Quality assurance for PV battery systems

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Solar Energy Systems ISE

15. Battery Experts Forum

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Fraunhofer ISE

Agenda

- Introduction to Fraunhofer ISE battery activities and services
- 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
- Services towards certification
- Conclusions

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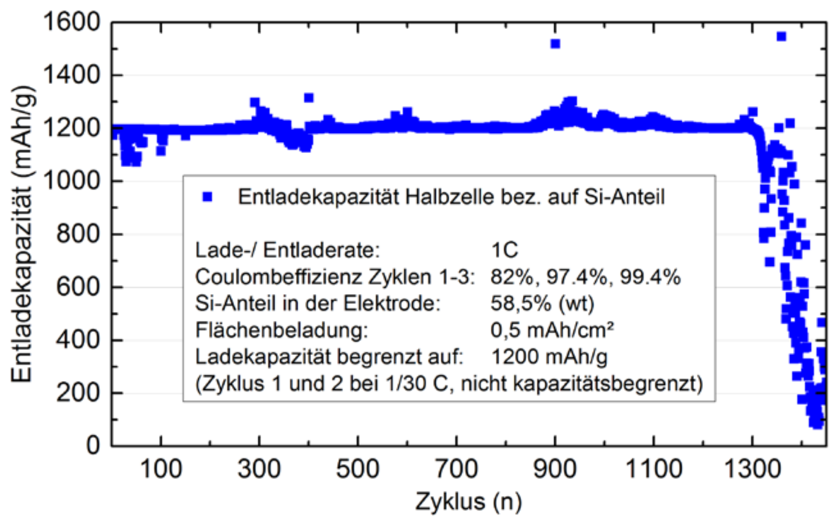
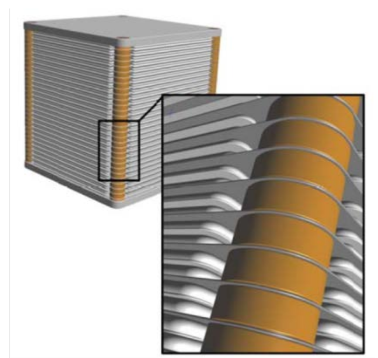
Development of battery cells at Fraunhofer ISE

Current focus topics

- **Silicon anodes** for high performance lithium-ion batteries: Novel carbon coating process for silicon particles
- **Sodium-ion battery cells** for stationary storage: Development of an aqueous electrolyte based cell
- **Supercaps:** Carbon based materials developed in collaboration with University of Freiburg
- **Solid state battery cells:** Simplified processing technologies based on smart glass know-how at Fraunhofer ISE





Geplante Architektur der Na-Ionen Batteriezelle (Kantenlänge ca 15 cm)

Gefördert vom Wirtschaftsministerium BW

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Battery system technology at Fraunhofer ISE
Research and development at a glance

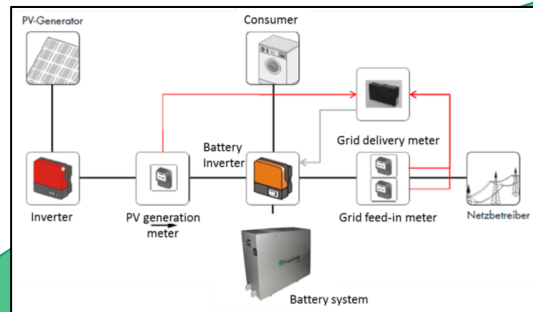
- **Formation of battery cells:** Last production step, essential for performance and life time of lithium-ion cells
- **Cell / module / system tests and analyses:** Performance, aging, reliability, functional safety, post mortem
- **Modeling and simulation:** From detailed aging and thermal models for life time prediction to performance models for system analyses
- **Battery module and system development:** From small home storage applications to large hybrid systems
- **Battery management:** From algorithms for state estimation and operating control strategies to hardware implementation
- **Thermal management:** From passive to high efficient active methods with model predictive control for optimized operation
- **Integration in energy systems:** From interface specification and energy management systems to implementation
- **Quality assurance, safety and certification:** Accompanying of product developments and implementation projects (e.g. commercial PV battery systems) via cooperation with renowned partners

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

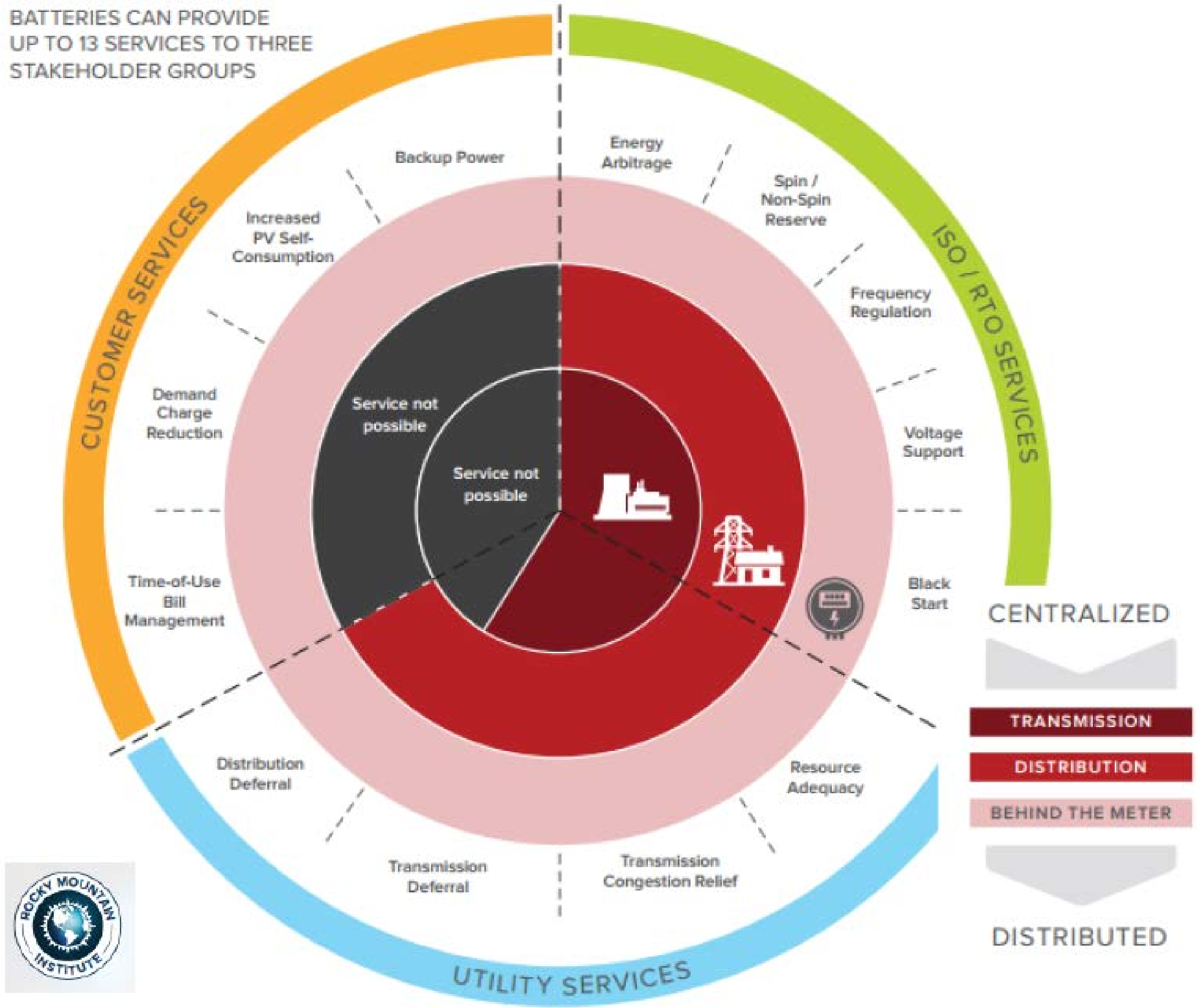
- Simulation based system design and optimization
- Elaboration of specifications
- Support in component selection and system setup
- Laboratory tests
- Consultancy in product selection
- Neutral contact point for financial and insurance sector
- Consultancy for construction

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

Overview of global electrical energy storage trends

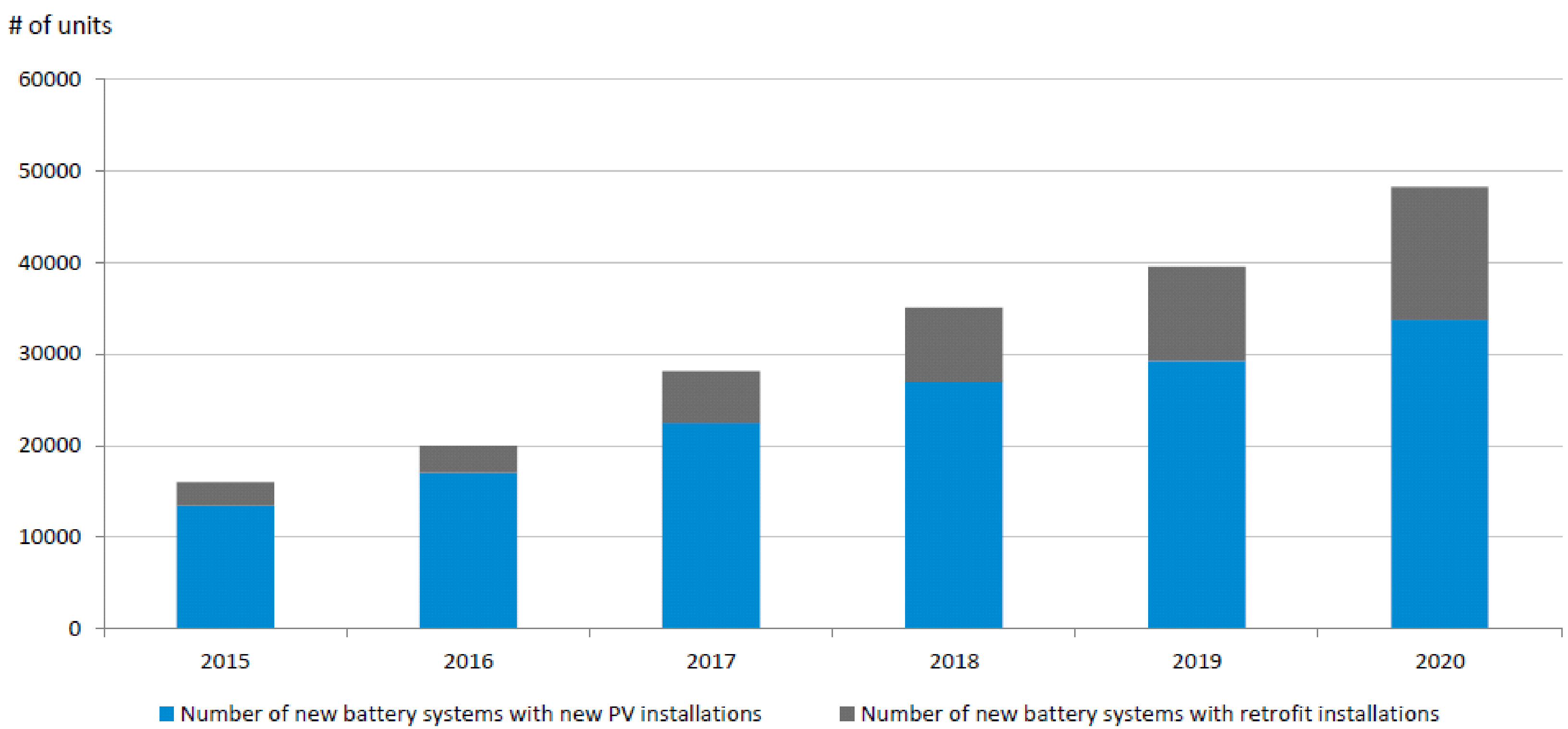
Services and benefits



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

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



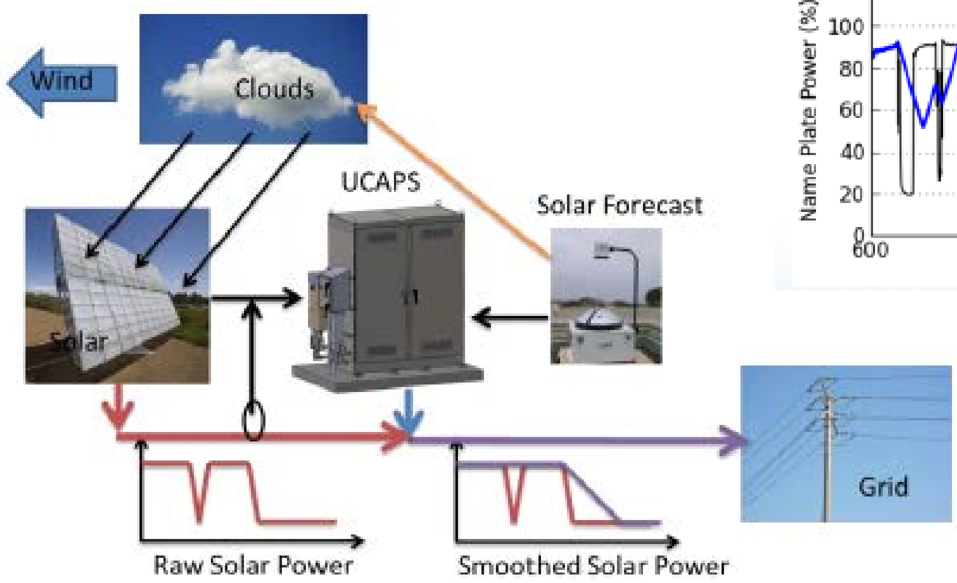
Note: assumptions: new annual PV installations 2015-2020: 1.4 GWp. Source: year 2015: Federal Network Agency, KfW Speichermonitoring 2016; year 2016: preliminary projection by ISEA RWTH Aachen; years 2017-2020: own calculation and estimate, 2017

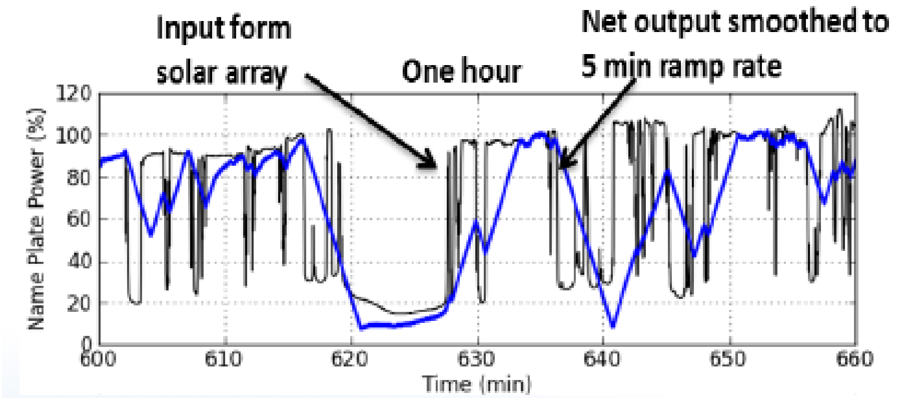
Source: A. Bräutigam: Business models for energy storage in Germany and hot spot markets, ees conference, Munich 2017.

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

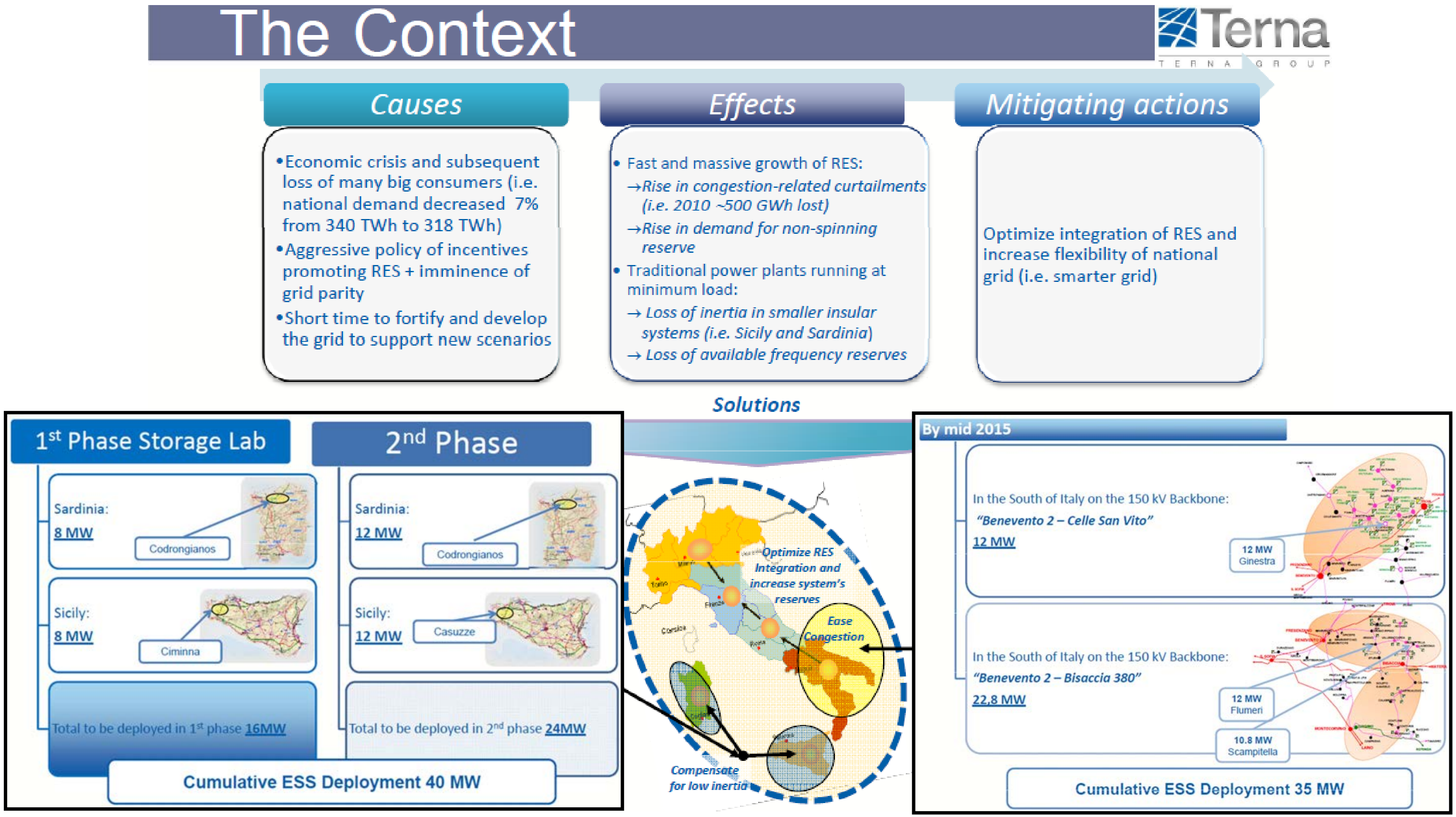




Source: K. McGrath: Increasing the value of PV: Integration ultracapacitors with renewables, NAATBatt storage workshop July 10, 2014.

Overview of global electrical energy storage trends

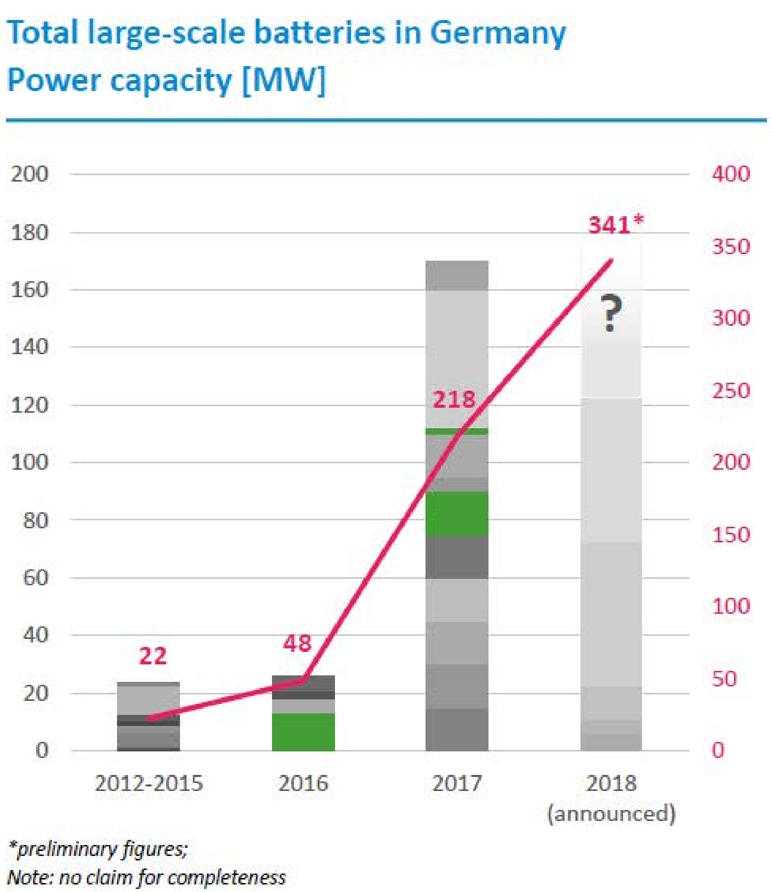
Example Italy: Batteries for grid support

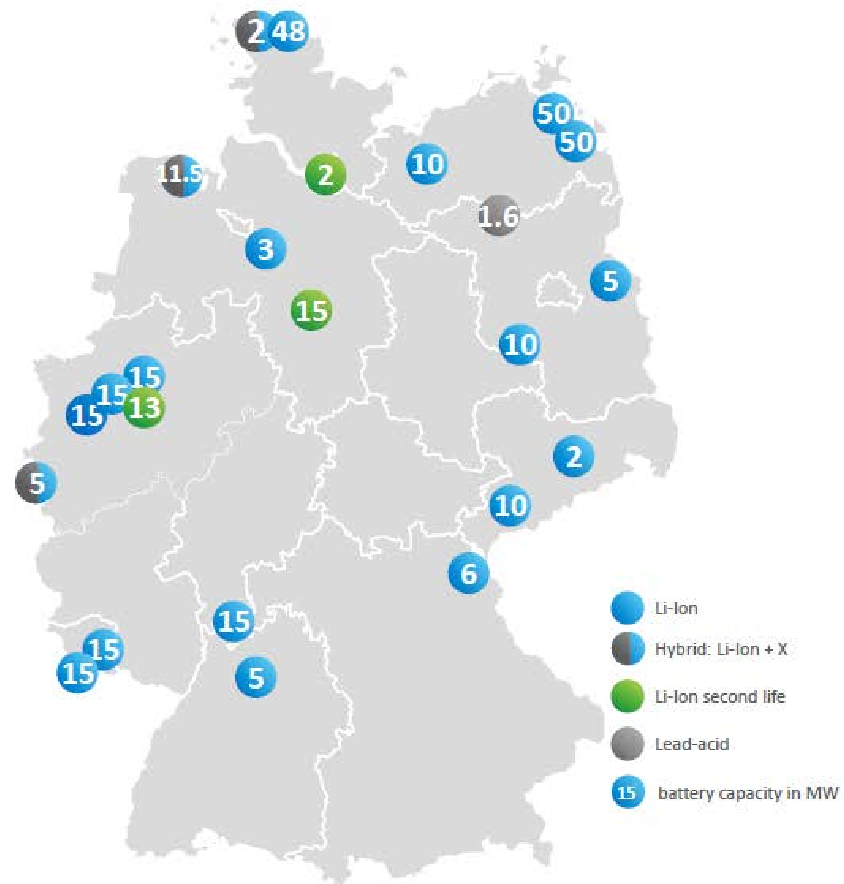


Source: A. Tortora, Terna Group, Energy Storage World Forum, Rome, 2015.

Overview of global electrical energy storage trends

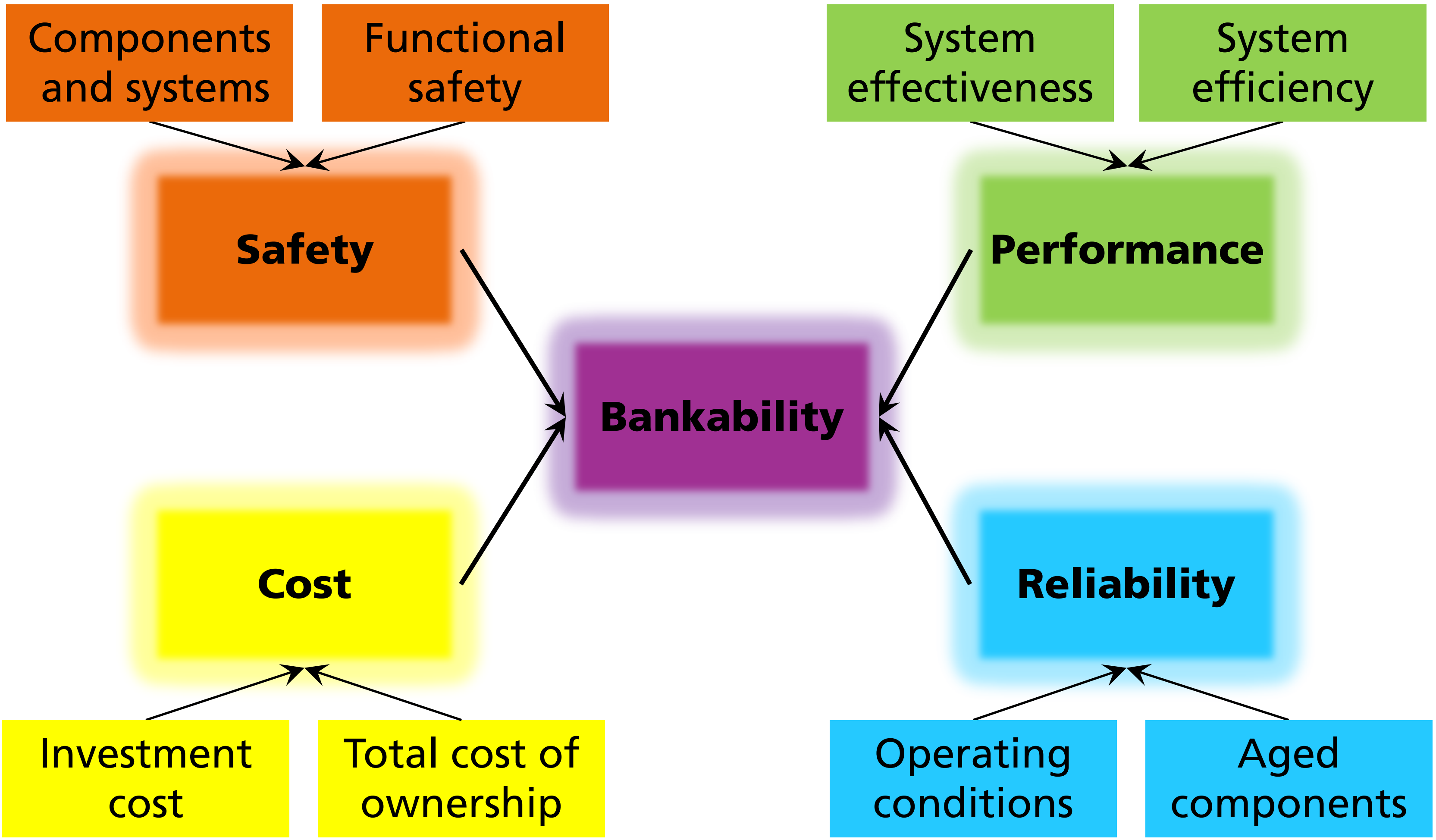
Example Germany: Primary control power





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

Key factors affecting bankability of renewable energy + storage projects



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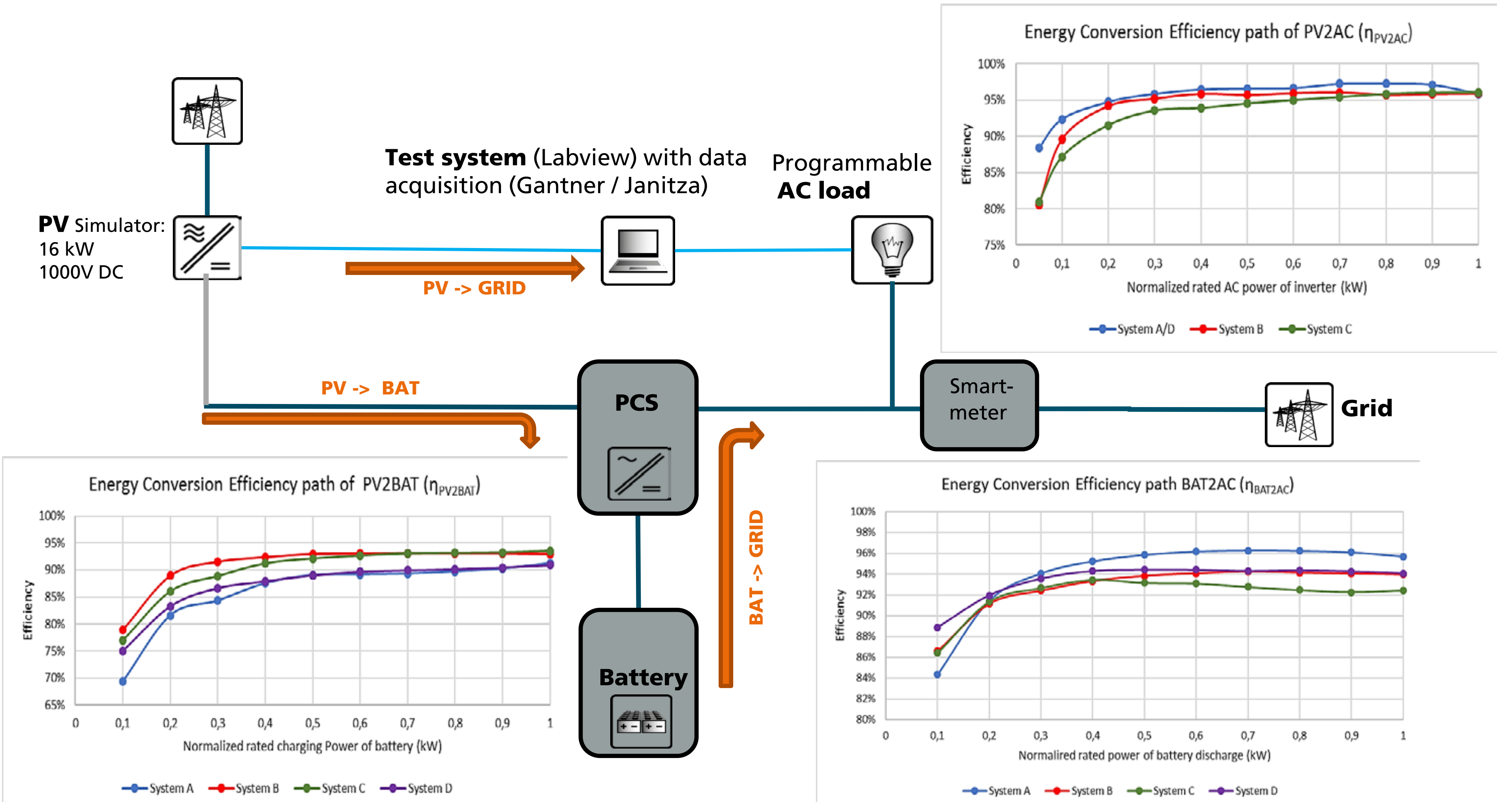
Quality assurance for residential PV battery systems
System testing – Analyses of efficiencies



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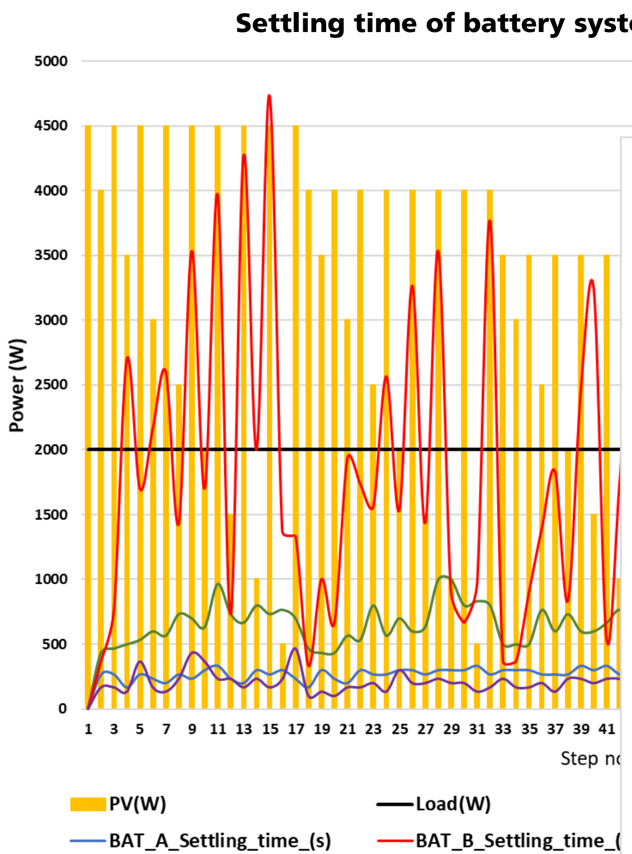
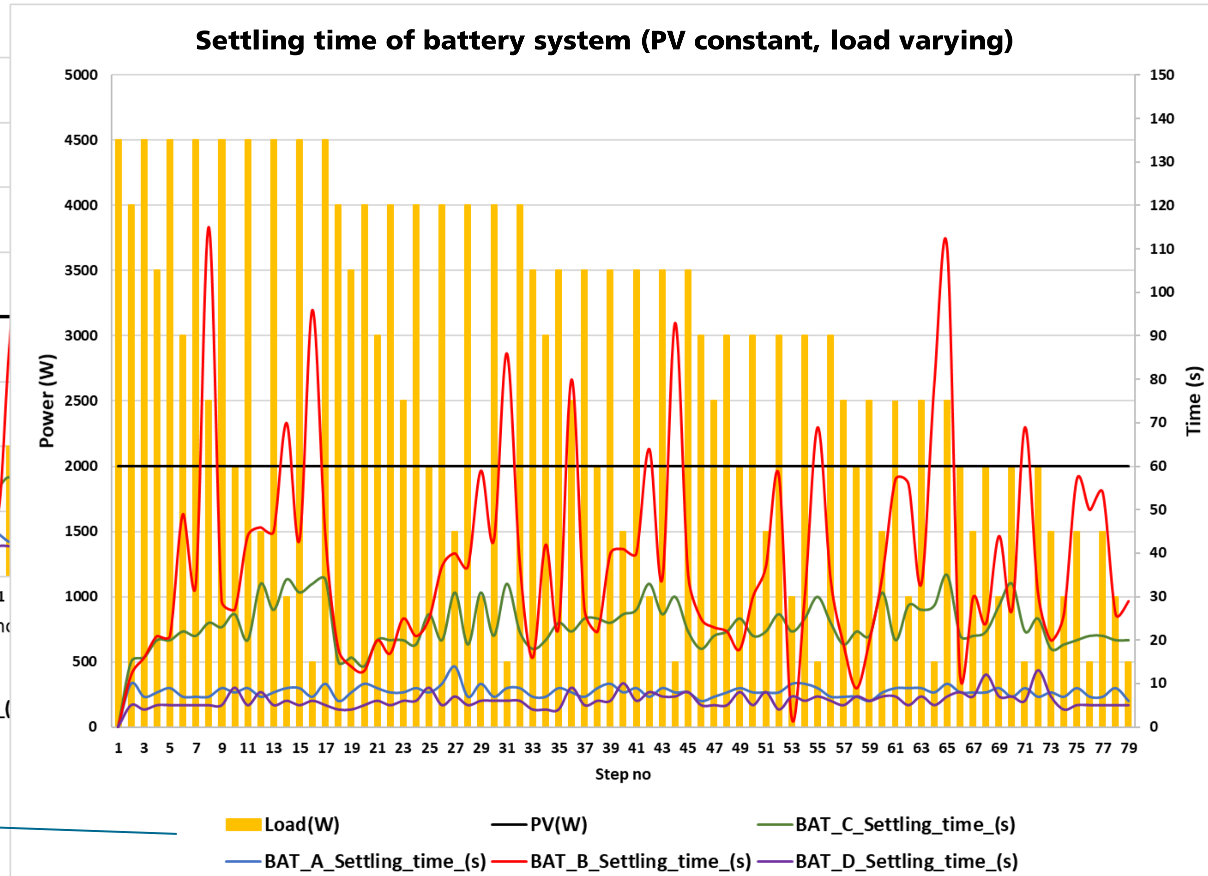
Quality assurance for residential PV battery systems

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

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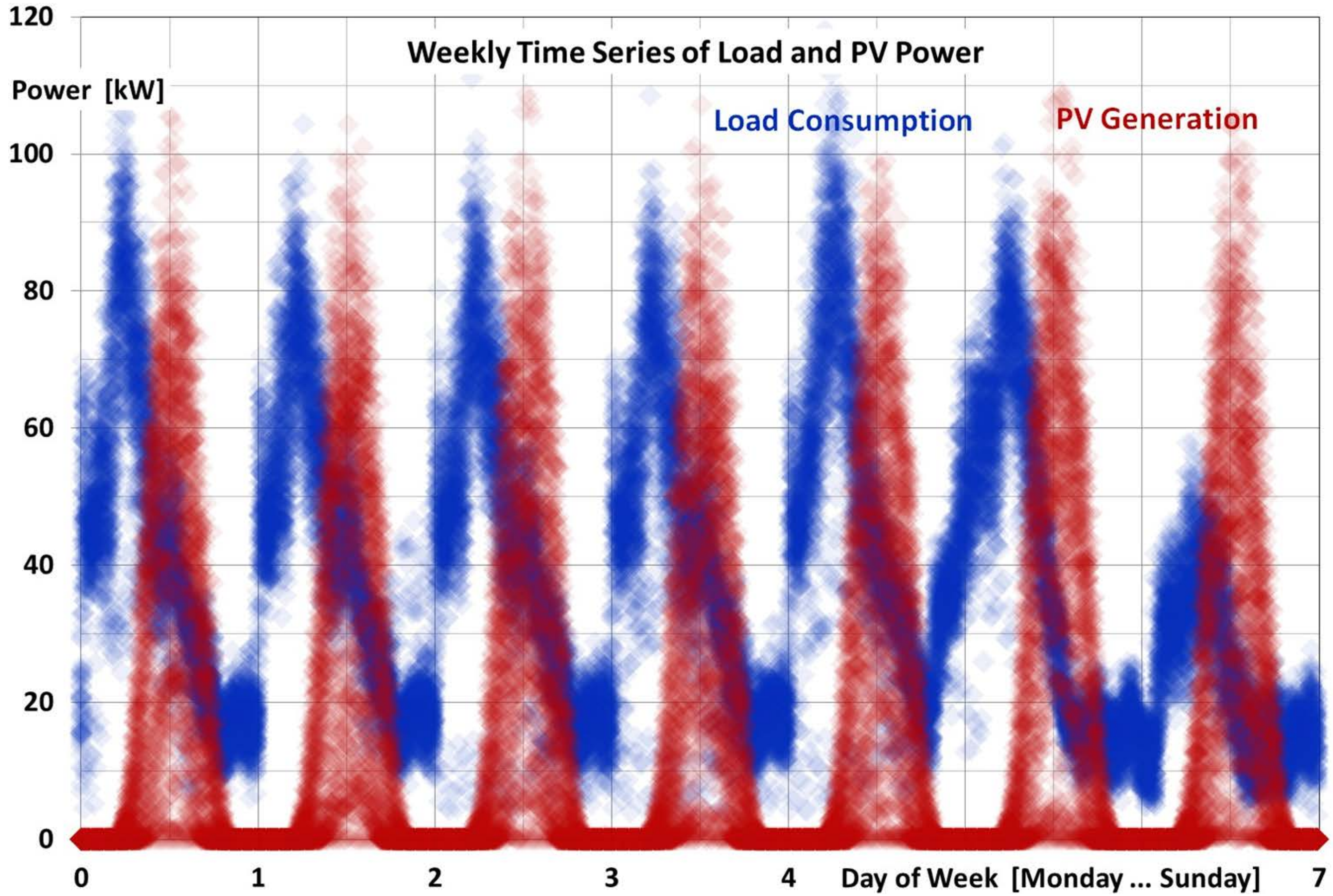
Project example: Commercial PV battery system
Analysis of load profile and PV generation profile

Load (bakery):

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

PV example:

- Size: 150 kWp
- Production: 135 MWh



Project example: Commercial PV battery system

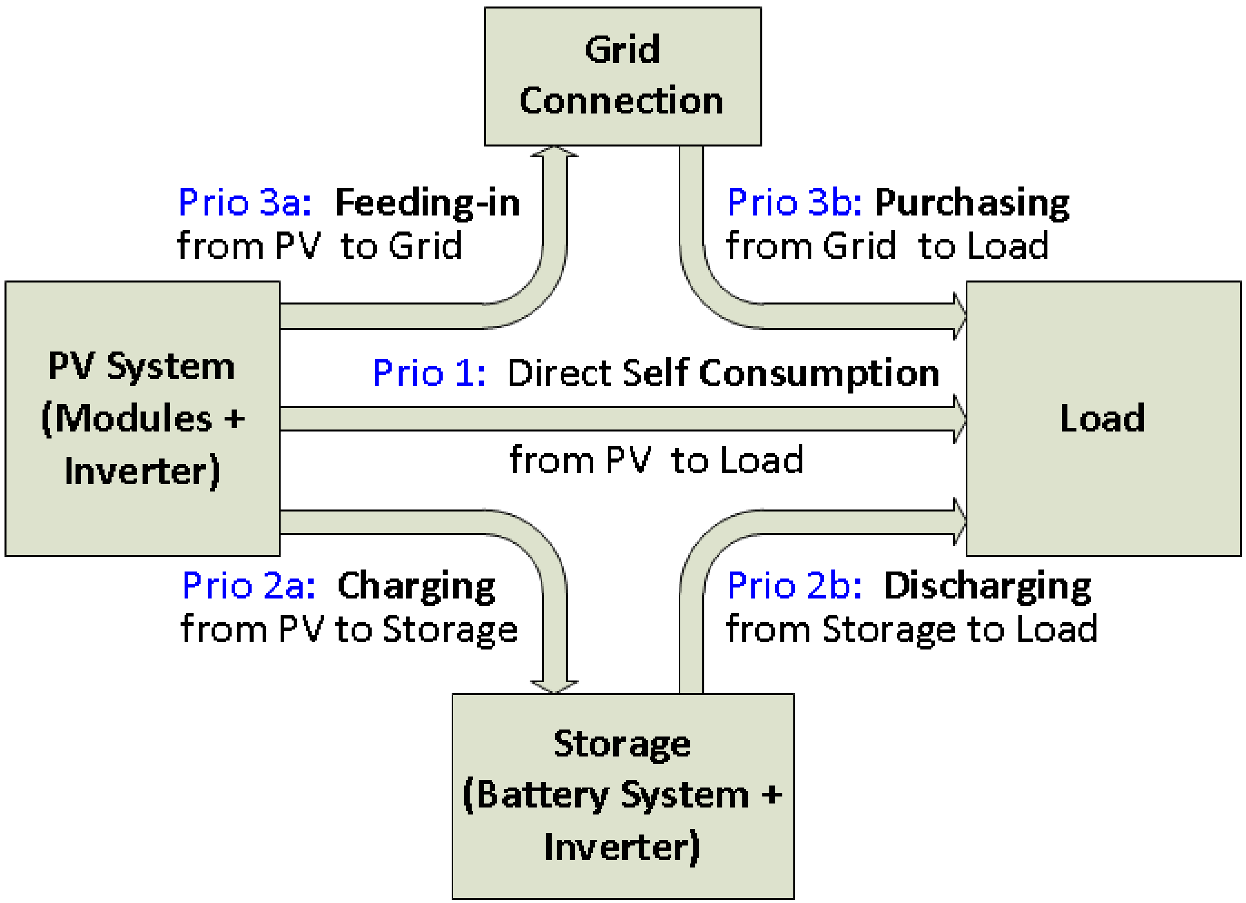
Simulation based system analysis and design

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



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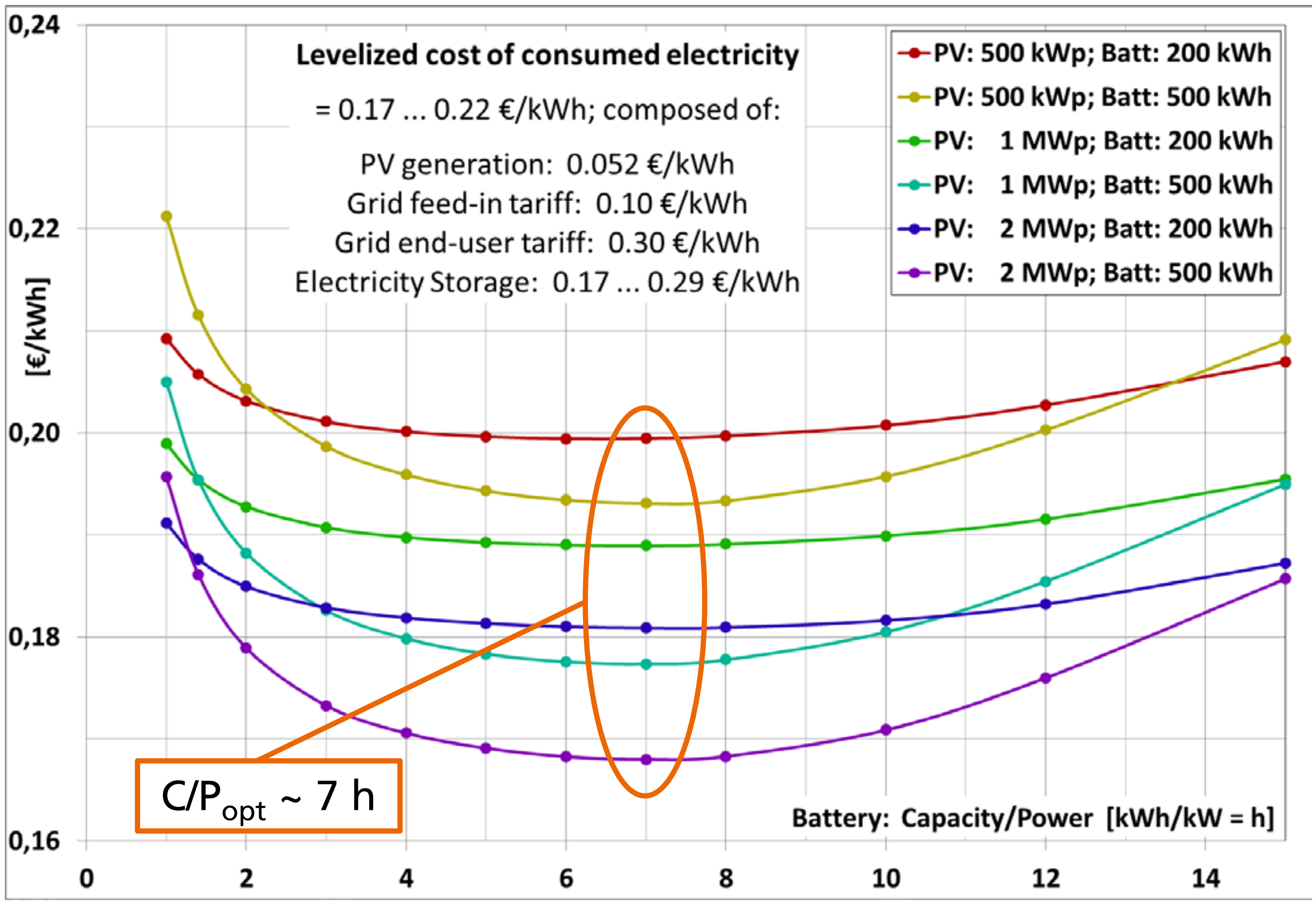
Project example: Commercial PV battery system
Simulation based system analysis and design

Levelized cost of energy

Main parameters:

- PV system: 840 €/kWp
- Battery system: 600 €/kWh
- Battery inverter: 215 €/kW
- Interest rate: 3 %/a



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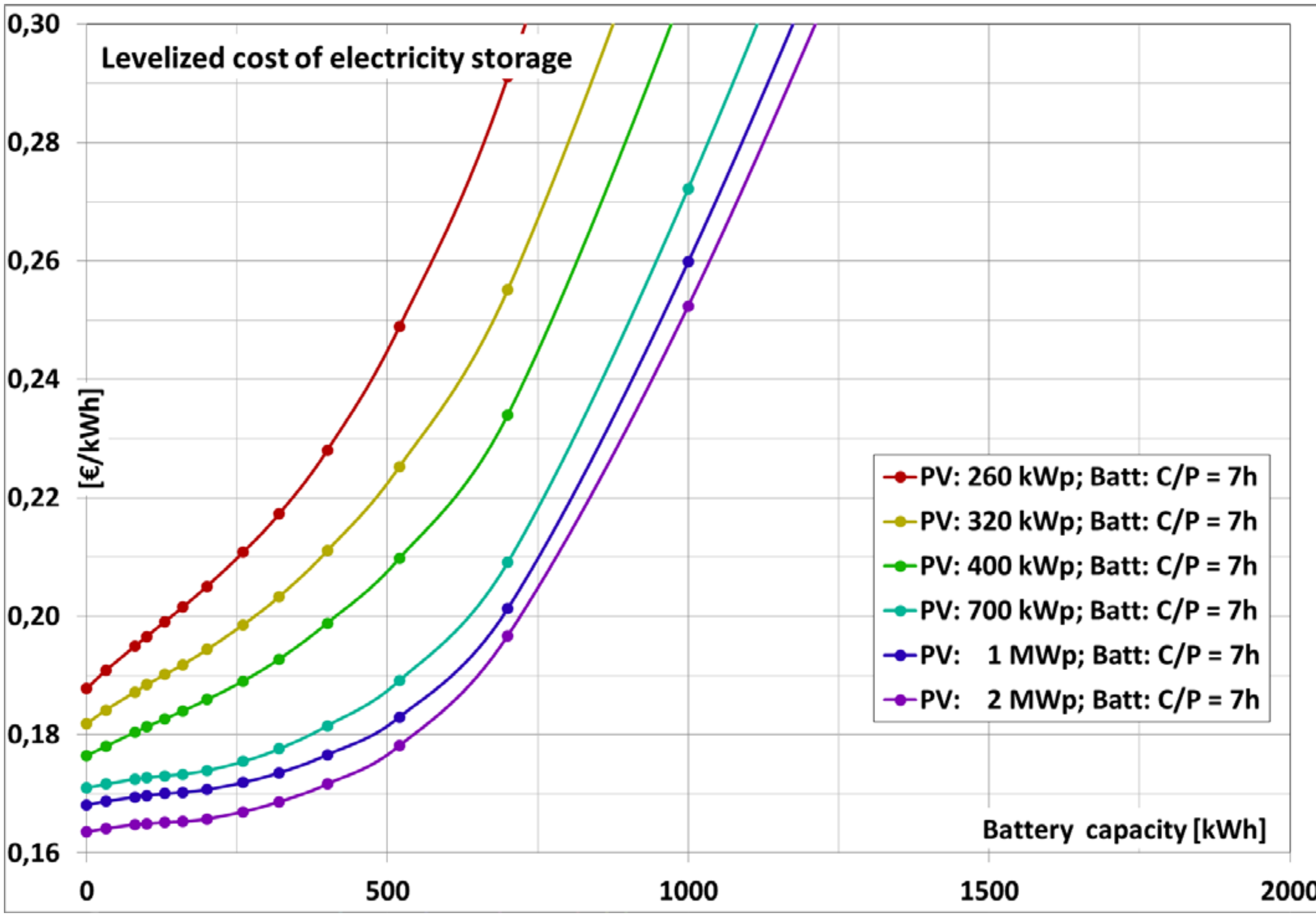
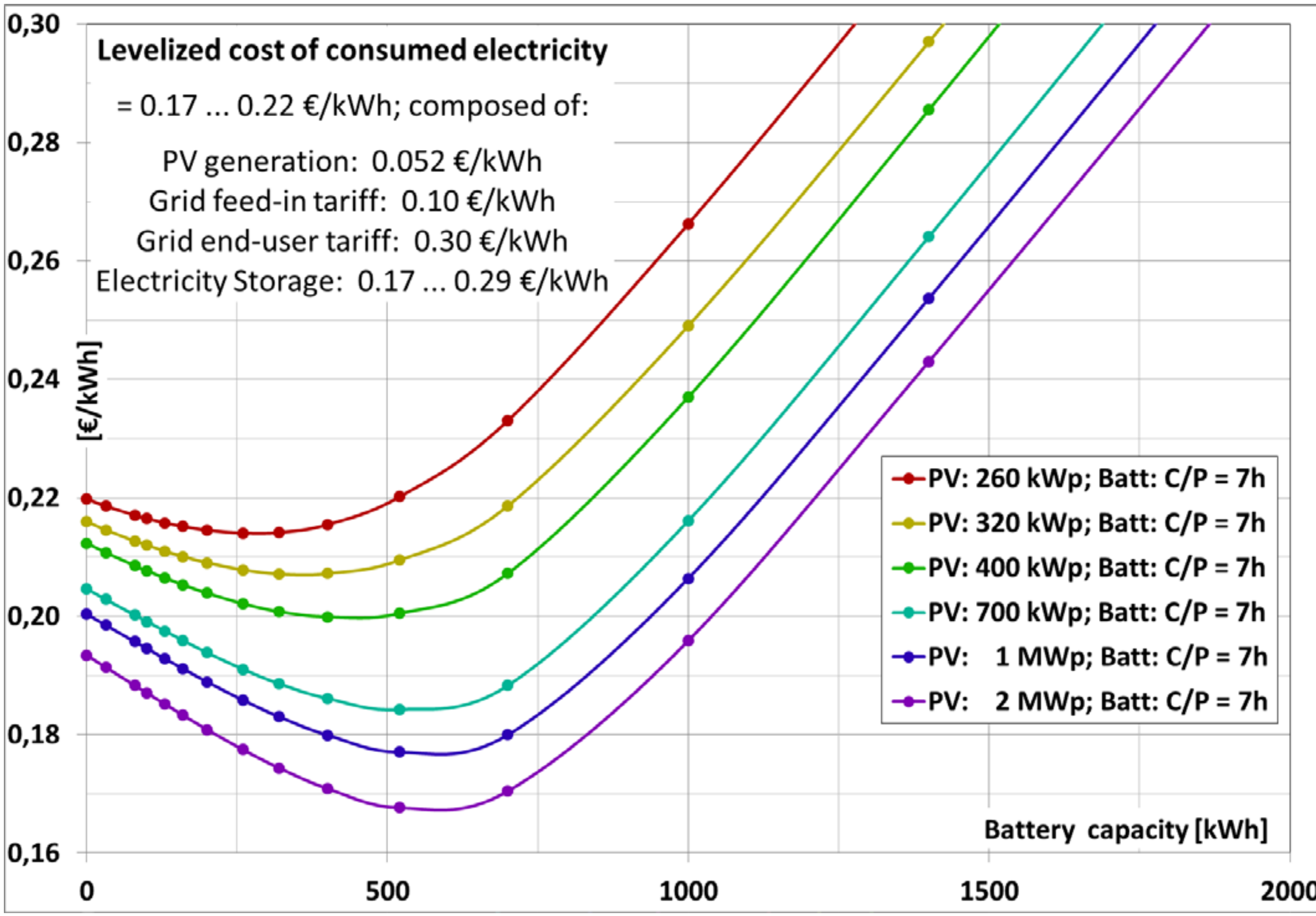
Project example: Commercial PV battery system
Simulation based system analysis and design

Levelized cost of electricity storage



Project example: Commercial PV battery system
Simulation based system analysis and design

Levelized cost of consumed electricity



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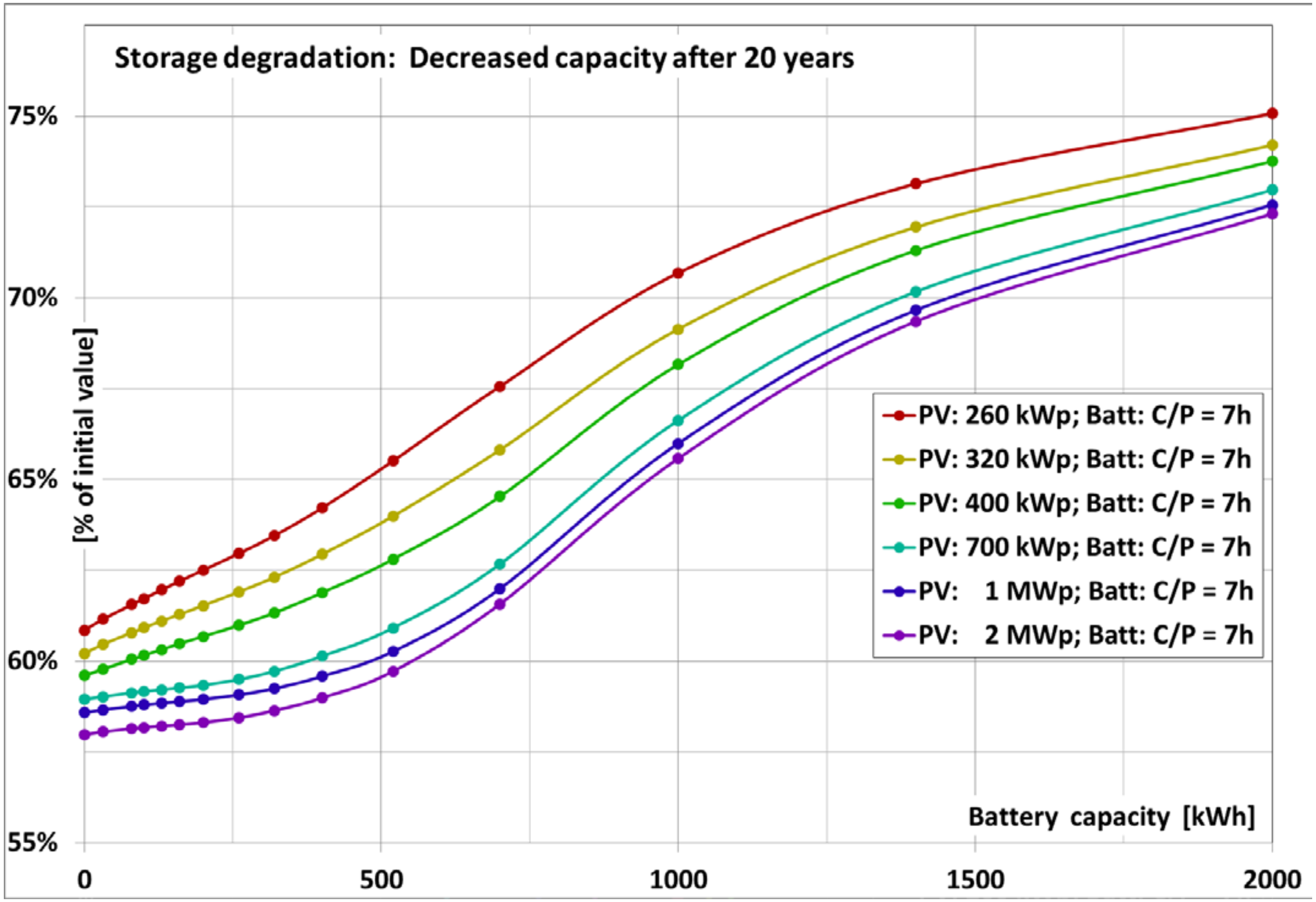
Project example: Commercial PV battery system

Simulation based system analysis and design

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



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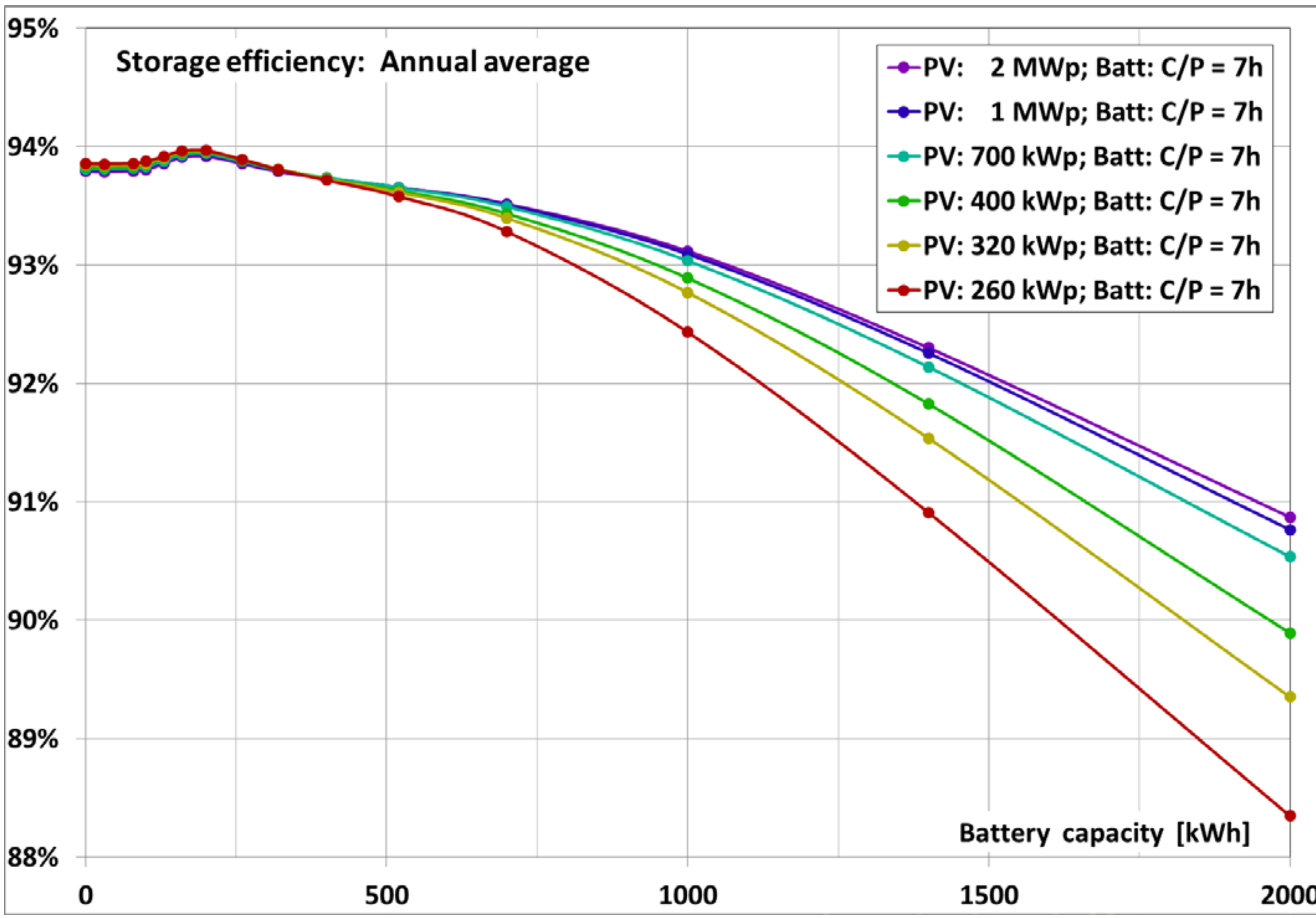
Project example: Commercial PV battery system
Simulation based system analysis and design

Battery storage: Annual average storage efficiencies



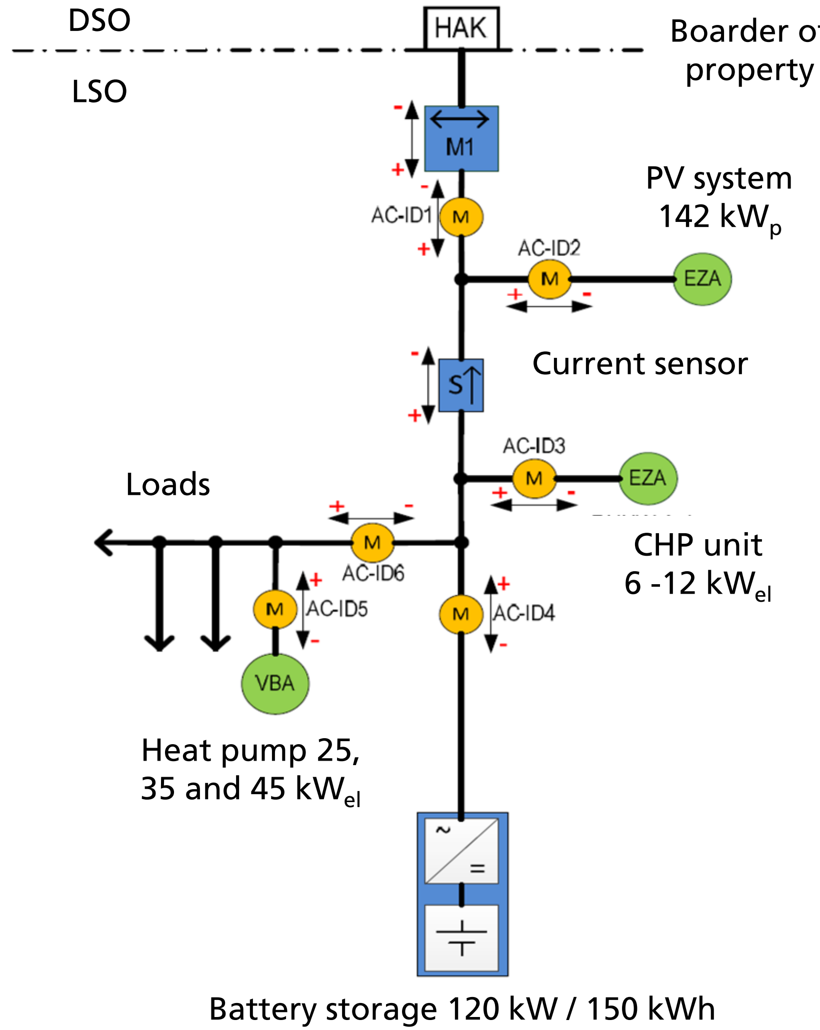
Project example: District storage system – "Weinsberg"

Simulation based system design

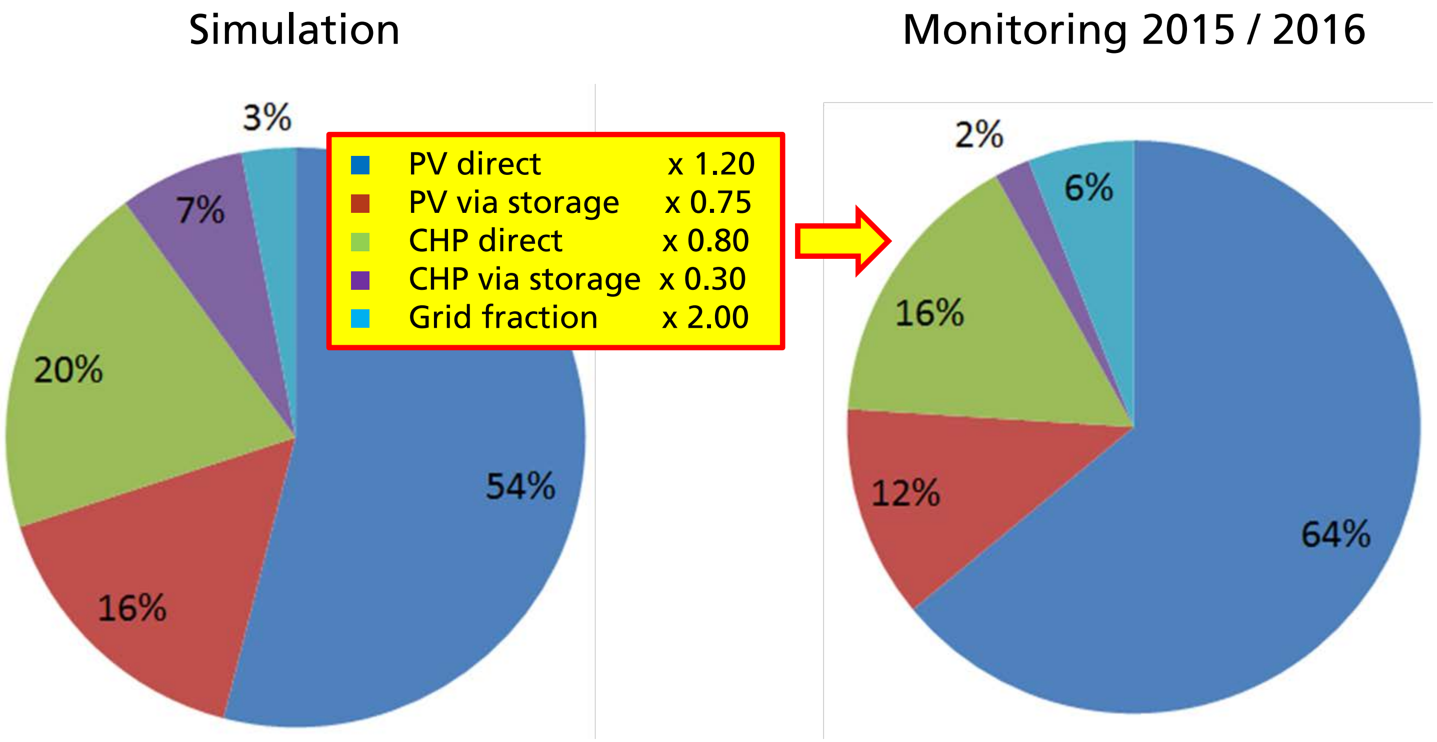
Optimization criteria:

Minimization of grid dependency –

Physically not only accumulated



Project example: District storage system – "Weinsberg"
Monitoring: Accumulated annual electrical energies

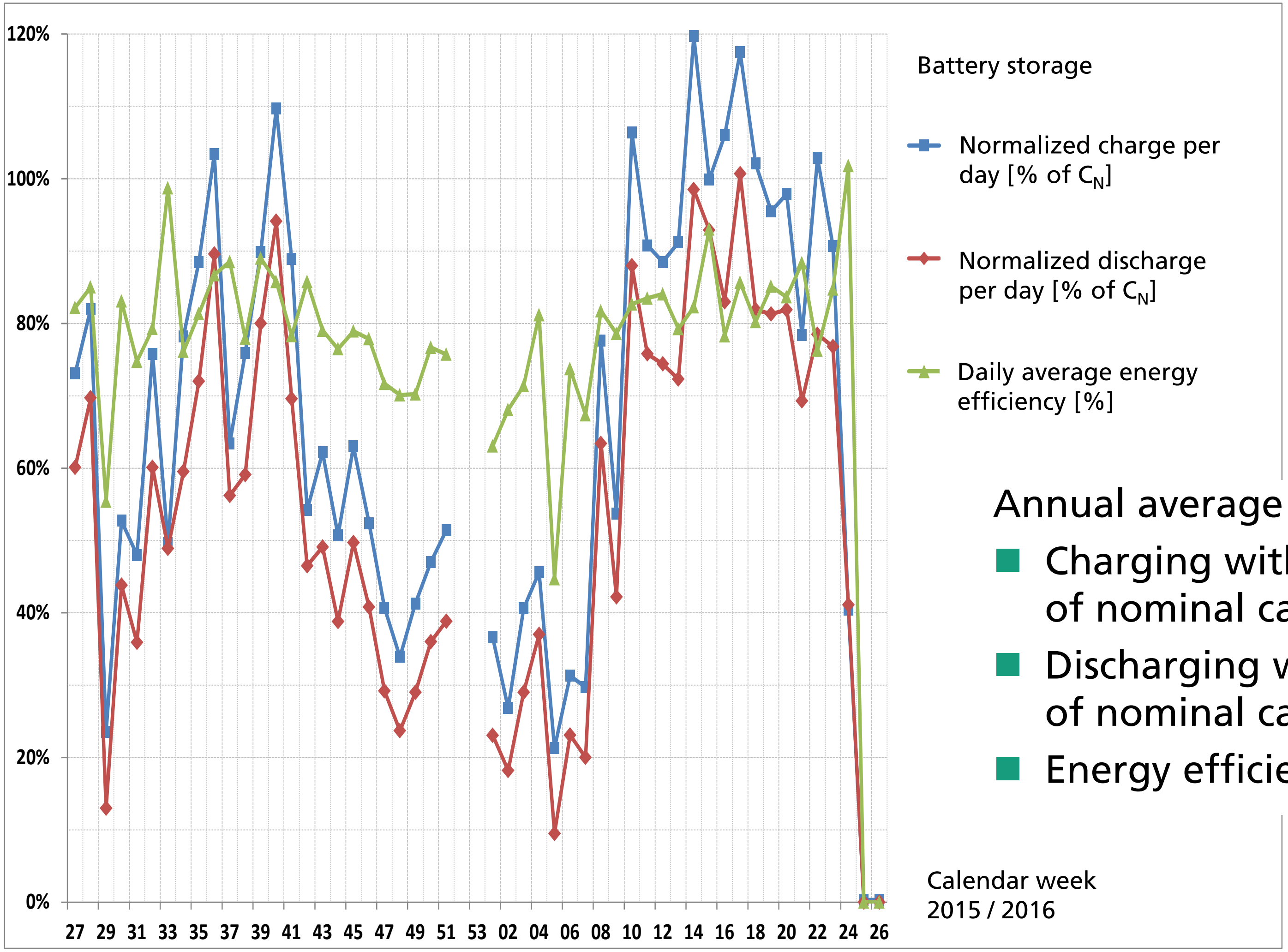


Reasons for differences:

- 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 example: District storage system – "Weinsberg"

Monitoring: Analysis of storage operation



Annual average values:

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

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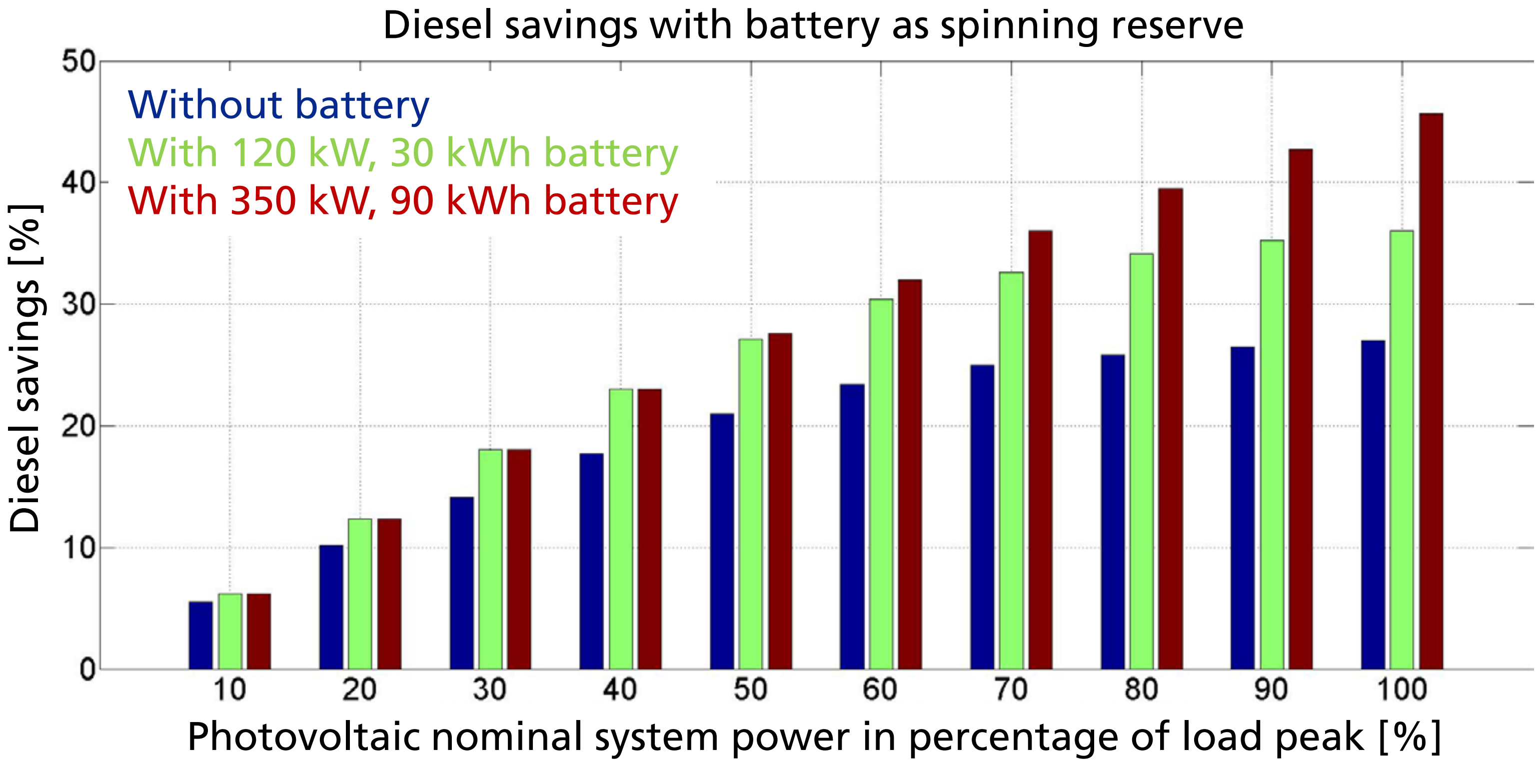
Project example: Mini-grid – Industrial site in Egypt
Simulation based system analysis for PV integration

- Load:
  - Peak: 420 kW
  - Annual consumption: 1120 MWh
- 2 Diesel generators:
  - 350 kW
  - 120 kW



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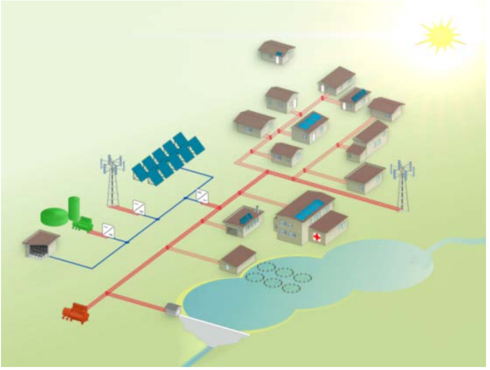
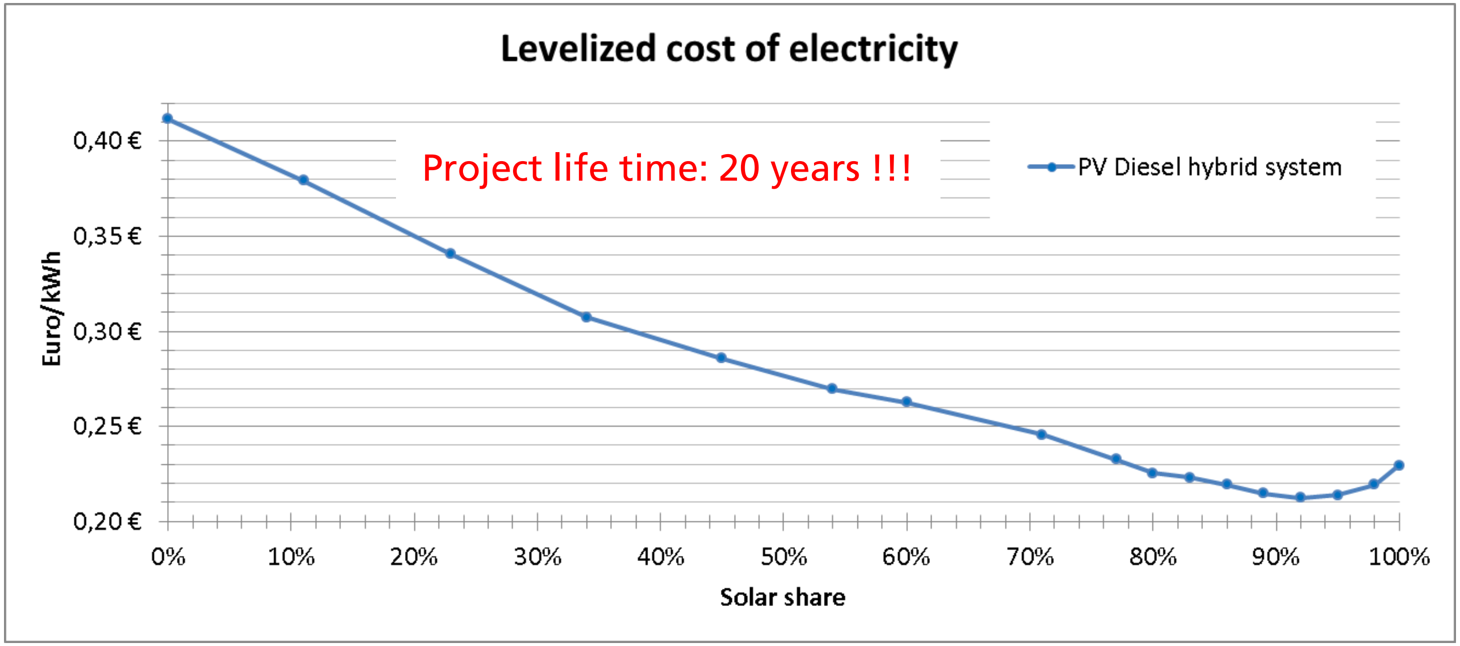
Project example: Mini-grid – Uganda
Simulation based system analysis for PV integration



- 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



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Services towards certification
From product development to project implementation

Strategic partnership of Fraunhofer ISE and VDE Renewables

Product design and project planning ▶

- Analyses of load profiles
- Technical advice with focus on product design and optimization
- Simulation-based system design and component dimensioning
- Yield prediction
- Recommendations on component selection

Testing and project development ▶

- Economic feasibility studies using simulation-based system analyses
- Characterization of components
- Performance testing
- Lifecycle testing
- Conformity testing
- Electrical safety and EMC testing
- Benchmark tests
- Environmental simulation
- Abuse tests
- United Nations Transport Test

Certification and implementation

- Certification of whole energy storage systems
- System testing
- Certification and compliance of grid interconnected components
- Ongoing quality monitoring

Testing and certification for batteries and energy storage systems

From product development to project implementation

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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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