WHICH ECONOMIC AND TECHNICAL VALUE DO INTEGRATED CHARGING SOLUTIONS YIELD FOR HIGH POWER CHARGING (HPC) PARKS?

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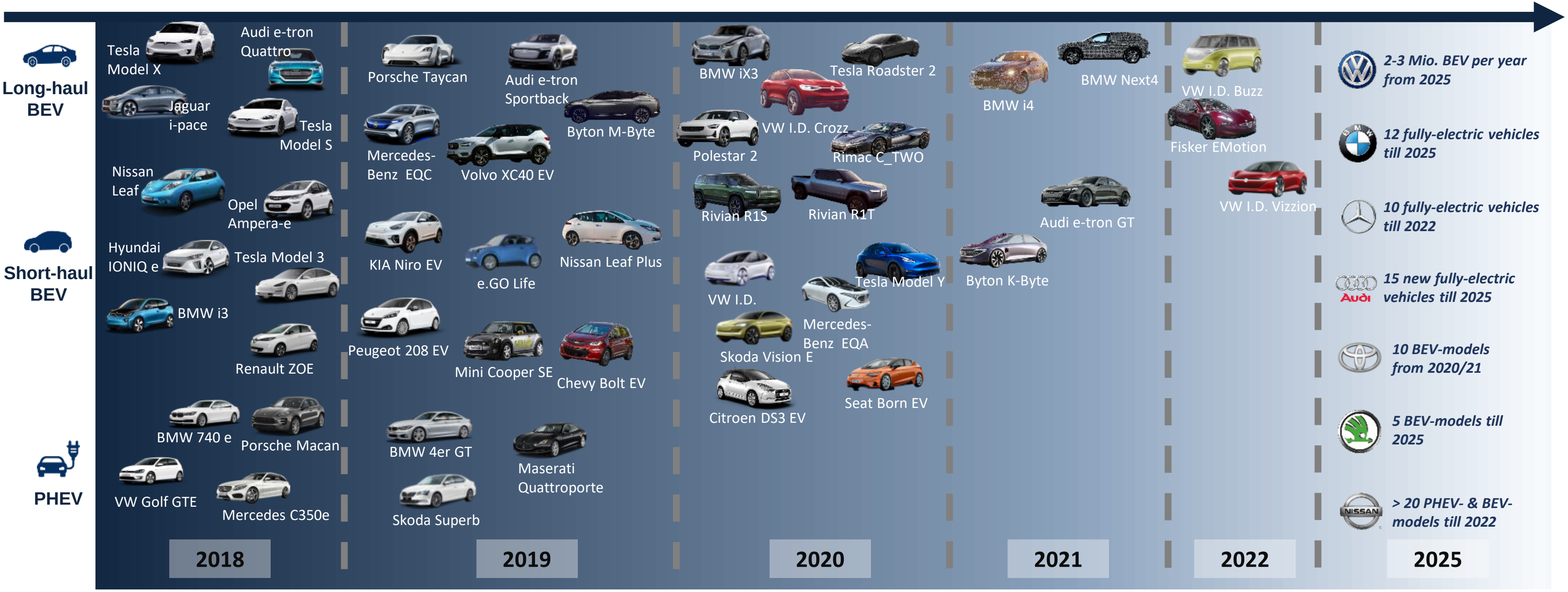
MOTIVATION: EV ROADMAP

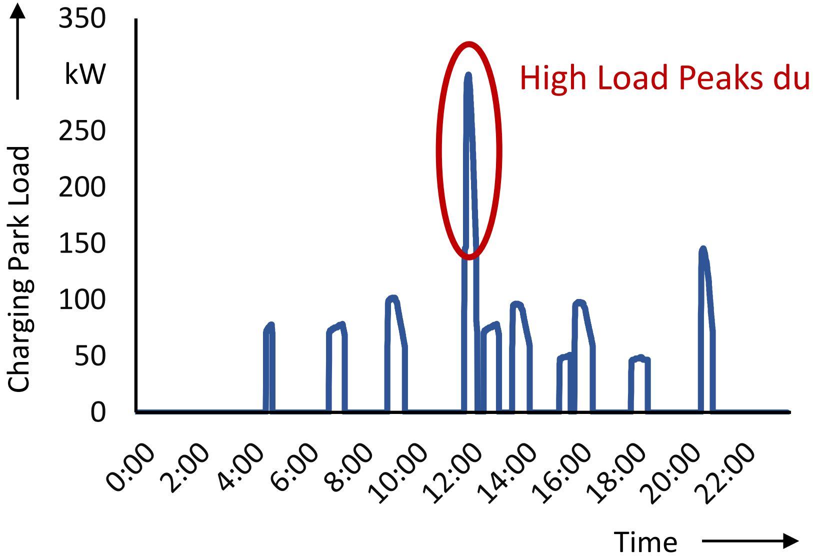
A wide variety of models is coming to the markets in the following years. Around half of the announced models have a range of 350 km maximum.

Timeline of today's and future xEVs*



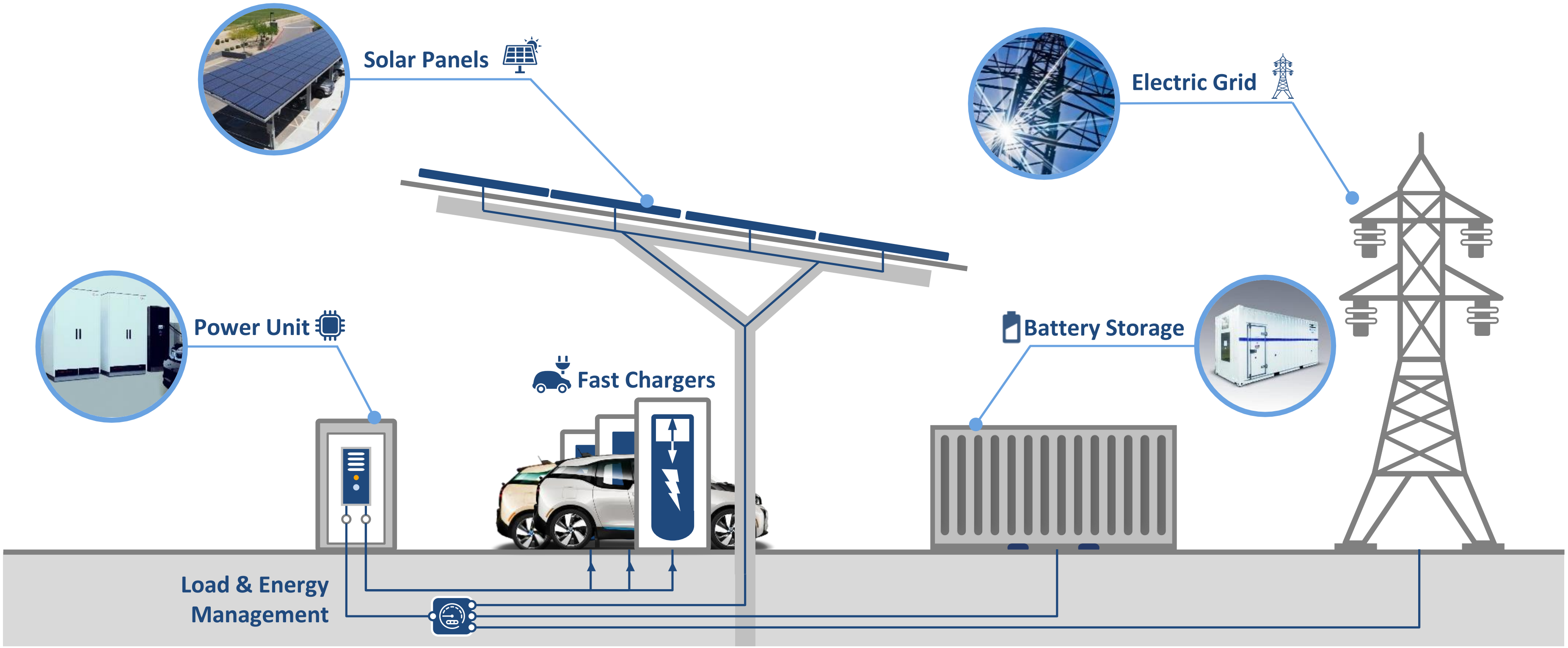
* xEVs = Vehicles with electrified powertrain; No claim made for completeness of the announcements.

Challenges: Economical & Technical



- **Economical challenge:** Charging park operator
  - ➢ High xEV charging powers lead to high grid connection capacities: High installation and operational costs
- **Technical challenge:** Grid operator
  - ➢ High variation in load could lead to grid instability

Tomorrow‘s charging park?



Tomorrow‘s charging park!

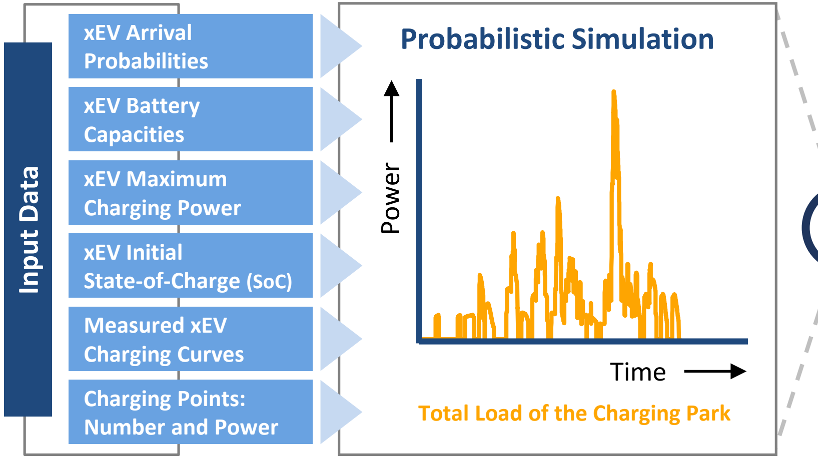
Source: Fastned fast charging station Uffenheim Germany (windkraft-journal.de)

Source: Kreisel Chimero (presseportal.de)

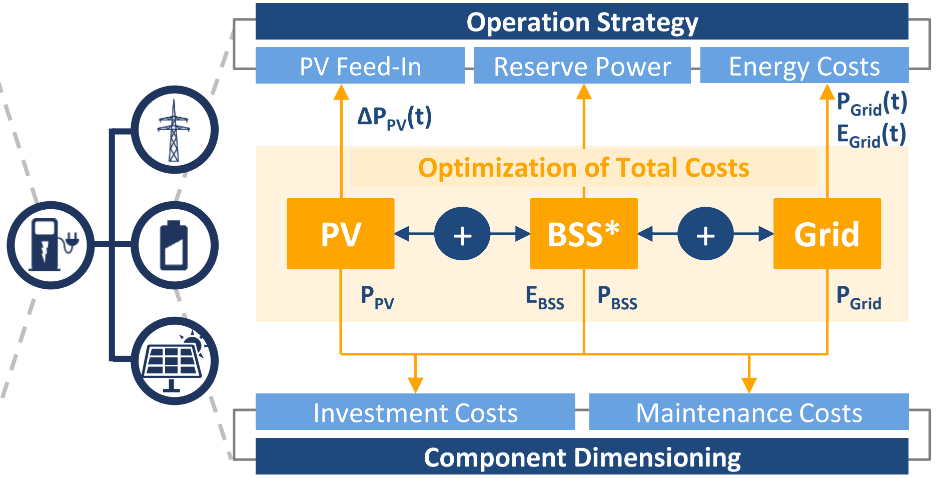
Source: Porsche Newsroom

Simulating the charging park operation and optimizing its component dimensions & use

1 xEV-Charging Park Load Simulation



2 xEV-Charging Park Optimization Model



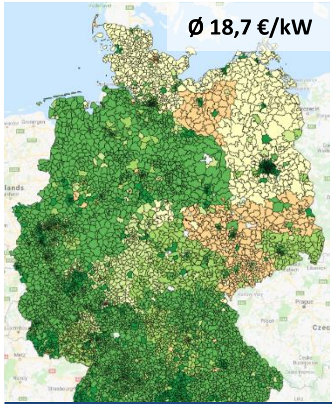
*BSS = Battery Storage System

MODEL DESCRIPTION

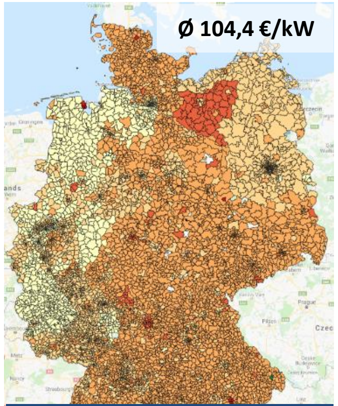
Many influencing cost factors vary from region to region and/or within great bandwidths

Example: Grid Connection Fees (GCF) on low voltage level

Capacity charge [€/kW]



Full Load Hours: <2500 h/a

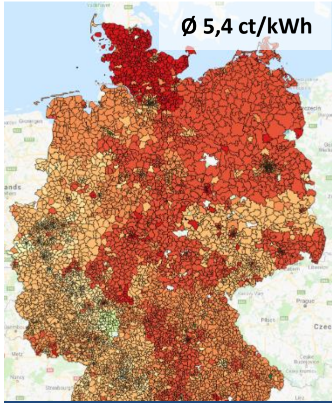


Full Load Hours: >2500 h/a

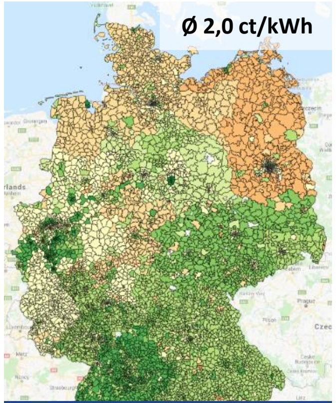
Legend:
Low Voltage Level
Capacity Charge [€/kW]

- 0.9 - 10.0
- 10.0 - 20.0
- 20.0 - 30.0
- 30.0 - 40.0
- 40.0 - 50.0
- 50.0 - 100.0
- 100.0 - 150.0
- 150.0 - 200.0
- 200.0 - 216.1

Energy Rate [ct/kWh]



Full Load Hours: <2500 h/a



Full Load Hours: >2500 h/a

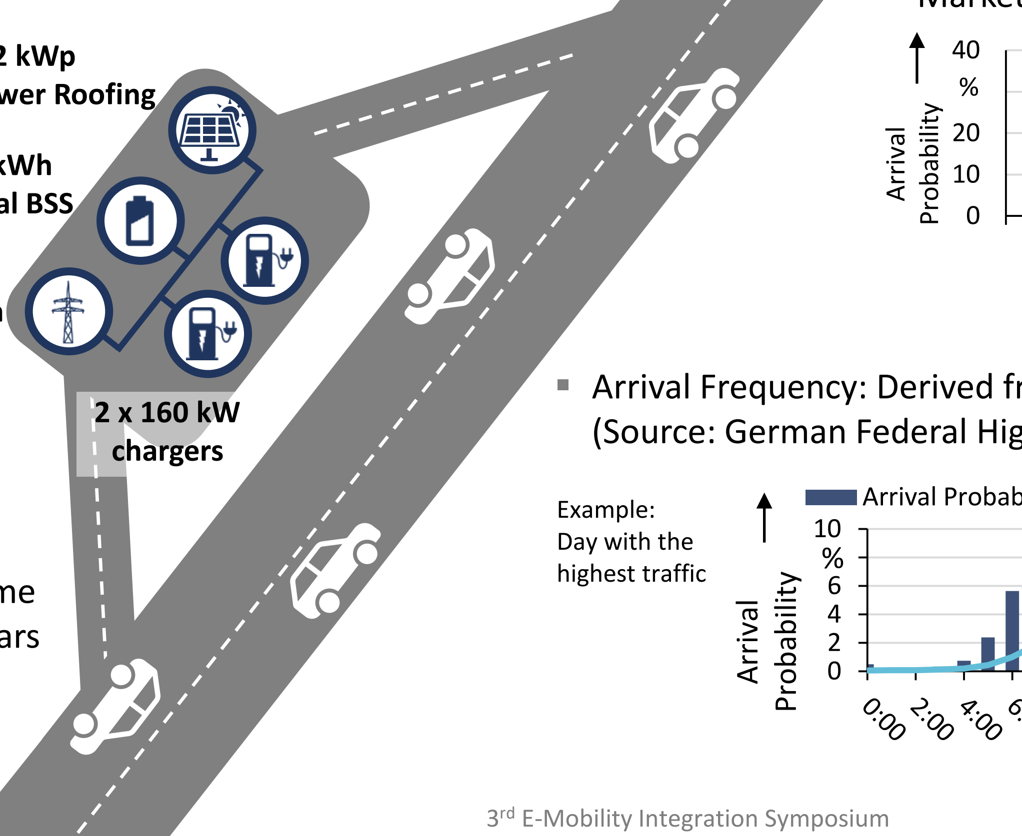
Legend:
Low Voltage Level
Energy Rate [ct/kWh]

- 0.02 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- 2.50 - 3.00
- 3.00 - 4.00
- 4.00 - 5.00
- 5.00 - 6.00
- 6.00 - 7.00
- 7.00 - 8.00

Further cost factors & assumptions made:

- Building cost subsidies (BCS) for grid connection: Ø 65 €/kW (vary with grid operator as well)
- BSS costs: Ø 470 €/kWh
- PV system costs: Ø 1170 €/kWp

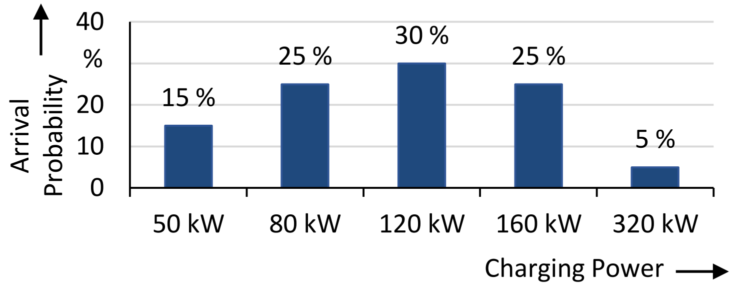
Small HPC charging park in catchment area of a German city



- Simulation time period: 20 years

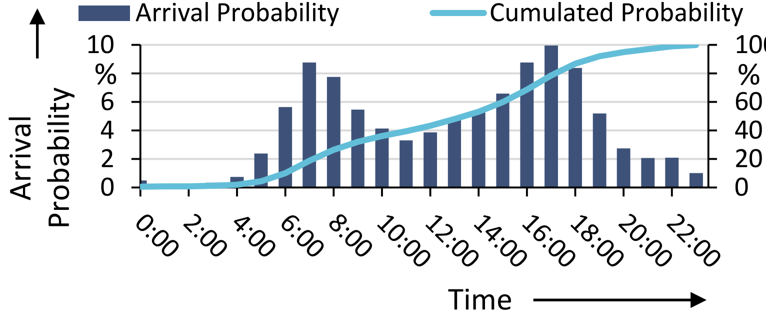
xEV assumptions:

- Market Distribution:

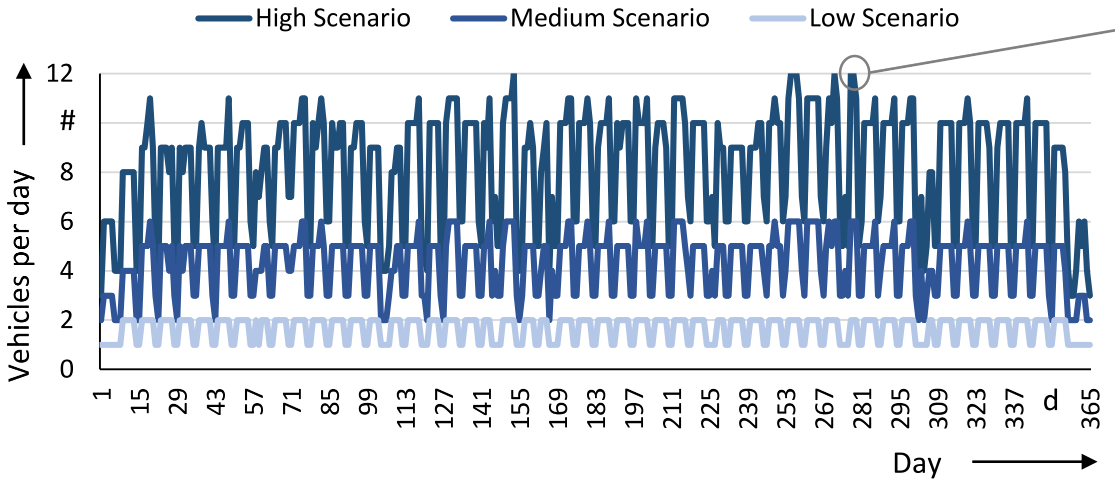


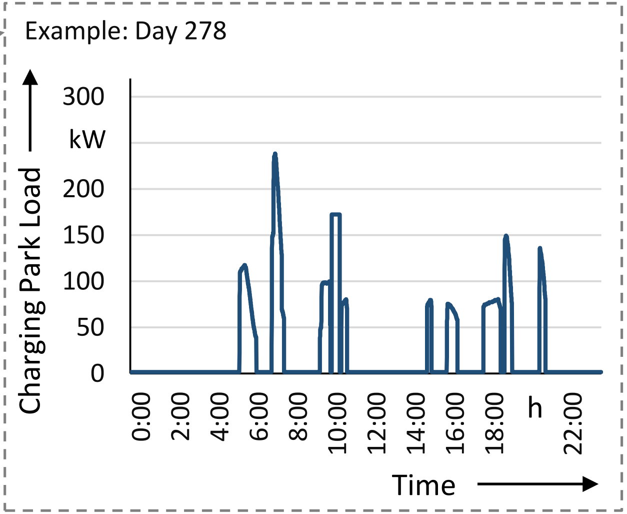
- Arrival Frequency: Derived from highway vehicle counting (Source: German Federal Highway Research Institute)

Example:
Day with the highest traffic



Maximum vehicles per day derived from xEVs arrival frequency & market distribution





- **Maximum vehicles per day:** Number of vehicles that can be charged without having to reject further vehicles
  → Depending on arrival frequency of xEVs
  → High Scenario = Max vehicles per day (100%); Medium Scenario = 50%; Low Scenario = 20%

OPTIMIZATION MODEL RESULTS

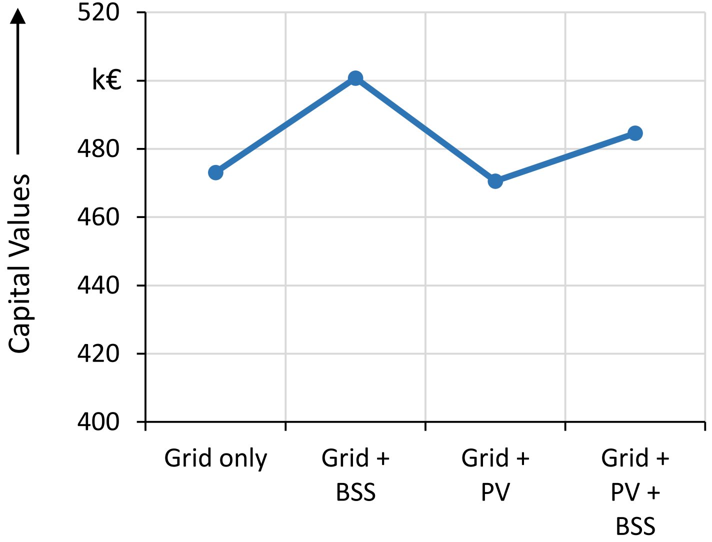
Different charging park configurations (medium utilization scenario)

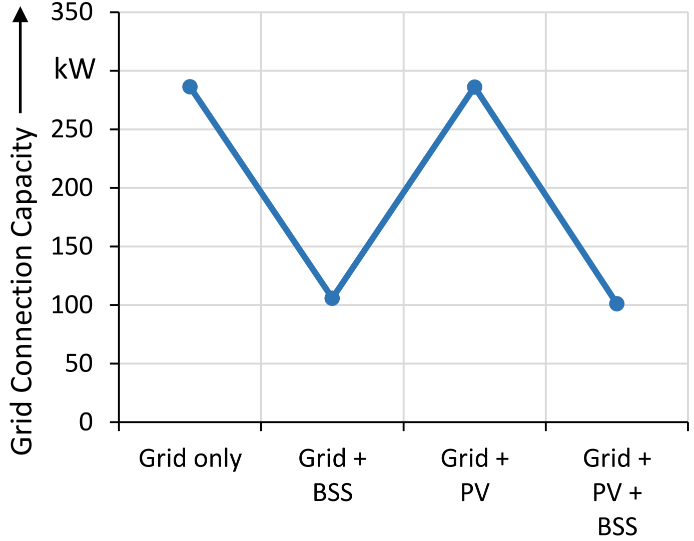
Capital Value
= Discounted
(Costs – Revenues)
i = 1%
T = 20a
Not included:
Charging revenues
& construct. costs

Components

BSS = 150 kWh

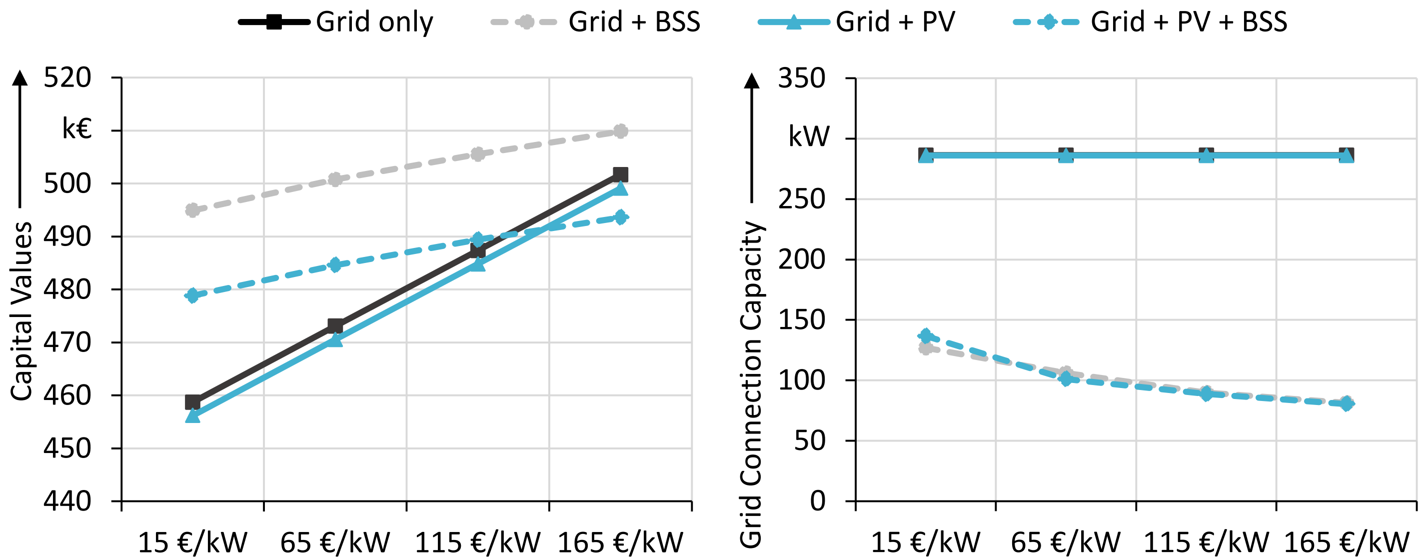
PV = 4.2 kWp





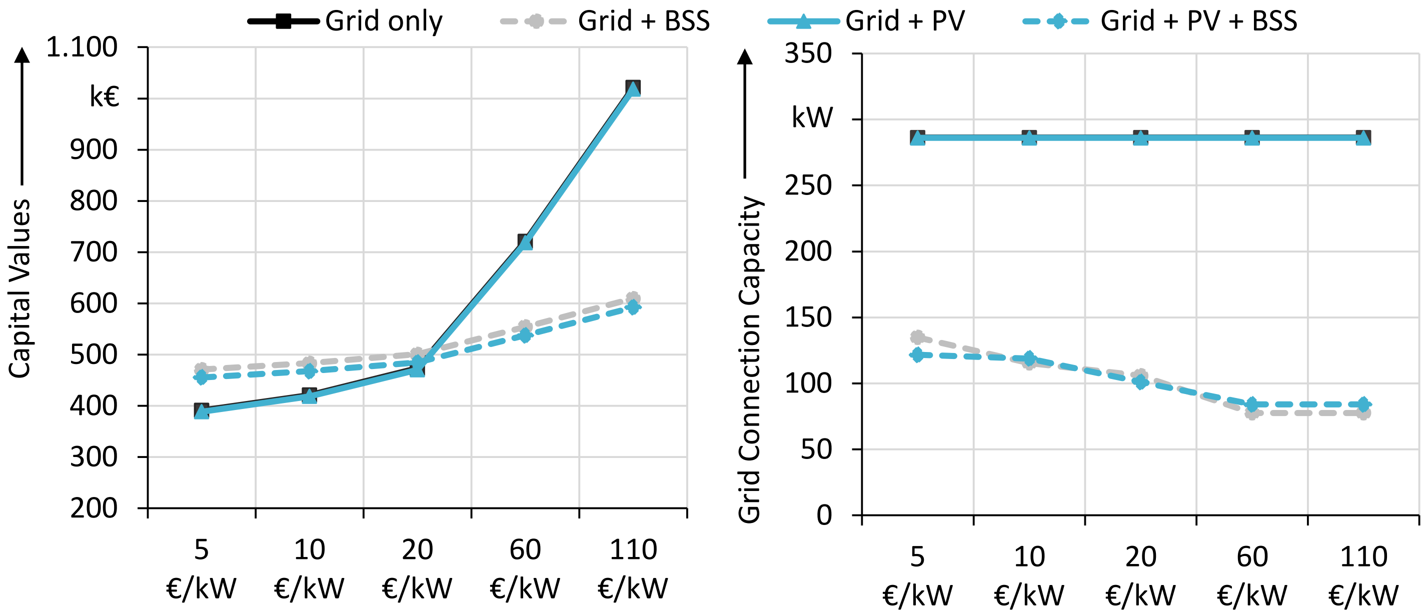
- **No economic advantage when assuming average costs** for analyzed solution with integrated 150 kWh BSS over the gird only solution
- **Grid connection capacity can be reduced by up to 65%**, but cost savings cannot compensate additional BSS costs
- **4.2 kWp PV plant too small to have a major impact** on the economic efficiency of the BSS

Varying building cost subsidies (BCS) [€/kW] for the grid connection point



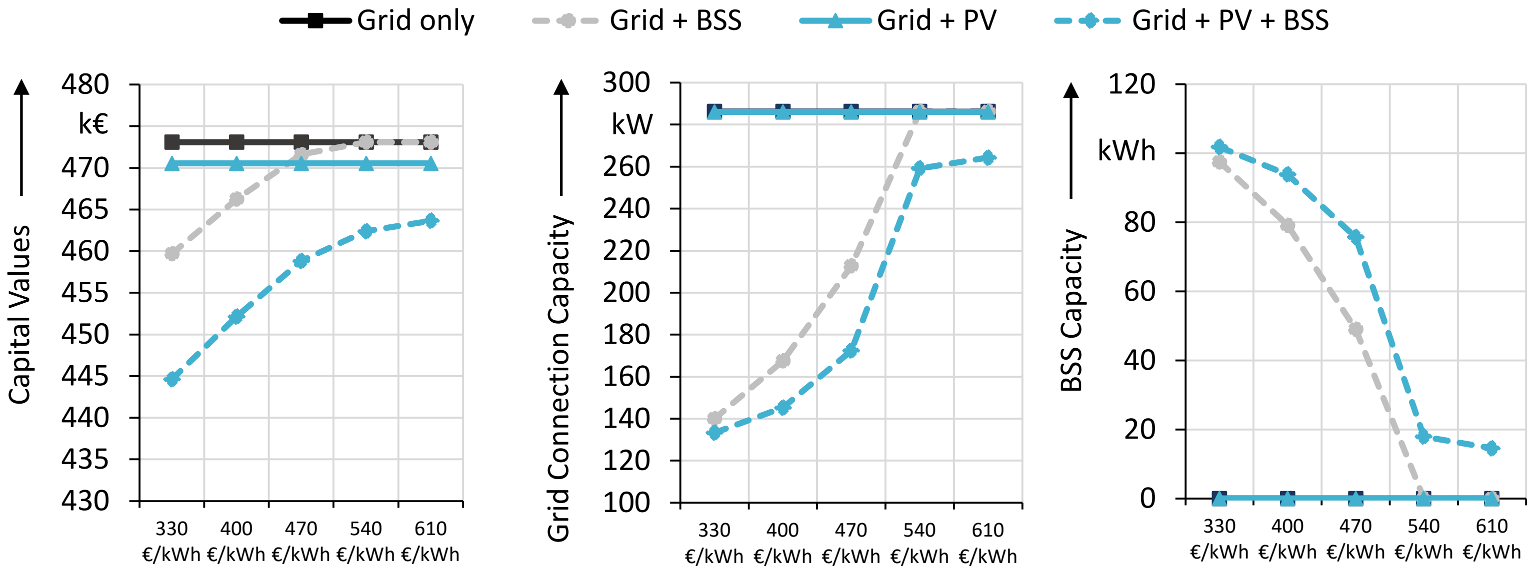
- **150 kWh BSS only provides additional economic value** in scenarios **with a PV plant** and in areas in which **high BCS of about 165 €/kW** are charged for the grid connection point
- **Grid connection capacity can be steadily decreased down to 80 kW**, but limited effect on the economic value of the BSS, because **BCS is only charged once** during installation of the grid connection point

Varying capacity charges [€/kW] for the yearly peak load



- In contrast to BCS the **capacity charge is charged every year**, which explains its **high impact on the economic value of the BSS**
- With **above average capacity charges of 60 €/kW cost reductions of 23%** (without PV) and **25%** (with PV) can be achieved
- In areas with **high capacity charges of around 110 €/kW** cost reductions could reach **72%**

Optimized BSS capacity depending on BSS costs



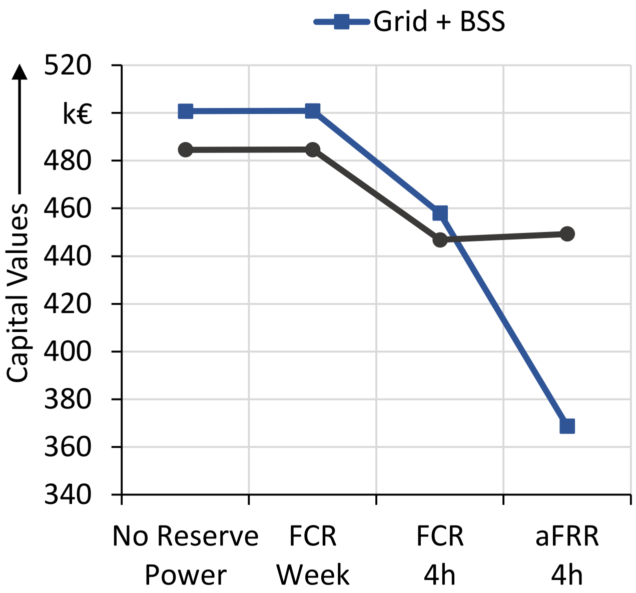
- Without PV: **Larger sized BSS (80 to 100 kWh) only economically profitable** if extra costs for BSS don't exceed **400 €/kWh**
  Assuming **average costs of 470 €/kWh the optimized BSS capacity** is considerably lower: **50 kWh**
  When extra costs reach **540 €/kWh the BSS contains no economic value** and is not installed
- With PV: **Increased profitability of the BSS:** Even at high costs (> 470 €/kWh) a small BSS (15 to 18 kWh) is installed

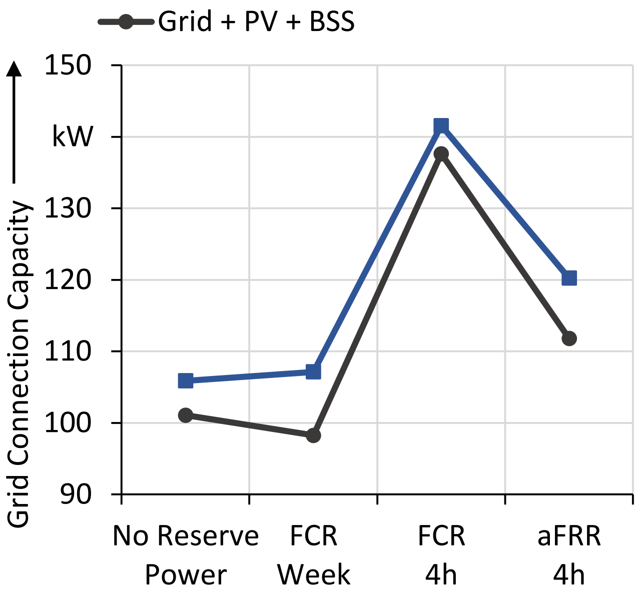
OPTIMIZATION MODEL RESULTS

Provision of reserve power with the integrated BSS (150 kWh)

Abbreviations:

- FCR = Frequency Containment Reserve
- aFRR = Frequency Restoration Reserve





- Provision of **FCR as weekly product** yields **no economic benefit** due to inflexibility
- Provision of **FCR as 4h-products could be economically profitable** for the regarded scenario **(overall cost reductions of up to 8.5%)**
- **FRR even more economically beneficial (26%)**, because the **asymmetrical product allows avoiding grid connection fees (GCF)**
- **GCF especially limit the profitability of FCR provision:** Without GCF overall cost reductions of up to 17% could be achieved

Provision of reserve power with the integrated BSS (150 kWh)

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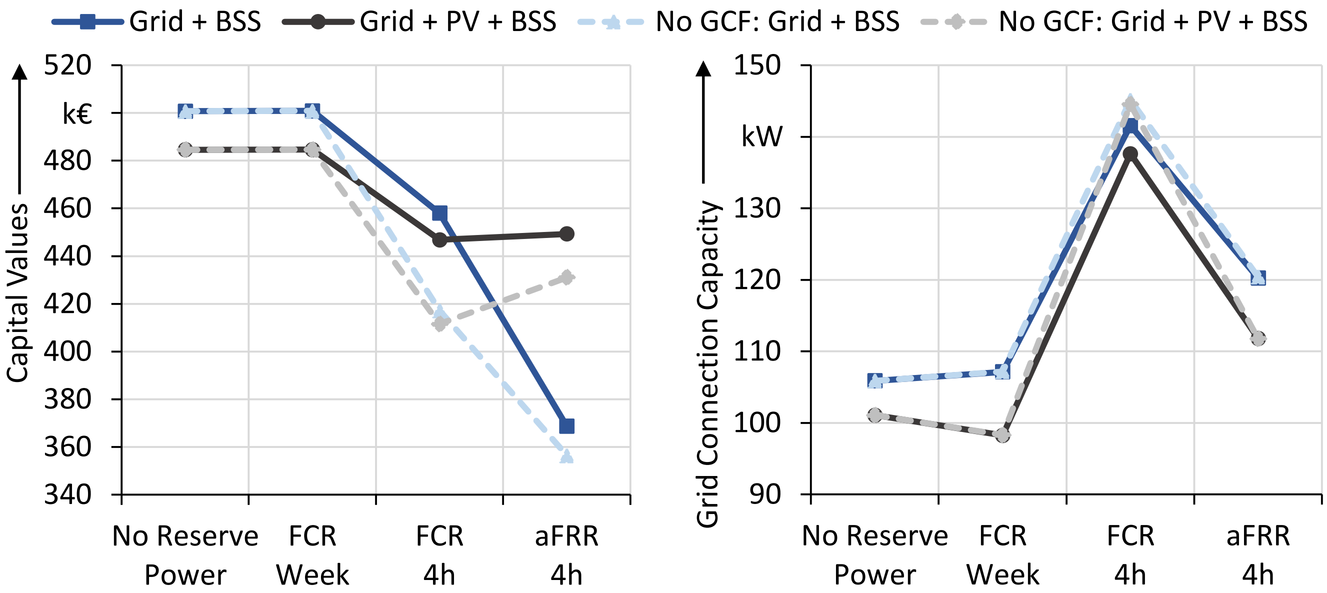
- aFRR = Automatic Frequency Restoration Reserve
- GCF = Grid Connection Fees



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- **aFRR even more economically beneficial (26%)**, because the **asymmetrical product allows avoiding grid connection fees (GCF)**
- **GCF especially limit the profitability of FCR provision:** Without GCF overall cost reductions of up to 17% could be achieved

Conclusion & Outlook

Result Summary

- **Economical value of the integrated 150 kWh BSS highly depends on local cost factors & BSS costs**
  - No eco. advantage with average German costs
  - Big eco. potential in areas with above average capacity charges (>20 €/kW)
  - Smaller sized BSS of 50 kWh (average BSS costs) to 100 kWh (very low BSS costs) would increase the systems profitability
- **Provision of reserve power shows high potential**
  - FCR and aFRR as 4h-products
  - Grid connection fees limit economic potential

Outlook

- **Vehicle-to-grid (V2G)**
  - New source for network services and revenues
  - Examination of the revenue potential of V2G
- **Energy Management System**
  - Development based on the output of the optimization model
  - Use of machine learning algorithms