Decentralized PV Battery Storage Systems
System Design, Integration and Operation

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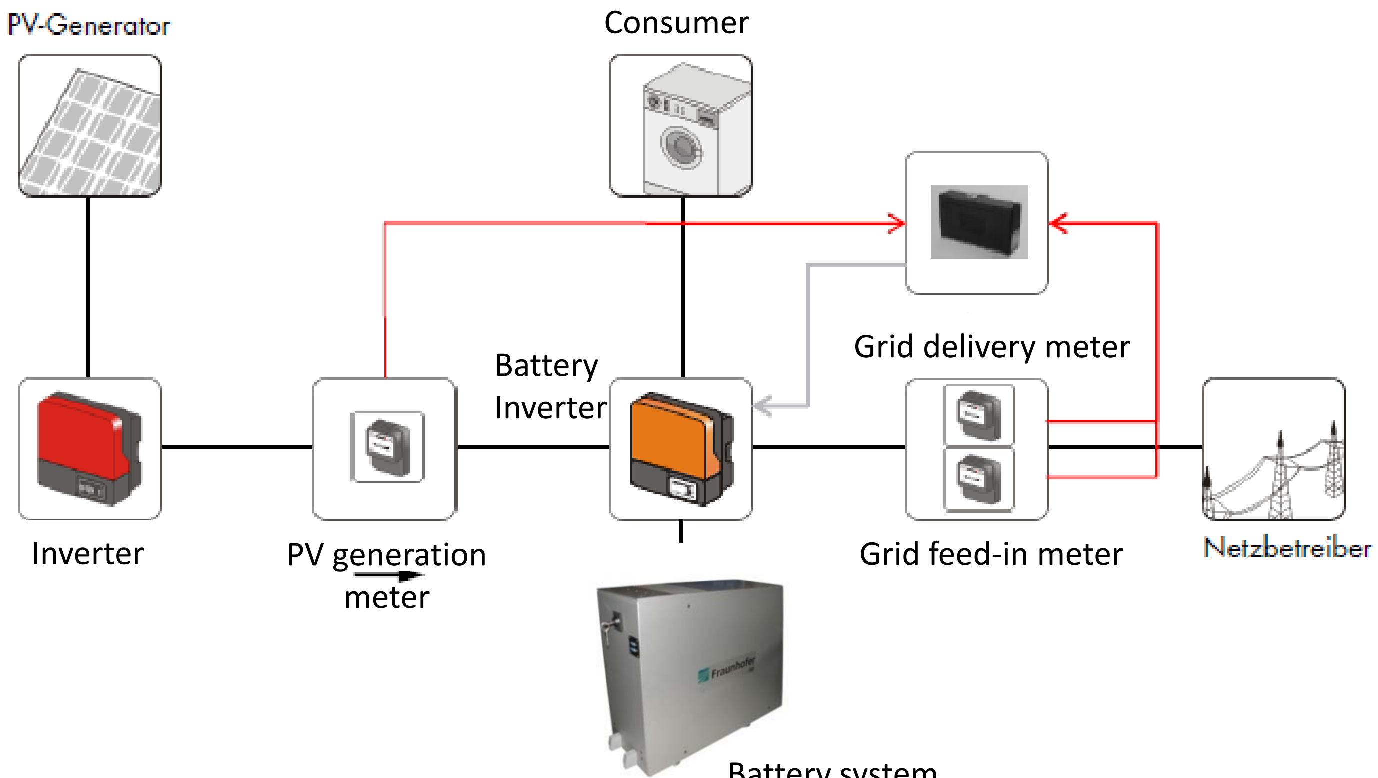
Agenda

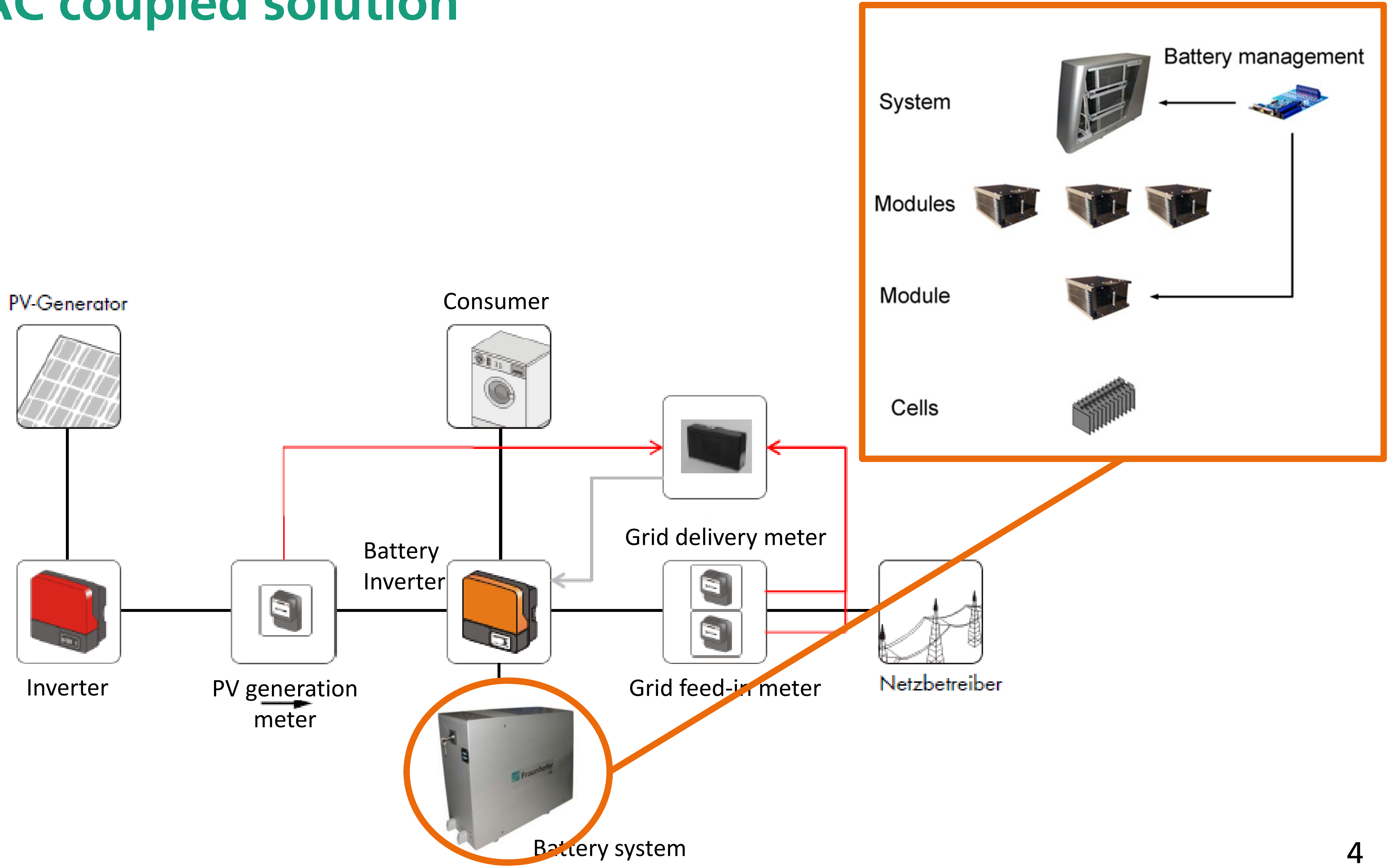
- Design of decentralized (residential) PV battery systems – Example AC coupled solution
- System integration
- Battery management
  - State estimation
  - Influence of operating ranges on life time
- Energy management and cost analyses
  - Self consumption
  - Grid issues
- Conclusions

Example: Building integrated PV battery systems
AC coupled solution



Example: Building integrated PV battery systems

AC coupled solution



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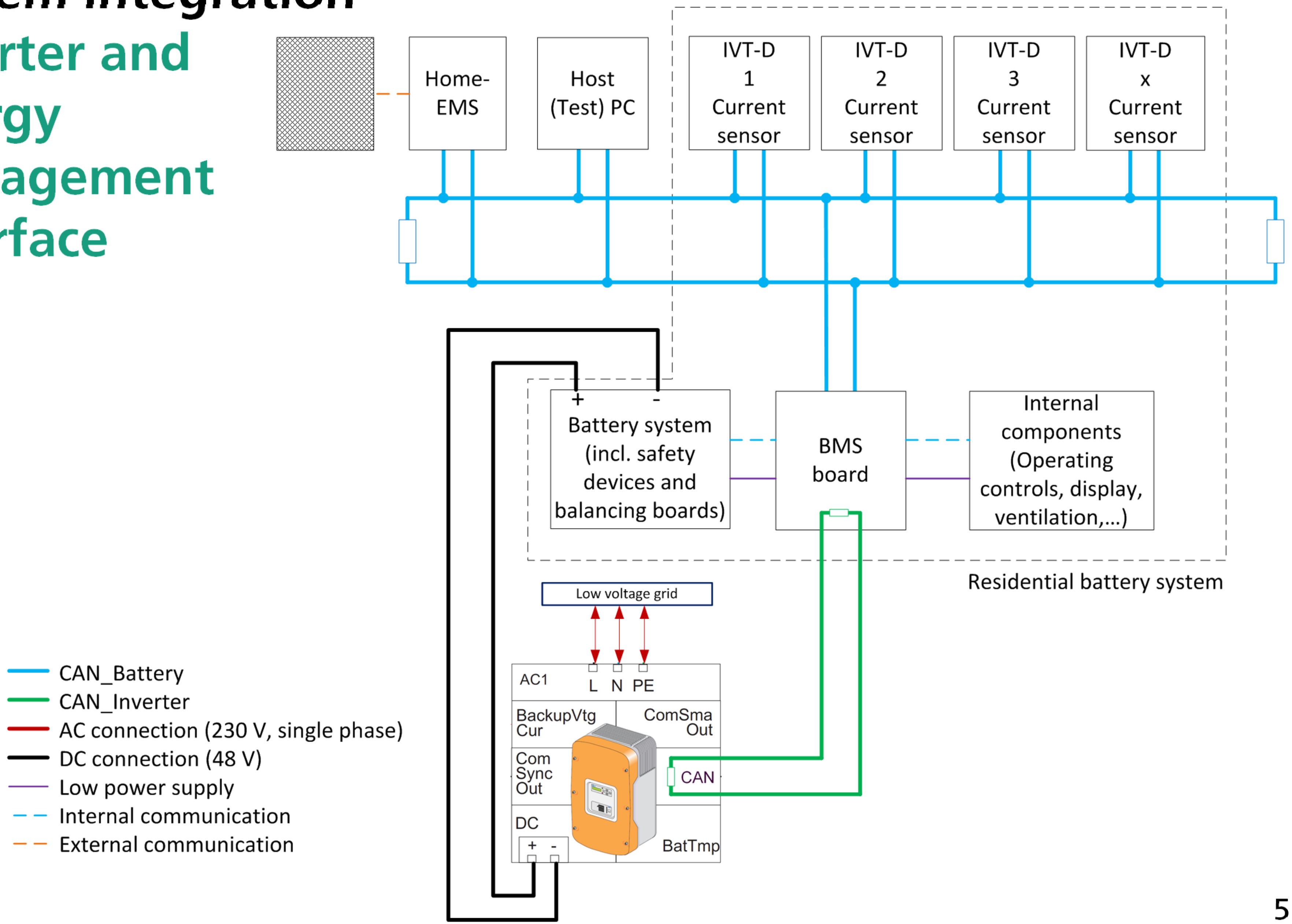
System integration

Inverter and energy management interface



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System integration
Interface to distribution grid

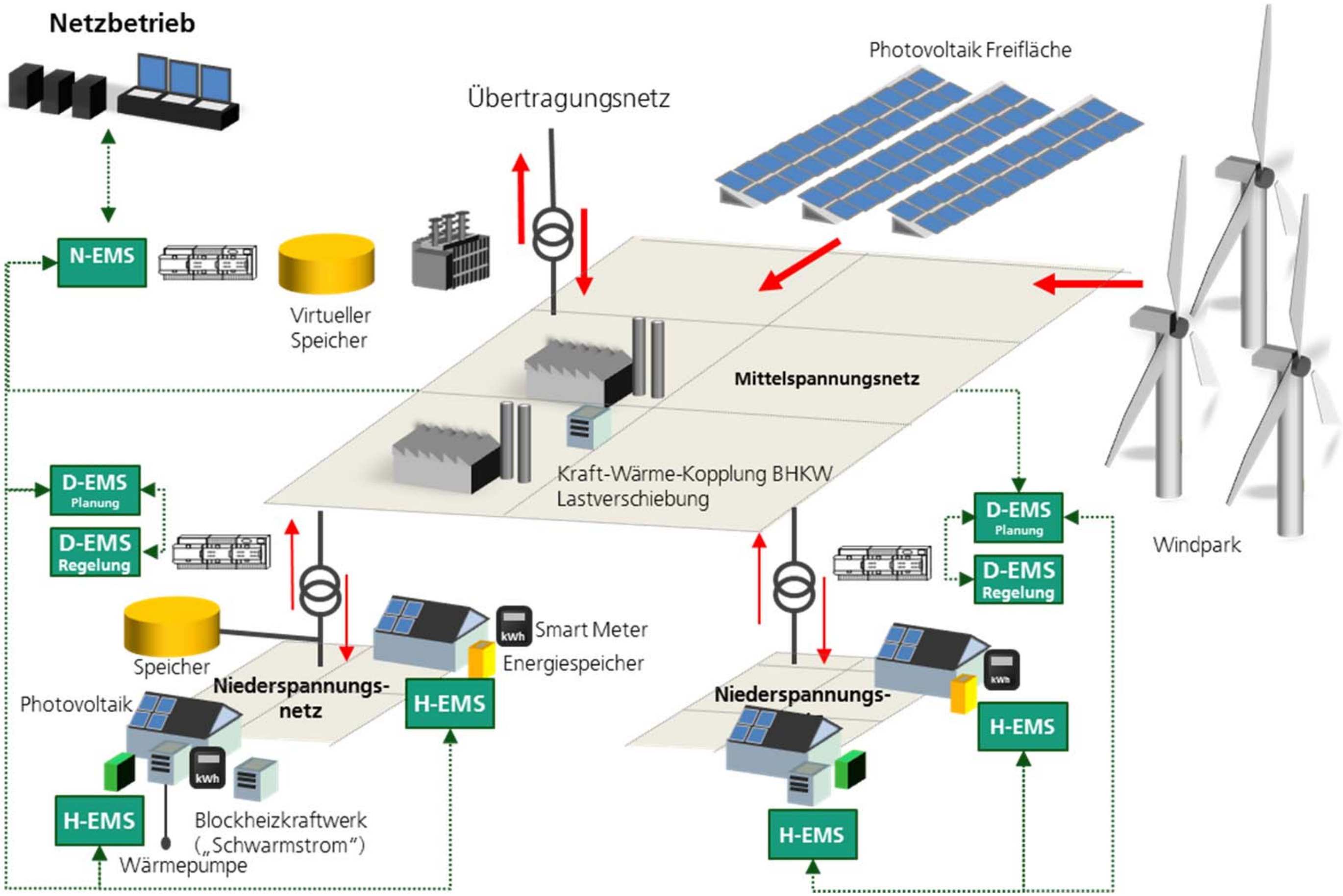
Operating control
Distribution grid
Control center

Energy management
Distribution grid
GRID-EMS

Energy management
Local network
D-EMS planning

Control
Local network
D-EMS control

Energy management
Households
H-EMS



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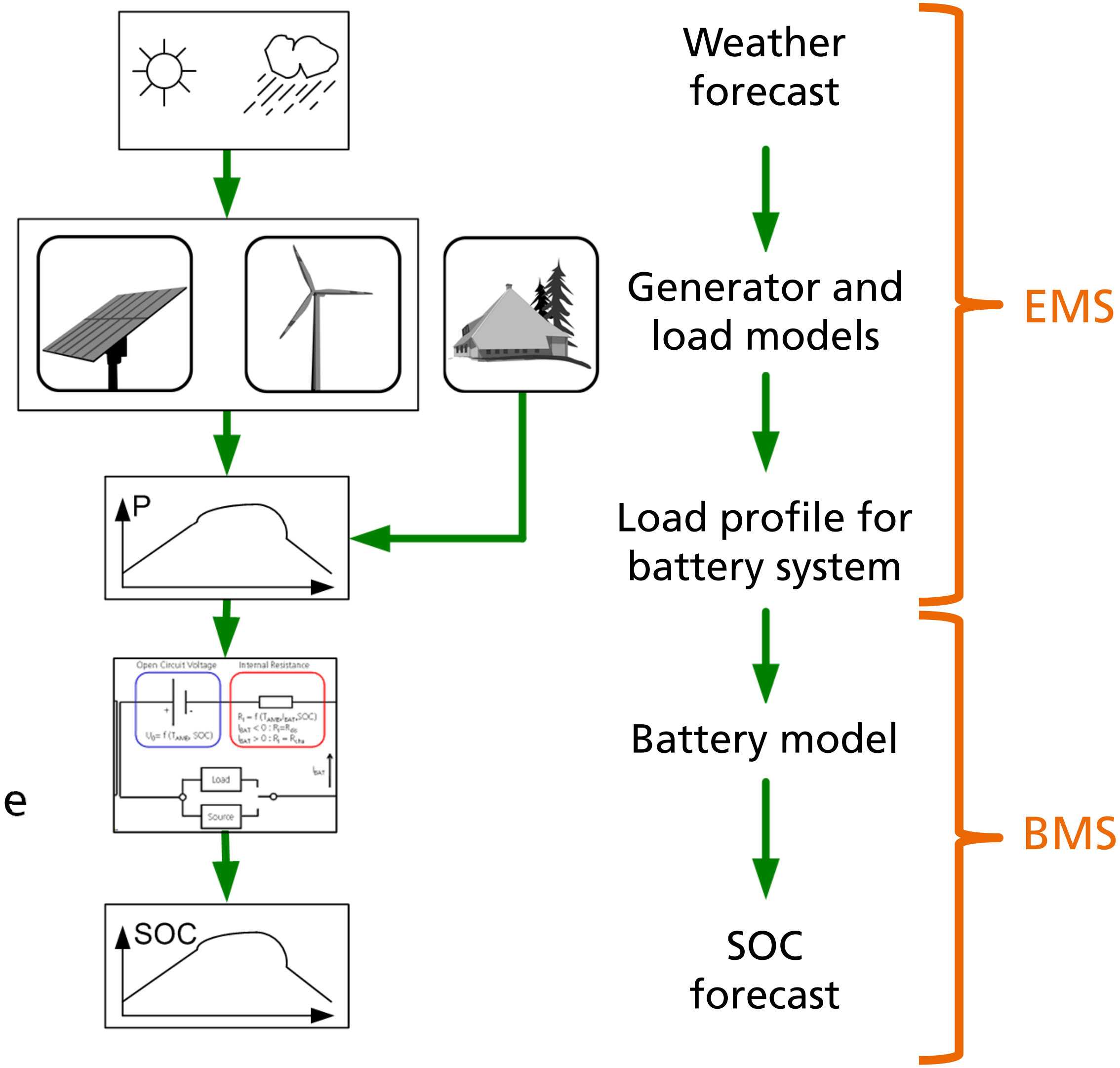
Smart battery management as part of an optimized energy management

- 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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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

Error management
- Safety for cells

Battery Management System

Thermal management
- Thermal battery models
- Thermal control

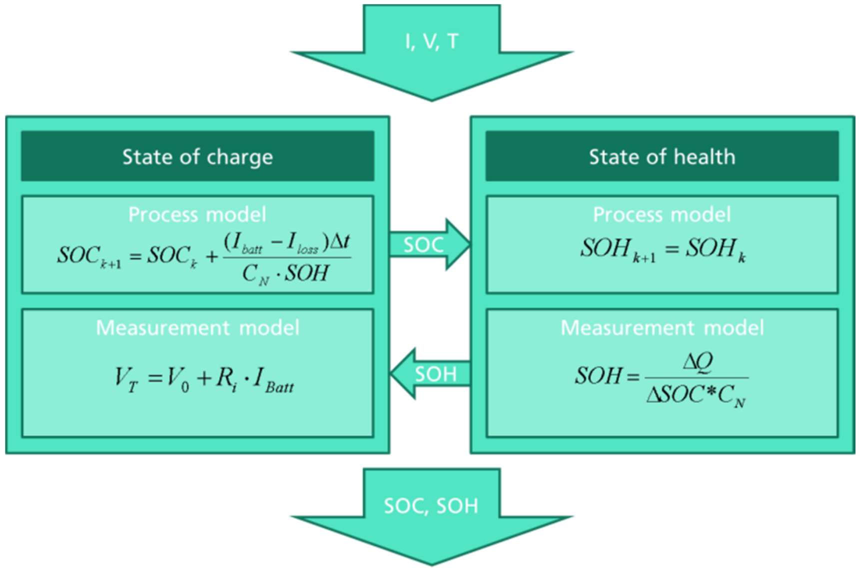
safety layer

Measurement and monitoring
- Cell voltages
- Temperature
- Current

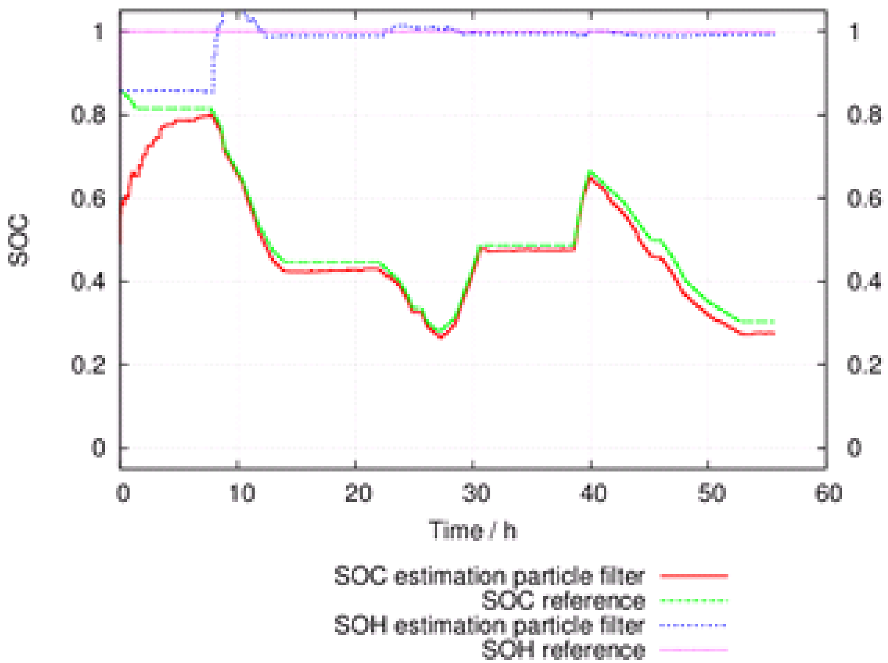
Communication
- Internal
- To external components

functional layer

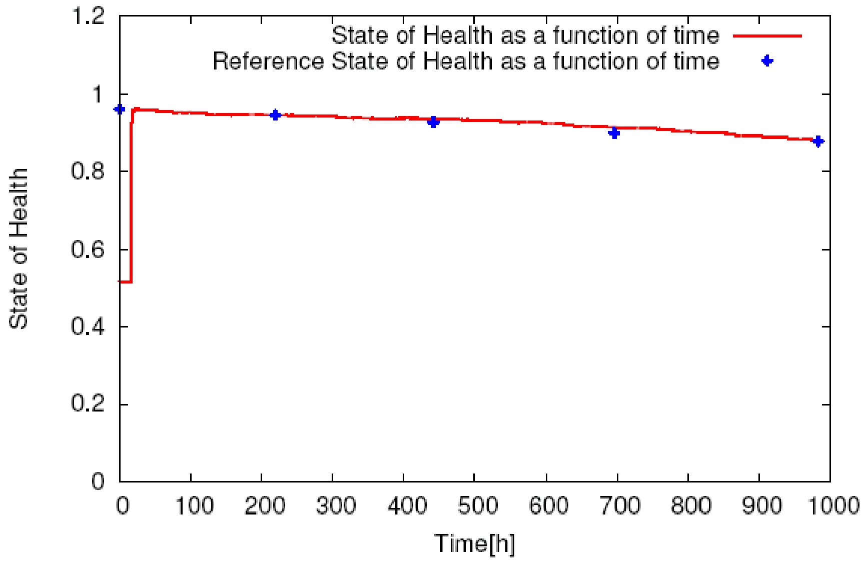
Particle filter approach for state estimation



State of charge and state of health for $LiFePO_4$



State of health for NMC



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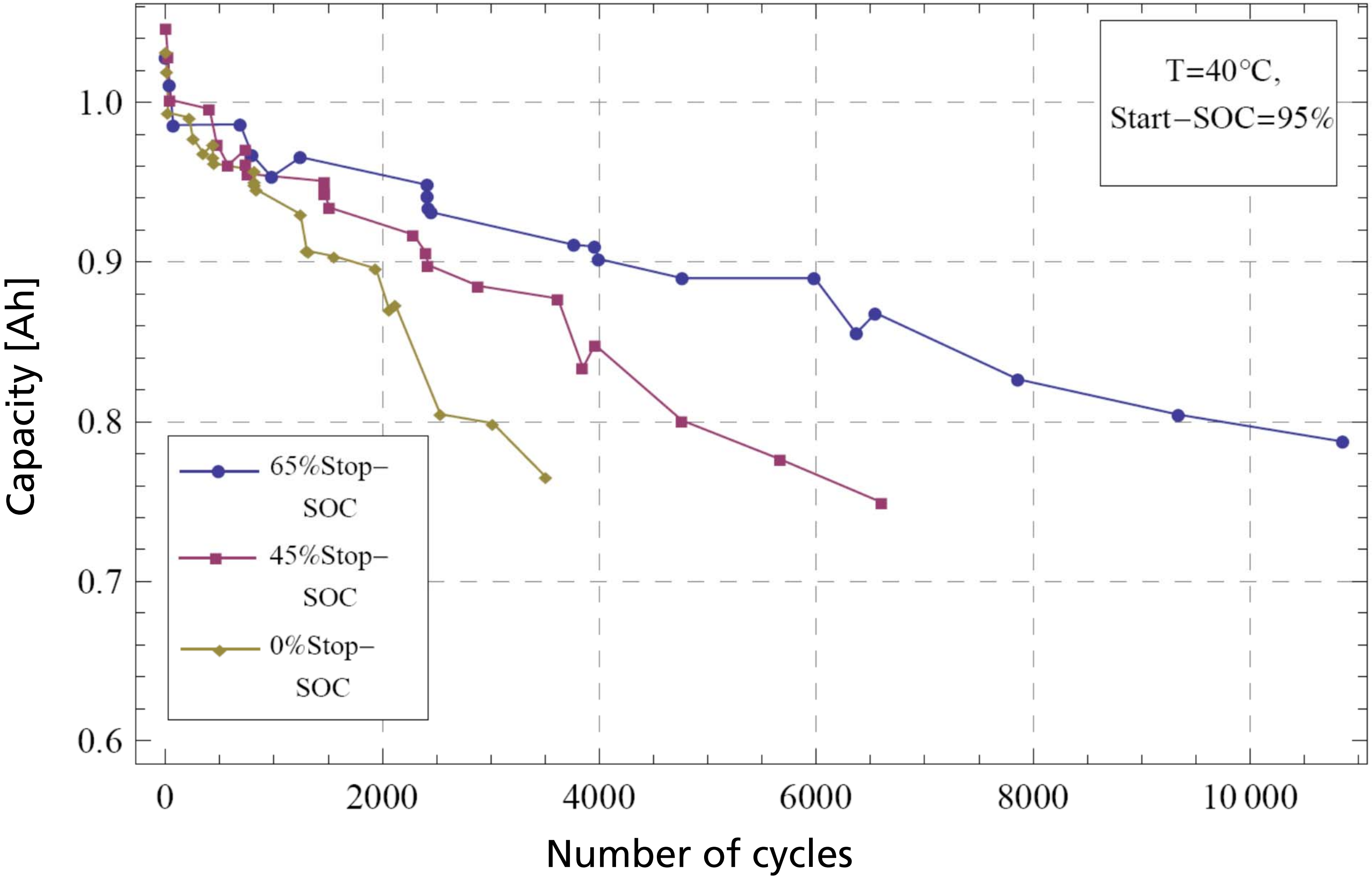
Influence of operating range
Example $LiFePO_4$ batteries



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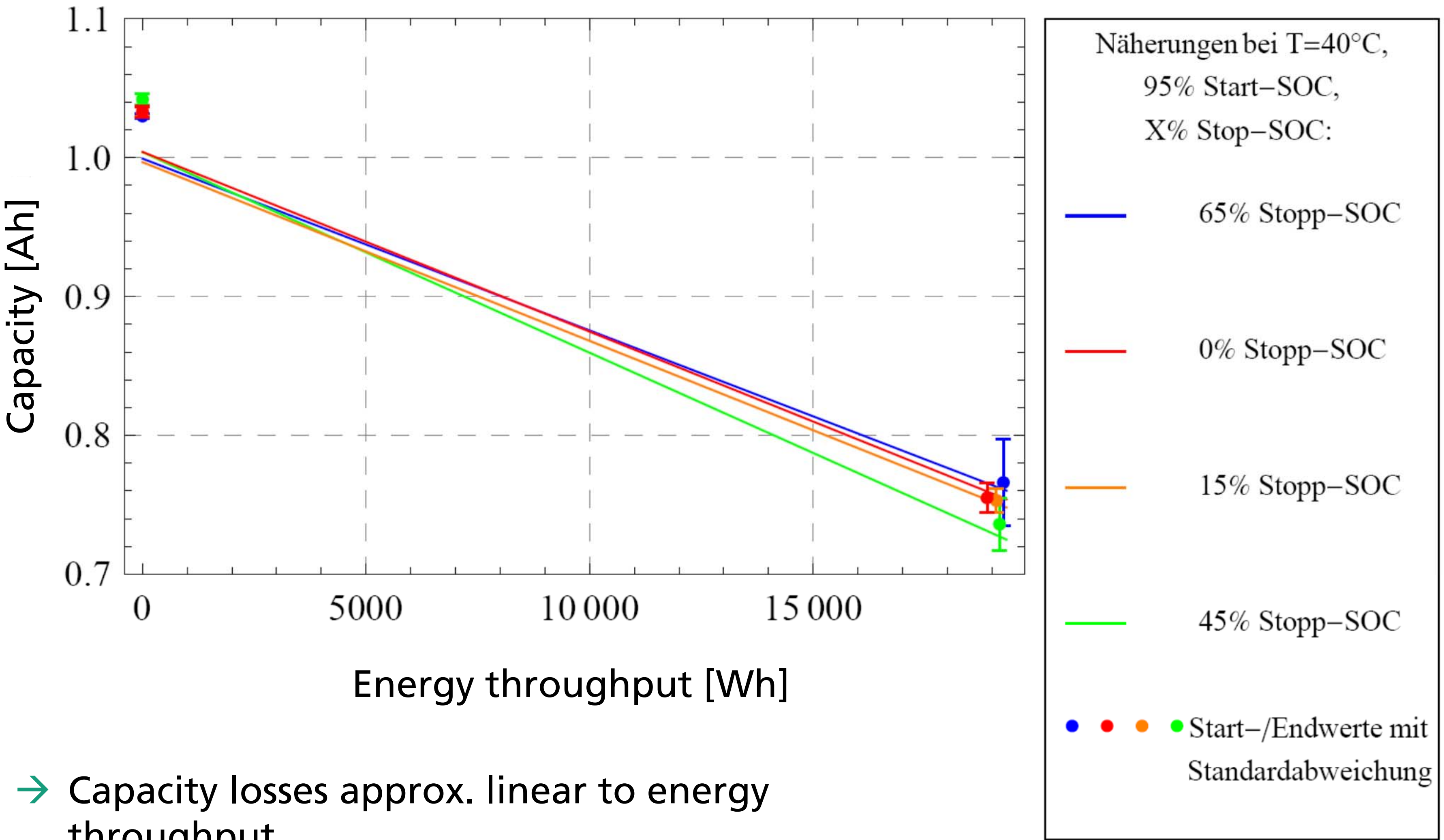
Influence of operating range
Example $LiFePO_4$ batteries



→ Capacity losses approx. linear to energy throughput

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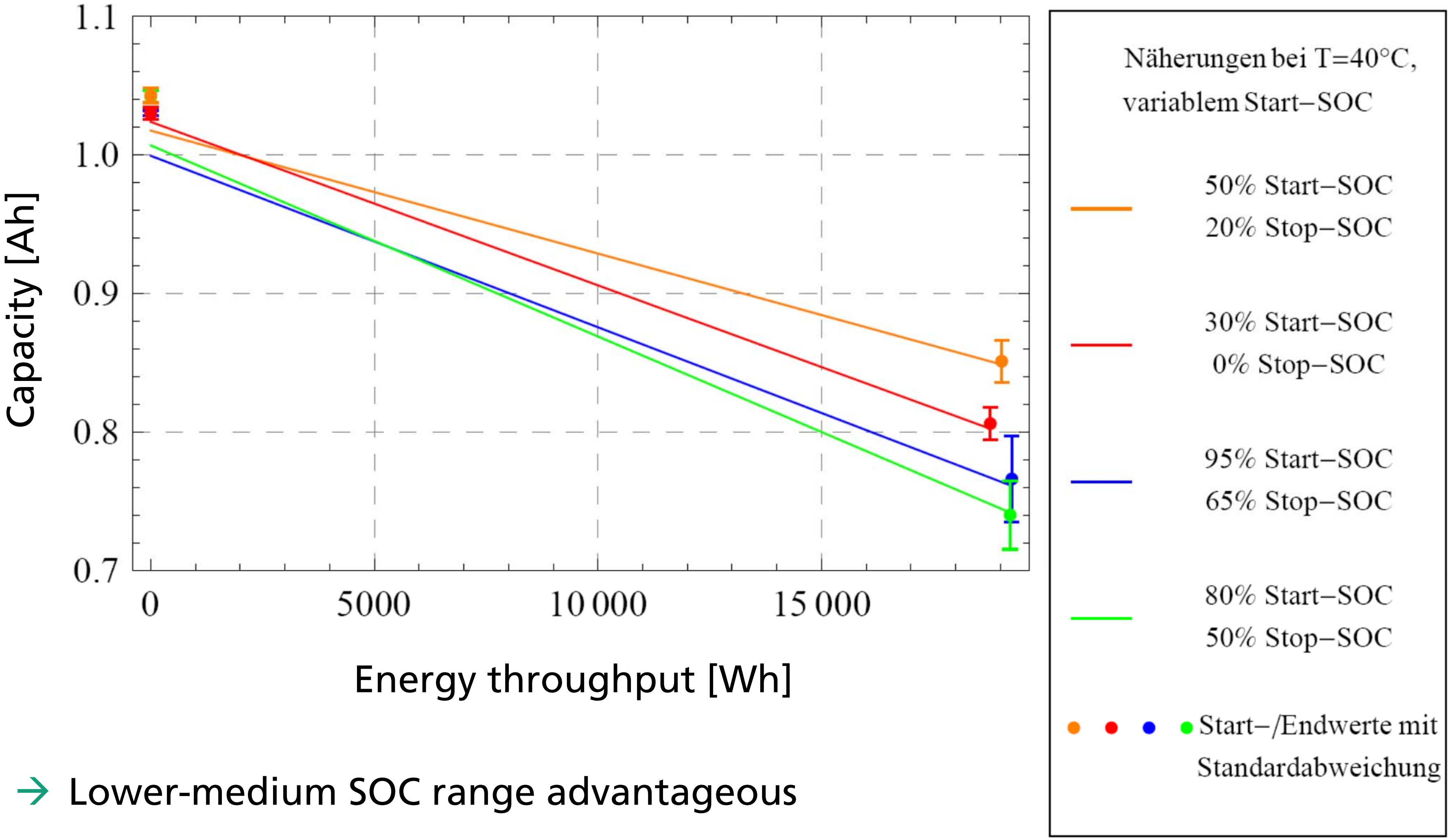
Influence of operating range

Example $LiFePO_4$ batteries



→ Lower-medium SOC range advantageous

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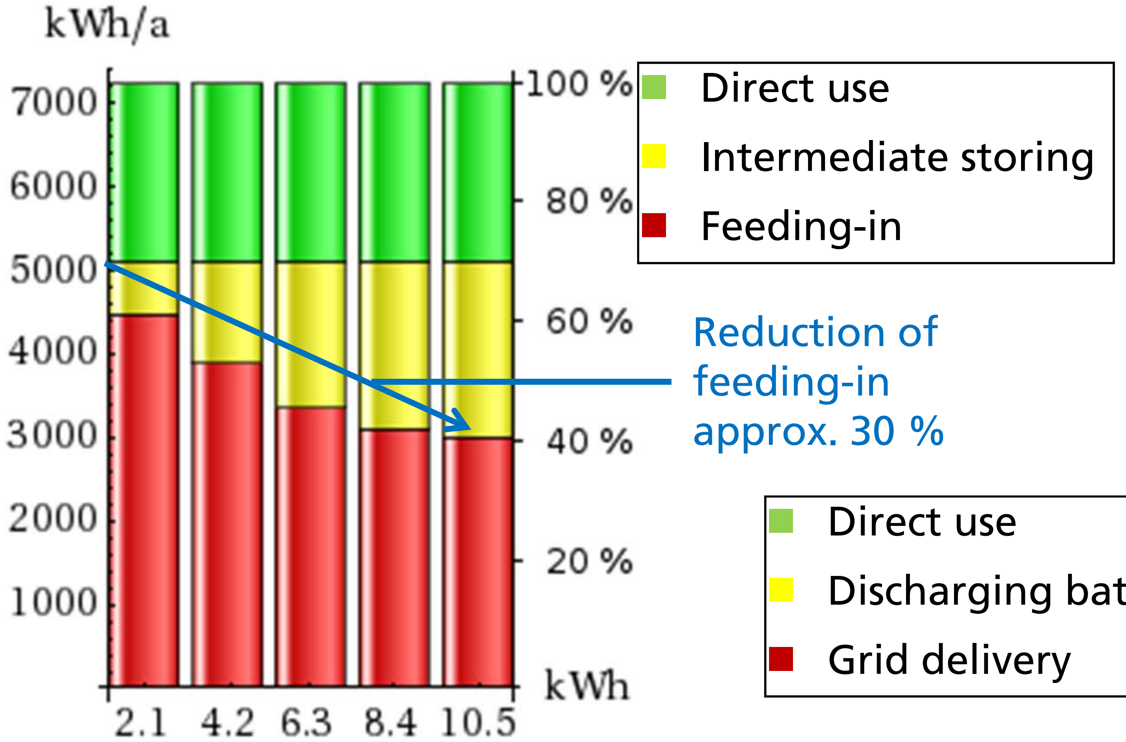
Energy management – Optimization of self-consumption
Analysis of energy fluxes (results of system simulation)

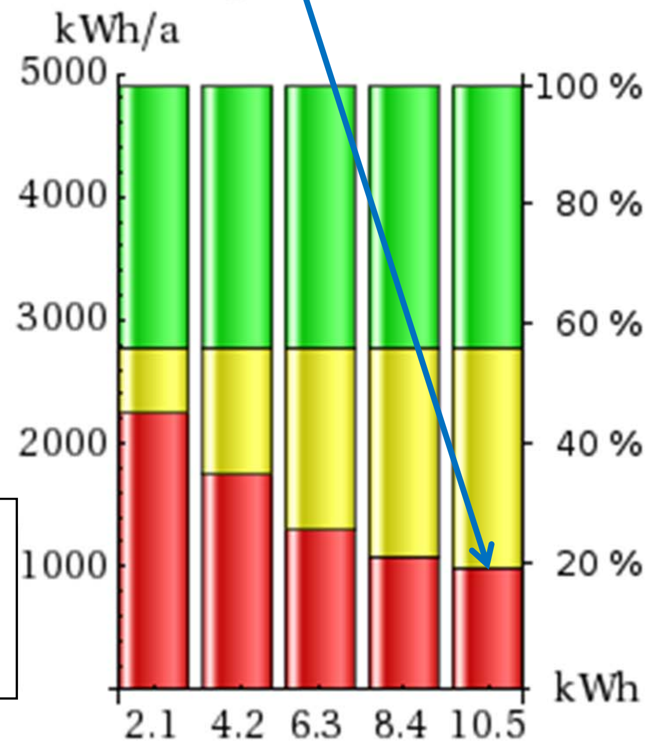
- Load: 4900 kWh/year
- PV generator size: 6 kWp
- Lithium-ion battery system: Variation of usable capacity

Only ~ 20 % have to be purchased from the grid

Energy production



Energy consumption



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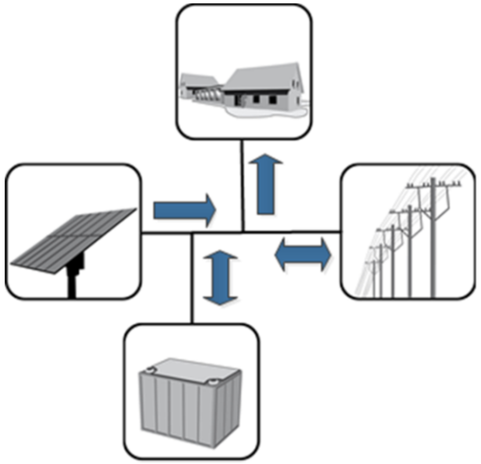
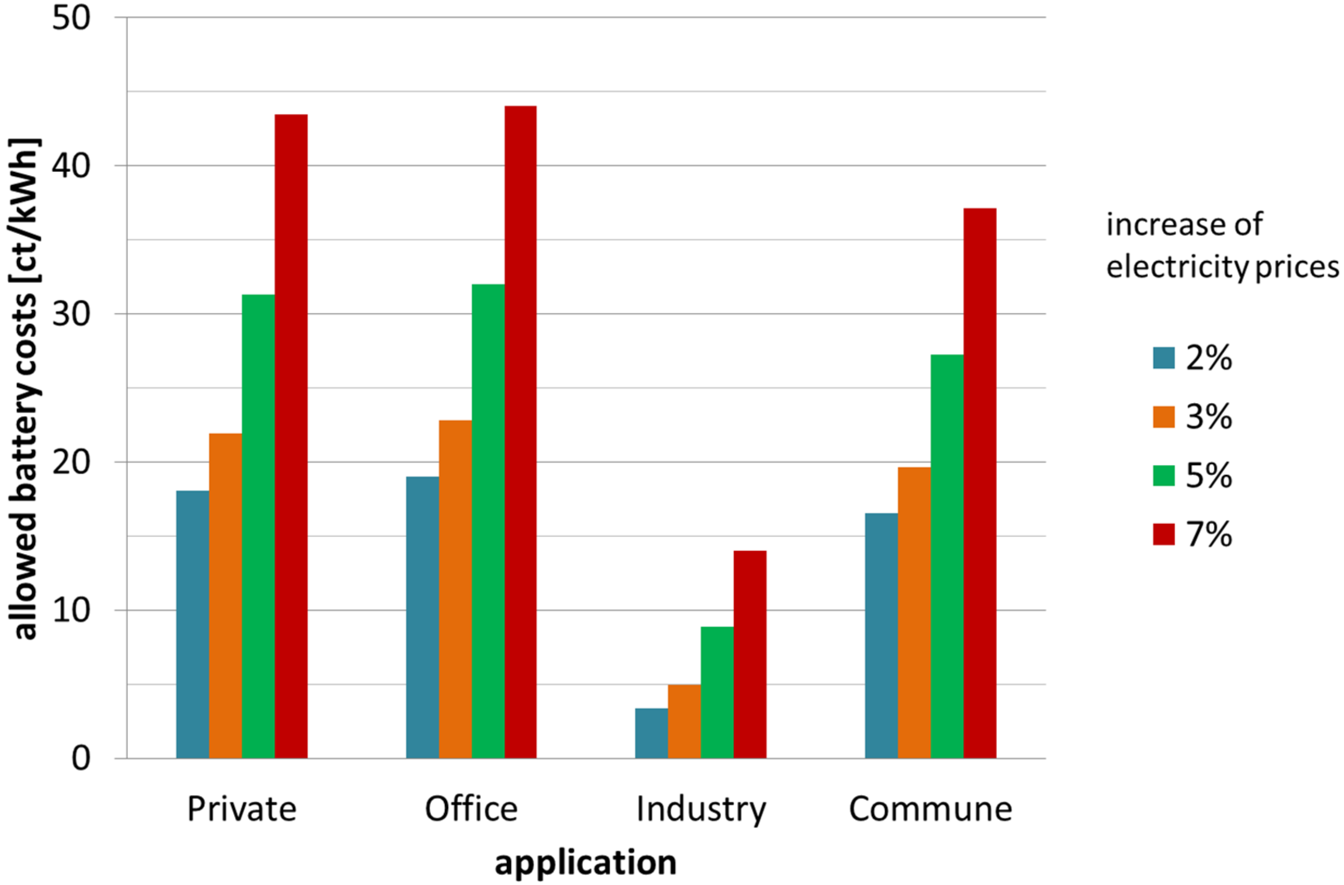
Energy management – Optimization of self-consumption
Cost analyses

Allowed cost for 4 self consumption applications

- Private / residential
- Office
- Industry
- Municipality





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Energy management – Optimization of self-consumption
Cost analyses

Allowed cost for 4 self-consumption applications

- Private / residential
- Office
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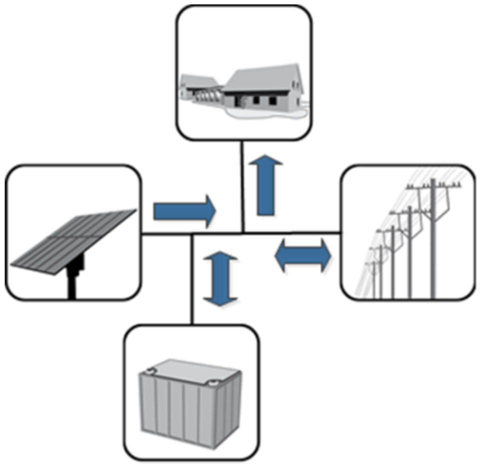
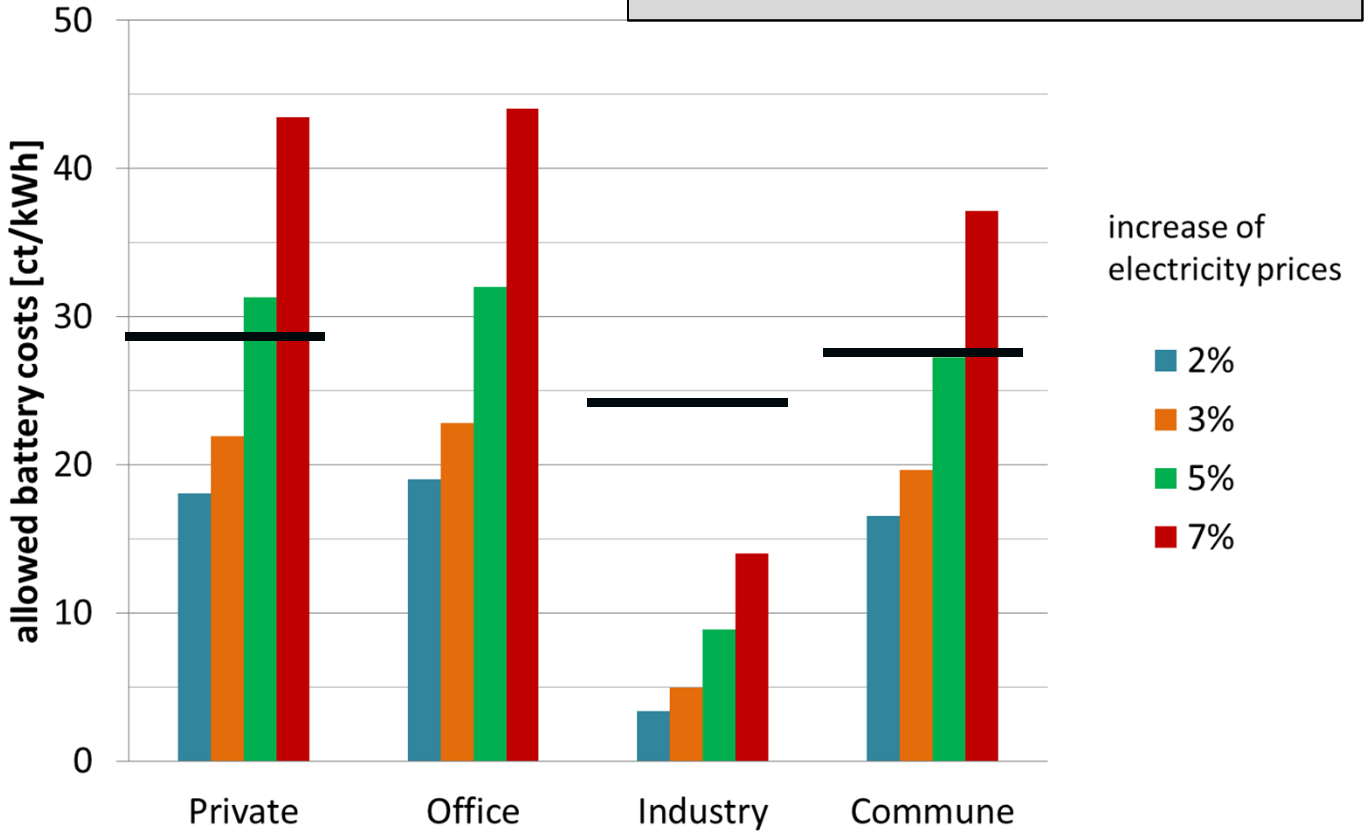
Current cost calculated with Investment cost of 600 €/kWh



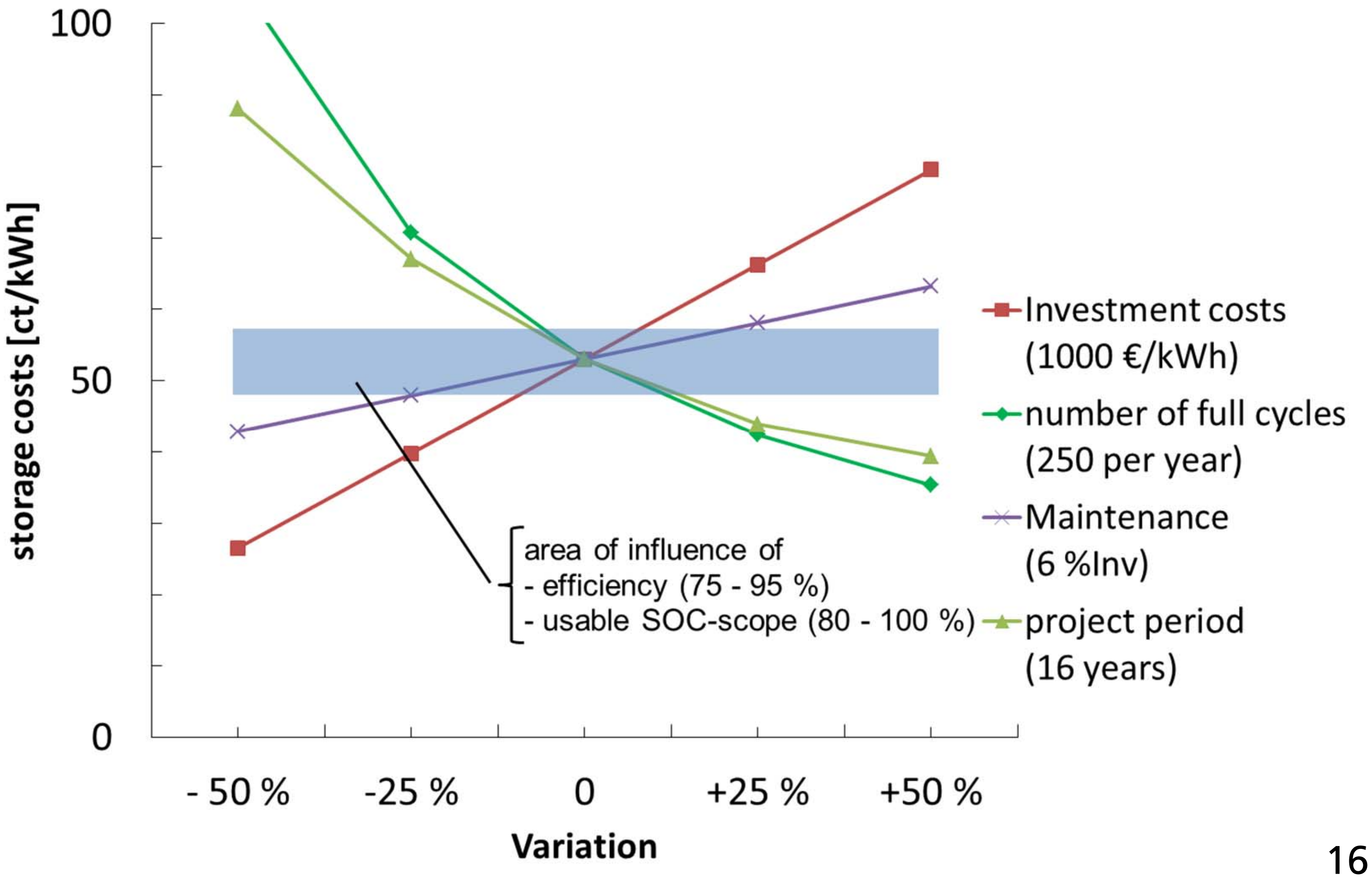


Cycles per year	221	75	256	227
Storage cost ct / kWh	28	81	24	27

Energy management – Optimization of self-consumption
Cost analyses

Cost drivers

- Investment cost
- Cycle number
- Operation and maintenance
- Project period



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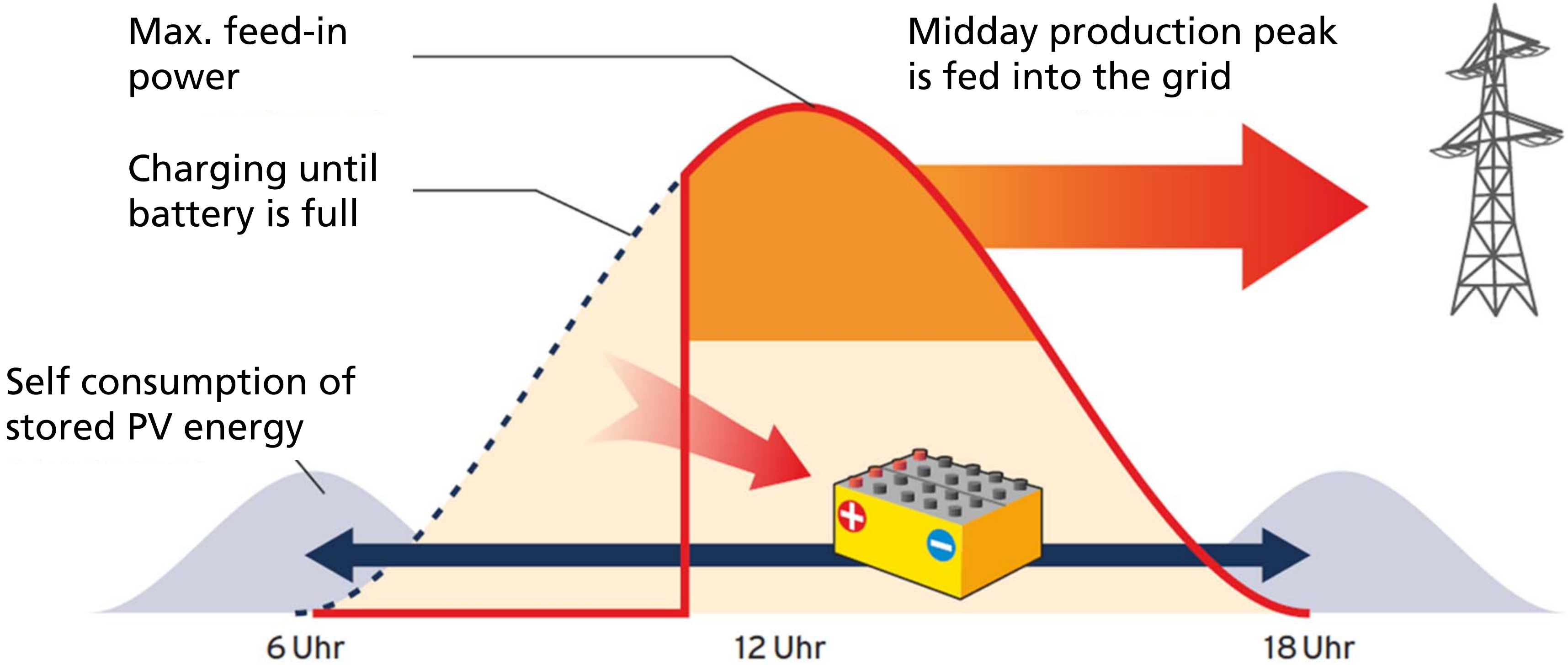
Energy management
Operating control strategies

→ Conventional storage strategies have no significant positive effects for the distribution grid

Conventional storage strategy



Source: J. Mayer (BSW), C. Wittwer (ISE), Batteriespeicher: Ein sinnvolles Element der Energiewende. Berlin, Pressefrühstück 25.1.2013

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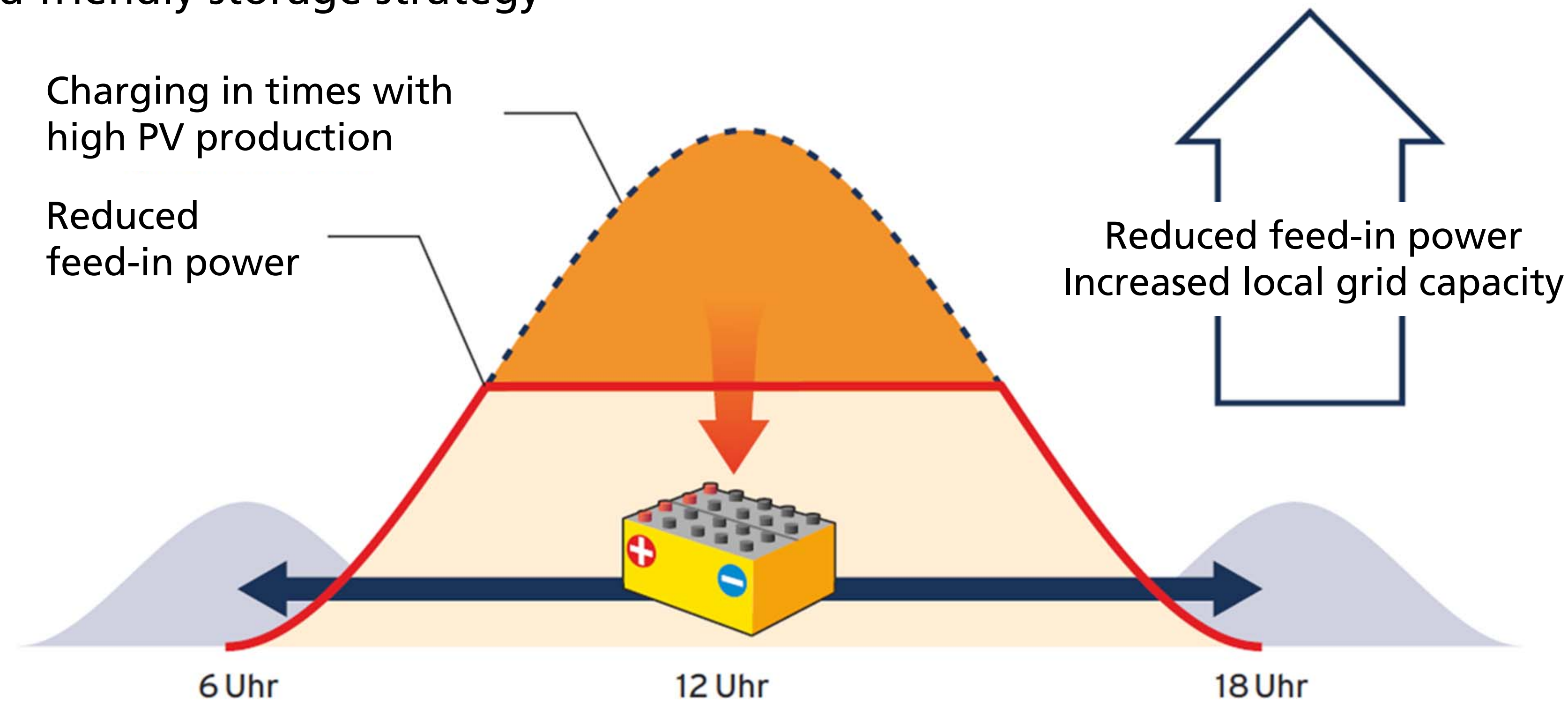
Energy management
Operating control strategies

→ Reduced feed-in peak power decreases problems in the distribution grids
→ Reduced feed-in peak power up to 40 % without yield losses
→ 66 % increase of PV power in local distribution grids possible

Grid friendly storage strategy



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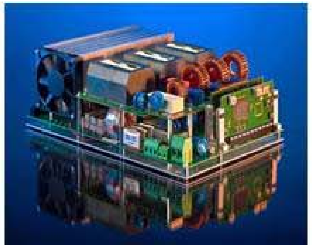
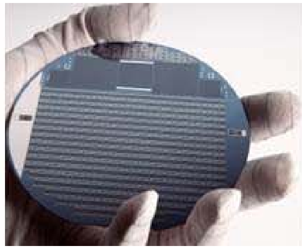
Conclusions

- Lithium-ion battery systems are very interesting and promising for the use in decentralized grid-connected PV applications
- Lithium-ion battery systems:
  - Have always an integrated battery management
    - Precise state of charge and state of health estimation crucial
    - Operating ranges have an impact on life time
    - Future: Integration of end of life / remaining life time predictions
  - On the way to be profitable, dependent on the specific application and the boundary conditions
  - But: Cost have still to be decreased → Detailed cost analyses very important
- Energy management for decentralized PV battery systems:
  - Operating control strategies for increased self-consumption are "state of the art", but not sufficient for enabling the "energy transition"
  - "Intelligent" energy management, which considers grid issues, enables further large scale grid integration of PV systems

Thanks for your attention !!!

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