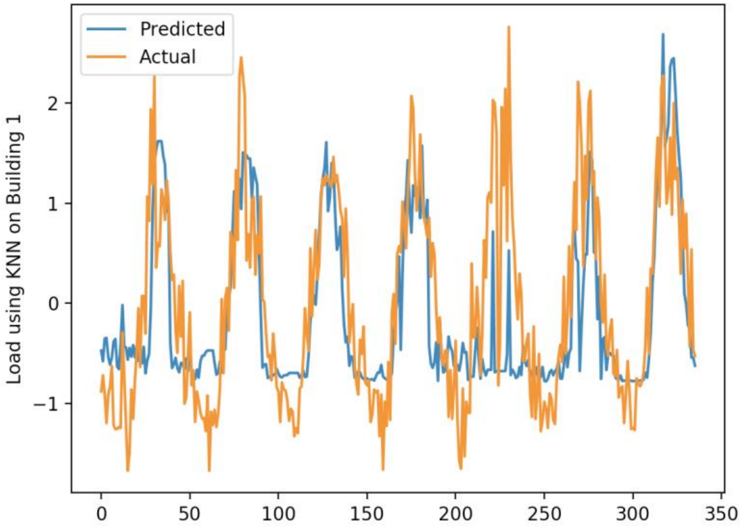


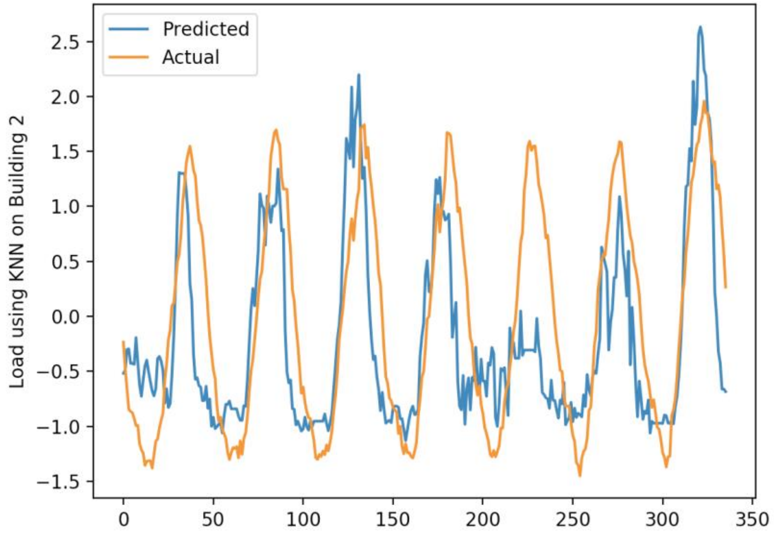
Prosumers: Forecasting and Optimization



Forecasting results for the grid model

► K Nearest Neighbor Approach

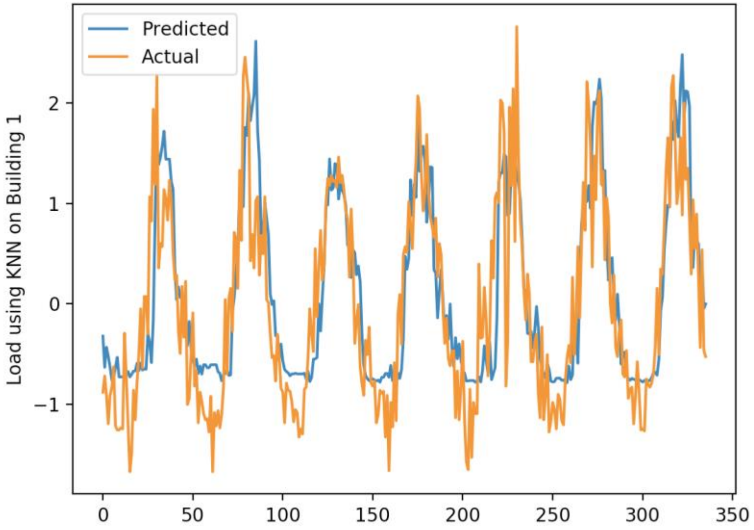


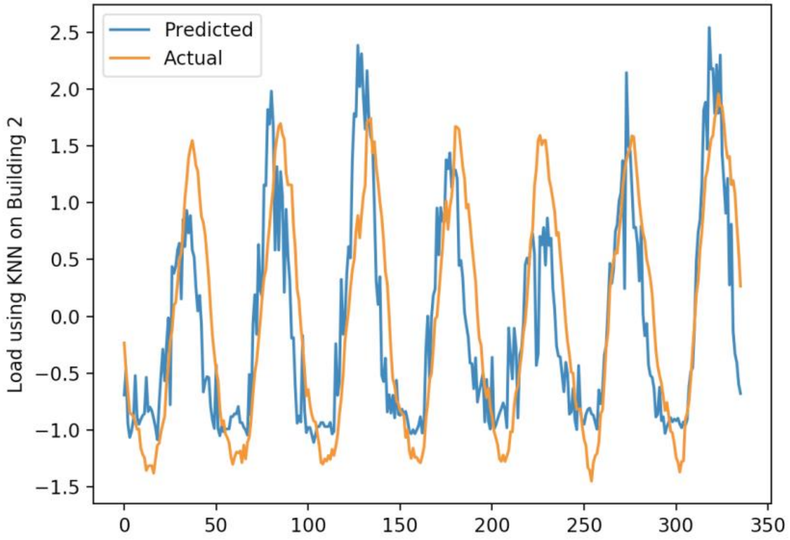


- Standardized the data
- Used timestamps and temperature as features

Results:

- R-square: 82.80% / 84.66%
- MSE: 0.52 / 0.56
- RMSE: 0.72 / 0.74





- Standardized the data
- Used timestamps, temperature and load of the other building as features

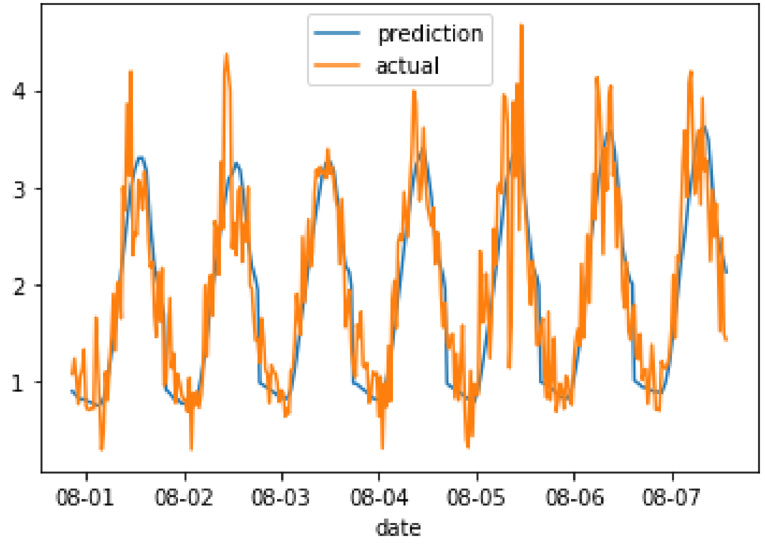
Results:

- R-square: 84.89% / 87.25%
- MSE: 0.34 / 0.38
- RMSE: 0.58 / 0.61

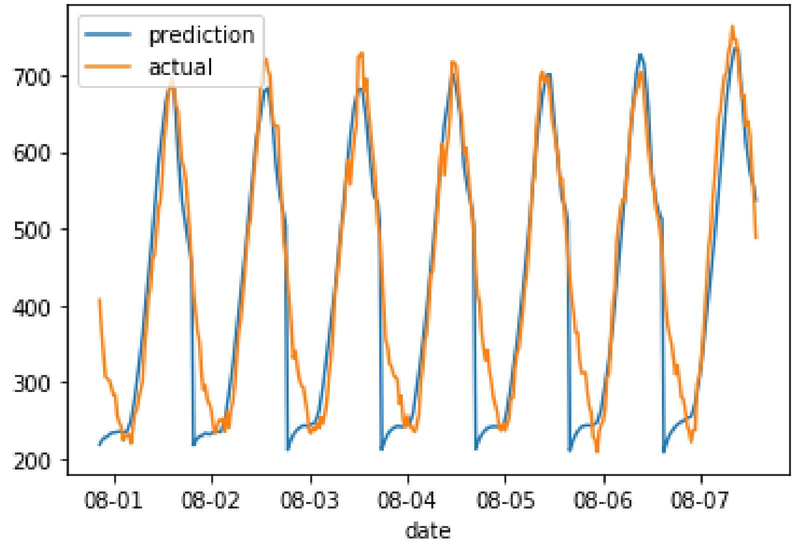
Forecasting results for the grid model

► Multiple Linear Regression Approach

Building 1



Building 2



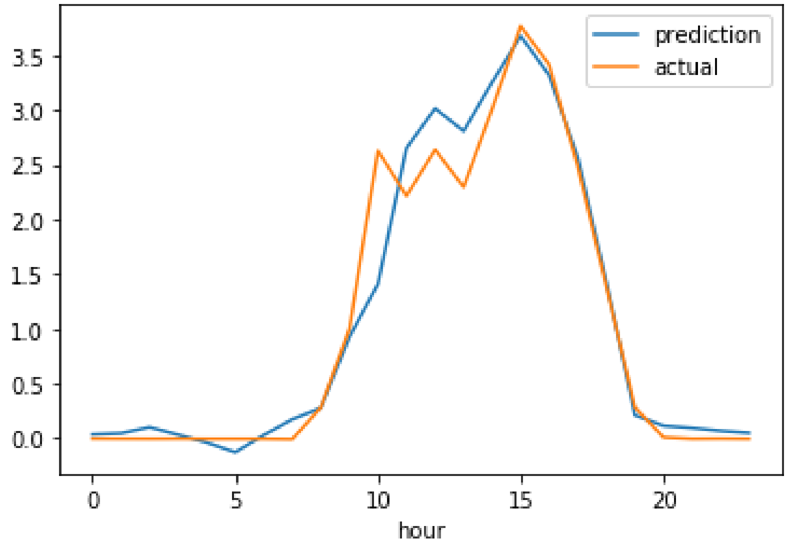
- Vanilla benchmark linear regression model

$$E(Load) = \beta_0 + \beta_1 \times Trend + \beta_2 \times Day \times Hour + \beta_3 \times Month + \beta_4 \times Month \times TMP + \beta_5 \times Month \times TMP^2 + \beta_6 \times Month \times TMP^3 + \beta_7 \times Hour \times TMP + \beta_8 \times Hour \times TMP^2 + \beta_9 \times Hour \times TMP^3, \quad (16)$$

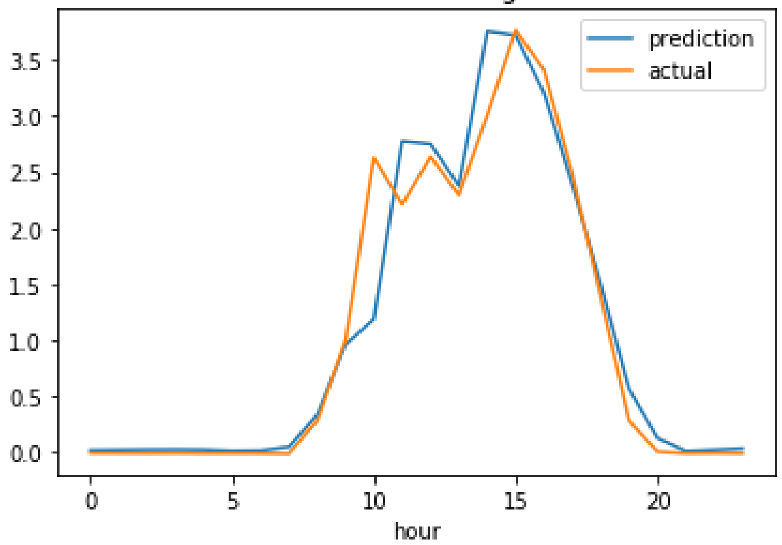
Results:

- R-square: 74.20% / 84.5%
- NRMSE: 0.25 / 0.14

PV forecast ANN



PV forecast Linear Regression



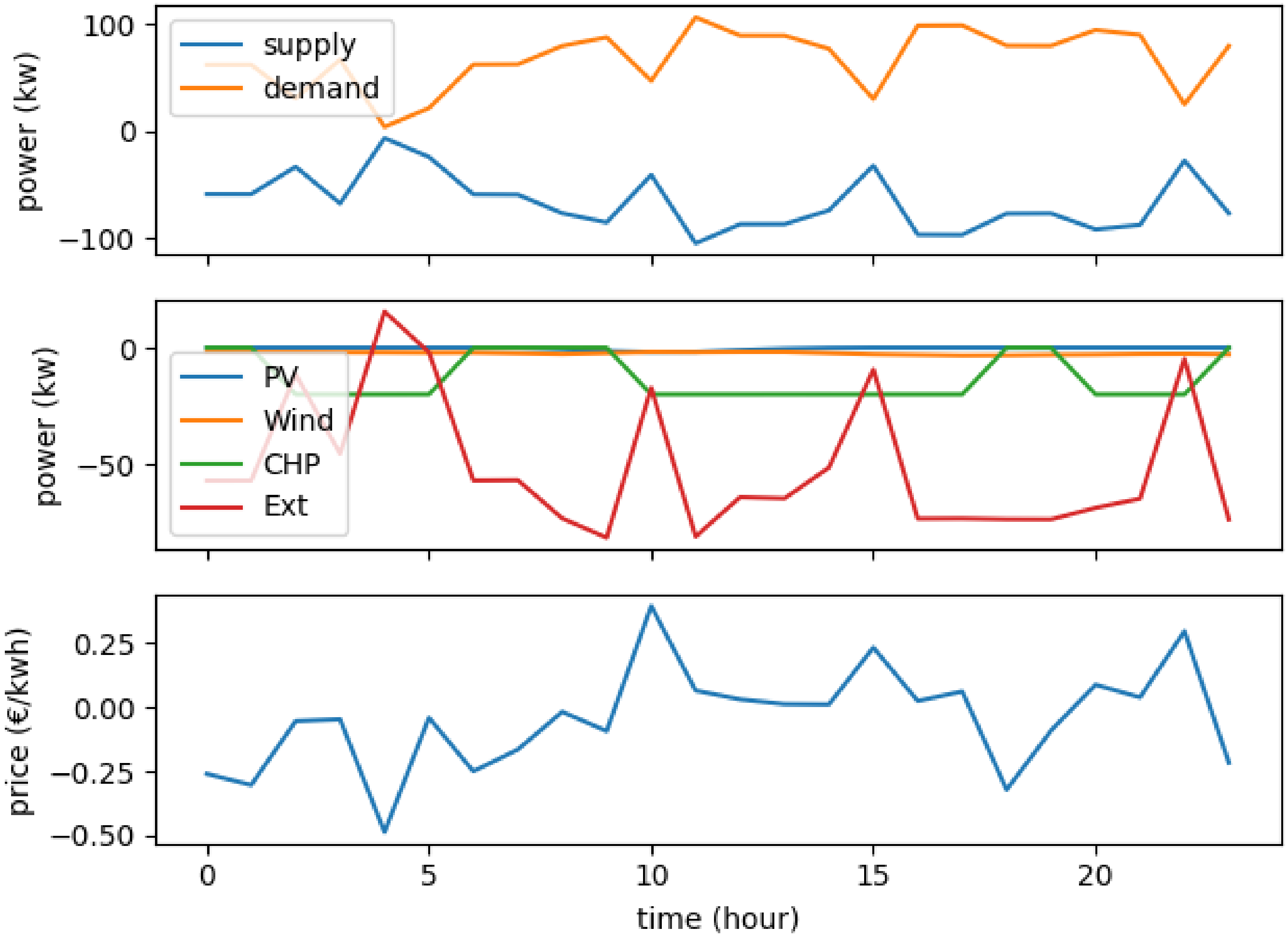
- Standardized the data
- Used hour, day, month and “visibility” as features

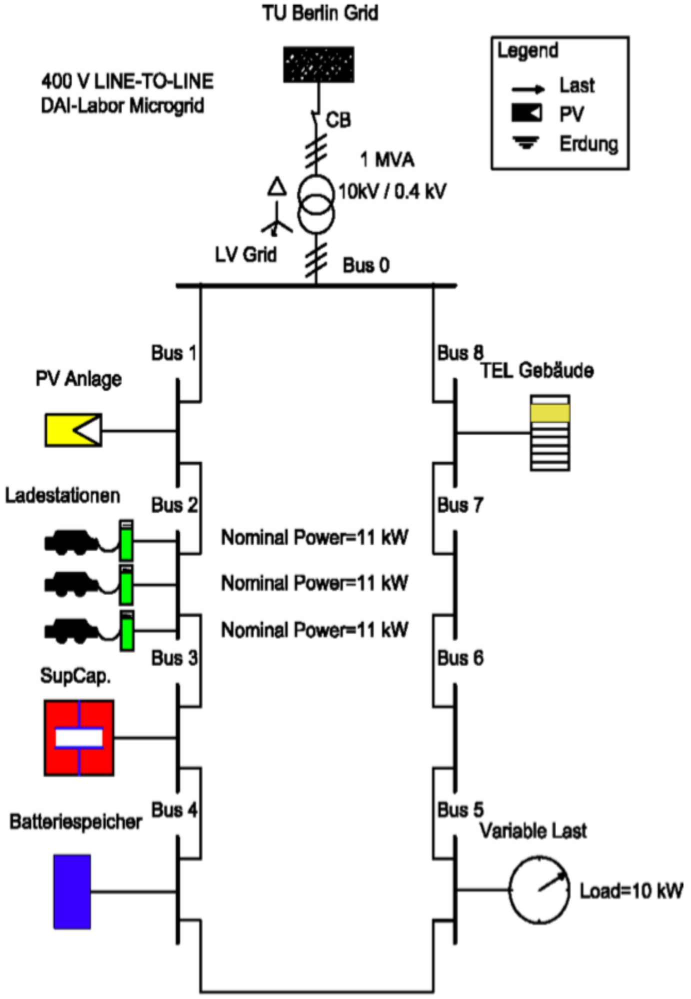
Results:

- MSE: 0.26 / 0.35
- RMSE: 0.49 / 0.53
- NRMSE: 0.69 / 0.67

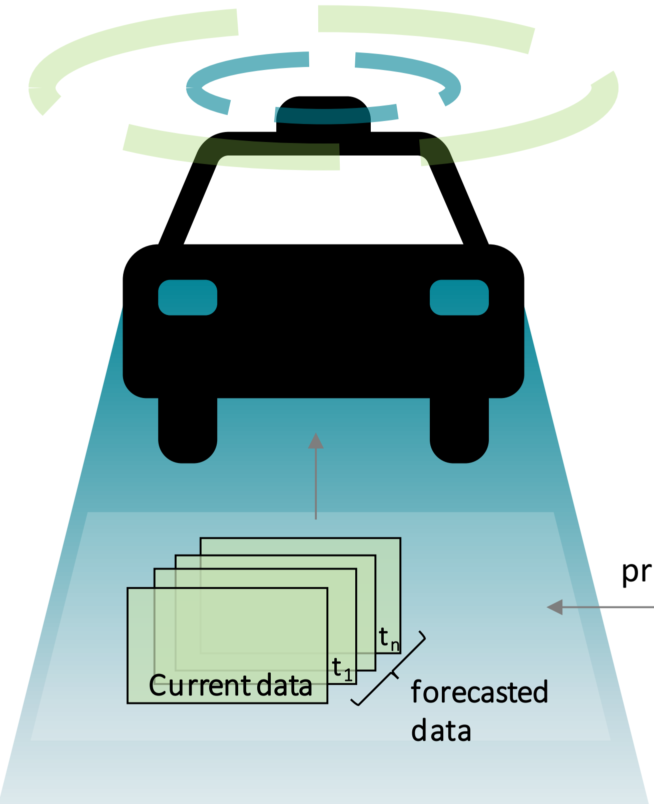
Optimal Balance between Supply and Demand

- Optimization based on Objective: Min(Costs)

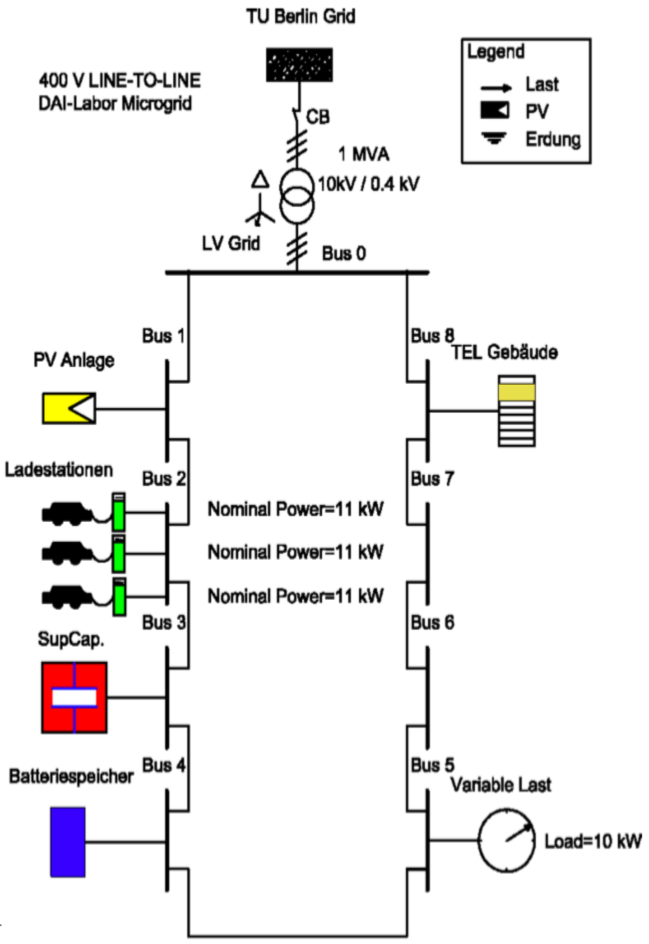




Data Aggregation within Autonomous Vehicle



price, location, availability and capacity



Optimal Decision for Autonomous Vehicle

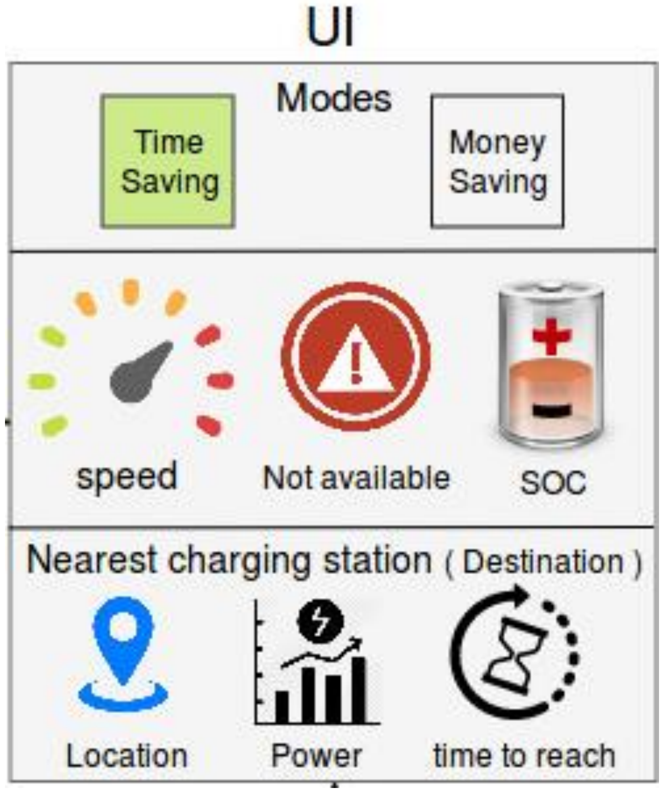
Decide which charging station to use.

- Decision based on:
  - $\min(Cost) = \min\left(P \cdot C_{energy\ per\ kWh}\right)$
  - $\min\left(t_{charging}\right) = \min\left(x_{distance} \cdot \bar{v} + \frac{C_{battery}}{P_{charging\ Station}}\right)$

Min(⏱)

Min($)

results



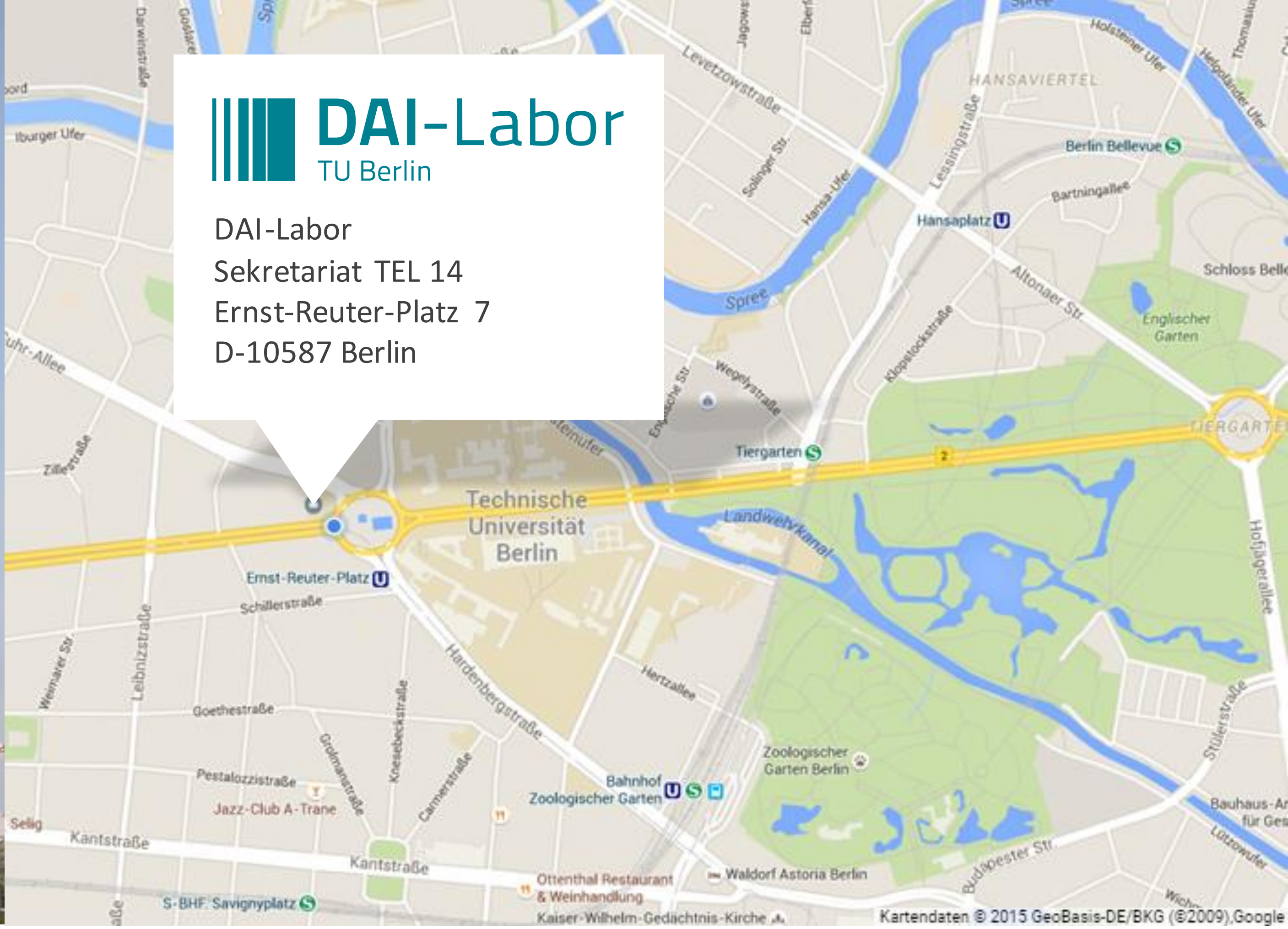
References

[1] conEdison. 2016. *Smart Grid*. [ONLINE] Available at: https://www.coned.com/en/our-energy-future/technology-innovation/smart-grid. [Accessed 15 December 2018].

[2] TESLA. 2018. Model S: Performance und Sicherheit. [ONLINE] Available at: https://www.tesla.com/de_DE/models . [Accessed 15 December 2018].

[3] BMW. 2018. *Weiter so.*. [ONLINE] Available at: https://www.bmw.de/de/neufahrzeuge/bmw-i/i3/2017/auf-einen-blick.html?bmw=sea:1434652045:59052874707:bmw%20i3. [Accessed 17 December 2018].

[4] Smart. 2018. *Wissenswertes zum Thema Elektromobilität*. [ONLINE] Available at: https://www.smart.com/de/de/index/smartemobility.html?ef_id=EAIaIQobChMIqrTlgqSm3wIVRrDtCh0MmQHyEAAYASAAEgKxW_D_BwE:G:s&s_kwcid=AL!3888!3!255660132162!e!!g!!smart%20elektroauto. [Accessed 17 December 2018].



Get In Touch

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Backup

Data Options

- Pecan Street's multi-state residental electricity
  - Energy use of ~1000 US houses & appartments
- Renewables ninja
  - Hourly Solar PV production based on lat/long
  - MERRA-2 europe based
  - time, local_time, output (kW) ,direct (kW/m2), diffuse (kW/m2), temperature
- in-home plug-in electric vehicle recharging profiles dataset
  - Based on 2009 RECS from Midwest US (data.gov)
  - ~200 household electricity demand profiles, 10 min resolution including electric vehicle recharging profiles for 348 vehicles

Combine energy use of selected houses, one or more electric vehicle recharging profiles and PV production