Quality Assurance for PV Battery Systems

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Solar Energy Systems ISE

Smart Energy Forum – ESS Conference

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Agenda

- Introduction to battery R&D and services of Fraunhofer ISE
- Overview of global electrical energy storage trends
- Key factors affecting bankability of energy storage projects
- Quality assurance for residential PV battery systems
- Quality assurance for larger PV battery systems – Concept and range of services
- Project examples
- Conclusions


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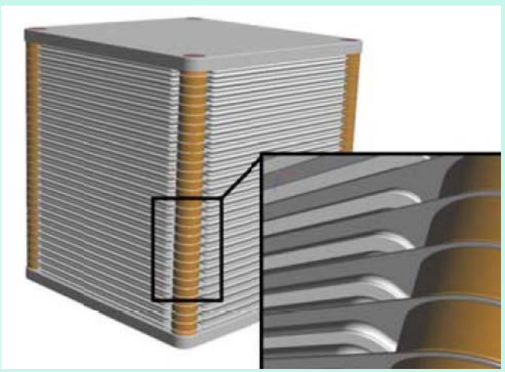
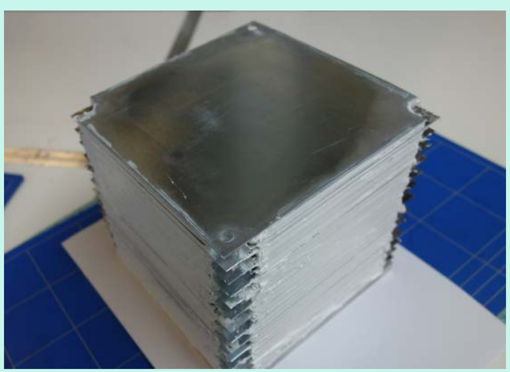
Battery materials and cells

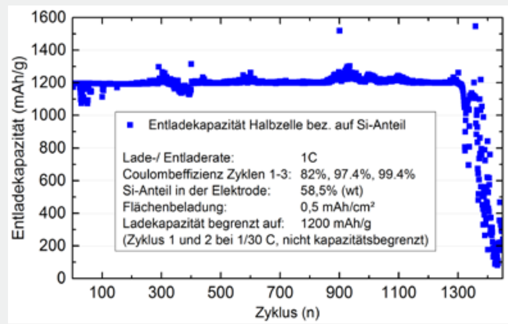
Current focus topics of Fraunhofer ISE

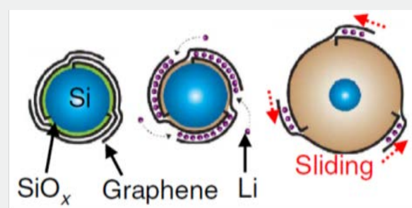
Aqueous batteries for stationary applications

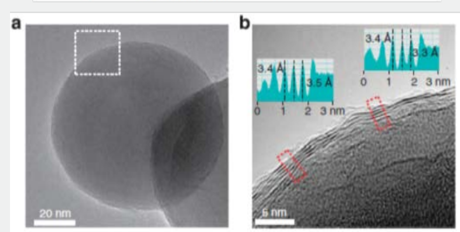




Silicon based anodes as *drop-in replacement* for lithium-Ion battery cells

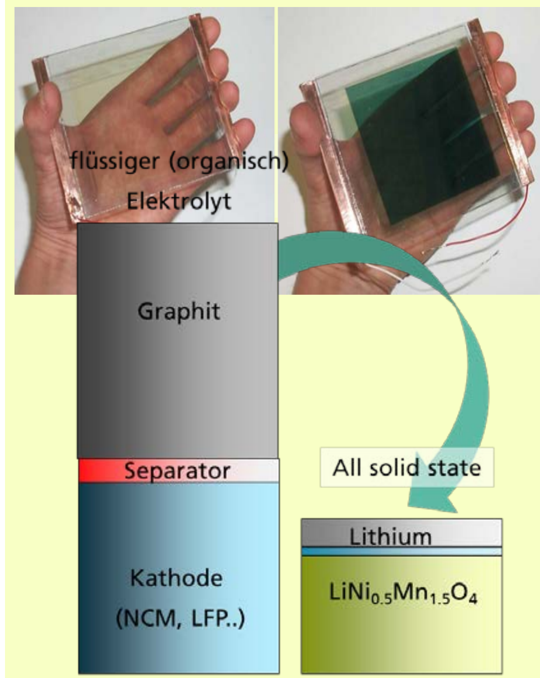






From DOI: 10.1038/ncomms8393

New materials and process technology for *solid state* batteries



~200 Wh/kg ~550 Wh/Liter

~650 Wh/kg ~1700 Wh/Liter

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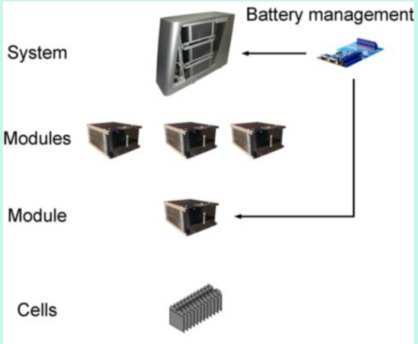
Battery systems and applications
R&D and services of Fraunhofer ISE

Battery system technology
From cells to systems



- Cell characterization
- Module and system design
- Battery management
- Thermal management
- Algorithms for state estimation and life time prediction
- Optimized charging and operating control strategies

Storage applications
System design, integration and quality assurance

- Consultancy during planning phase
- System design and analysis
- Simulation based storage sizing
- Elaboration of specifications
- Energy management systems
- Site inspections and testing
- Monitoring

Testing
Electrical, thermal, mechanical

- Safety: Components, systems including functional safety
- Aging: Calendric, cyclic
- Performance: Efficiency and effectiveness
- Reliability: Consideration of operating conditions and system performance with aged components

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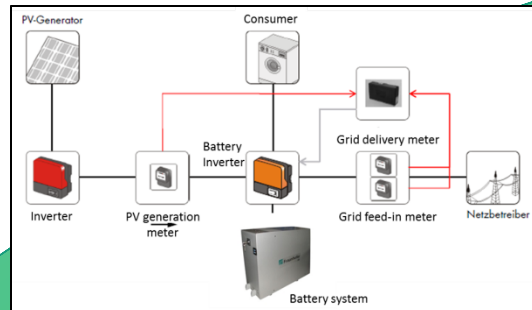
Independent engineering services of Fraunhofer ISE
Along the whole project life time

Planning phase
- Evaluation of project idea
- Potential analysis
- Definition of project requirements
- Identification of challenges
- Identification of risks
- Identification of chances and benefits



Development phase
- Simulation based system design and optimization
- Elaboration of specifications
- Support in component selection and system setup
- Laboratory tests
- Consultancy in product selection
- Neutral contact point for financial and insurance sector
- Consultancy for construction

Implementation phase
- Commissioning tests
- Ongoing quality monitoring
- Identification of component and system failures
- Identification of optimization potential
- Frequent reporting
- Support in Decommissioning
- Consultancy in terms of recycling

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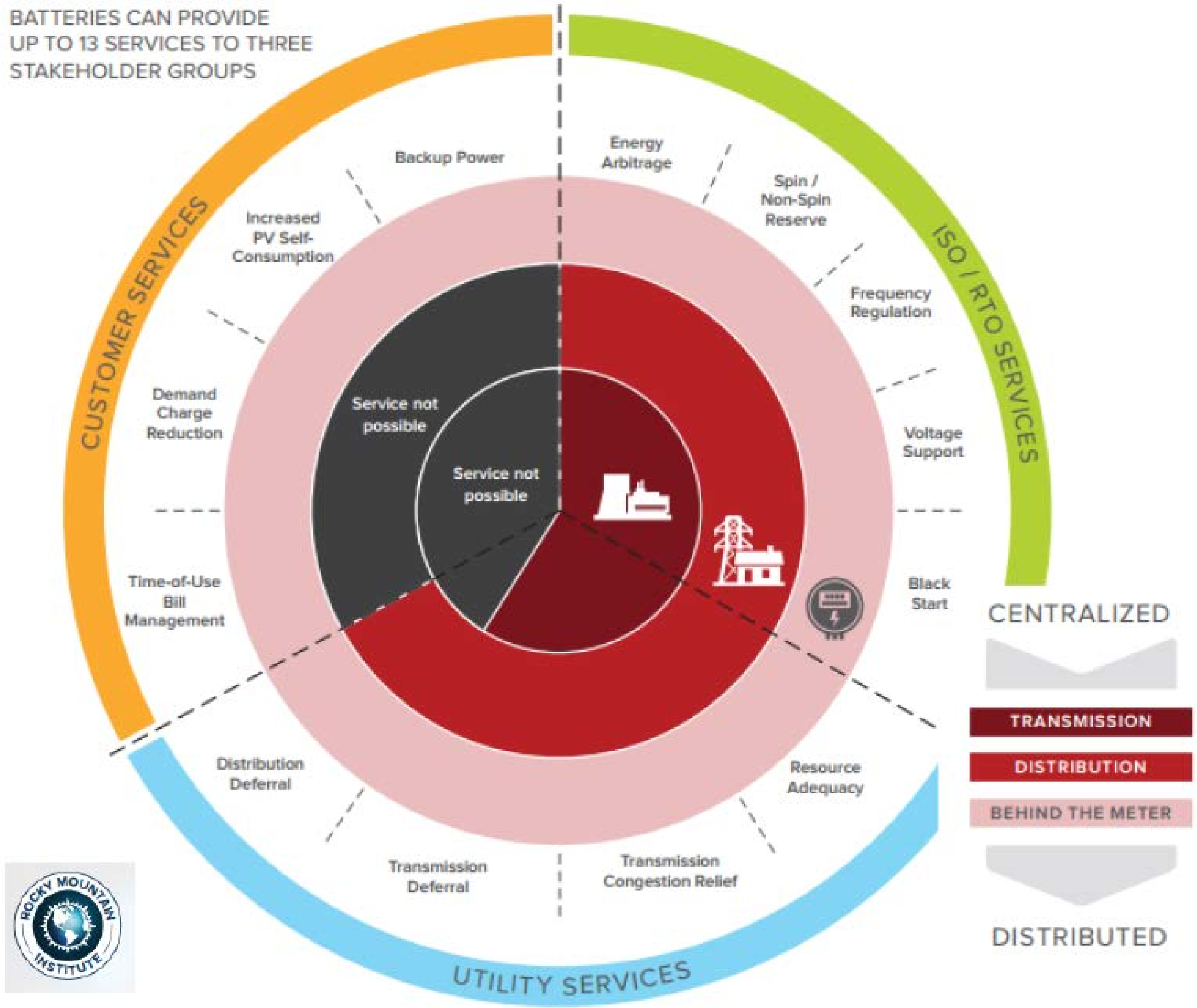
Overview of global electrical energy storage trends

Services and benefits



Source: F. Gattiglio: Battery energy storage in the EU, ees conference, Munich 2017.

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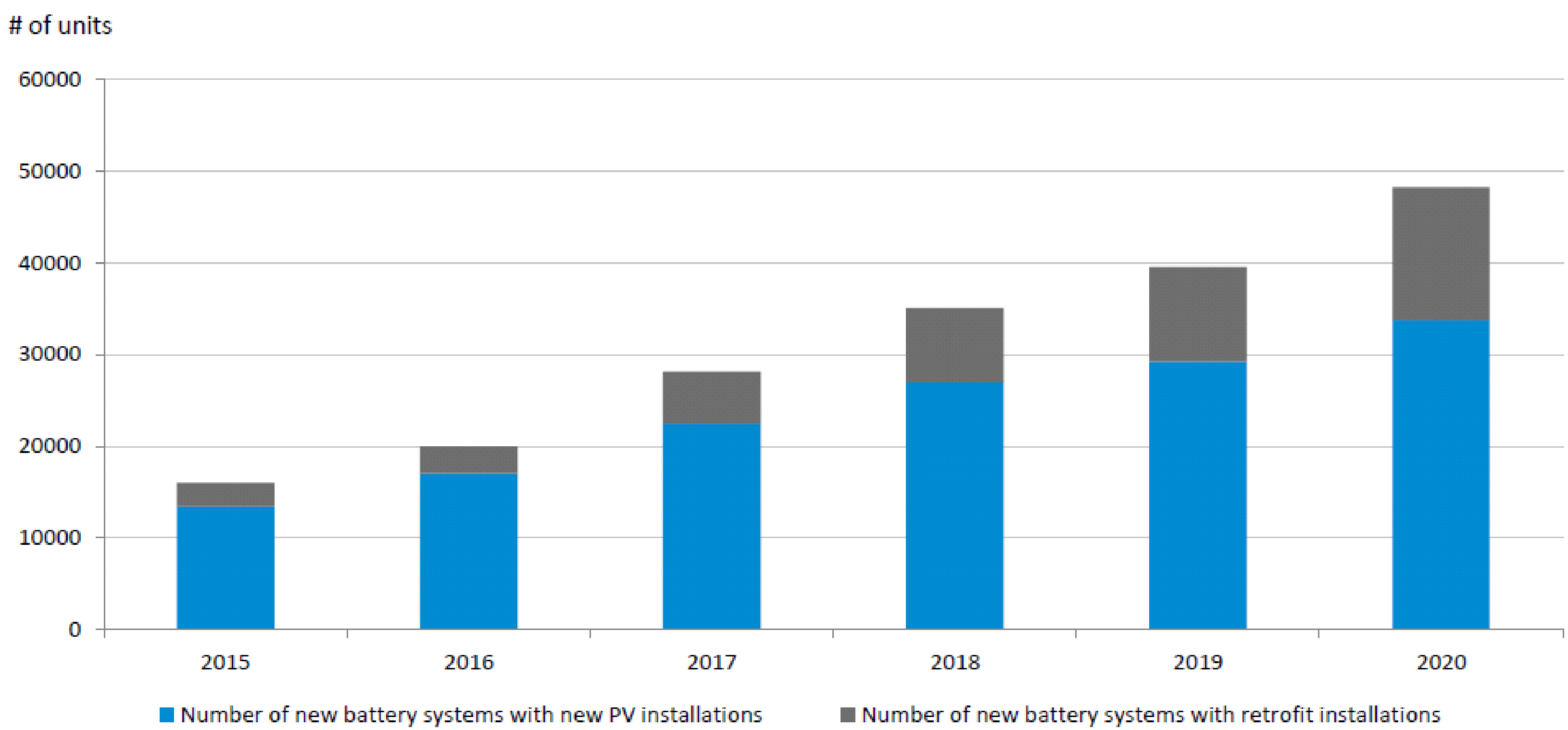
Overview of global electrical energy storage trends

Example Germany: PV self consumption / self sufficiency

Estimated number of newly installed Home PV-battery systems in Germany

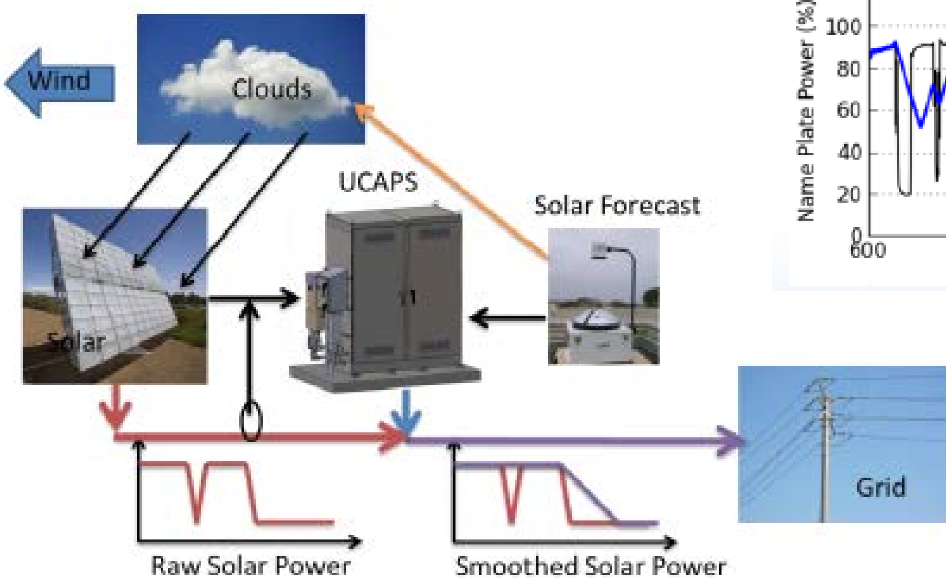


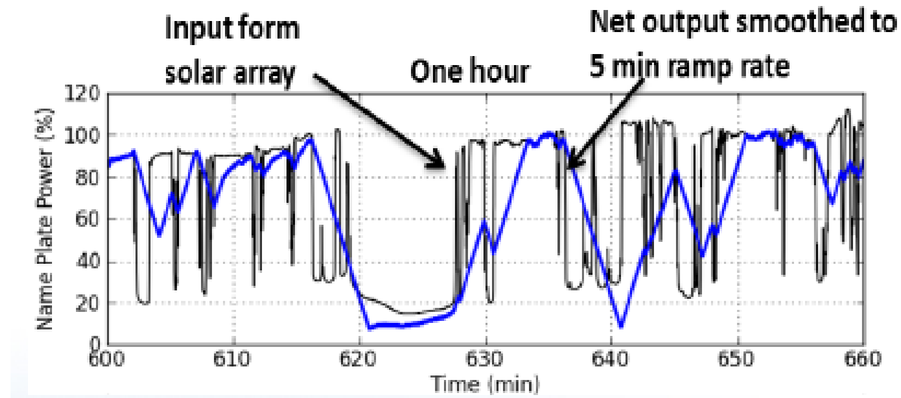
Note: assumptions: new annual PV installations 2015-2020: 1.4 GWp. Source: year 2015: Federal Network Agency, KfW Speichermonitoring 2016; year 2016: preliminary projection by ISEA RWTH Aachen; years 2017-2020: own calculation and estimate, 2017

Source: A. Bräutigam: Business models for energy storage in Germany and hot spot markets, ees conference, Munich 2017.

Overview of global electrical energy storage trends
Example USA: Solar firming (PV power plants)

- Stabilization of solar output for 5 min ramp rate grid regulation
- Approach with ultracapacitors





Source: K. McGrath: Increasing the value of PV: Integration ultracapacitors with renewables, NAATBatt storage workshop July 10, 2014.

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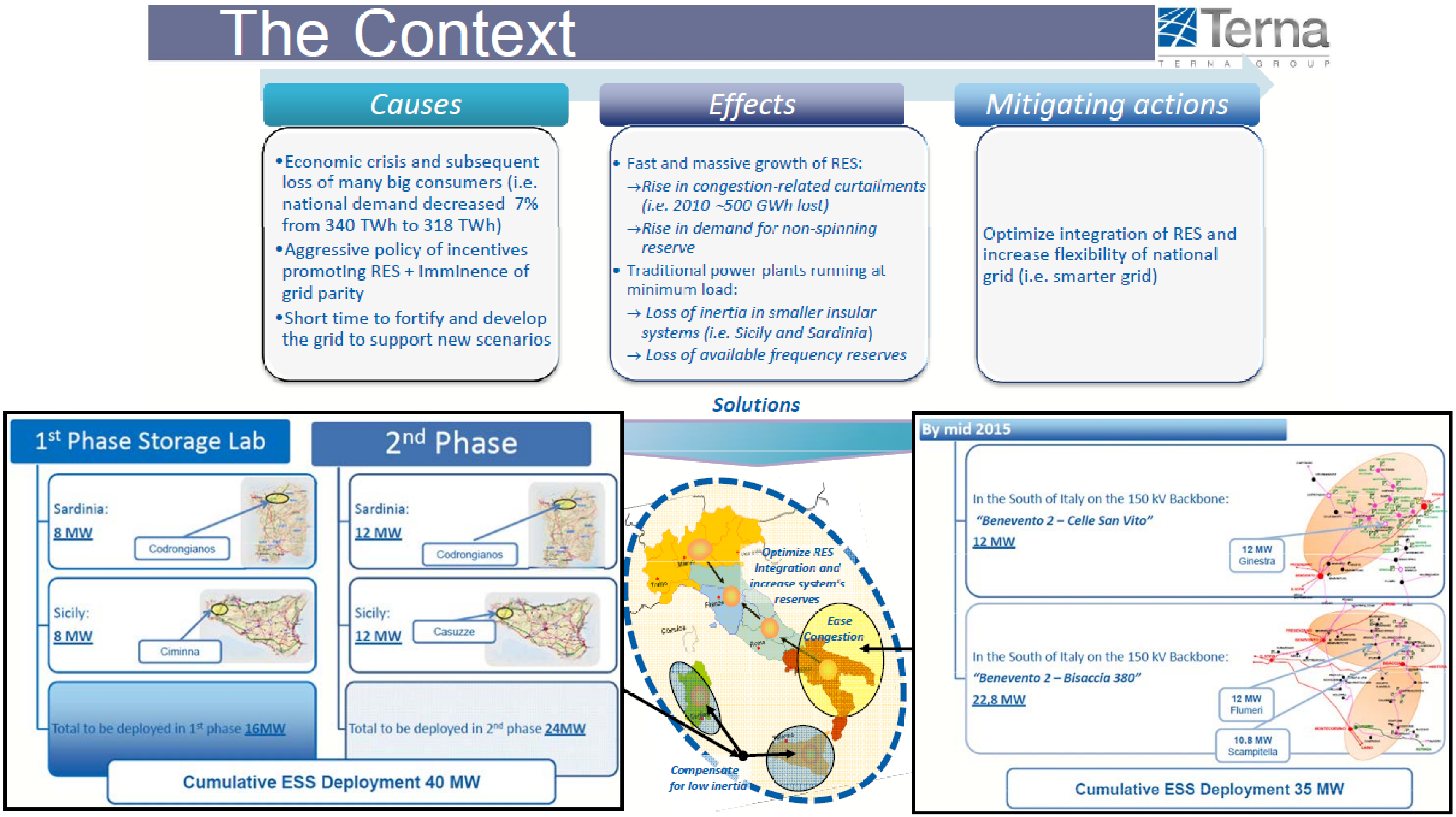
Overview of global electrical energy storage trends

Example Italy: Batteries for grid support



Source: A. Tortora, Terna Group, Energy Storage World Forum, Rome, 2015.

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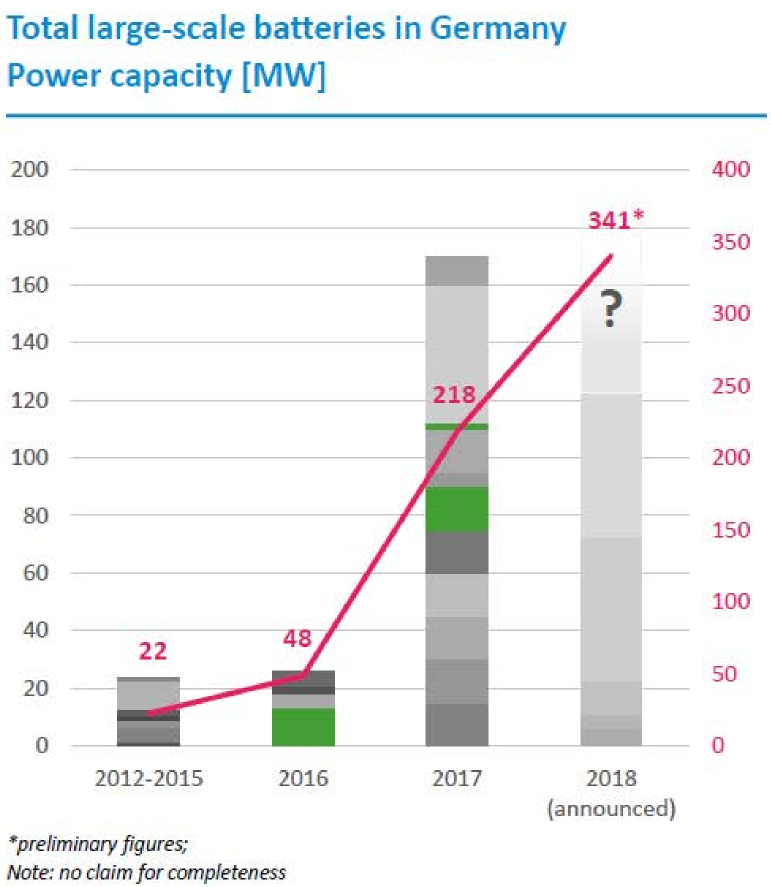
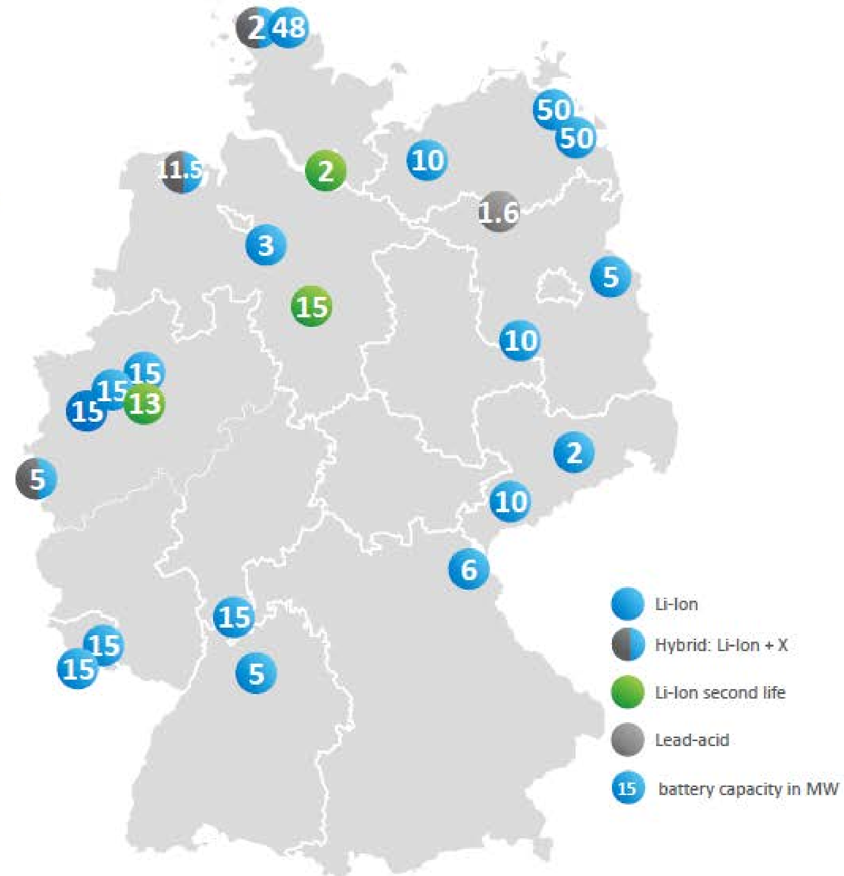
Overview of global electrical energy storage trends
Example Germany: Primary control power





Source: A. Bräutigam: Business models for energy storage in Germany and hot spot markets, ees conference, Munich 2017.

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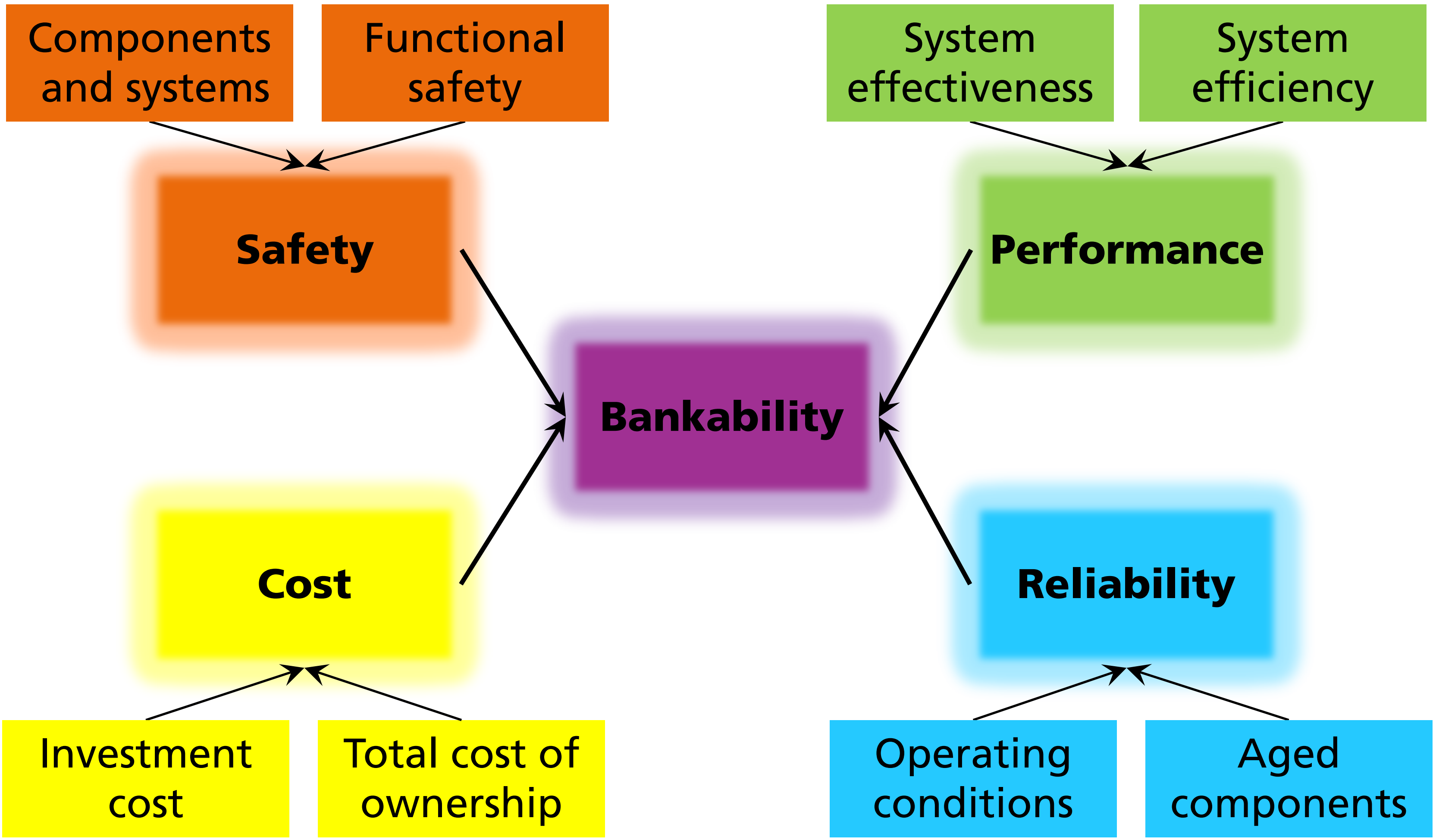
Key factors affecting bankability of renewable energy + storage projects



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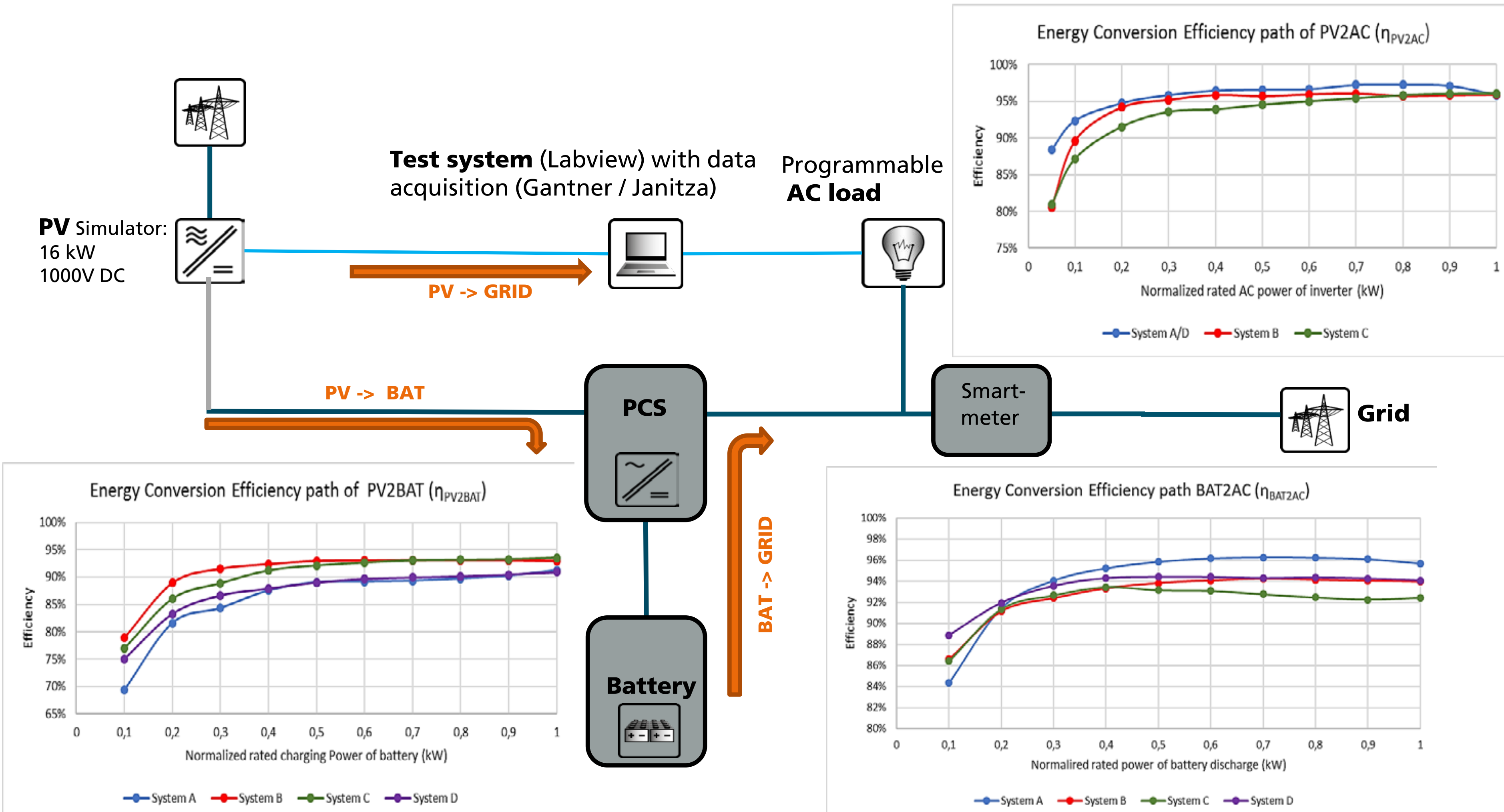
Quality assurance for residential PV battery systems

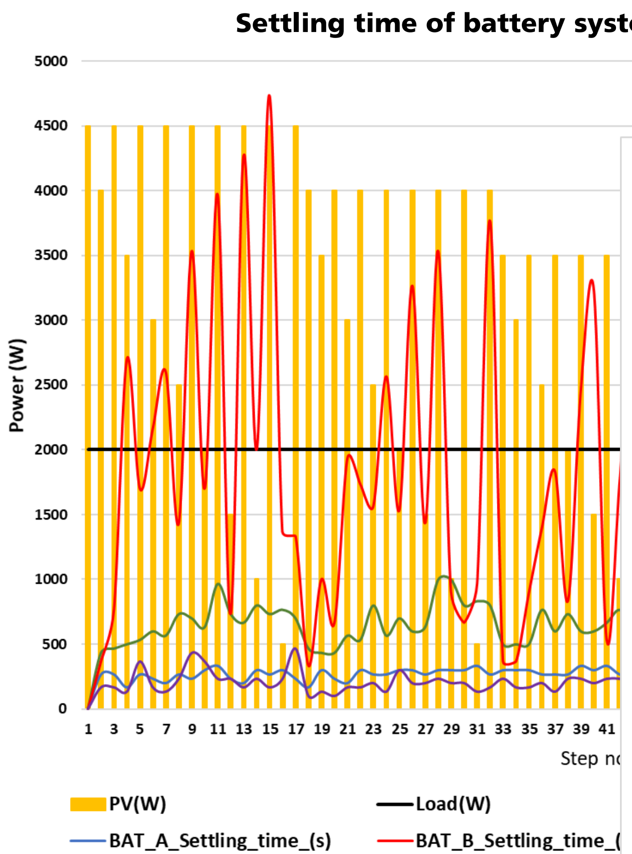
System testing – Analyses of efficiencies

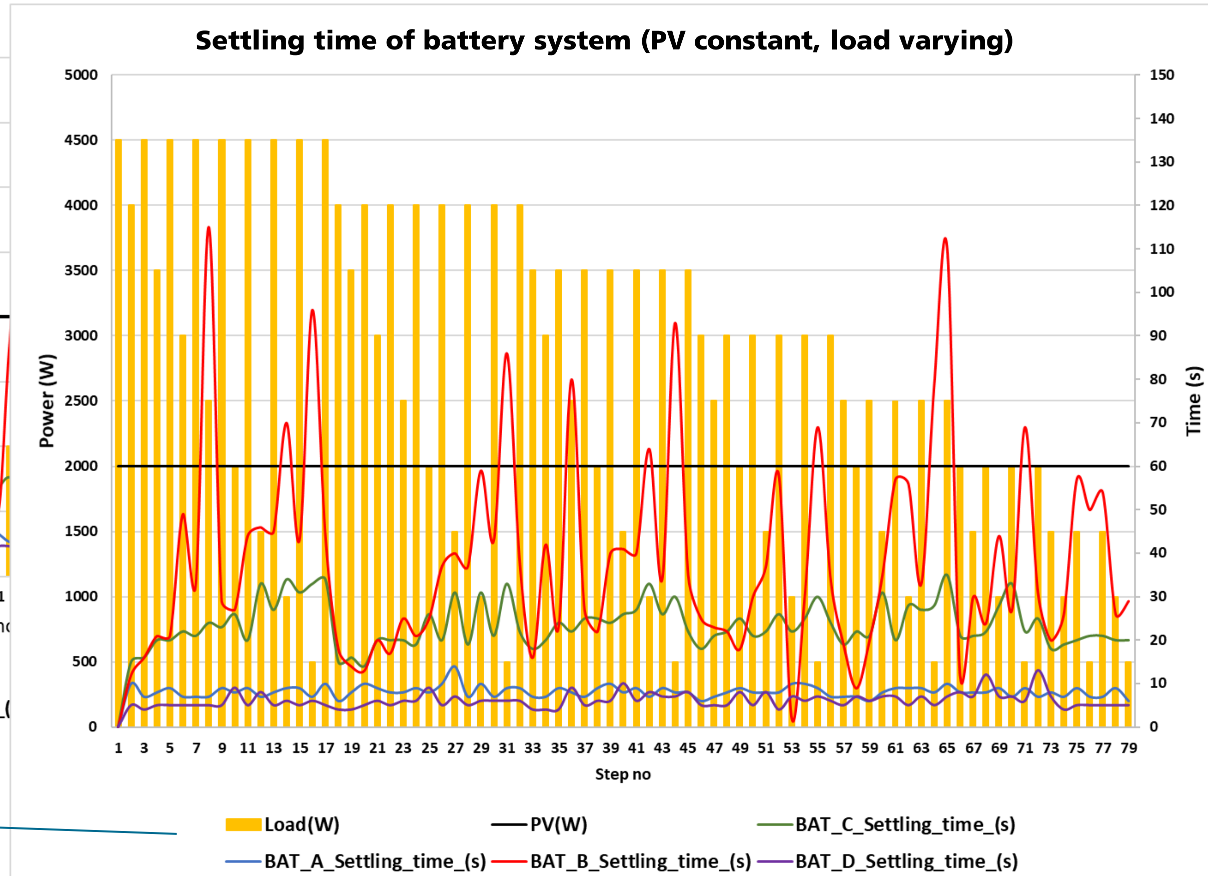


Quality assurance for residential PV battery systems

System testing – Analyses of effectiveness

Avg. Settling time
BAT A: 8.37s ; **BAT B**: 45.14s
BAT C: 20.61s ; **BAT D**: 6.48s





Avg. Settling time
BAT A: 8.11s ; **BAT B**: 38.33s
BAT C: 23.37s ; **BAT D**: 6.03s

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Quality assurance for larger PV battery systems
Power plants, commercial applications and mini-grids

Concept and range of services

- ANALYSES OF LOAD PROFILES
- SYSTEM DIMENSIONING & COMPONENT SELECTION
- CHARACTERIZATION OF SYSTEM COMPONENTS
- YIELD PREDICTION FOR THE PV SUBSYSTEM
- SYSTEM TESTING
- QUALITY MONITORING

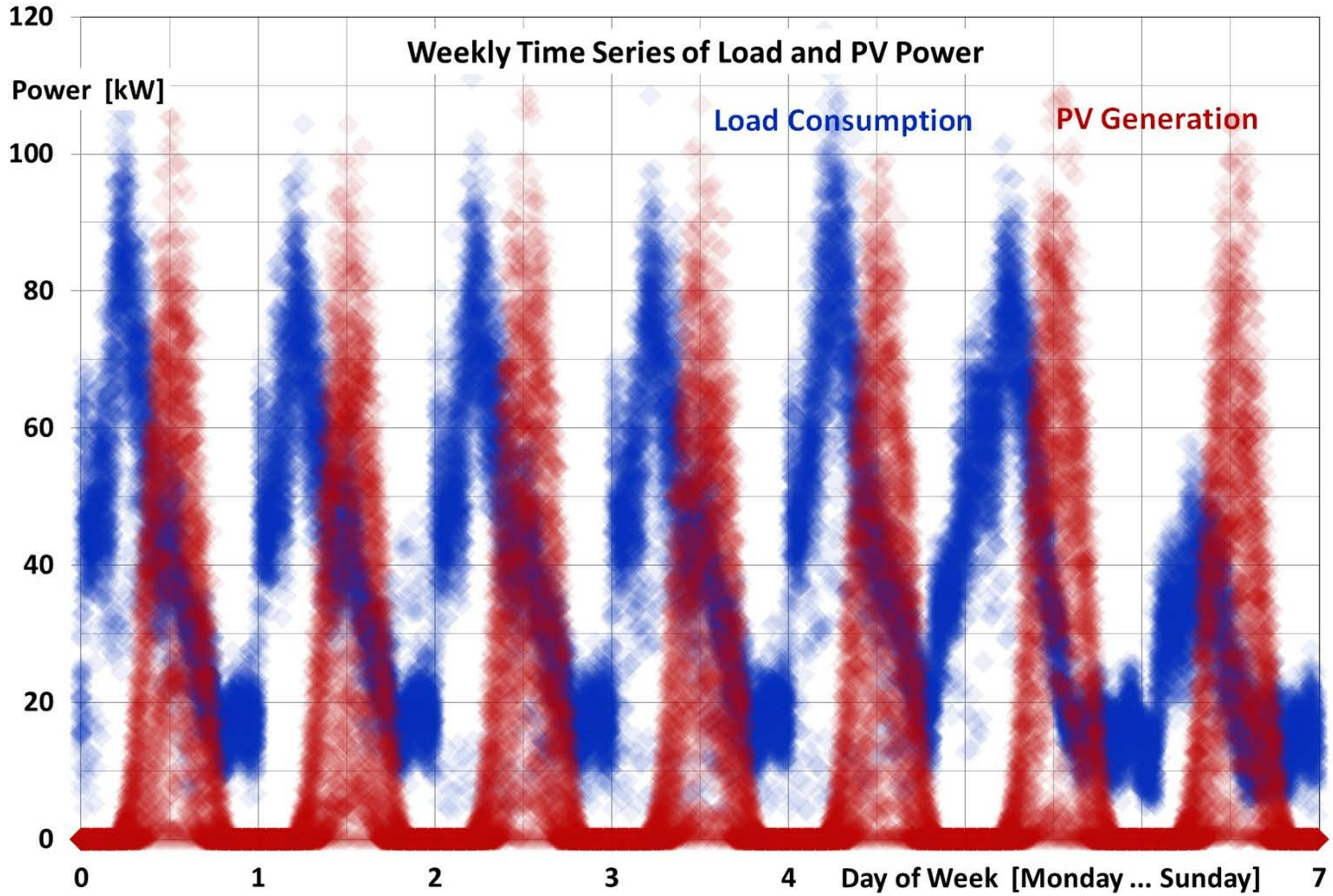
Project examples – System simulation and analyses
Commercial PV battery system – Load and PV generation

Load (bakery):

- Consumption: 335 MWh/a
- Max. power: 118 kW

PV example:

- Size: 150 kWp
- Production: 135 MWh



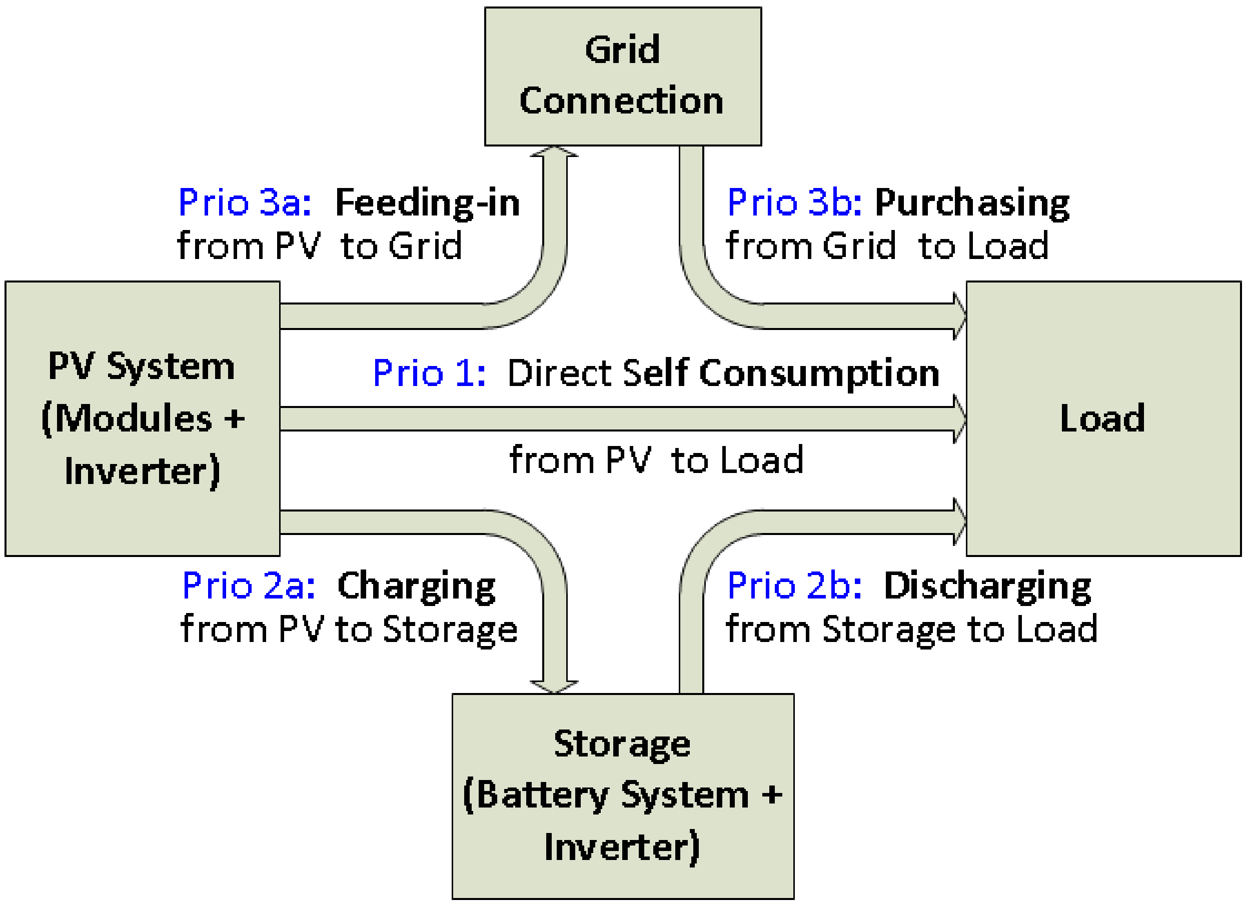
Project examples – System simulation and analyses
Commercial PV battery system – Control strategy

Load (bakery):

- Consumption: 335 MWh/a
- Max. power: 118 kW

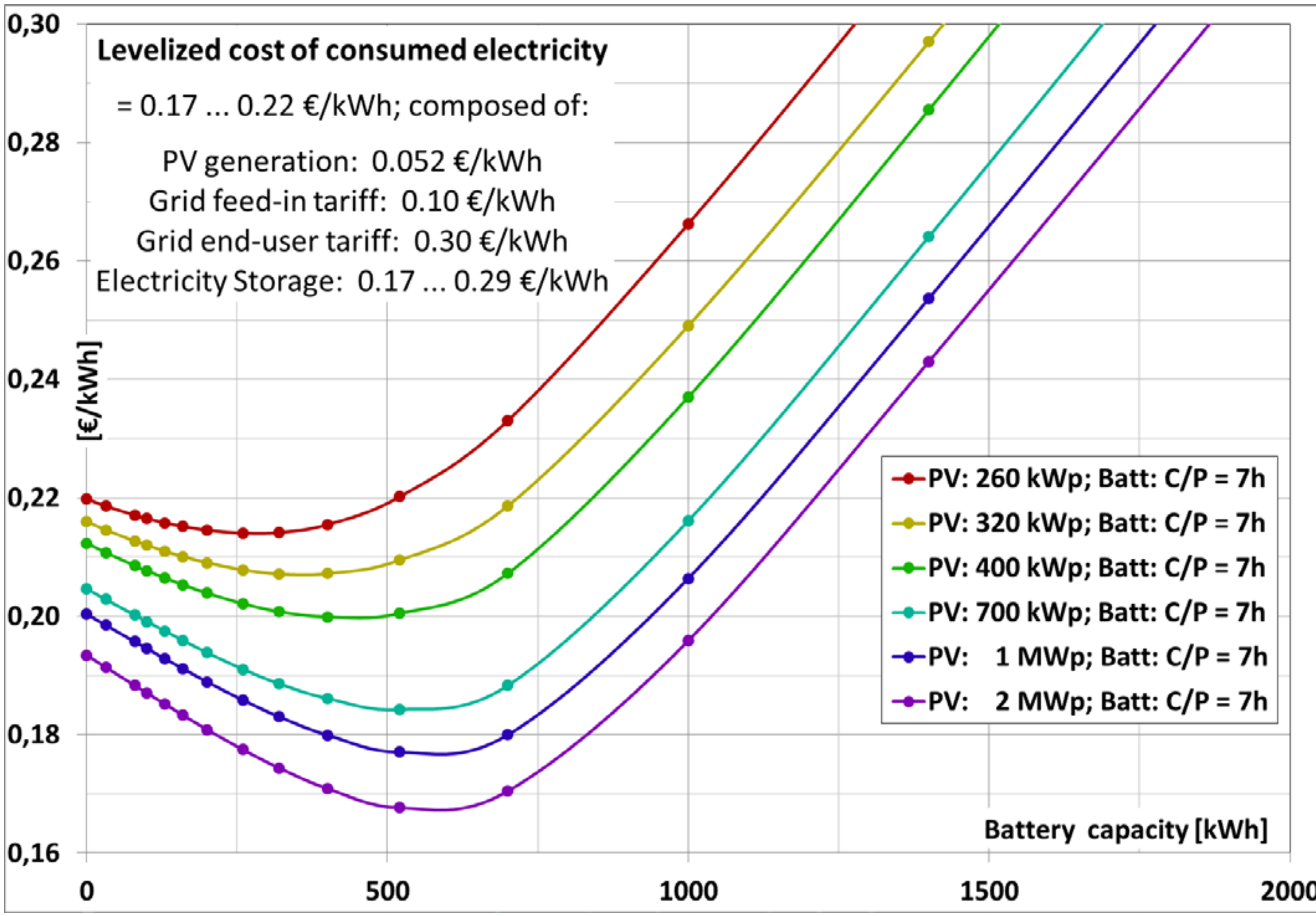
Integration of a PV system and a lithium-ion battery storage:

- Variation of PV system size
- Variation of battery storage size



Project examples – System simulation and analyses
Commercial PV battery system – Results

Levelized cost of consumed electricity



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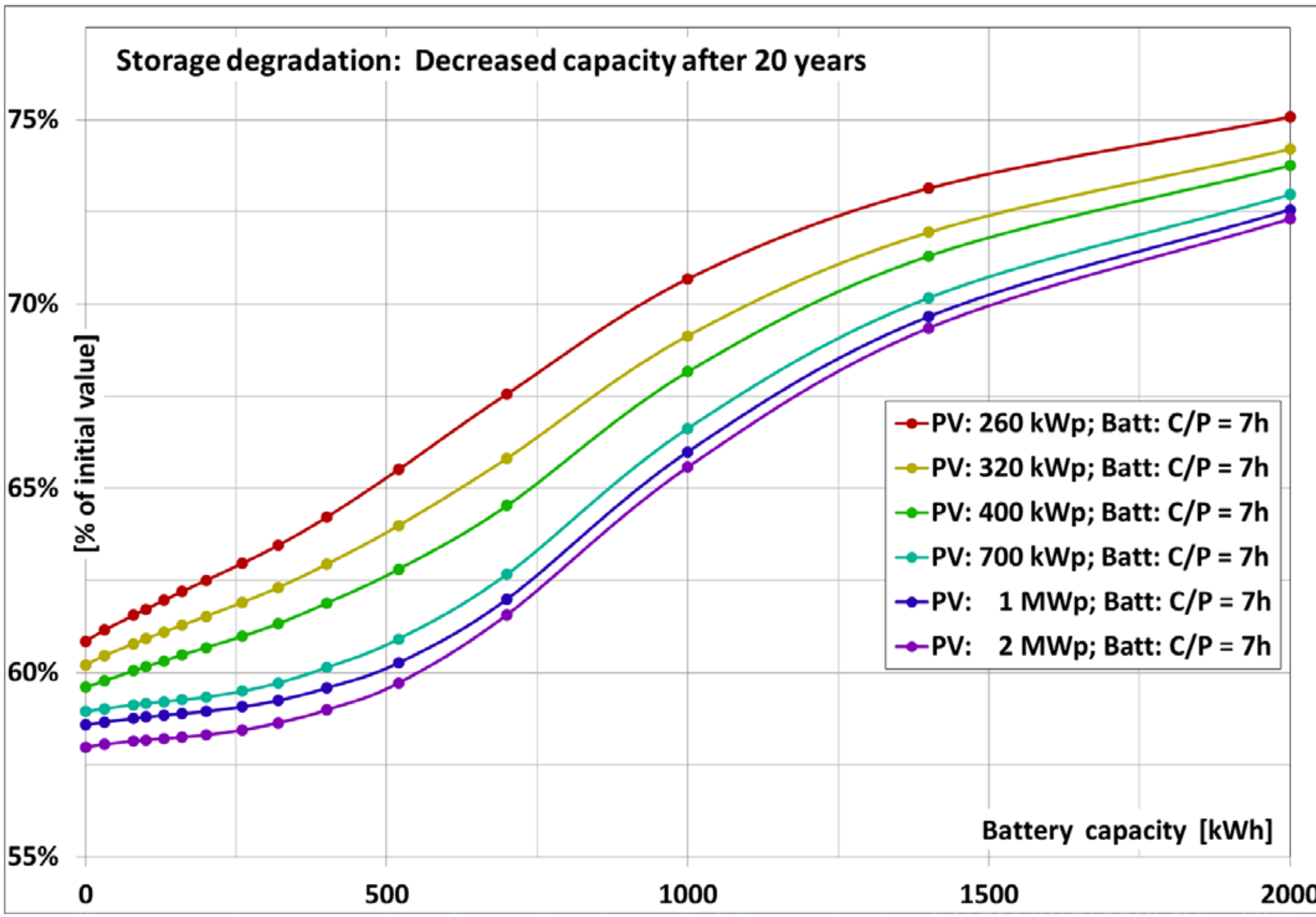
Project examples – System simulation and analyses

Commercial PV battery system – Results

Battery storage: Aging as a function of usable storage capacity and PV power



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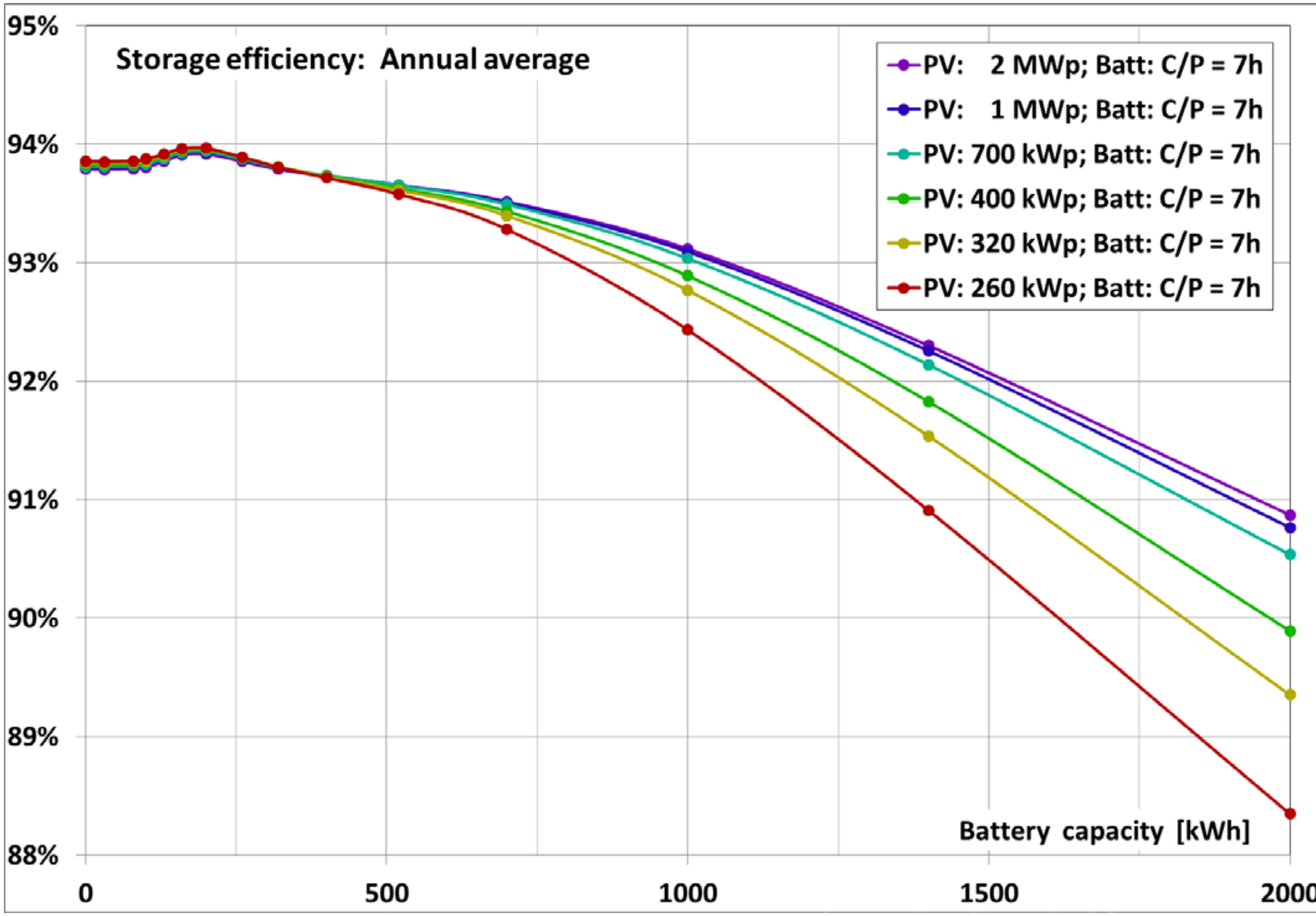
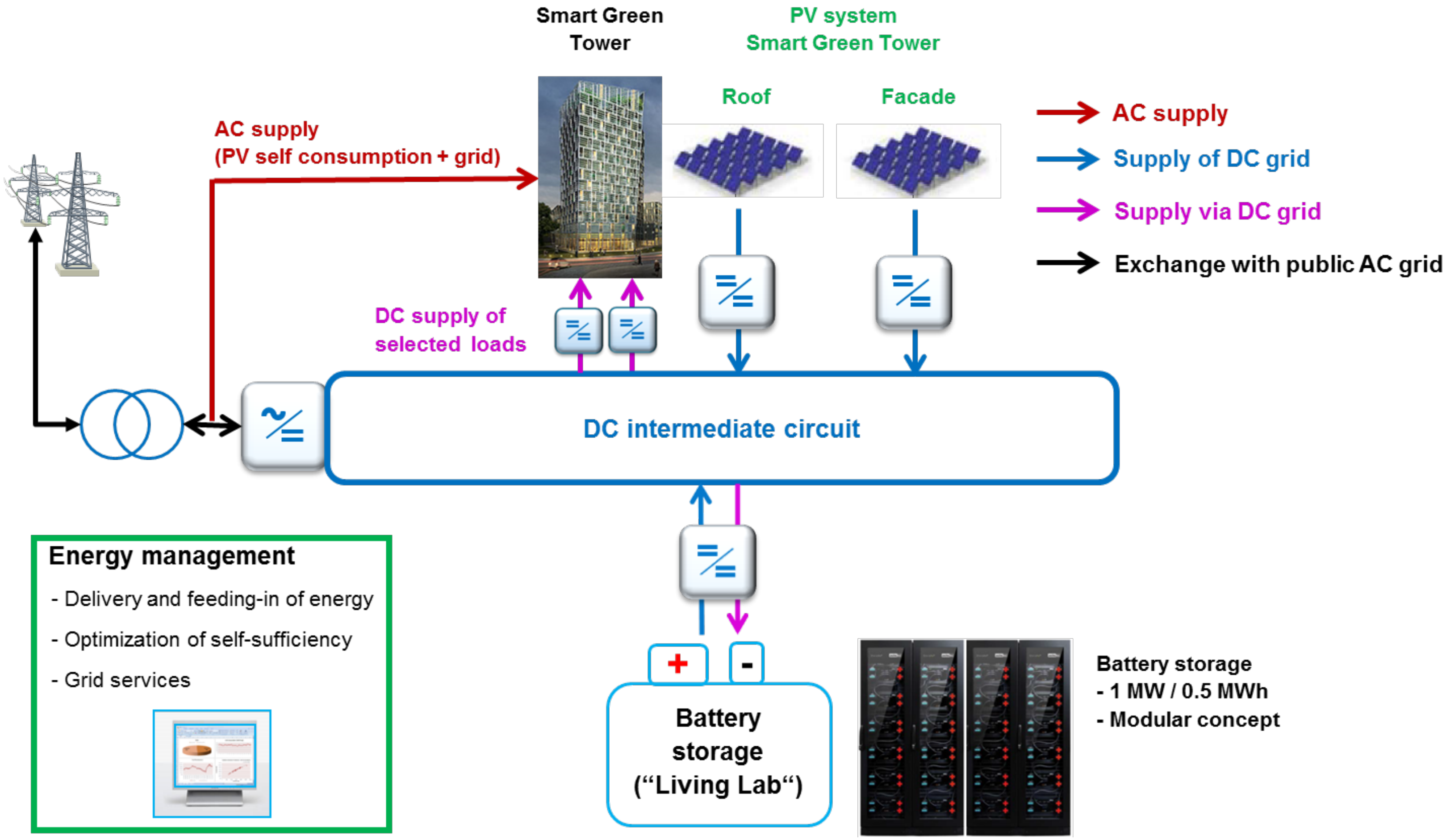
Project examples – System simulation and analyses

Commercial PV battery system – Results

Battery storage: Annual average storage efficiencies



Project examples – System simulation and analyses
Layout and sizing for “Smart Green Tower” in Freiburg



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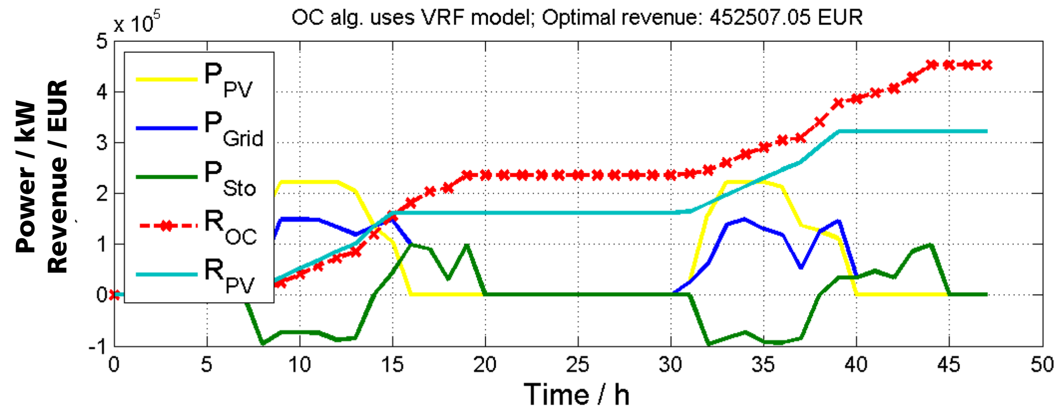
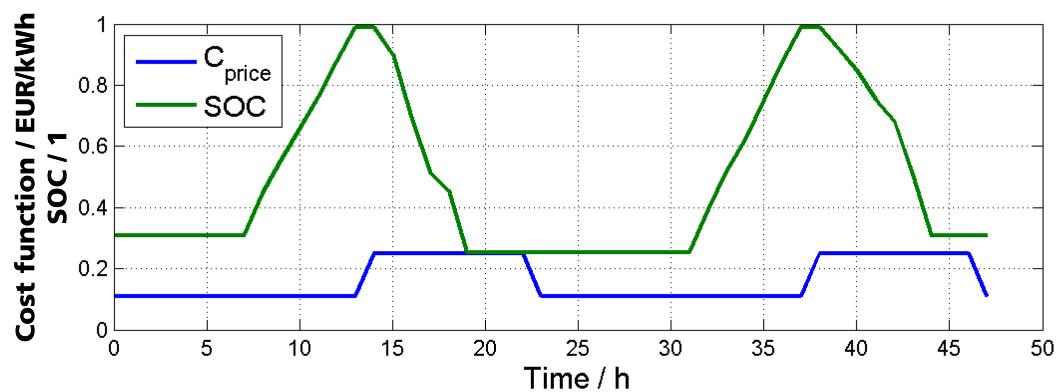
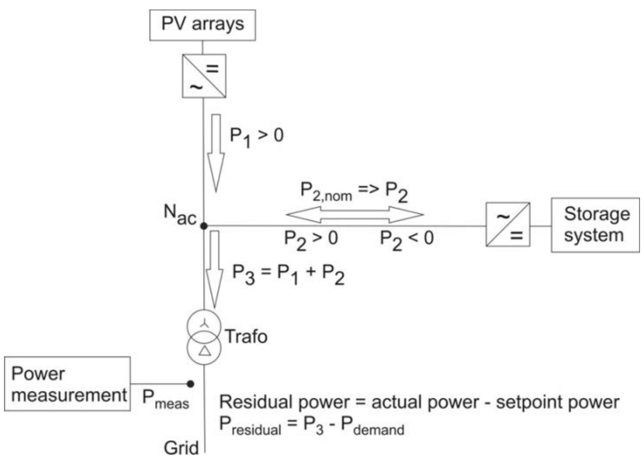
Project examples – System simulation and analyses

Grid connected PV battery power plant

- Optimal control problem: Maximization of the revenues
  - → Optimal dispatch plan for the storage power







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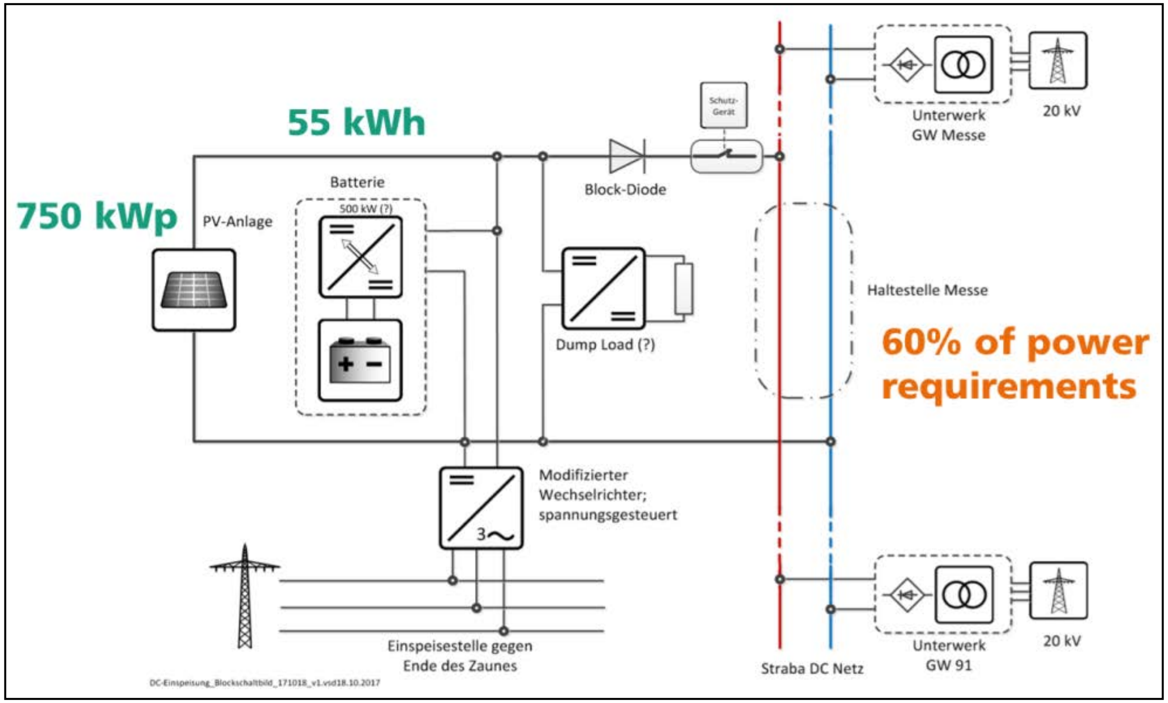
Project examples – System simulation and analyses

PV battery integration into light-rail system at new SC Freiburg soccer stadium

- Smart sector coupling
- Efficient DC integration of a PV battery system into the light-rail system of VAG
- Peak load: Up to 950 kW
- Energy consumption: ~ 1 MWh / day
- PV battery system: 750 kW_p and 55 kWh can cover in average 60 % of required power
- Via direct marketing to VAG economics of the PV battery system can be improved



Gefördert durch den Innovationsfonds Klima- und Wasserschutz
badenova Energie. Tag für Tag
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Project examples – System simulation and analyses

Layout and sizing of a PV mini-grid for SKA1 low radio telescope

Design proposal

- Central power plant powering 80 % of total telescope load (2.4 MW in average)
  - PV system: 17 MW_p
  - Lithium-ion battery storage: 40 MWh / 5.5 MW
  - Diesel genset: 3.2 MW
- 20 % outermost antenna clusters
  - Powered locally
  - 15 RPFs (distance from CPF > 10 km)
- LCOE: ~ 0.307 €/kWh

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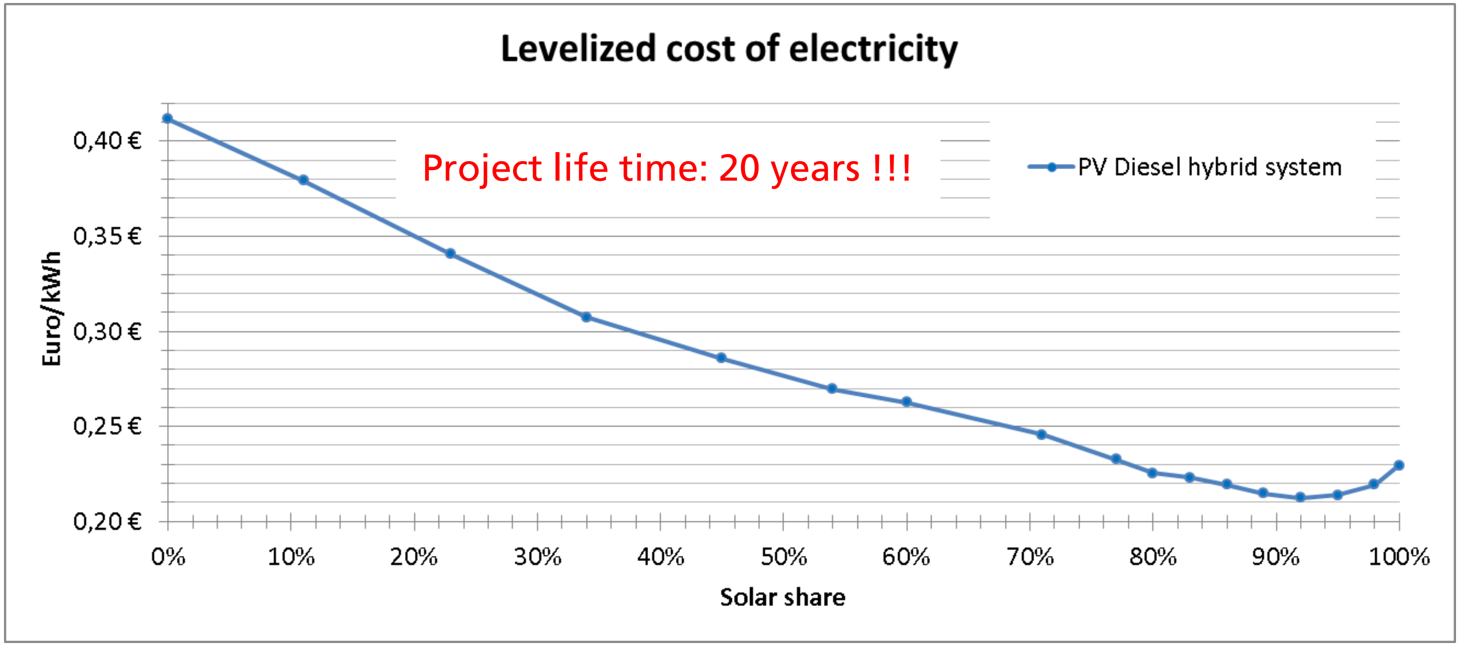
Project examples – System simulation and analyses
Techno-economical evaluation of a PV mini-grid in Uganda

- Example Uganda
- Load:
  - Peak load: 200 kW
  - Annual consumpt.: 574 MWh
- PV Diesel hybrid system:
  - PV system (incl. power electronics): 1.5 Euro/Wp
  - Battery system: 220 Euro/kWh
  - Diesel: Invest 273 $/kW; Fuel 1$/l; Maintenance: 0.7 $/h



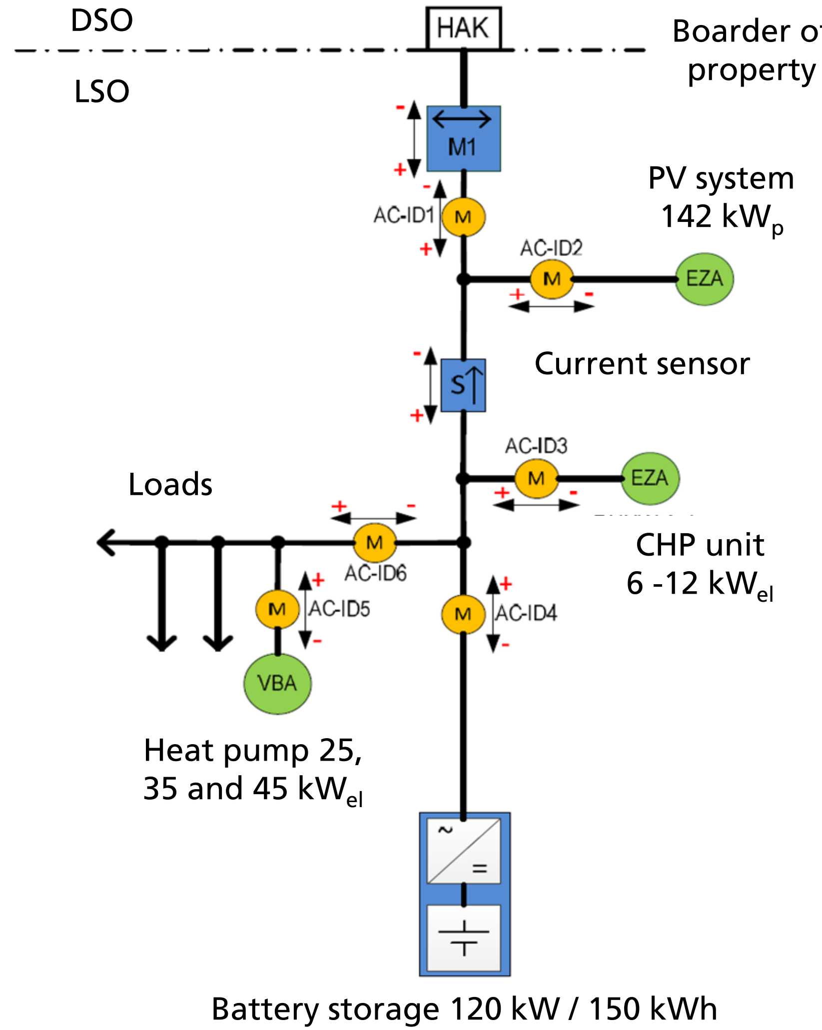
Project examples – Monitoring and system evaluation

District storage system – "Weinsberg"

Optimization criteria:

Minimization of grid dependency –

Physically not only accumulated



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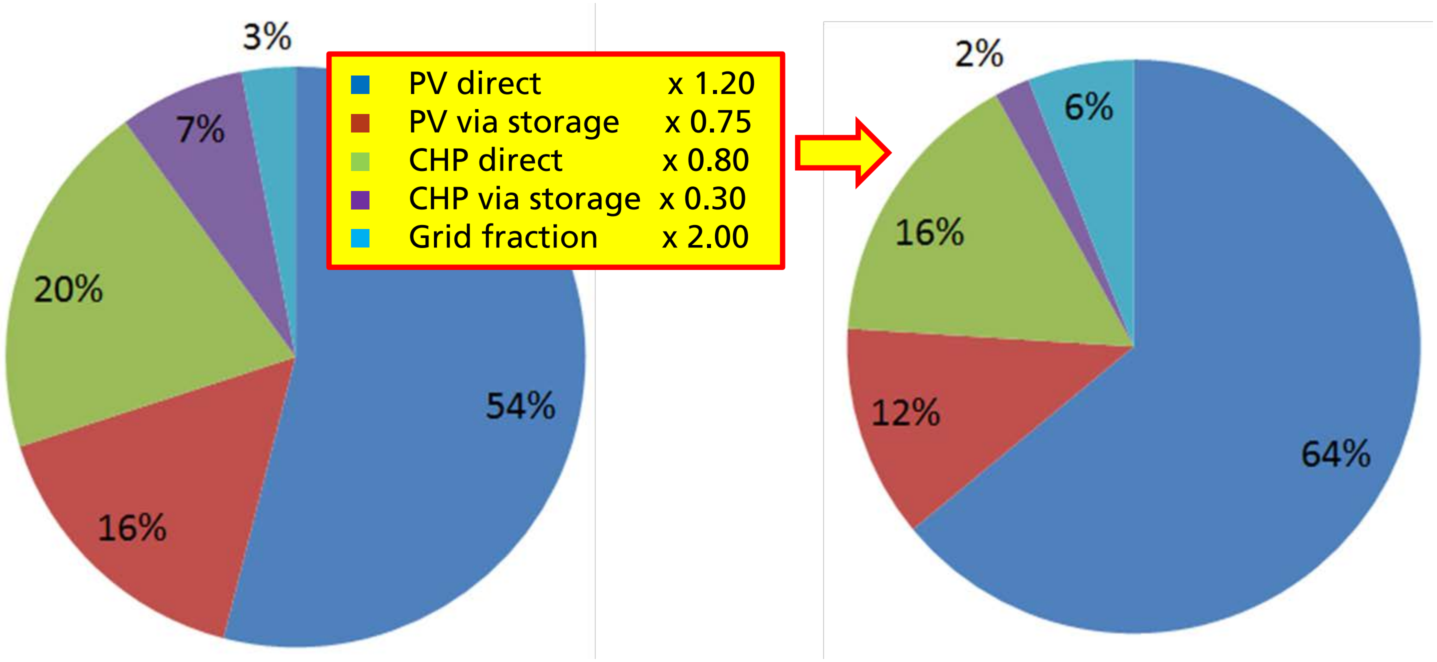
Project examples – Monitoring and system evaluation
District storage system – “Weinsberg”

Accumulated annual electrical energy quantities

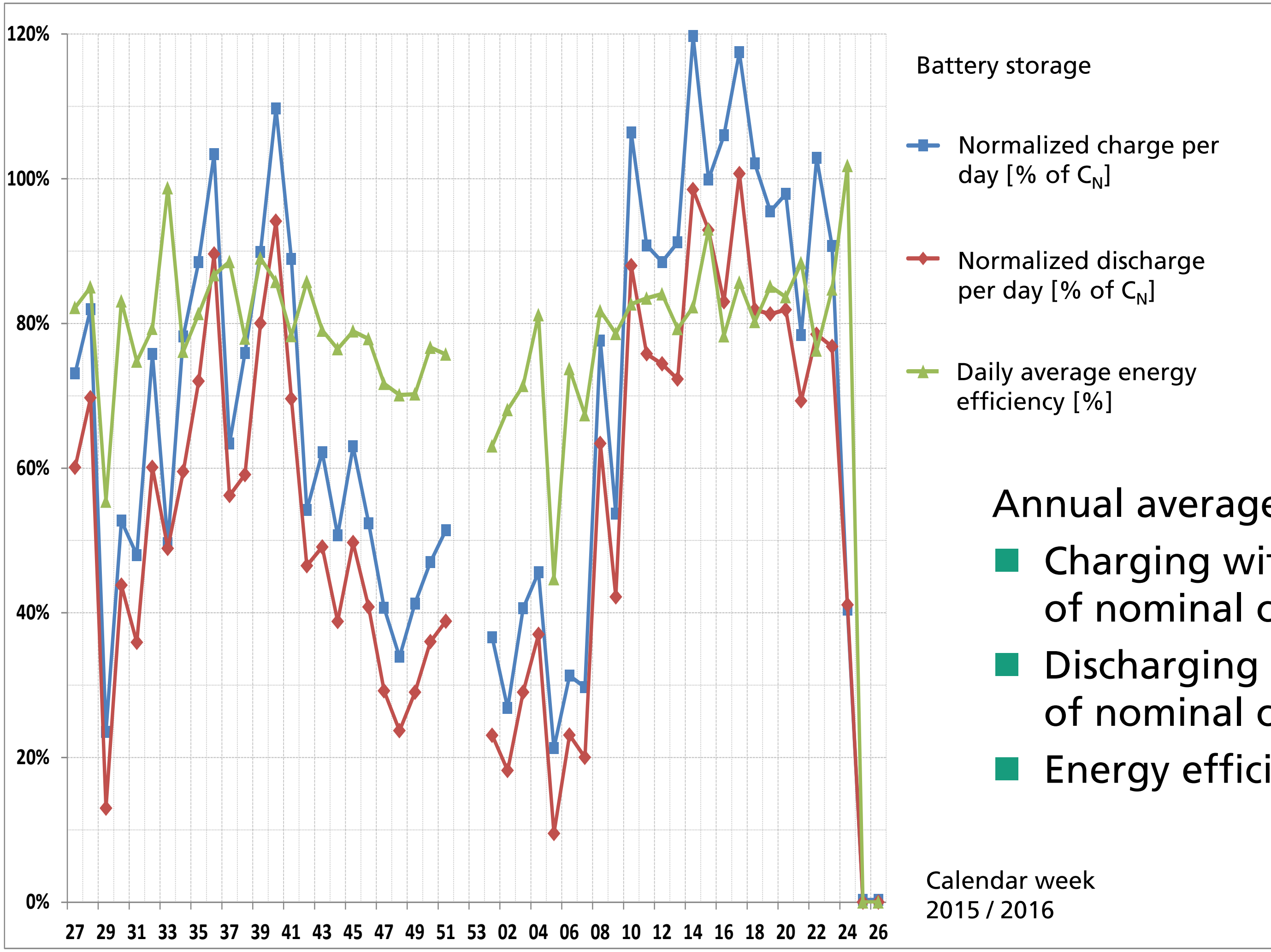
Simulation | Monitoring 2015 / 2016



Reasons for differences:

- Problems with air conditioning → To high temperatures in operation room → Shut-down of CHP unit and battery inverter
- Necessary maintenance interval of CHP unit in winter (!)
- End-users do not behave 100 % as predicted (!)

Project examples – Monitoring and system evaluation
District storage system – "Weinsberg"



Annual average values:

- Charging with 67 % of nominal capacity
- Discharging with 54 % of nominal capacity
- Energy efficiency: 81 %

Conclusions

- Large-scale integration of fluctuating renewable energies in power supply systems require storage (grid-connected and isolated mini-grid applications)
- Battery storage systems:
  - Modularity – Solutions from a view kWh to the Multi-MWh class
  - Advanced solutions along the whole value chain of the power supply (behind-the-meter and before-the-meter)
- Integration of battery storage requires several steps of quality assurance enabling bankable projects:
  - From detailed analyses of load pattern to system simulation and application specific system design
  - From characterization of components and systems in the laboratory to system testing in the field as well as quality monitoring
- Field experiences with "new" battery technologies still show huge optimization potential – Component and system level
- Renewable energy shares in power supply systems, e.g. mini-grids:
  - Economic optimum strongly depends on the considered project life-time (Levelized cost of energy computation)

Thanks for your attention !!!

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