s c c h
software competence center
hagenberg

Data Analytics and AI to control Energy Grids

29.04.2019

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SCCH ist eine Initiative der
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SCCH ist Teil des
softwarepark hagenberg

Contents

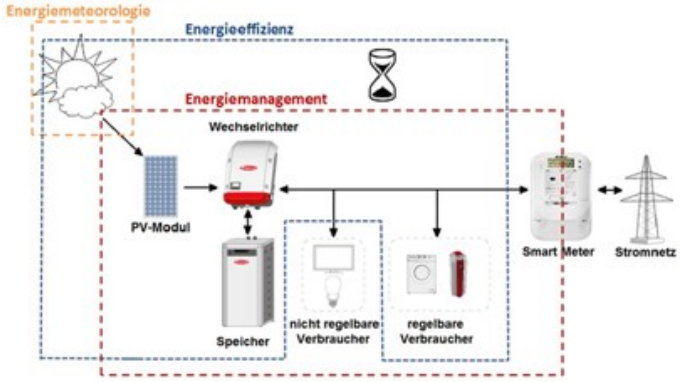
- Artificial Intelligence (AI)
  - What is AI ?
- Market Organization & Challenges
  - Current market structure
  - Future challenges
- Flexibility & Demand Response
  - Paradigm shift
- Conclusions & Discussion
  - AI in Smart-Grid

ARTIFICIAL INTELLIGENCE

What is Artificial Intelligence?

- For thousand of years, *we have tried to understand how we think*
  - How a human being can *perceive*, *predict* and *manipulate* the world
- Artificial intelligence (AI) goes further:
  - It attempts not just to understand but also to build ***intelligent/rational agents***
- What is an *intelligent* or *rational agent*?
  - Any decision making process, problem solver, etc., that does the right thing!
  - However, ***what is the right thing***?

Artifacts that behave as *humans*



Artifacts that behave *rationally*

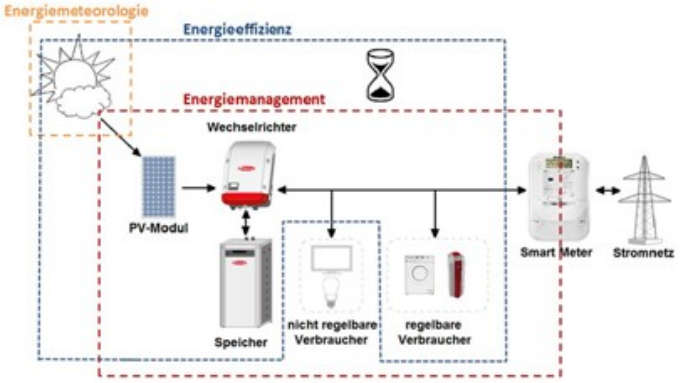
AI according to "giants"

Thinking Humanly	***Thinking Rationally***
"[The automation of] activities that we associate with human thinking, activities such as decision making, problem solving, learning, ..." (Bellman, 1978)	*"The study of the computations that make it possible to perceive, reason and act."* (Winston, 1992)
Acting Humanly	***Acting Rationally***
"The act of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)	*"AI... is concerned with intelligent behavior in artifacts."* (Nillcon, 1998)

“Driven by Needs” vs “Driven by Challenges”

- Build artifacts driven by challenges
  - *Build a robot that walks*
  - *Build a robot that greets people*
  - *Build a robot that jumps*
- Build artifacts driven by needs
  - *Energy consumption should be minimal*
  - *System should be stable*
  - *Increase absorption of renewables*

Artifacts that behave as *humans*

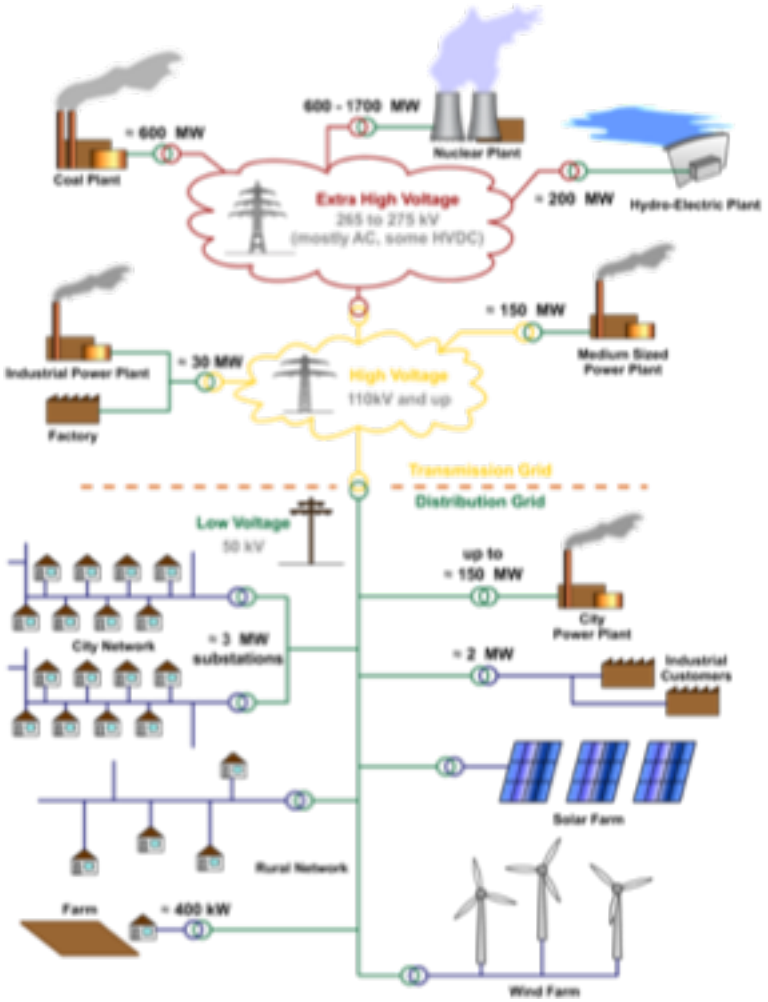


Artifacts that behave *rationally*

MARKET ORGANIZATION & CHALLENGES

Organization of the Electricity Grid

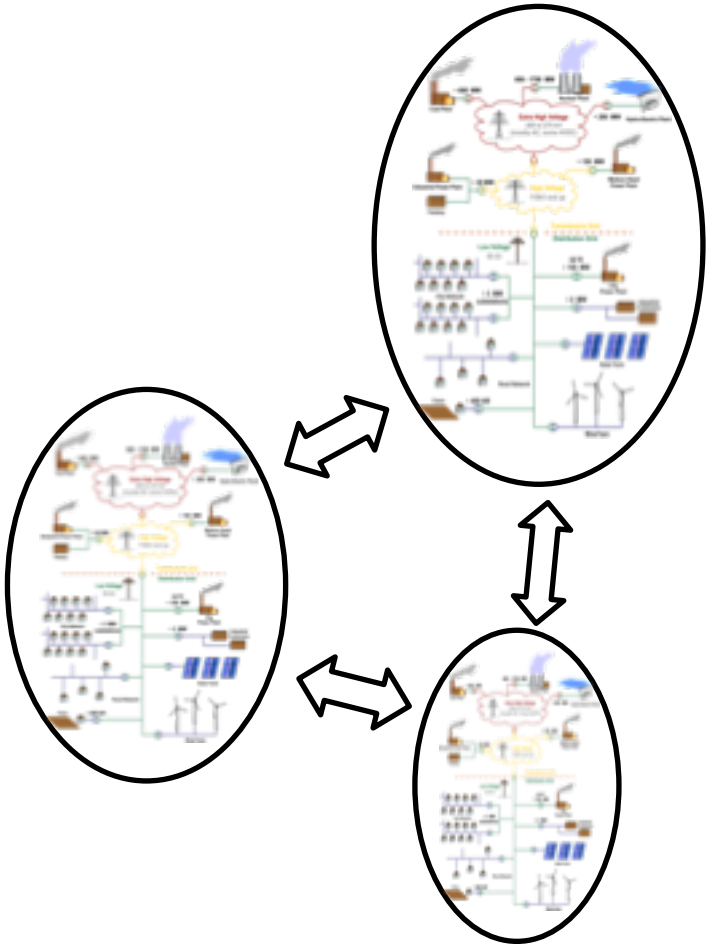
- Multiple stakeholders
  - *SO (System Operator)*
    - *Operator of Transmission/Distribution Grid*
  - *CAM (Control Area Manager)*
    - *Checks and accepts schedules between BG's and other control areas*
  - *CSA (Settlement and clearing agent)*
    - *Clearing and settling balancing within a control area*
  - *BRP (Balance responsibility party)*
    - *Representing a balance group to CSA*
  - *Suppliers/Producers*
  - *Traders/Consumers*



Microgrids/Balance Groups for Resilience

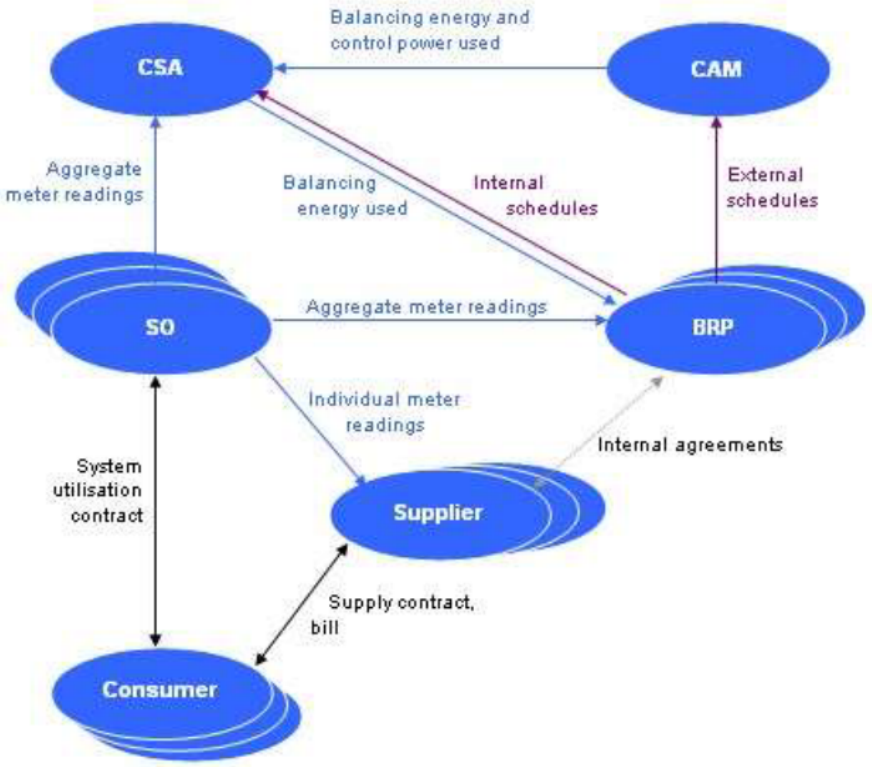
- Distribution of control management
  - Schedules/Balancing are controlled separately by independent *balance groups* or *microgrids*
  - A balance group contains both suppliers and consumers
  - Injection and withdrawl of electricity is balanced
  - Exchange of electricity between balance groups

- Increased resilience due to
  - Better control of renewables integration
  - Easier scheduling of electricity exchanges
  - Easier/secure integration of demand response
  - Immediate response to local imbalances



Austrian Electricity Market

- Balance-Group Organization
  - Receives meter readings from SO
  - Receives contract/bill agreements between suppliers and consumers
  - Sends *internal schedules* (between BGs of the same control area) to CSA
  - Sends external schedules (between BGs of different control areas) to CAM
- Schedules
  - calculated based on *forecasted* quantities
    - Load consumption
    - Weather data
    - Renewables' generation



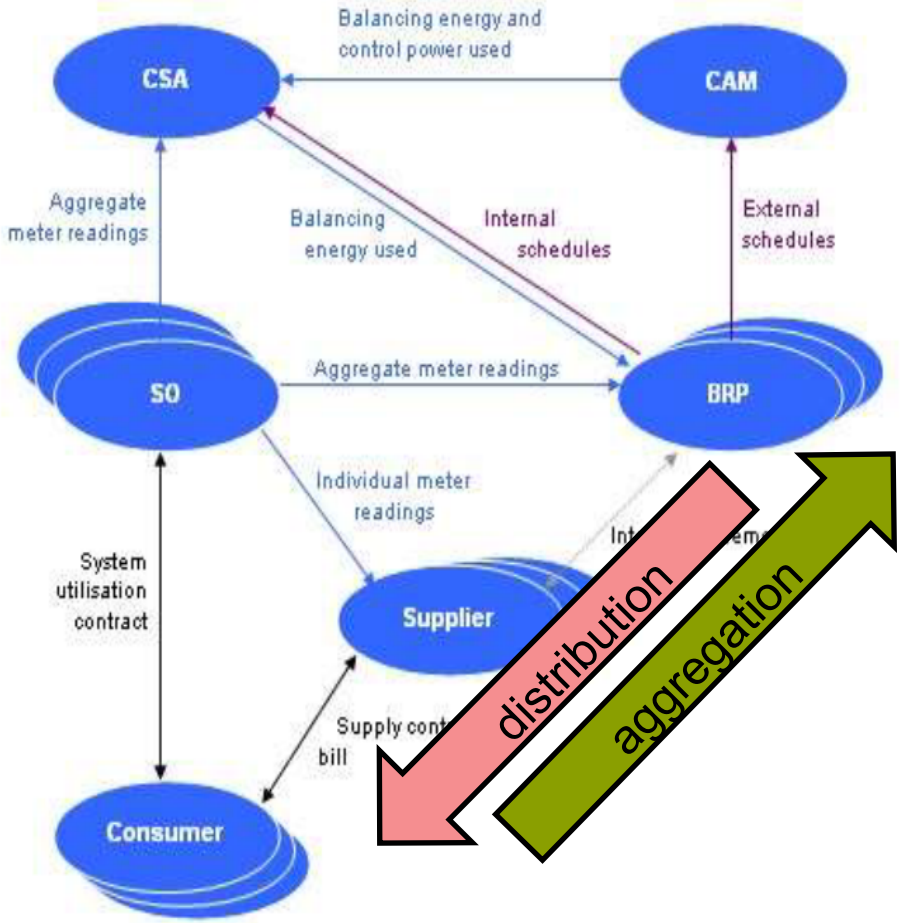
Challenges/Issues: *Market Design*
(based on T&D Europe)

- *Equal access to markets*,
  - Consumers should be given the incentives to provide flexibility in consumption
  - Technological advancements are required to enable this
- *Contractual arrangements*
  - The regulatory framework shall enable the creation of clear, simple and transparent contractual arrangements for demand response
  - Clear principles for residential and non-residential customers
  - *Enabling and integrating varying and diverse consumer preferences/behaviors*
- *Data management*
  - Data management shall be implemented by the whole value chain
  - Privacy and security, transparency, accuracy are of vital importance
- *Grid operators should enable and use flexibility*
  - An EU initiative is needed to incentivize grid operators' investment into smart-grid solutions

FLEXIBILITY
& DEMAND RESPONSE

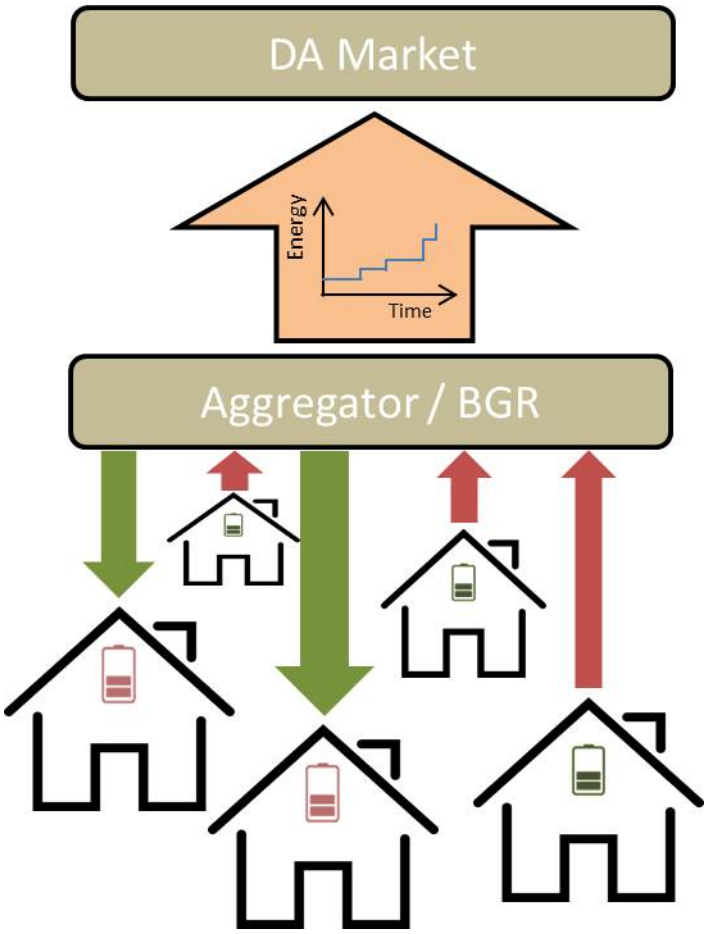
The role of AI

- Higher integration of consumers
  - for more flexible demand response
  - for higher absorption of renewables
  - for efficient utilization of energy
  - for reducing energy dependencies
- The role of AI
  - Aggregator/group level
    - Enable group-level flexibility exchange
  - Inter-building level
    - Enable inter-building electricity exchanges
  - Building level
    - Actively control and optimize energy
    - Optimally respond to market signals
    - Efficiently integrate users' preferences and behavior



Demand Response @ Aggregator Level (1/3)

- Direct control over batteries
  - Aggregator *forecasts* the amount of energy that could additionally be stored or withdrawn from the users' batteries
  - Aggregator *calculates* the optimal amount of electricity that can be exchanged (energy-price curve)
- Advantages
  - Apart from forecast uncertainties, the available flexibility can be directly computed/exchanged
  - *Higher degree of security!*
- Disadvantages
  - Limited amount of flexibility
  - *Users are not part of the optimization!*



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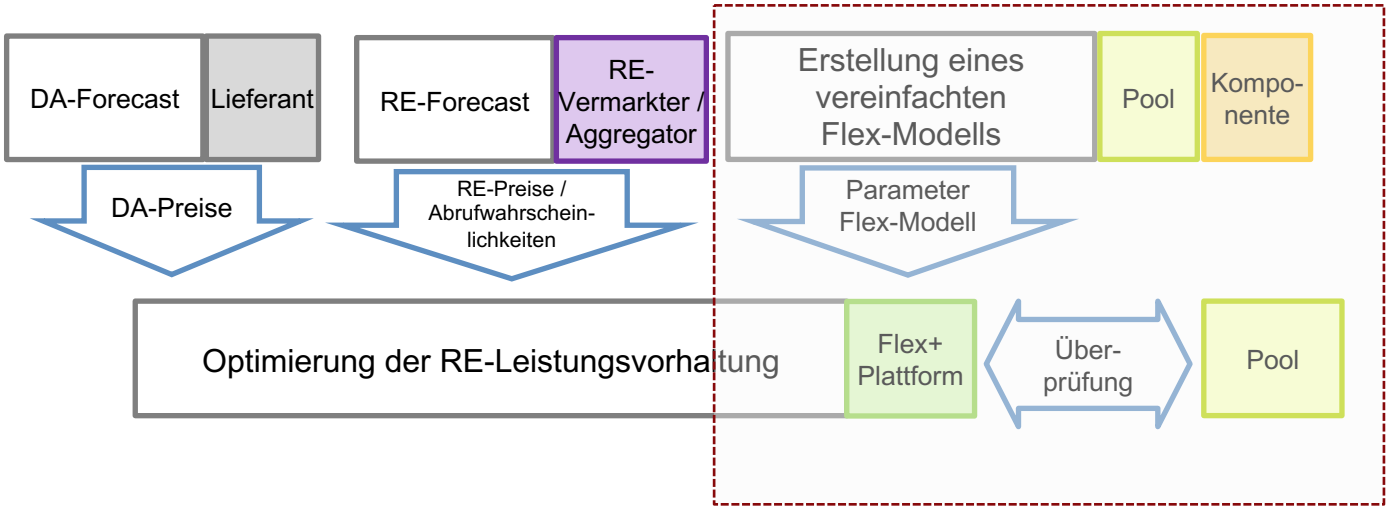
Demand Response @ Aggregator Level (2/3)



- Challenges
  - Information exchange and data management
  - Optimization complexity and accuracy
  - *Multiple optimization levels* (depending on the market participation: RE/DA/ID)
  - *Multiple modeling/approximation* levels (flexibility modeling/forecast, cost approximation)
  - *Real-time response*

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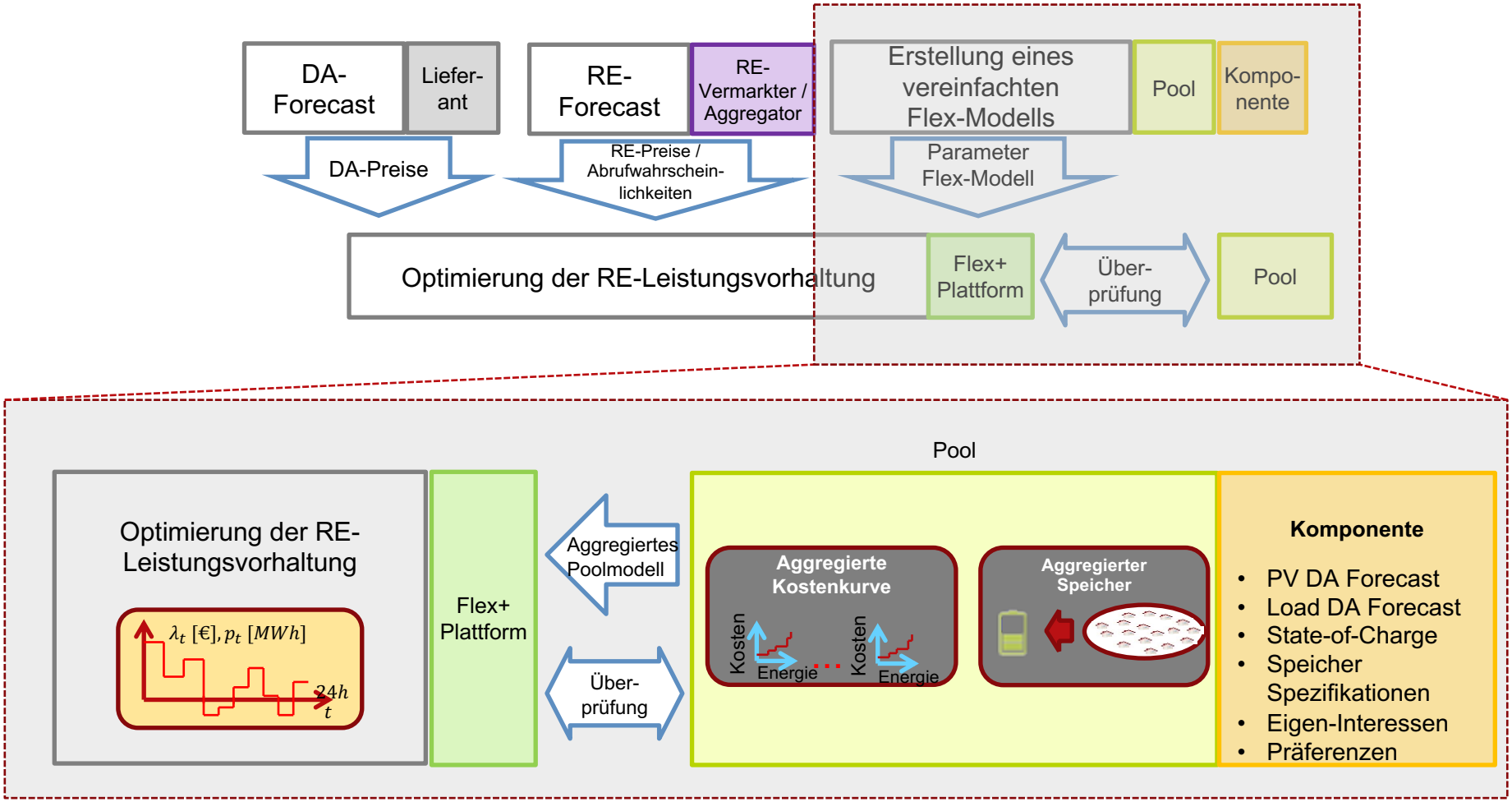
Demand Response @ Aggregator Level (3/3)



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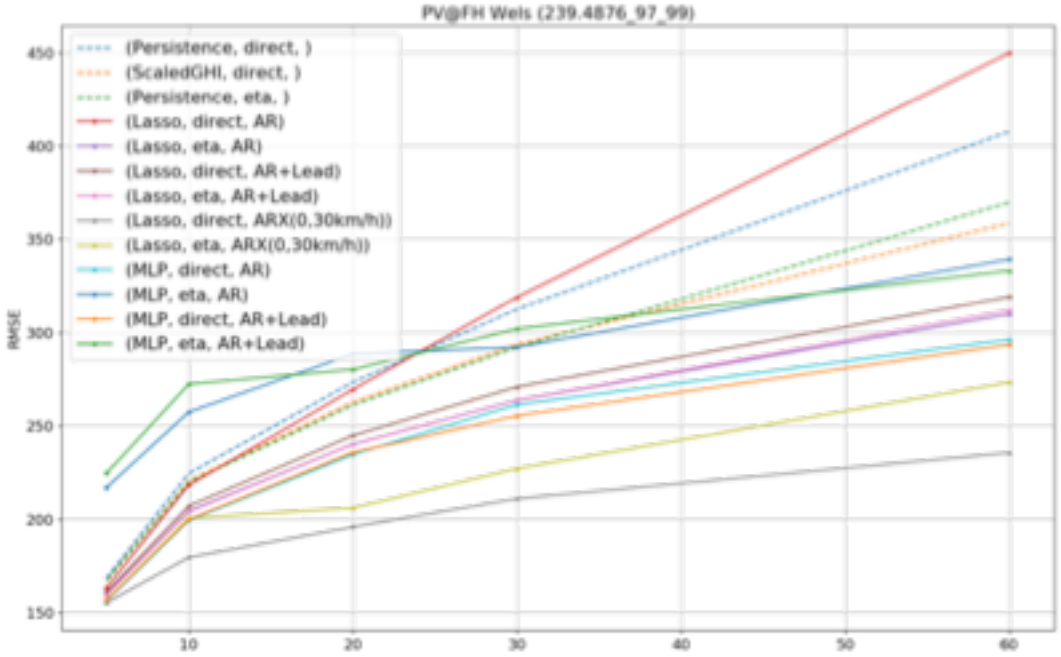
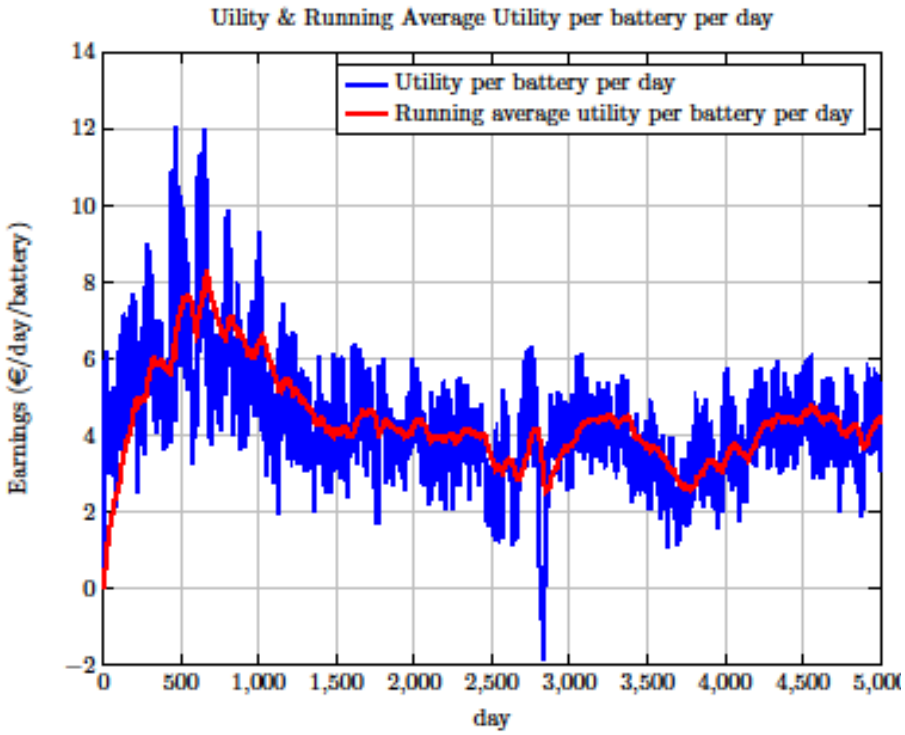
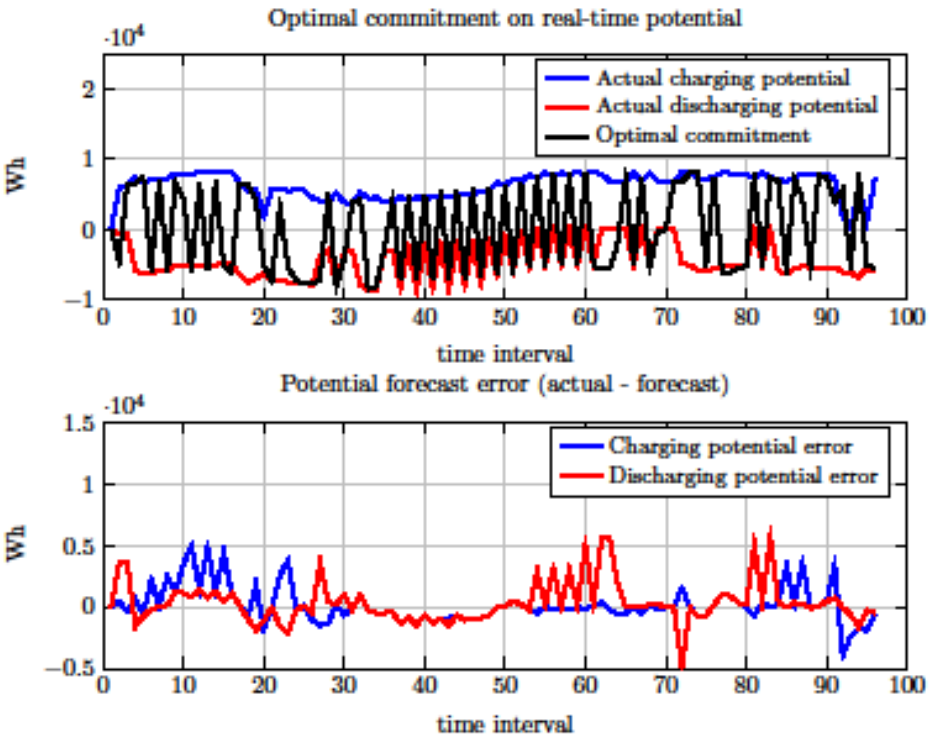
PV Forecast Accuracy & AI Challenges



- Challenges
  - Bad forecast accuracy for long horizons
  - Flexible optimization (ability to update/correct decisions during the day)
  - Need for *lower-level* and *real-time* corrections (inter-building real-time exchange)

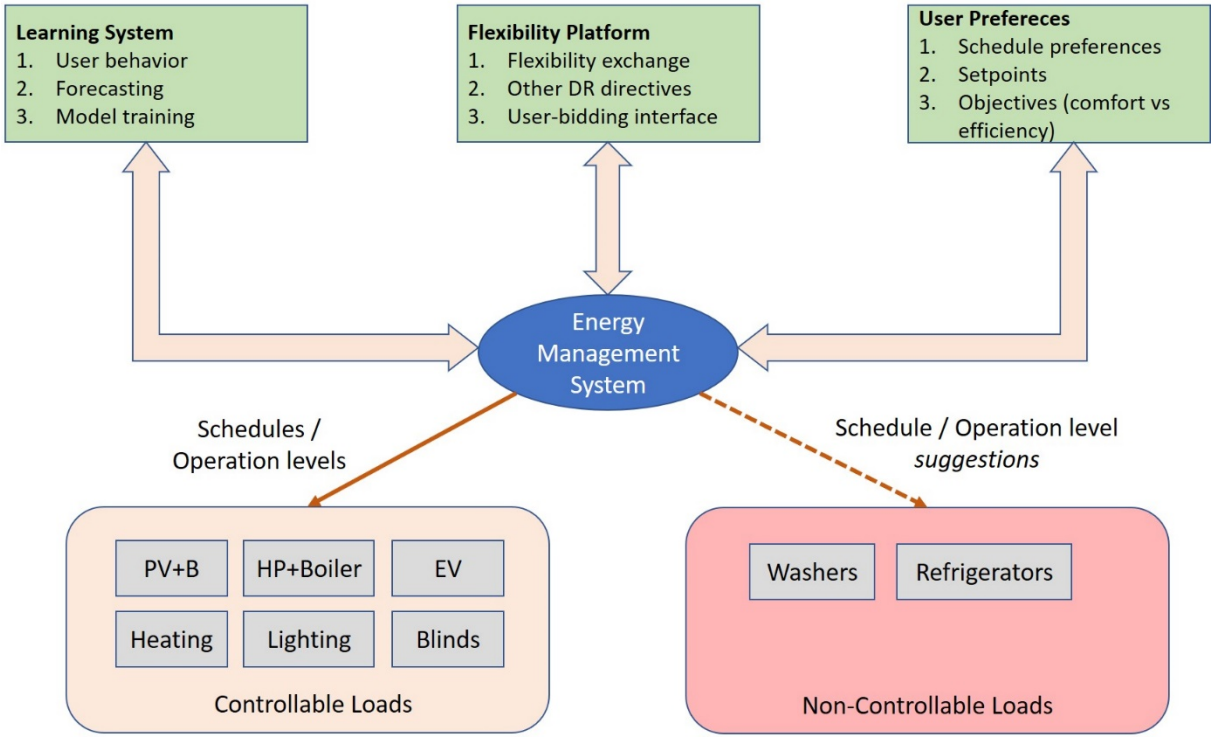
Reinforcement Learning for Optimal Flexibility Extraction





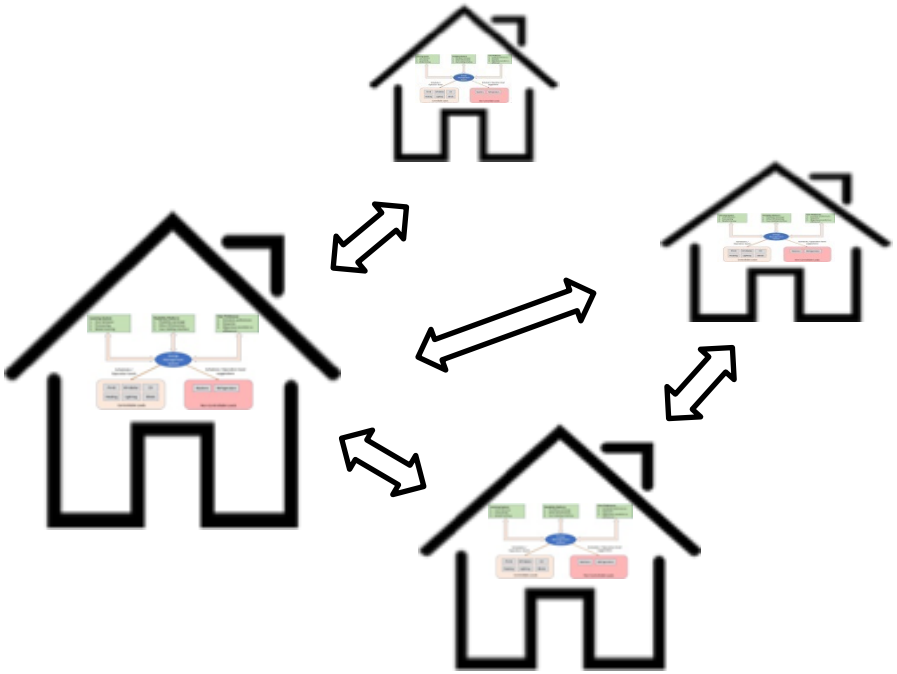
- Challenges
  - Learning-based optimization to minimize the effect of forecast errors

Demand Response @ Building Level



- Challenges
  - Increase flexibility by integrating aggregator/DR objectives to scheduling equipment
  - Adjust optimization to user behavior and incorporate user preferences
  - Upgrade of building equipment (sensors/actuators)

Demand Response @ Intra-Building Level

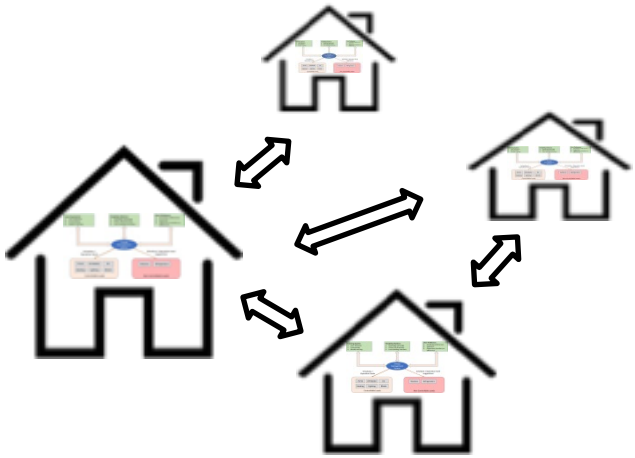


- Challenges
  - Increase flexibility by allowing real-time exchange of flexibility between buildings
  - New market design paradigm

CONCLUSIONS & DISCUSSION

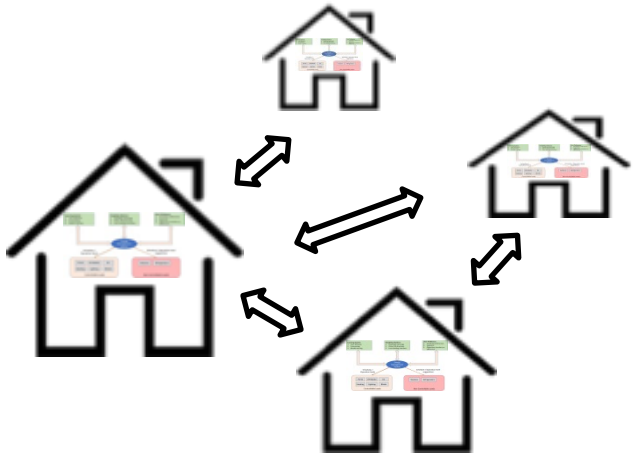
Paradigm Shift

- End-users as “first-class citizens”
  - No clear separation between generation and consumption
  - Active participation of end-users in demand-response
  - Increased *flexibility* in adjusting load
  - Increased *efficiency* and reduced prices
  - Increased *security* through active load adjustments
- Equipment upgrade
  - New technologies for active market interaction
  - New sensors/actuators for efficient energy management
- The role of AI
  - Develop “rational”/”intelligent” distributed *agents*
  - Distribution implies new challenges/opportunities for
    - Stability, Resilience, Efficiency
  - Modeling Approximation for complexity reduction
  - Forecasting (for improving accuracy)



AI in Smart-Grid

- AI for forecasting
  - Advanced methodologies for increased forecast accuracy
  - Aggregation/Modeling and Complexity is a great challenge
  - Exploit/develop deep-learning and aggregation techniques
- AI for optimization
  - Multiple optimization levels (aggregator, building, intra-building)
  - Extremely high complexity for standard optimization techniques
  - Distributed (learning-based) optimization seems appropriate
- AI for resilience and security
  - Preventive response to failures
  - Cyber-security



THANK YOU!