Urban hybrid energy storage – Enabling large-scale integration of renewables

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Agenda

- Motivation
- Concept and topics of the urban hybrid energy storage
- Development of residential lithium battery systems
- Concept of the control system (FlexController)
- Conclusions

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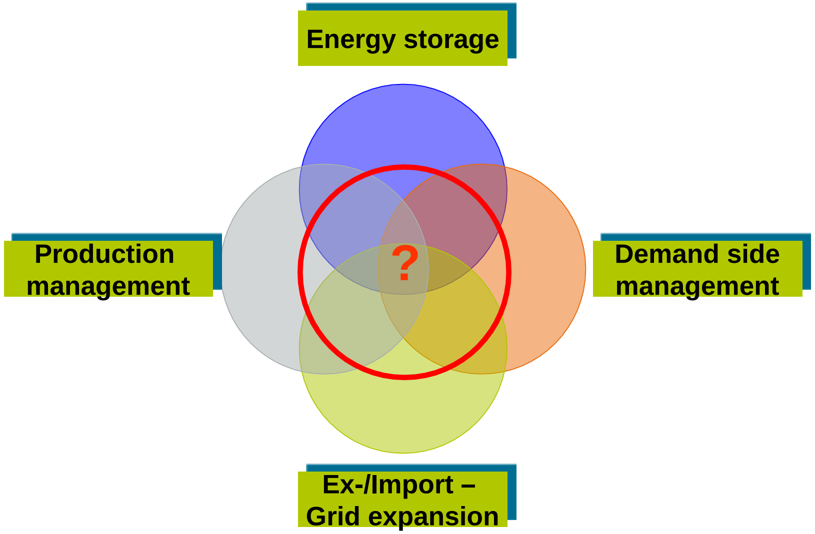
URBAN HYBRID ENERGY STORAGE

Challenge in the grid:
Permanent spatiotemporal balance of power

- Energy storage
- Demand-side management
- Generation management
- Grid expansion



But…

- Energy storage… (still) very expensive
- Demand-side management... “difficult” potentials
- Generation management… high losses
- Grid expansion... costs, acceptance problems

➡ Not a single solution solves the problem

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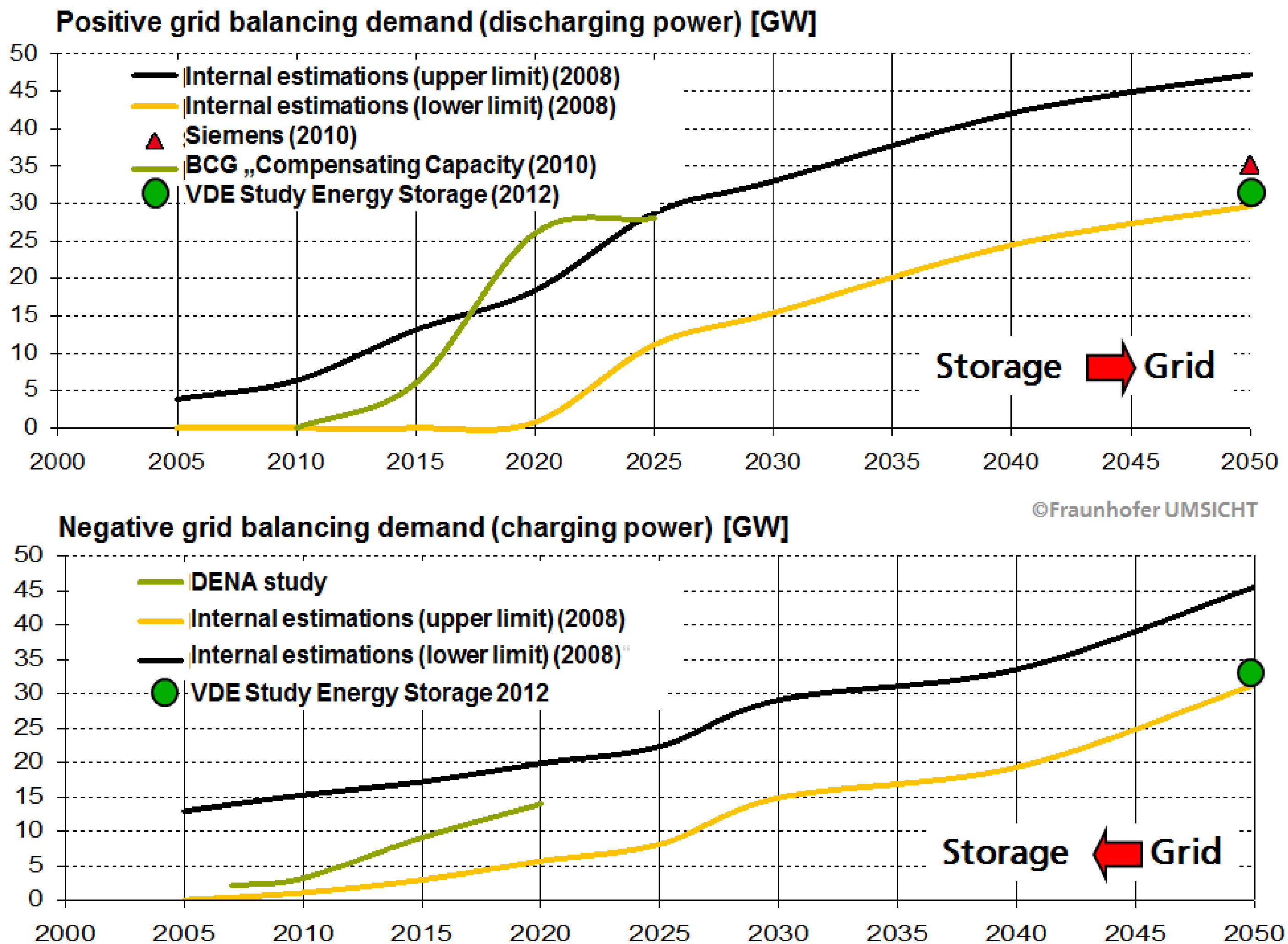
Estimations for grid balancing demand
(Germany, Peak Load 90 GW)



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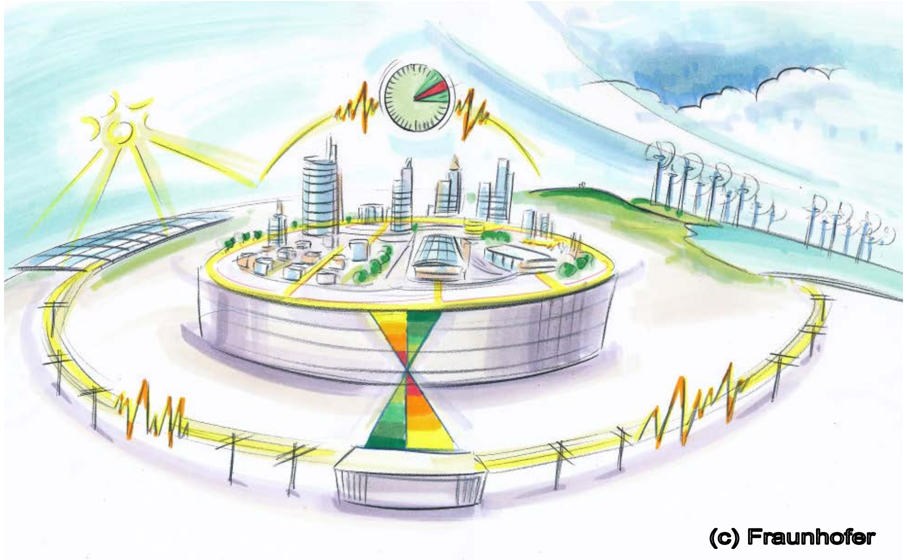
Solution idea

- Power balance on a regional level
- Reduction of necessary new and expensive transmission lines



Solution concept

Technological advancement and combination of measures:

- Physical storages
- Demand-side management
- Generation management

Combination of different technologies within an *urban hybrid energy storage*

→ Storing of energy in the city

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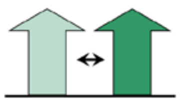
Components of the urban hybrid energy storage

Additive generation

- Application: rare short-term peak loads
- Technology: e.g. emergency power units (hospitals)

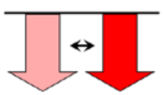


Dispatchable generation

- Application: frequent and high short-term peak loads
- Technology: Micro-CHP (virtual power plants)

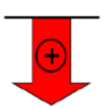
Electric power storage

- Application: daily balancing of power demand and generation
- Technology: e.g. lithium battery (decentralized), redox flow battery (central)



Dispatchable load

- Application: frequent and high short-term generation peaks
- Technology: e.g. heat pumps



Additive load

- Application: rare generation peaks
- Technology: e.g. electrical heating (domestic hot water, district heating)

Structure of the urban hybrid energy storage

Urban hybrid energy storage

▶ Sale of storage capacity

Central electric storage

▶ E.g. redox flow battery

Decentralized electric storage

▶ Lithium battery

Heat storage

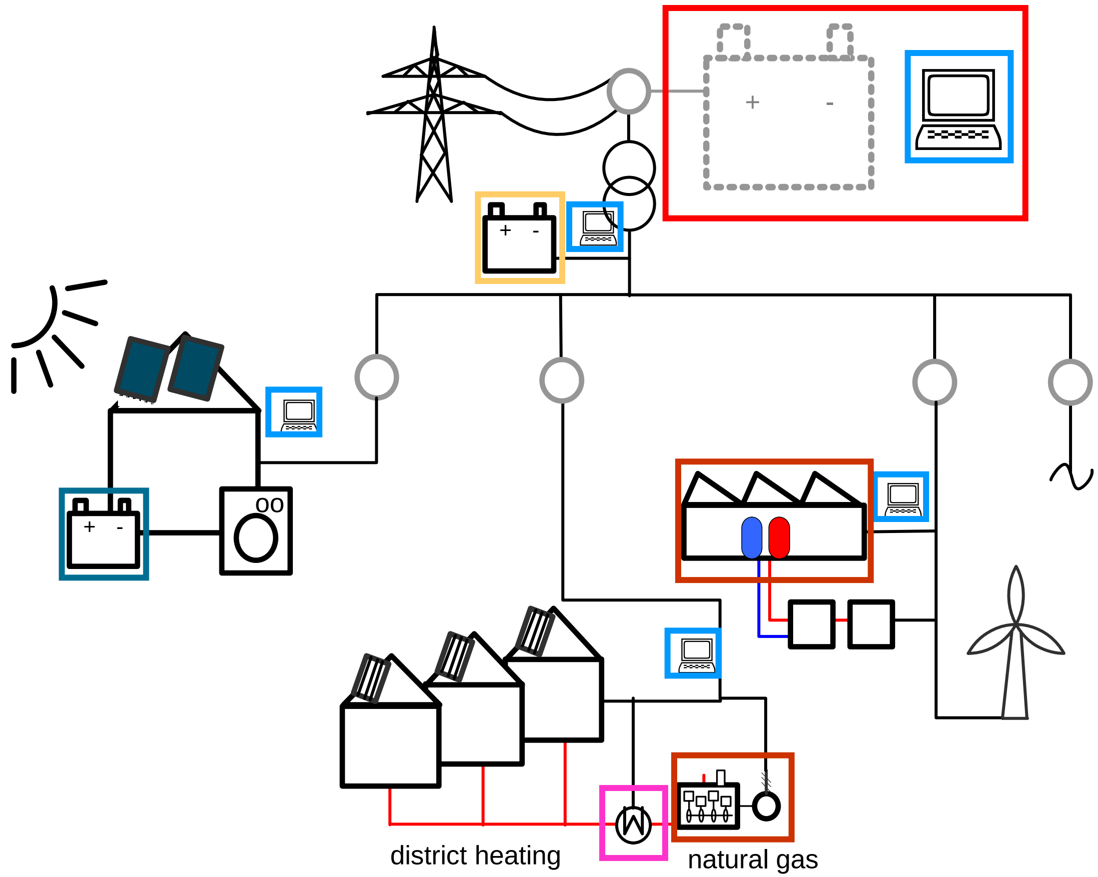
▶ CHP, heat pump, domestic hot water

Additive load

▶ District heating system

FlexController

▶ Controls all sub-systems



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Relevance and potential

- Germany ~ 558,000 low voltage grids
- Assumption: 10 % of the low voltage grids with...
  - ➢ 2 lithium batteries (5 kW)
  - ➢ 4 hot water storages (20 kW)
  - ➢ 1 micro-CHP (6 kW)
  - ➢ 1 heat pump (4 kW)
  - → ~ 6 GW additional storage power

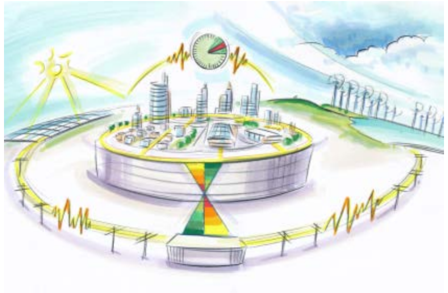
    (Installed power of current pumped hydro storages in Germany: ~ 7 GW)

www.hydrogenambassadors.com/background/deutsches-hochspannungsnetz.php

Urban hybrid energy storage
Development of technologies

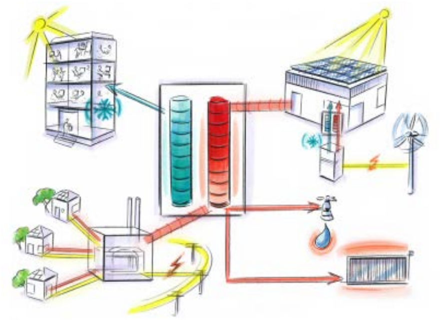
Lithium battery systems

- Scalable, economic, inherent safe and durable lithium battery for integration in buildings



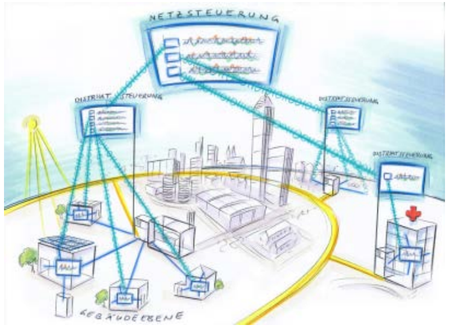
LowEx-storage for houses

- High dense thermal storages (phase change emulsion) to store heat up to 72 hours



FlexController

- Real time controlling with 24 hours forecast for optimized operation of decentralized storage components as one virtual storage unit
- Development of hardware and software



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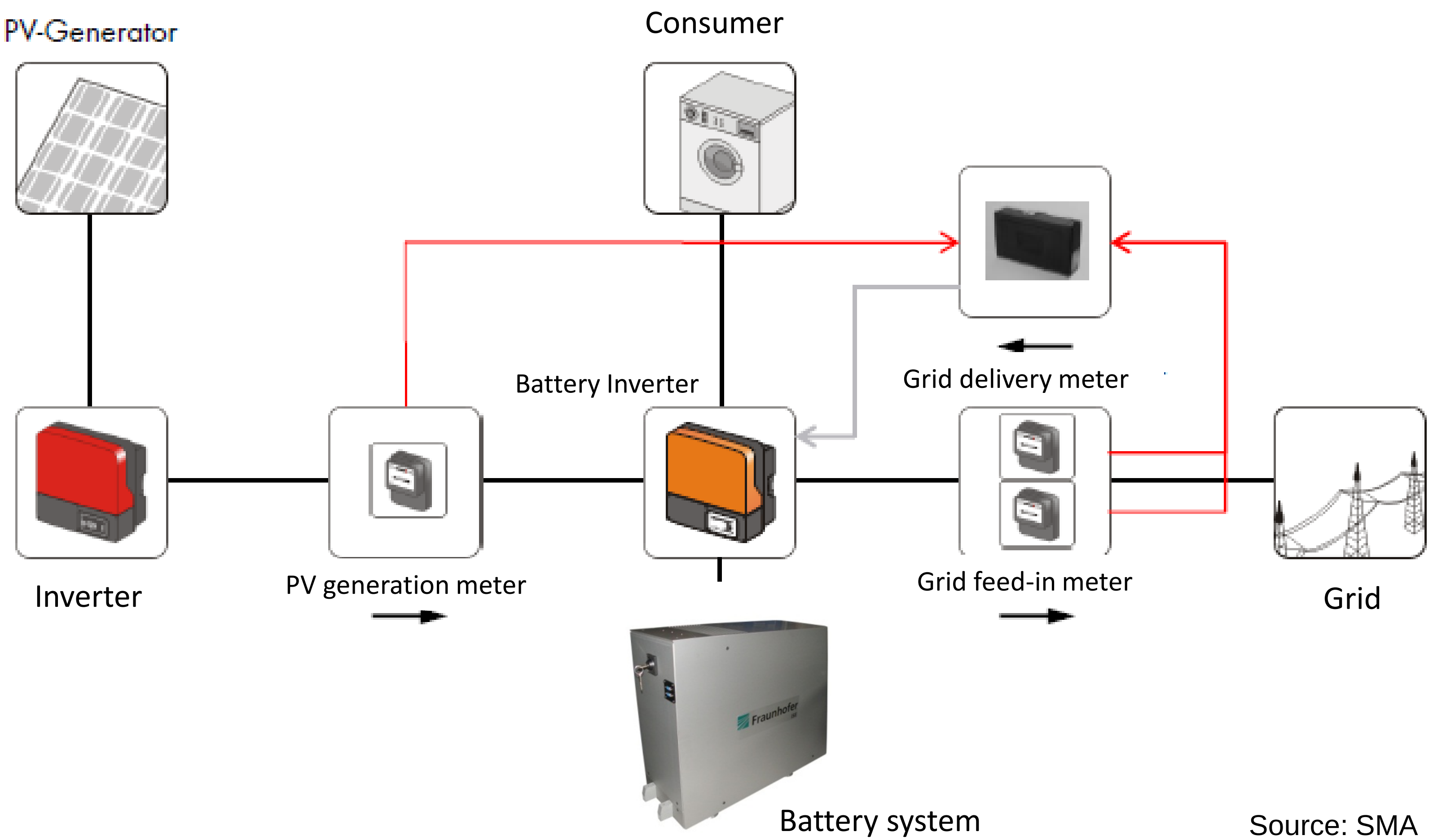
Example of residential PV battery system



Source: SMA

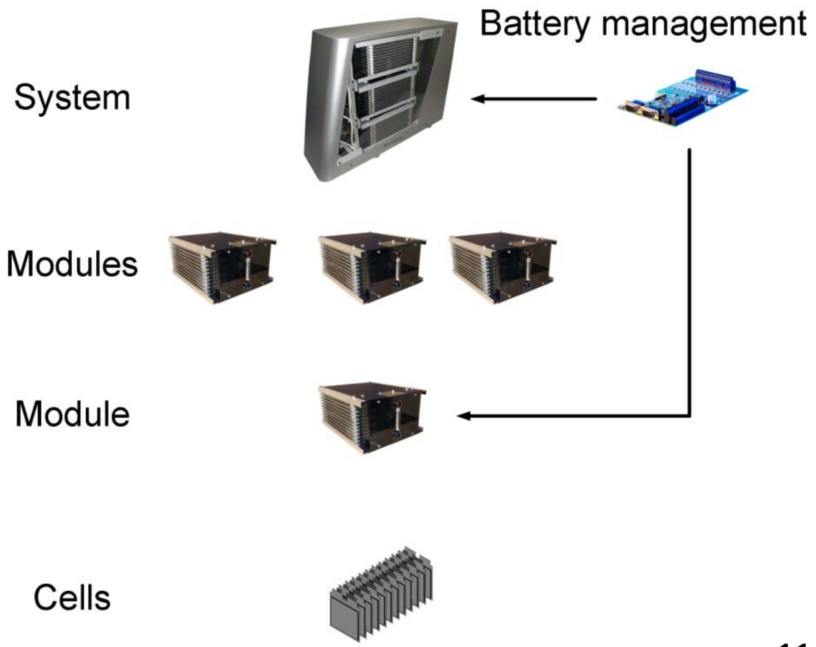
Modular residential lithium battery system

Objectives

- High calendar life times
- High cyclic stability up to 7000 @ DOD ~ 95 % and increased energy densities
- Reduced peripheral losses
- Improved producibility and maintainability
- Improved monitoring of state of charge and state of health
- Improved system integration
  - "Standardized modules" easily adaptable for other cell chemistries
  - Standardized field bus communication (CiA 454)

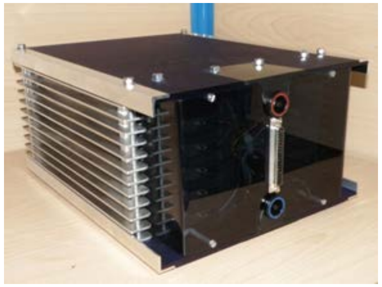
System design

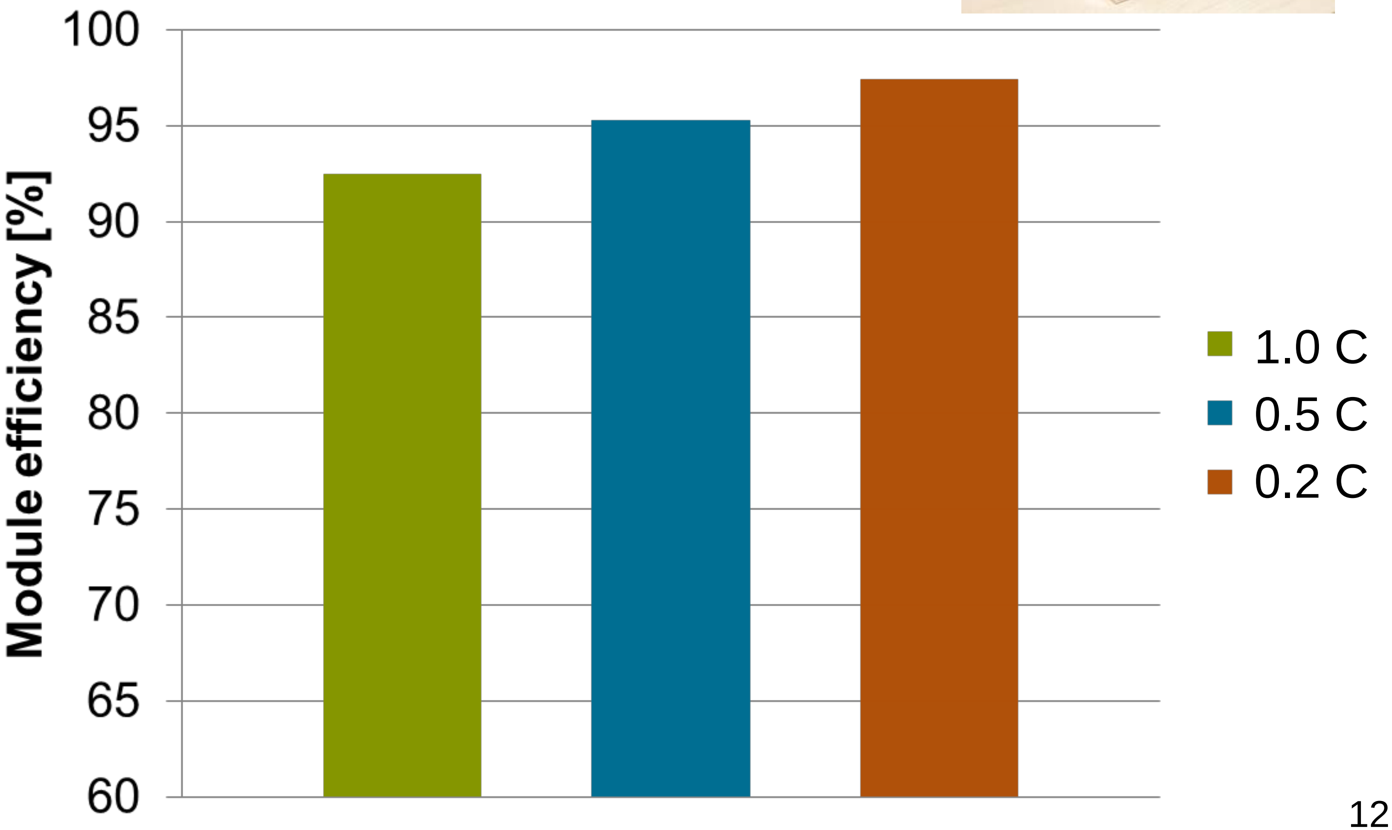
- 5 kWh
- 3 Modules à 12 cells
- 1 Battery management
- Air cooled



Modular residential lithium battery system

- Laboratory tests – module level





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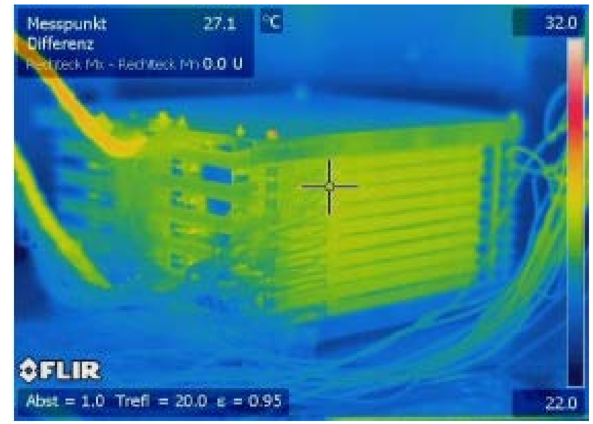
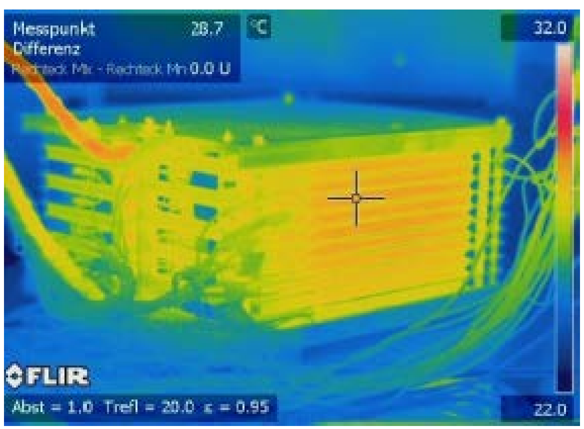
Modular residential lithium battery system

Laboratory tests – module level, discharging with 1C

t=0min

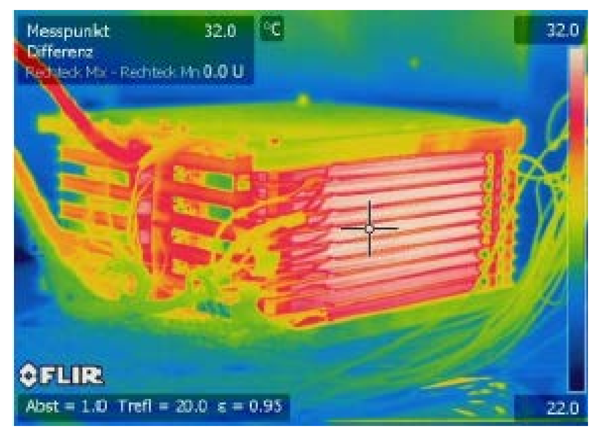
t=7min





t=11min

t=18min



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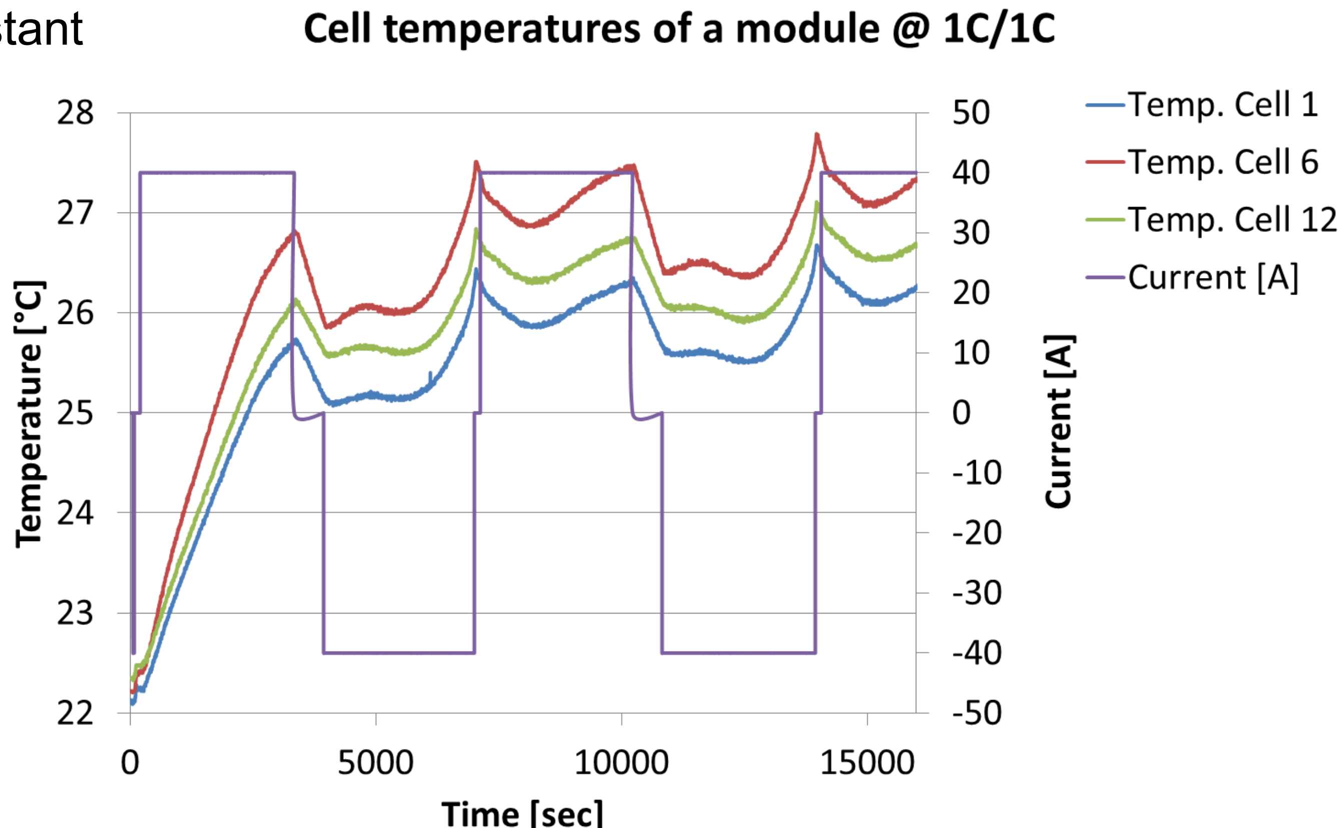
Modular residential lithium battery system

Laboratory tests – temperature profiles inside a module, 1 C rate

- ΔT almost below 1 K
- ΔT nearly constant



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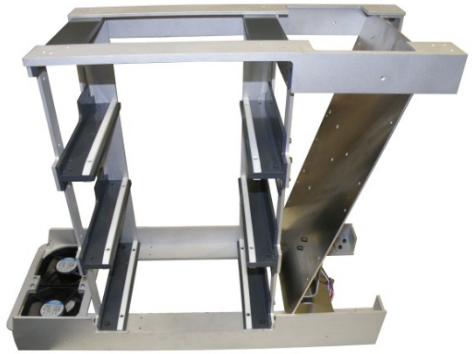
Modular residential lithium battery system

Construction of the system



- Base frame

- Retractable modules
- Standard connectors

- Aluminum housing
- Key switch
- CAN bus interface

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Battery management system
Overview and function blocks

State estimation
- SOC
- SOH
- Other states (optional)

Control system
- Actuators and switches
- Battery models
- Load management
- Energy management (optional)

control layer

Battery Management System

Error management
- Safety for cells

Thermal management
- Thermal battery models
- Thermal control

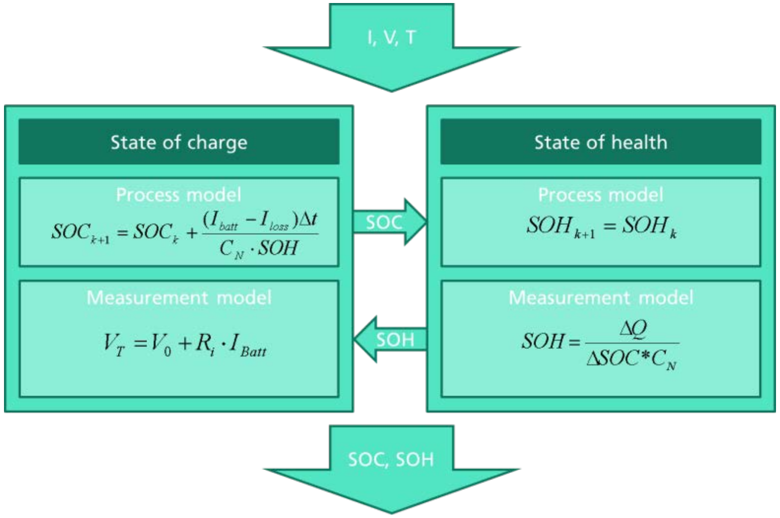
safety layer

Measurement and monitoring
- Cell voltages
- Temperature
- Current

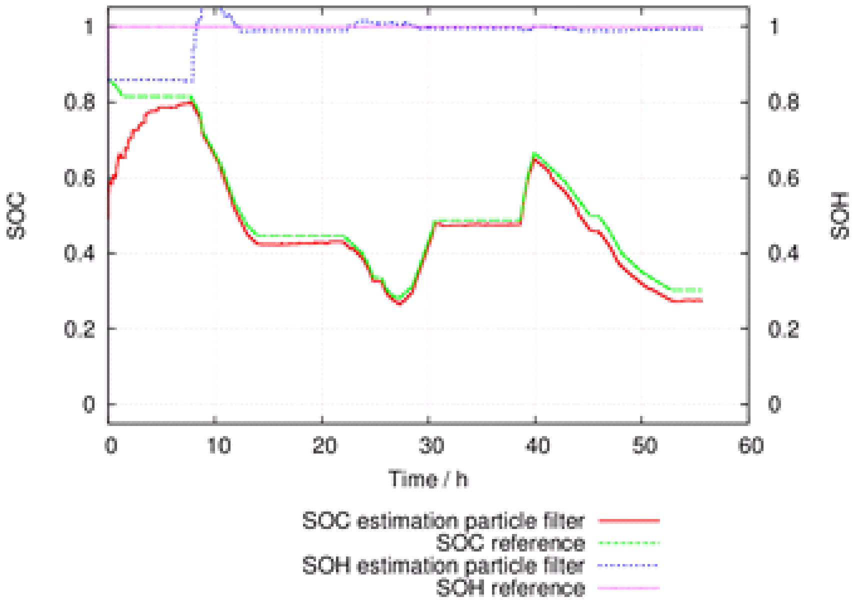
Communication
- Internal
- To external components

functional layer

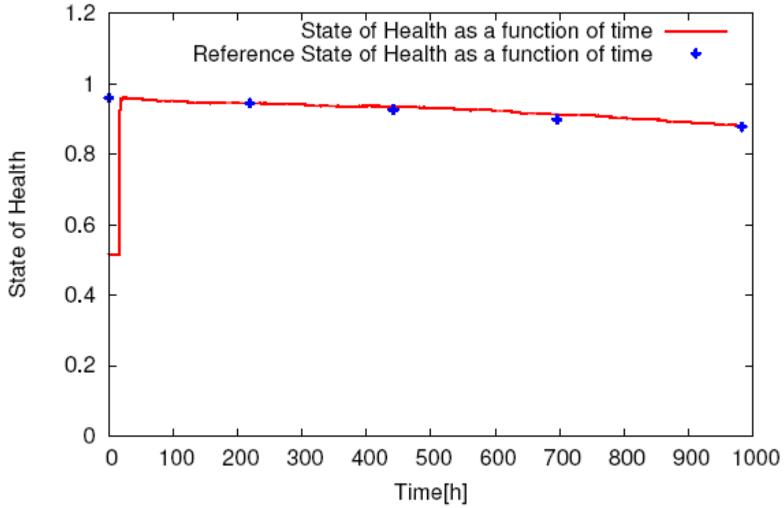
Particle filter approach for state determination



State of charge and state of health for $LiFePO_4$

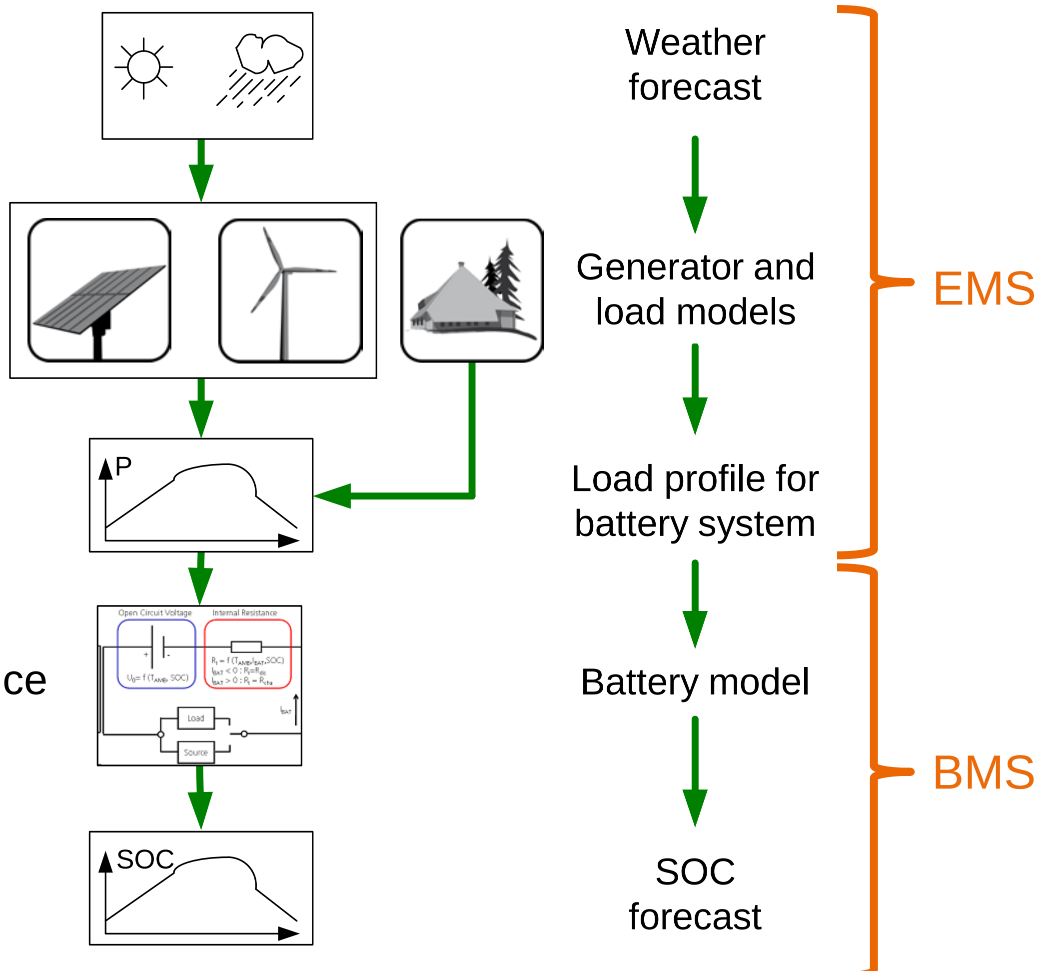


State of health for NMC



Smart battery management as part of an optimized energy management

- Communication interface between EMS and BMS
- Model based energy management
  - Load and generation management
  - Optimized operation of battery system
  - → Control of energy fluxes
- Model based battery management
  - SOC prediction in dependence on load profile forecast
  - Efficiencies in dependence on load profile forecast
  - Information on aging



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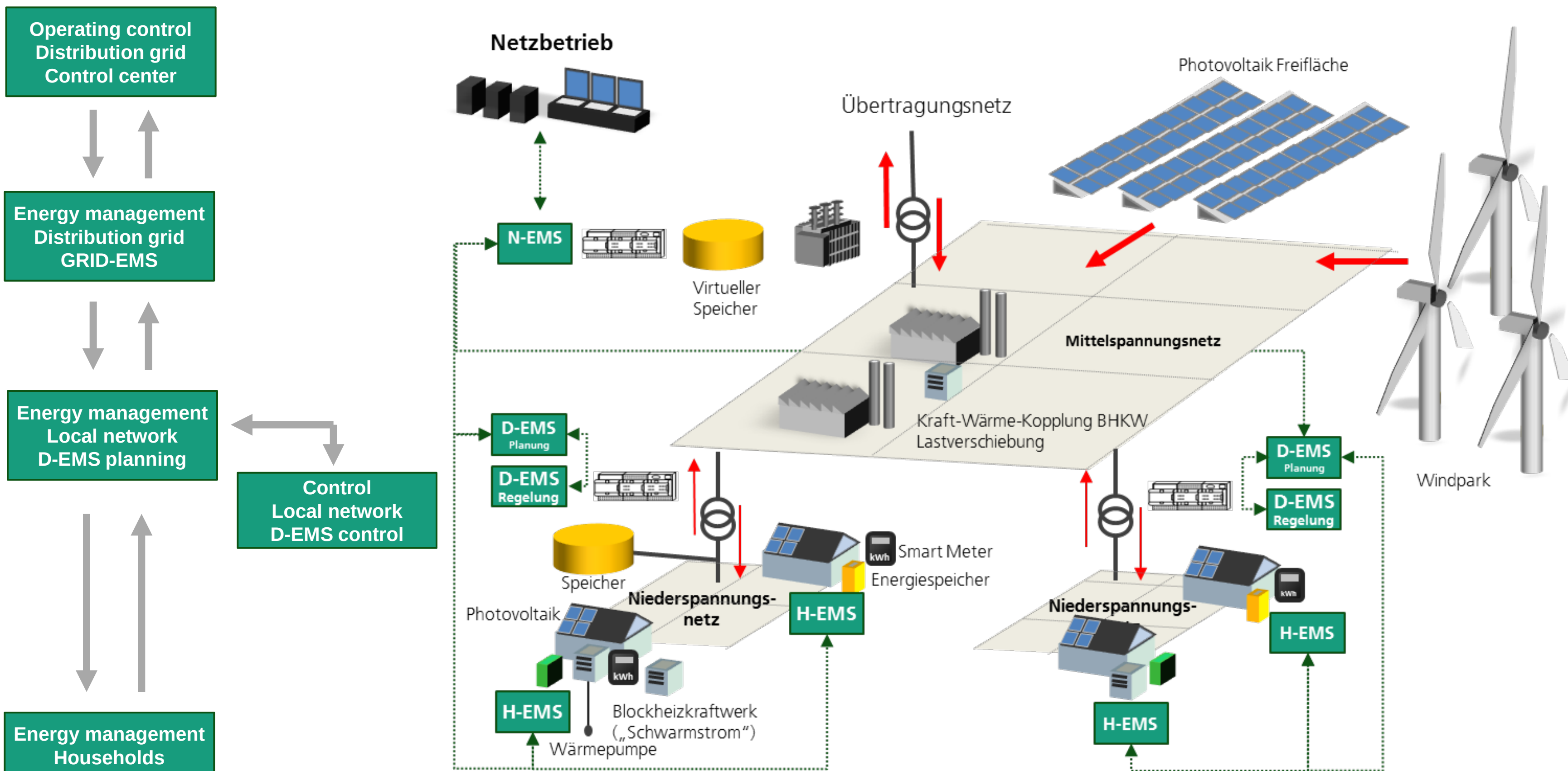
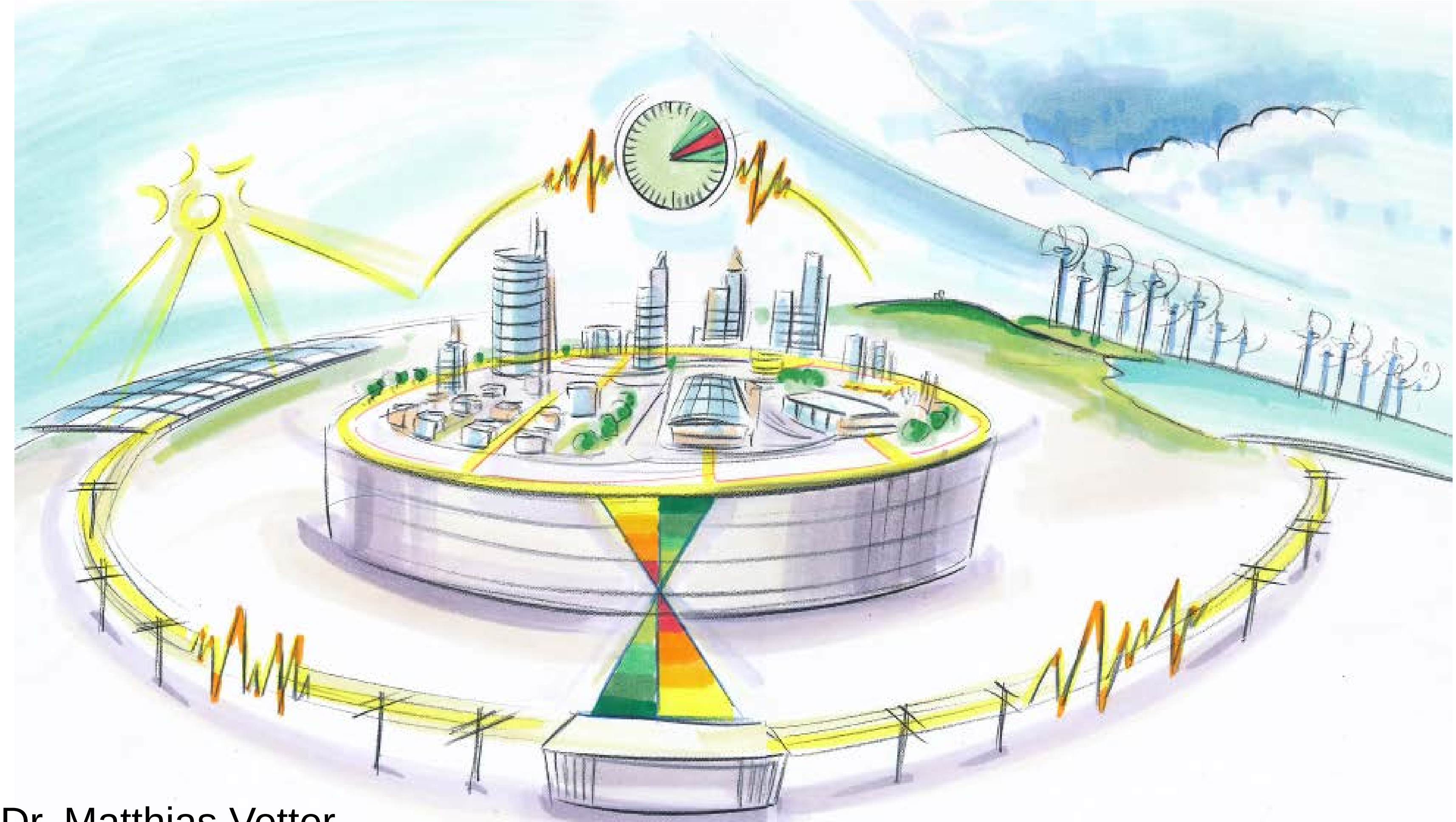
Control structure (FlexController)



Conclusions

- Development of residential lithium batteries with lower costs and higher durability
- Development of a LowEx thermal storage with higher capacity (3 times) and higher power rates (10...100 times) for heat pumps and micro-CHP
- Development of a FlexController with optimization algorithms as well as real time controlling
  - Control structure integrates intelligent battery management systems, home energy management systems, decentralized energy management systems and supervisory distribution grid management systems
- Combination and optimization of decentralized energy storage components as one *Urban Hybrid Energy Storage*
- But:
  - Huge control effort
  - Huge communication effort
  - Open regulatory questions
  - Strong interdependencies between grid operators and private house owners !

Thanks for your attention !!!



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