Smart Charging of Electric Vehicles in Energy Systems with high Shares of Renewable Energies

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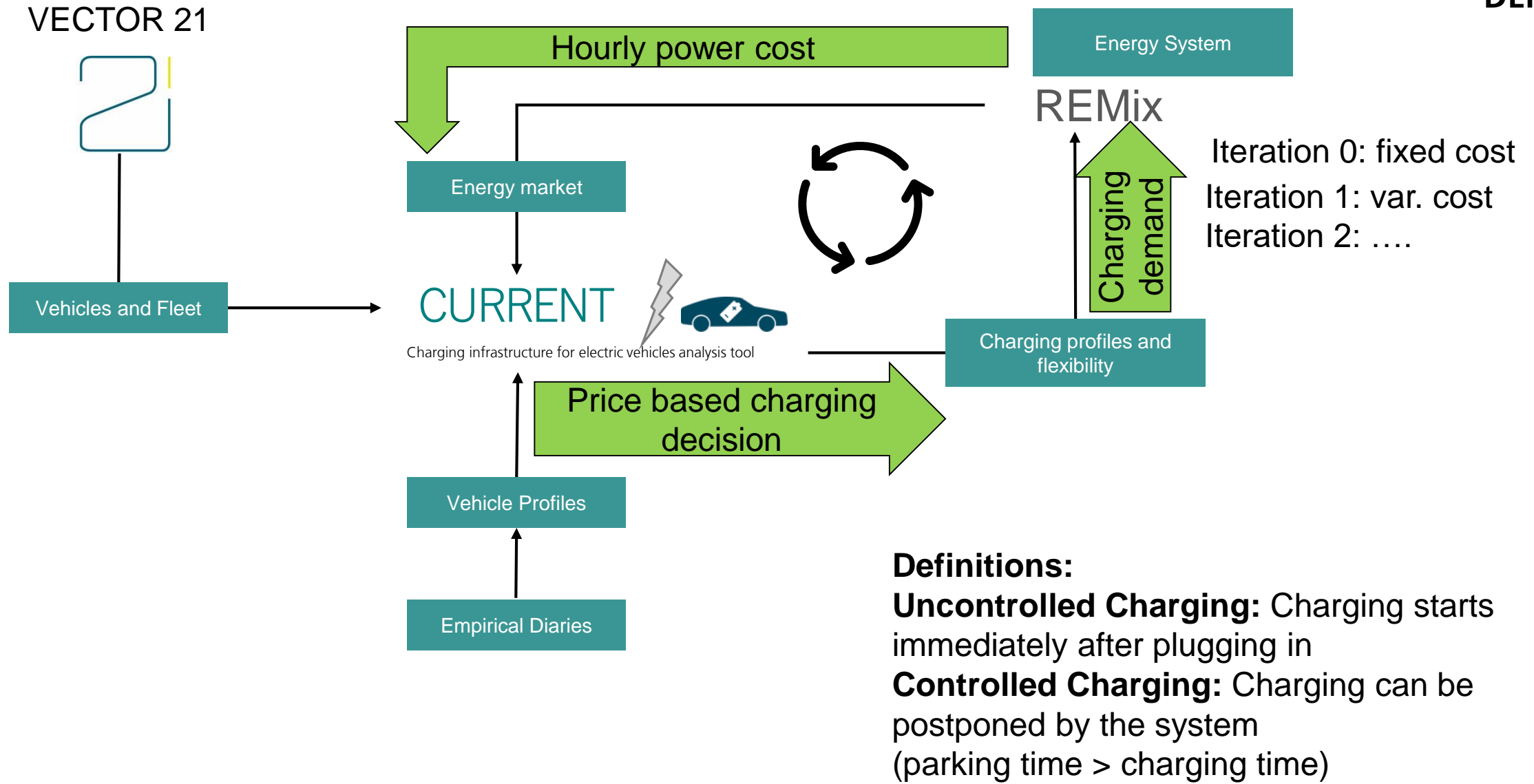
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Research Questions & Scenarios

Research Questions

- How do (weather dependent) electricity price signals influence EV users decisions to charge?

- How do connection decisions impact the optimization of the energy system?

Scenarios

- **BASE**
  Reference Scenario

- **DAY**
  Using the day peak, incentives for connection at daytime

- **FAST**
  Focus on fast charging comparable to filling stations today

- **FLEX**
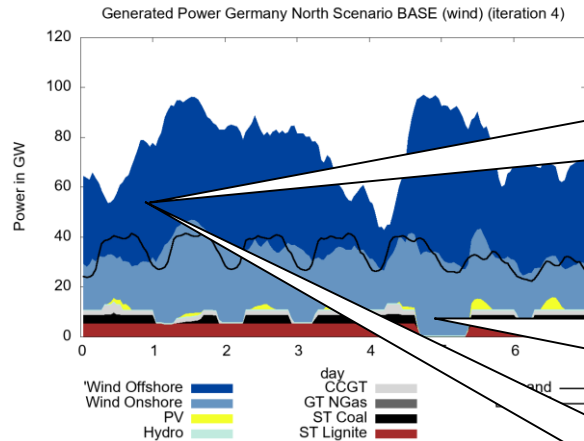 Incentives to connect cars as often as possible

Model Set-Up

VECTOR 21

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Hourly power cost

Energy System

REMix

Iteration 0: fixed cost
Iteration 1: var. cost
Iteration 2: ….

Energy market

Charging demand

Vehicles and Fleet

CURRENT

Charging infrastructure for electric vehicles analysis tool

Charging profiles and flexibility

Price based charging decision

Vehicle Profiles

Empirical Diaries

Definitions:
Uncontrolled Charging: Charging starts immediately after plugging in
Controlled Charging: Charging can be postponed by the system
(parking time > charging time)

Selected weather weeks

We will use this week in the further slides

Winter/wind week

Spring/PV week

Northern Germany

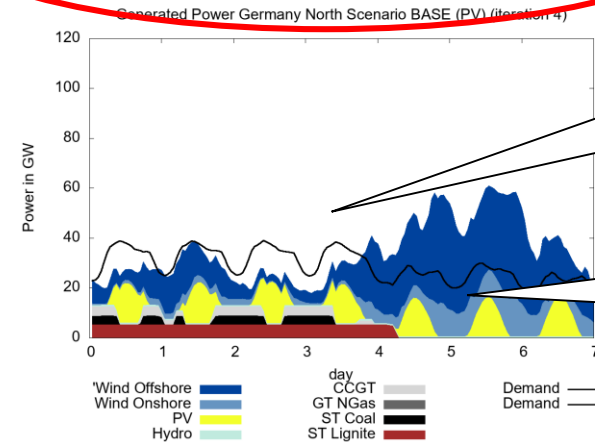Southern Germany

Generation is higher than demand at all timestamps

Strong wind: No conventional generation
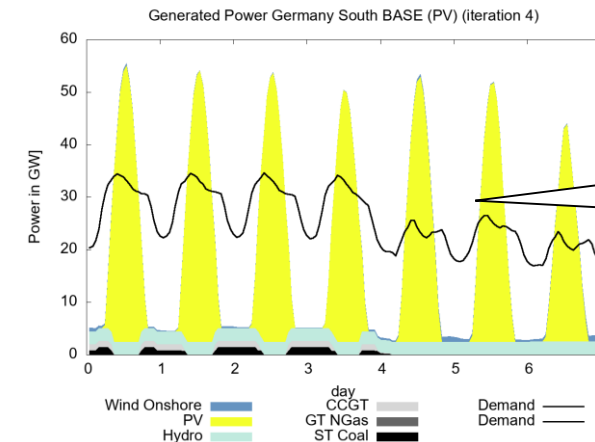
Variations in genartion are mainly driven by offshore wind
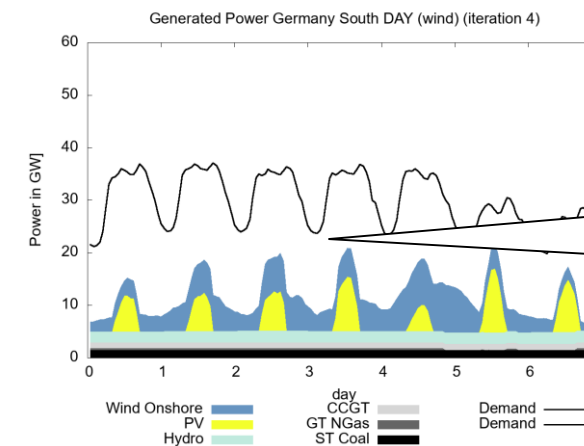
Import dependency in Southern Germany

Demand is higher than generation in some timestamps

No need for conventionals Friday through Sunday

Daily surplus of PV generation at noon

Charging Decisions

- CURRENT is a behavioural model for charging decisions

- The user can decide based on his knowledge of state of charge and expected prices where and when to charge.

- Here we have perfect foresight for charging prices
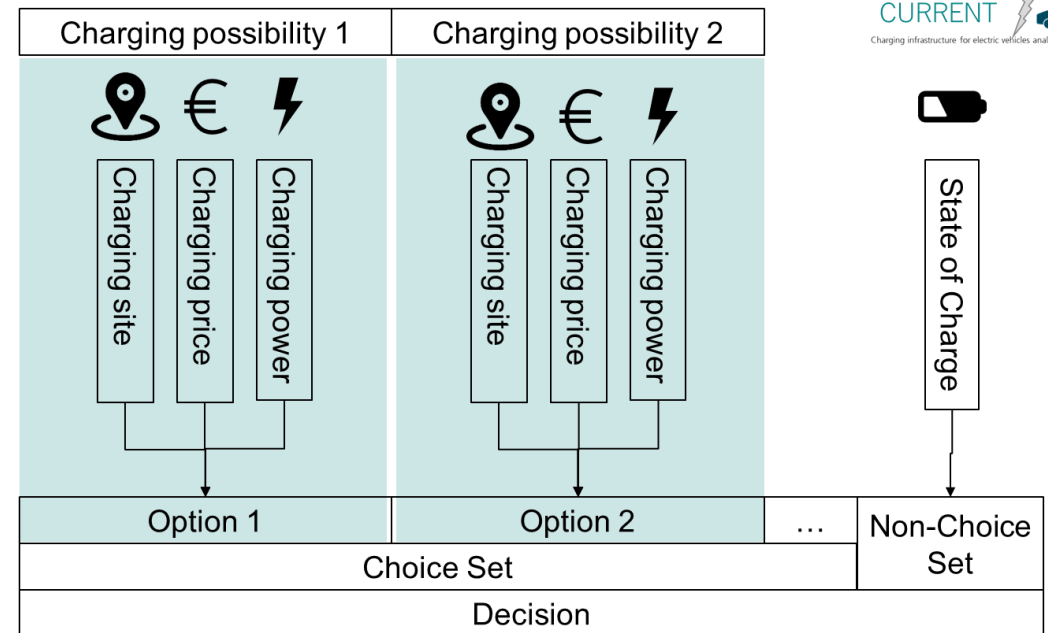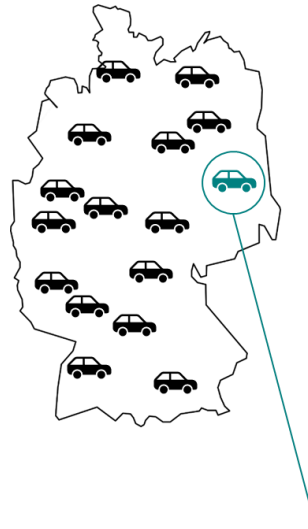
Resulting Charging Prices

- Charging prices were scaled from the marginal power generation cost in REMix to match a set average price

- Prices differ spatially between northern and southern Germany
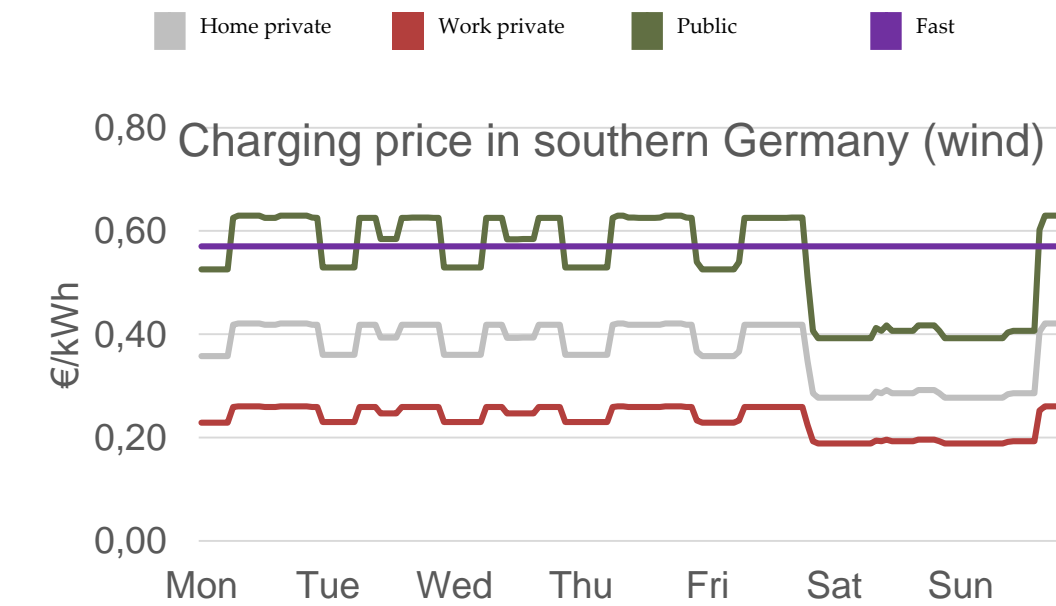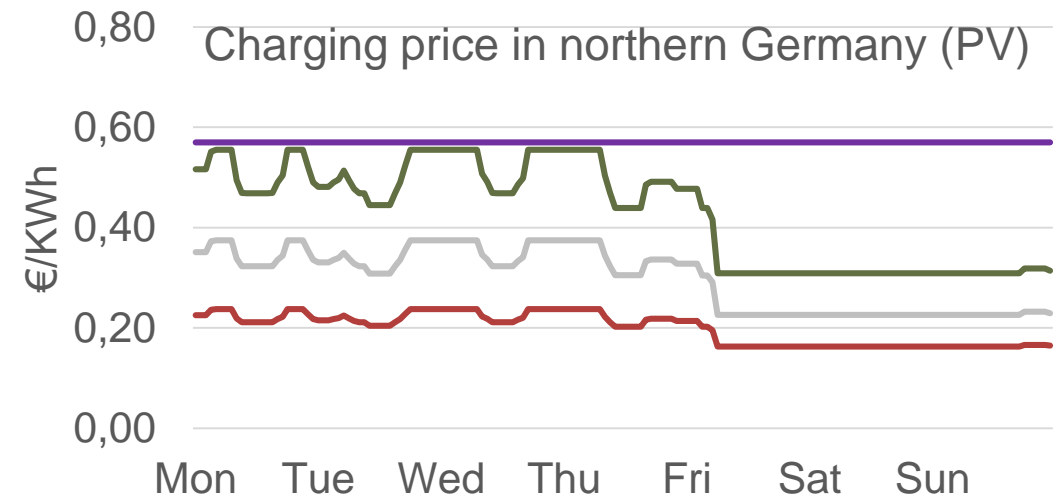
Average Charging price in €ct/kWh		BASE	DAY	FAST	FLEX
home	private	30	as Base	as Base	as Base
	public	43	as Base	as Base	as Base
work	private	20	5	as Base	as Base
	public	43	35	as Base	as Base
shopping	public	43	20	as Base	as Base
other	private	43	as Base	as Base	as Base
	public	43	35	as Base	as Base
fast		57	as Base	40	70

Charging price in northern Germany (PV)

Home private   Work private   Public   Fast

Charging price in southern Germany (wind)

Occupancy of charging points in northern Germany during the spring Week (in Million EVs)
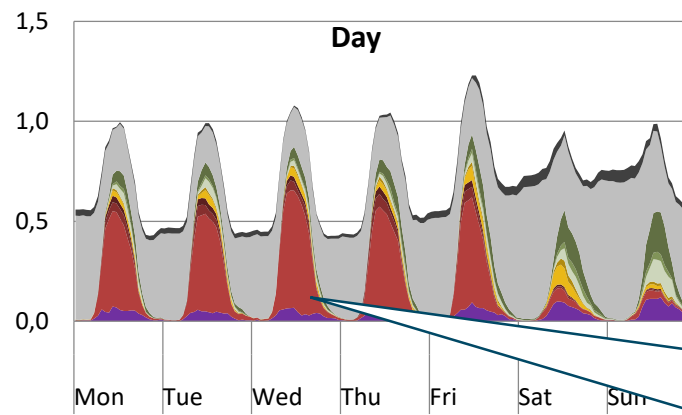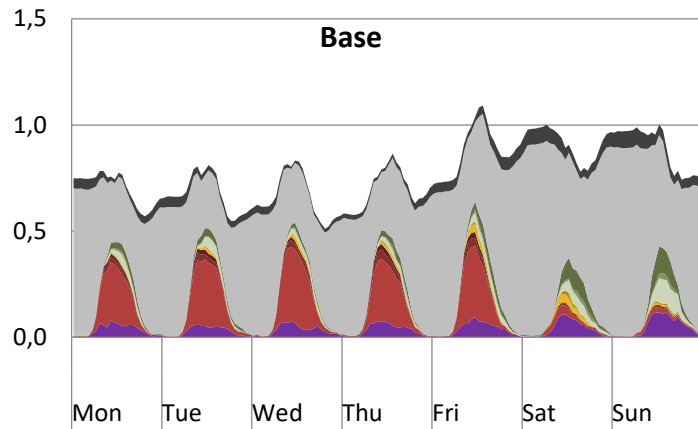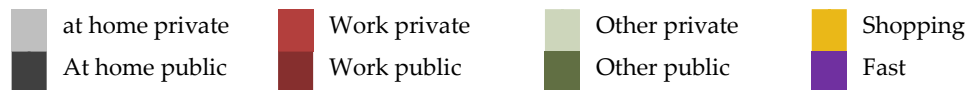

- Price signals can influence the charging decisions of electric vehicle owners and can push them to charge more system friendly

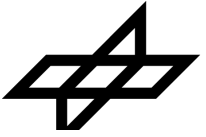DAY scenario increases occupancy during the day, esp. at work
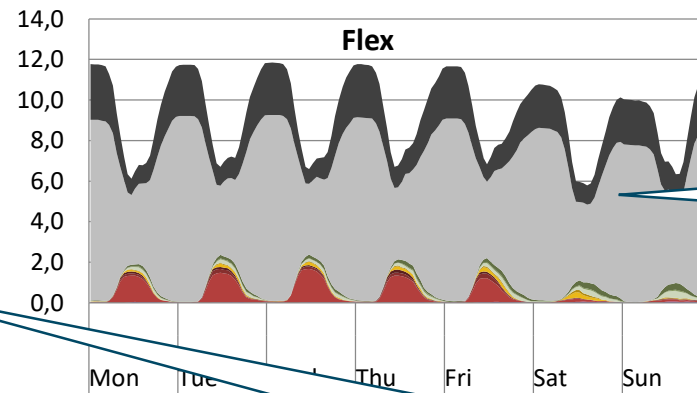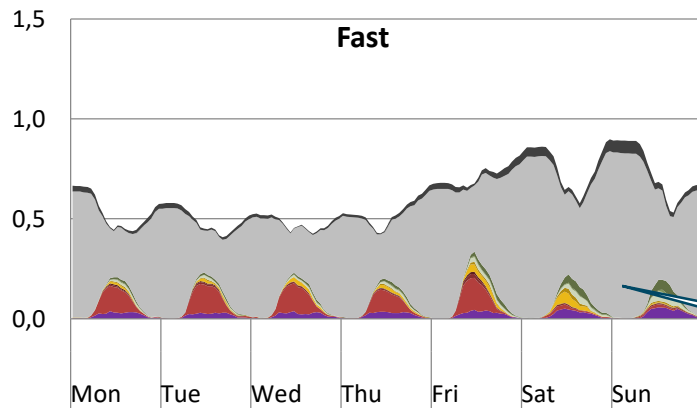
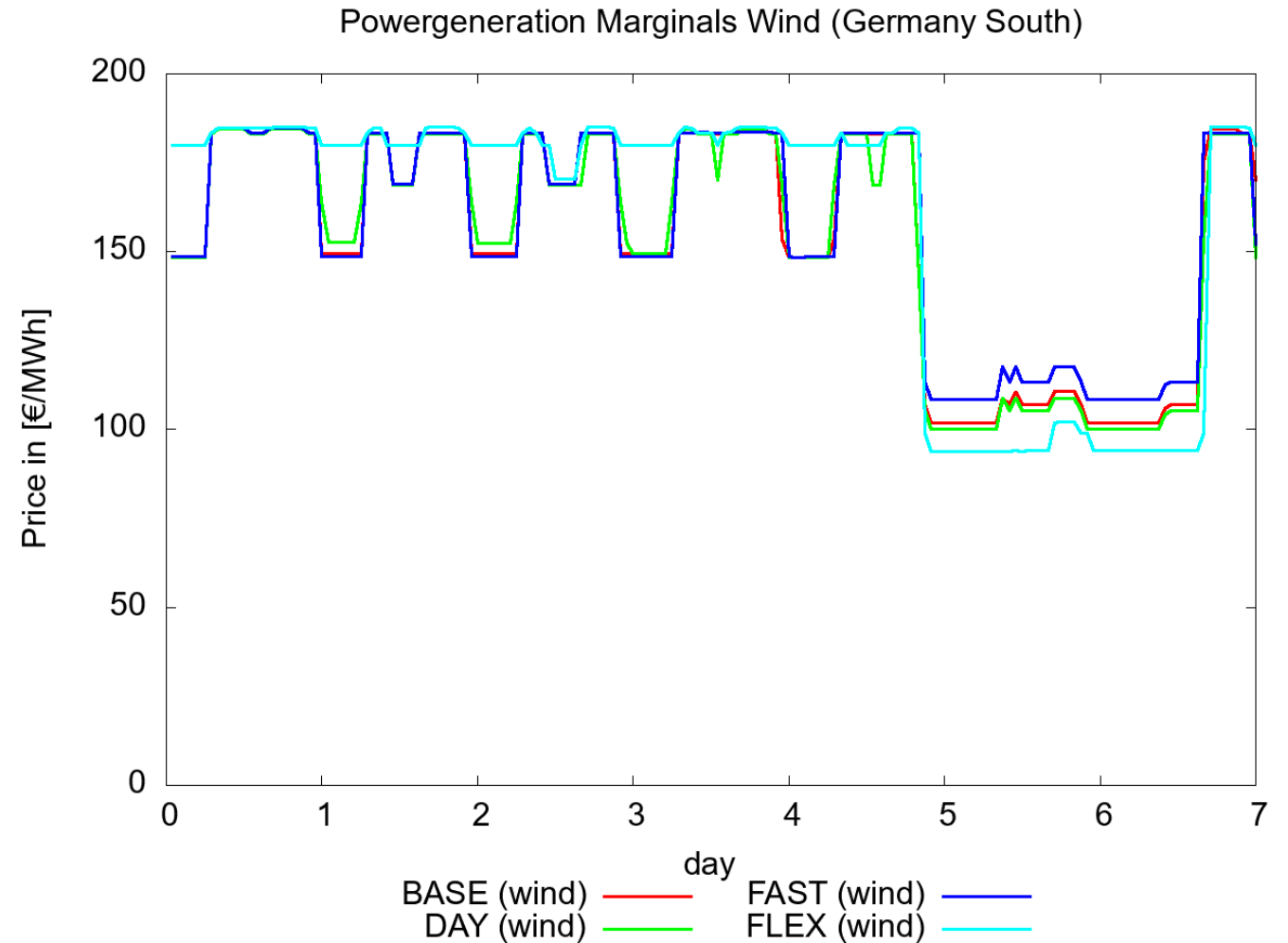FLEX scenario requires more charging infrastructure (different scale!)

FAST scenario leads to low usage of workplace charging

Legend:
- at home private
- At home public
- Work private
- Work public
- Other private
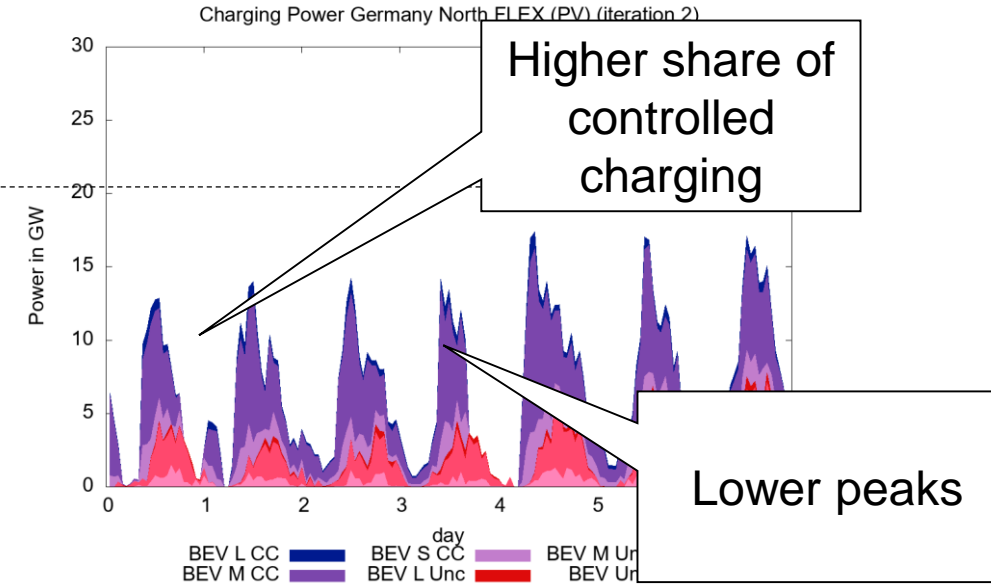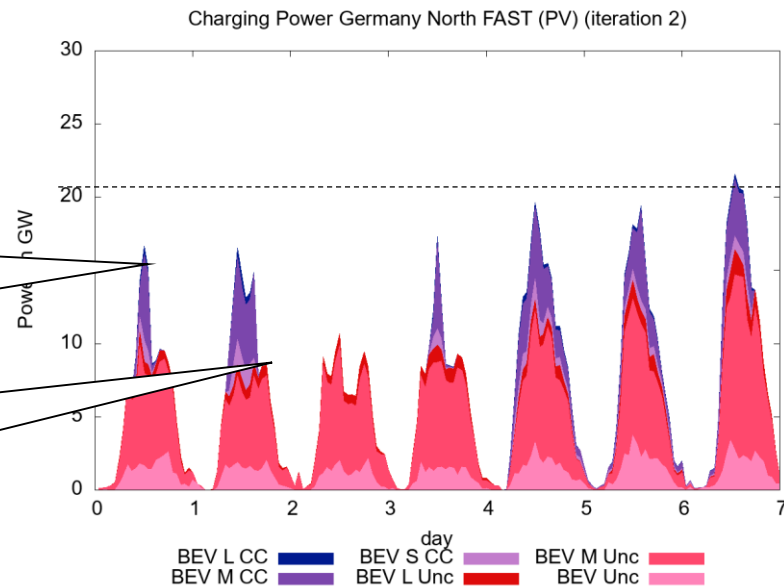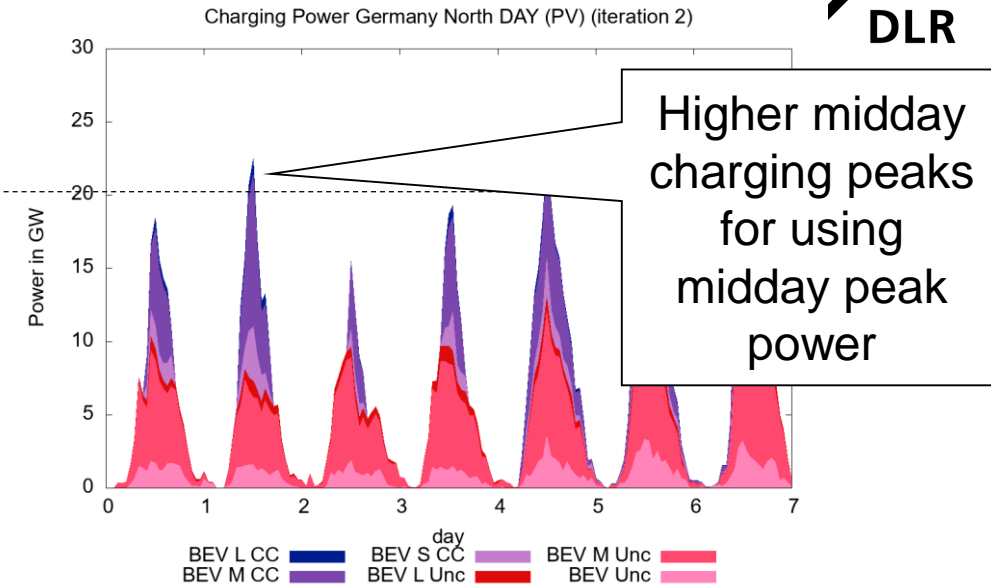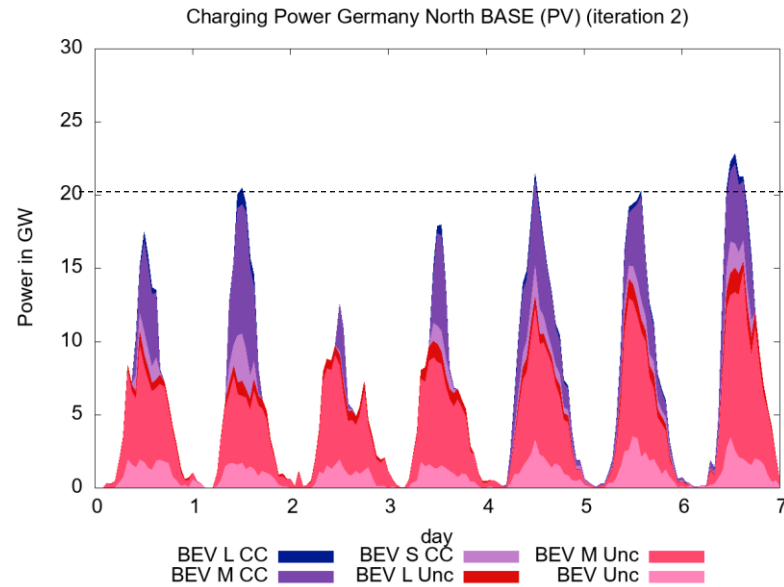- Other public
- Shopping
- Fast

Changes in Power Generation Marginals

- Difference charging strategies lead to different cost patterns

- FLEX scenario has the smoothest cost pattern

- DAY Scenario leads to a small cost drop

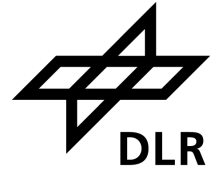- FAST leads to cost drops at midday, highest cost on the weekend.

Powergeneration Marginals Wind (Germany South)

BASE (wind) ——   FAST (wind) ——
DAY (wind) ——   FLEX (wind) ——

Controlled and Uncontrolled charging

Charging Power Germany North BASE (PV) (iteration 2)

Charging Power Germany North DAY (PV) (iteration 2)

Higher midday charging peaks for using midday peak power

Charging Power Germany North FAST (PV) (iteration 2)

Charging Power Germany North FLEX (PV) (iteration 2)

Lower charging peaks

Low share of controlled charging

Higher share of controlled charging

Lower peaks

Carsten Hoyer-Klick, Moritz Bergfeld, John Anderson Name, Smart
Charging of Electric Vehicles, ICEM 2023, June 27th, 2023

Stationary Storage Untilization in GWh

Winter/wind week

Spring/PV week
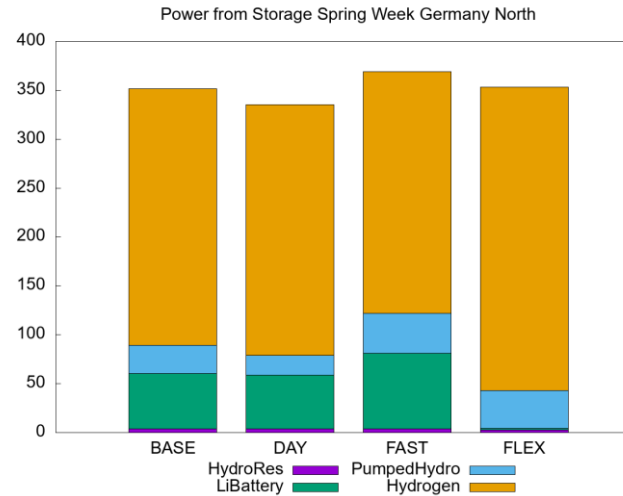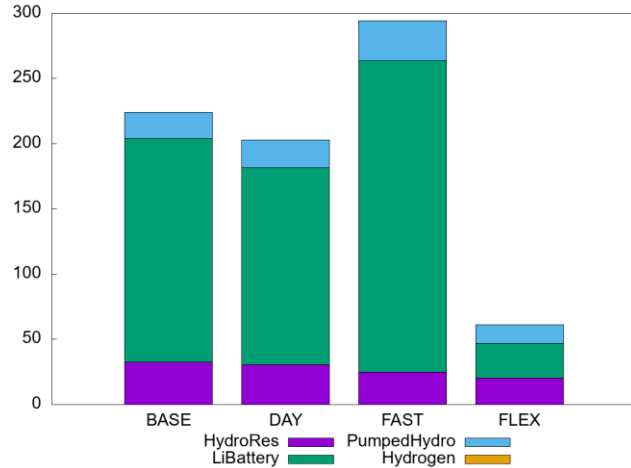
Northern Germany
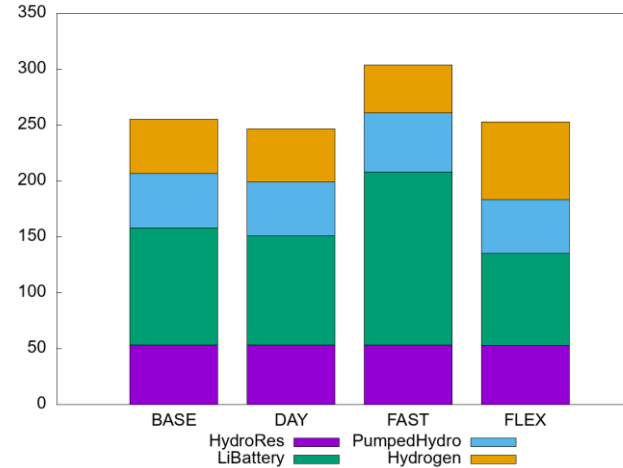
Southern Germany

- FAST charging is always more demanding on the energy system

- The DAY scenario needs less storage than BASE scenario, especially in southern Germany

- The FLEX scenario shows the strongest impact in the windy week, significantly reducing the storage demand but requires a proper charging infrastructure

- High share of hydrogen in northern Germany during spring week

Conclusions

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- Weather patterns will influence price patterns for EV charging

- Charging tariff design based on the analysis of weather and demand patterns can help to reduce the impact of EV charging to the energy system

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