

QUALITY ASSURANCE FOR PV BATTERY SYSTEMS IN MICRO-GRID APPLICATIONS



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Future Energy Asia

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AGENDA

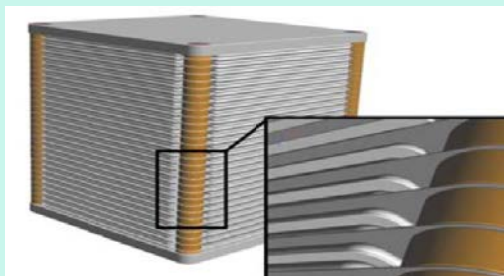
- Introduction to battery R&D and services of Fraunhofer ISE
- Overview of global electrical energy storage trends
- Key factors affecting bankability of energy storage projects
- Quality assurance for larger PV battery systems –
Concept and range of services
- Project examples
- Conclusions



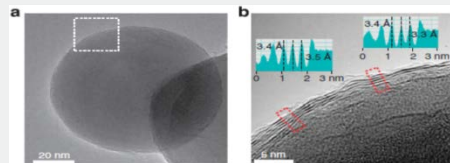
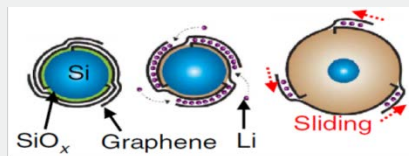
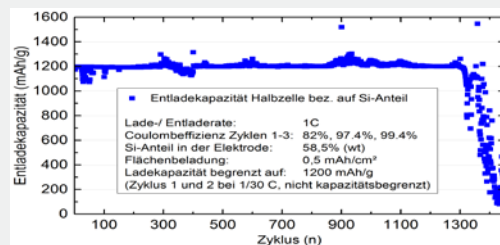
Battery cells

Current focus topics of Fraunhofer ISE

Aqueous batteries for stationary applications

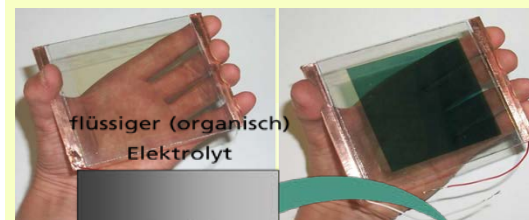


Silicon based anodes as *drop-in replacement* for lithium-ion battery cells

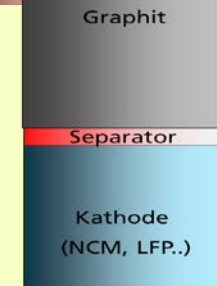


From DOI: 10.1038/ncomms8393

New materials and process technology for *solid state* batteries

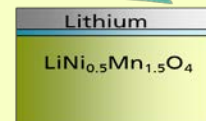


flüssiger (organisch)
Elektrolyt



~200 Wh/kg
~550 Wh/Liter

All solid state

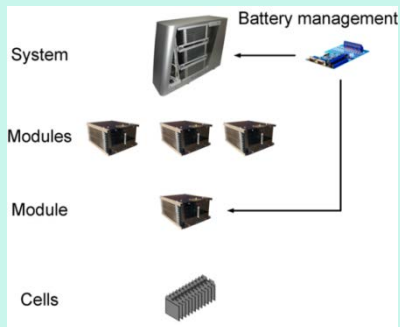


~650 Wh/kg
~1700 Wh/Liter

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

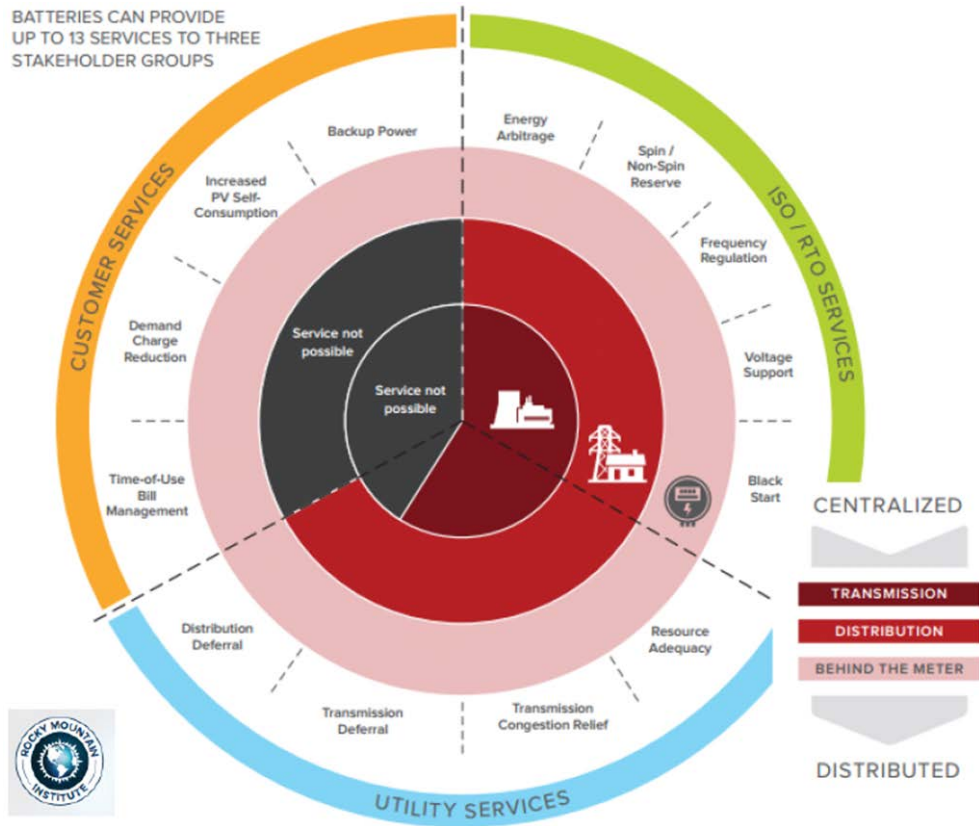
Electrical, thermal, mechanical



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

Overview of global electrical energy storage trends

Services and benefits

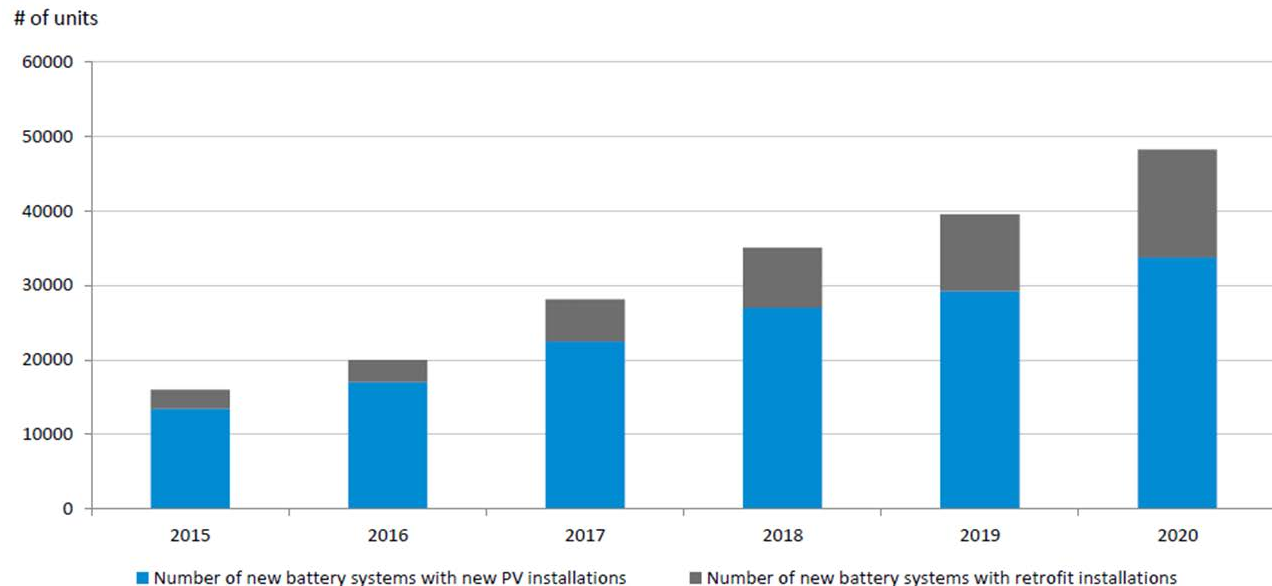


Source: F. Gattiglio: Battery energy storage in the EU, ees conference, Munich 2017.

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



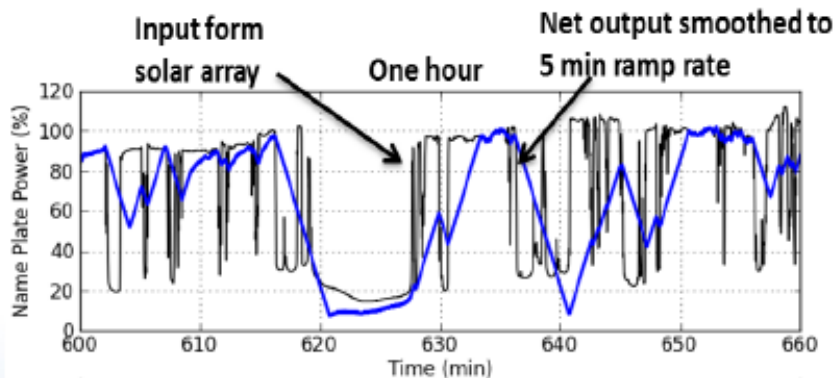
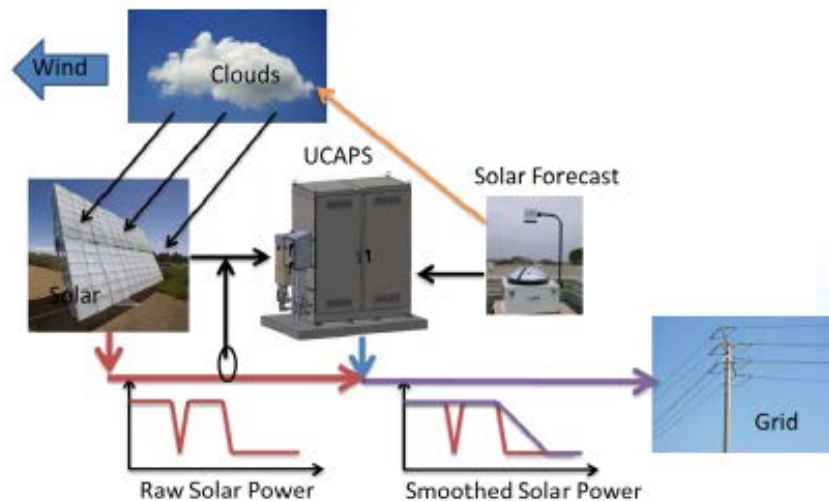
Source: A. Bräutigam:
Business models for energy
storage in Germany and hot
spot markets, ees conference,
Munich 2017.

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

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

The Context



Causes

- Economic crisis and subsequent loss of many big consumers (i.e. national demand decreased 7% from 340 TWh to 318 TWh)
- Aggressive policy of incentives promoting RES + imminence of grid parity
- Short time to fortify and develop the grid to support new scenarios

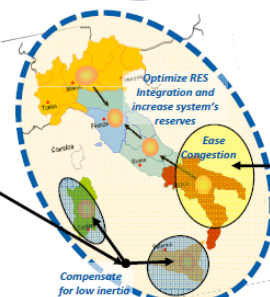
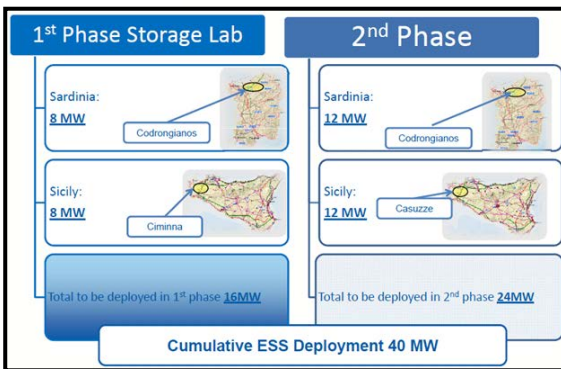
Effects

- Fast and massive growth of RES:
→ Rise in congestion-related curtailments (i.e. 2010 ~500 GWh lost)
→ Rise in demand for non-spinning reserve
- Traditional power plants running at minimum load:
→ Loss of inertia in smaller insular systems (i.e. Sicily and Sardinia)
→ Loss of available frequency reserves

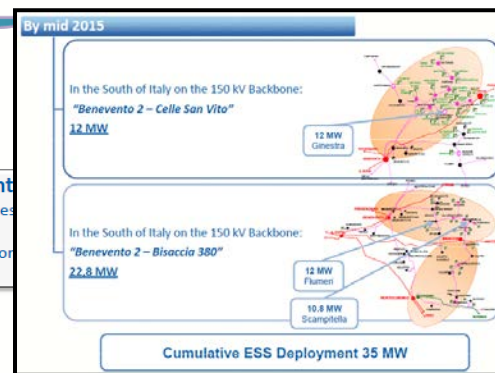
Mitigating actions

Optimize integration of RES and increase flexibility of national grid (i.e. smarter grid)

Solutions

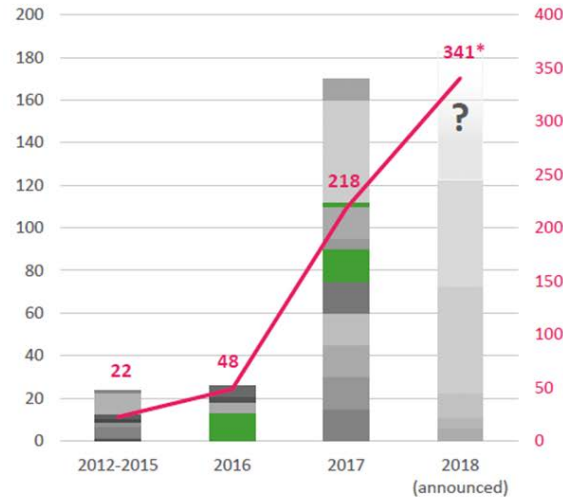


Energy Int
Reduce congestion
ensuing
occurring
backbones



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

Example Germany: Primary control power



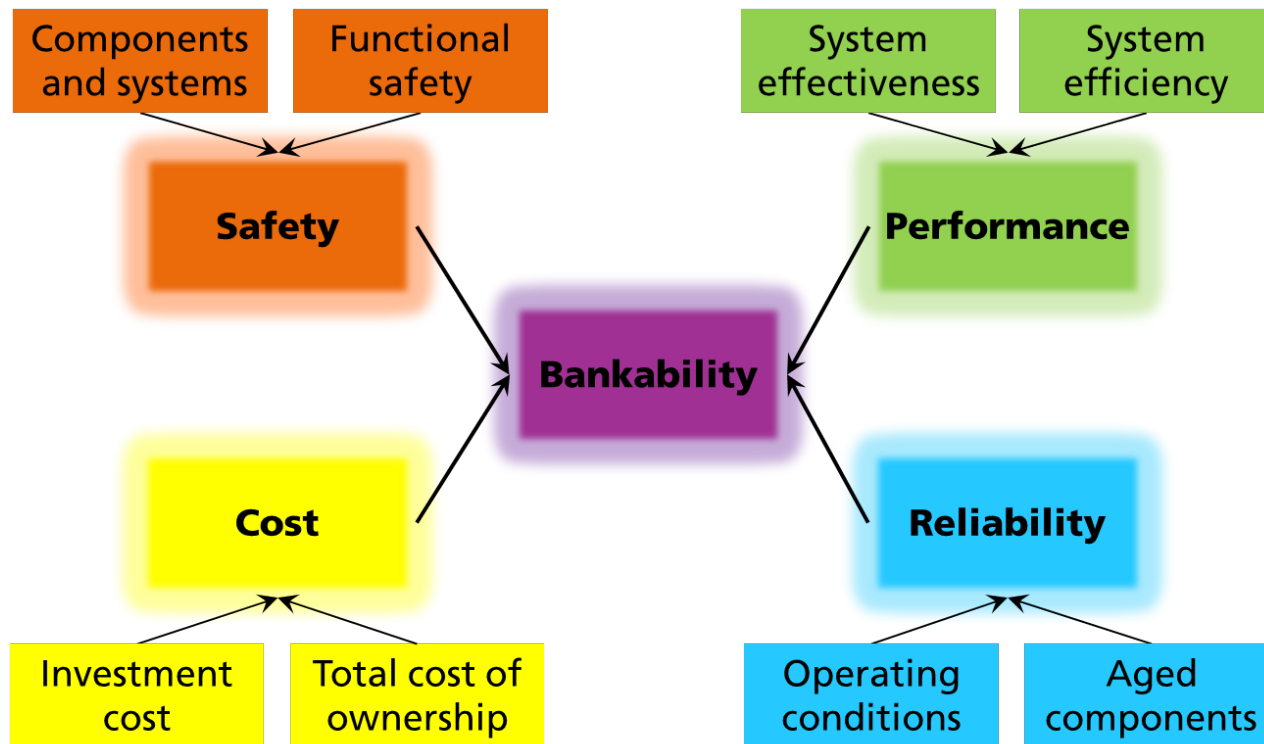
Map of Germany showing the distribution of battery capacity by region and technology type. The map is color-coded by technology: blue for Li-Ion, dark grey for Hybrid (Li-Ion + X), green for Li-Ion second life, and light grey for Lead-acid. Numbers in circles indicate capacity in MW.

Legend:

- Li-Ion
- Hybrid: Li-Ion + X
- Li-Ion second life
- Lead-acid
- 15 battery capacity in MW

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Key factors affecting bankability of renewable energy + storage projects



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

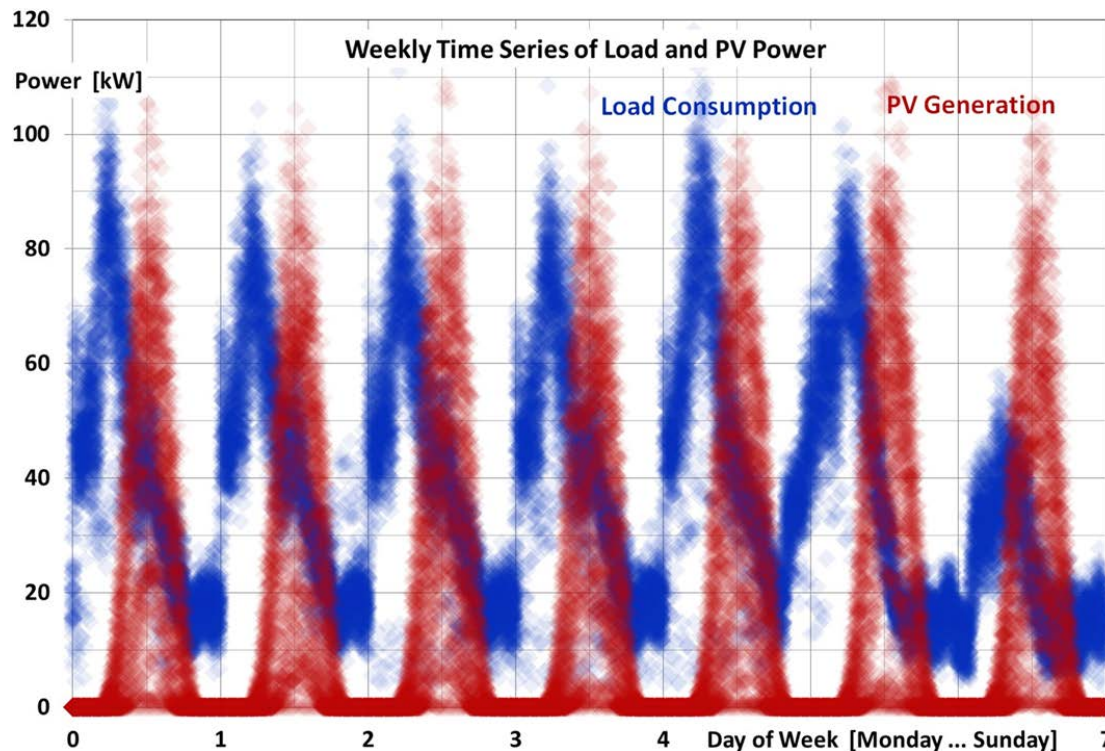
Commercial PV battery system – Load and PV generation

Load (bakery production line):

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

PV example:

- Size: 150 kWp
- Production: 135 MWh



Project examples – System simulation and analyses

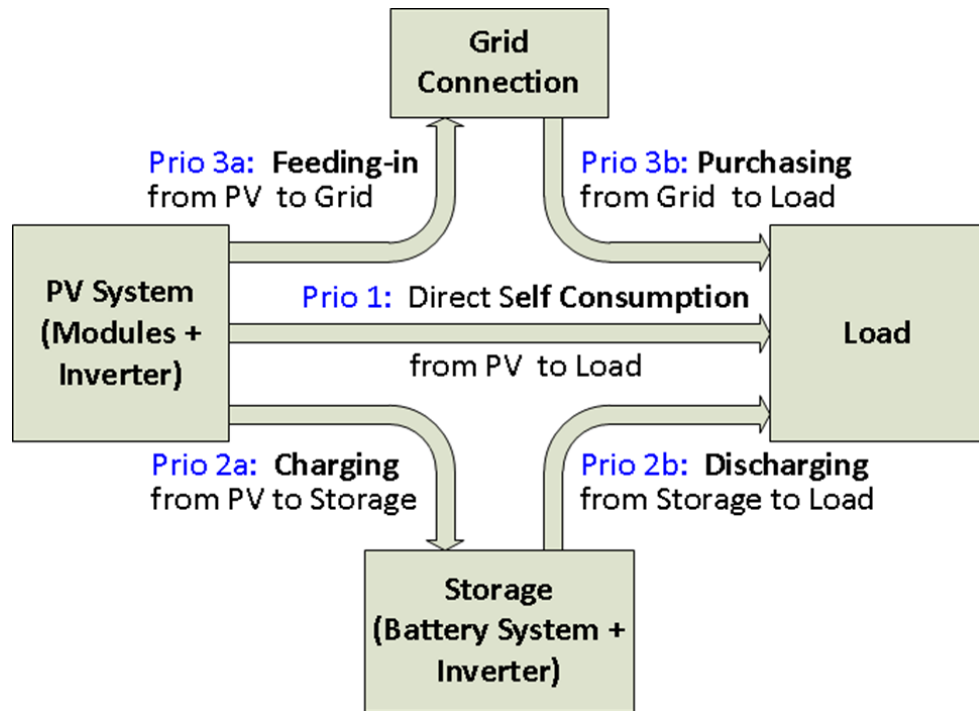
Commercial PV battery system – Control strategy

Load (bakery production line):

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

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

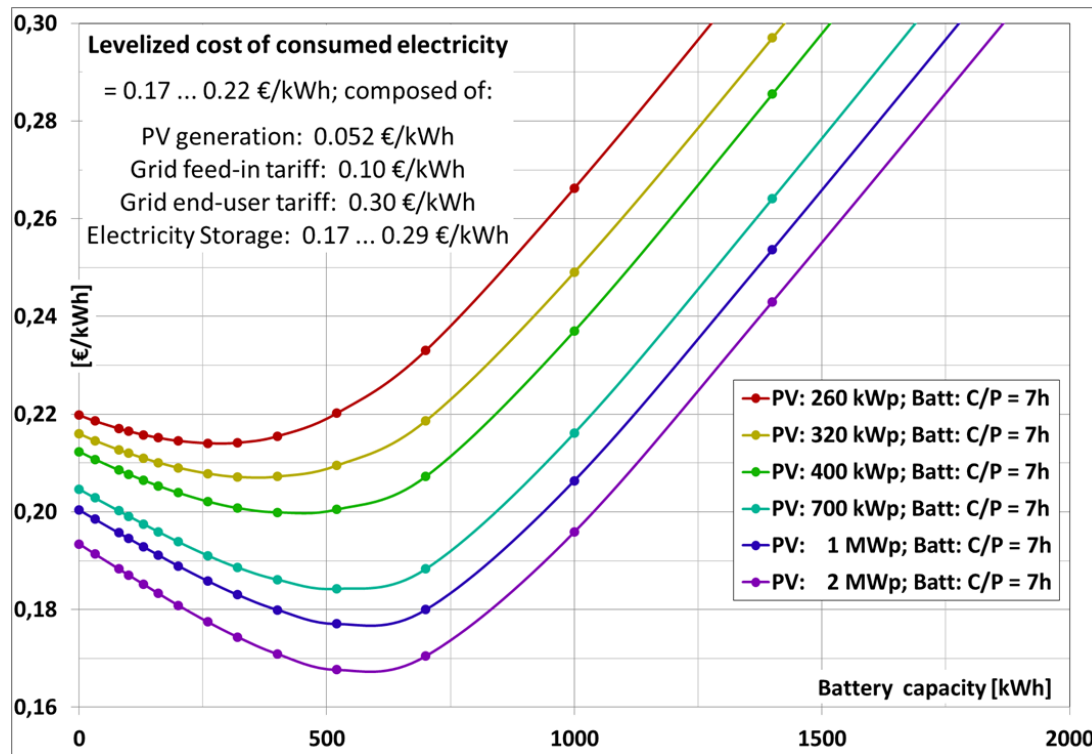
- Variation of PV system size
- Variation of battery storage size



Project examples – System simulation and analyses

Commercial PV battery system – Results

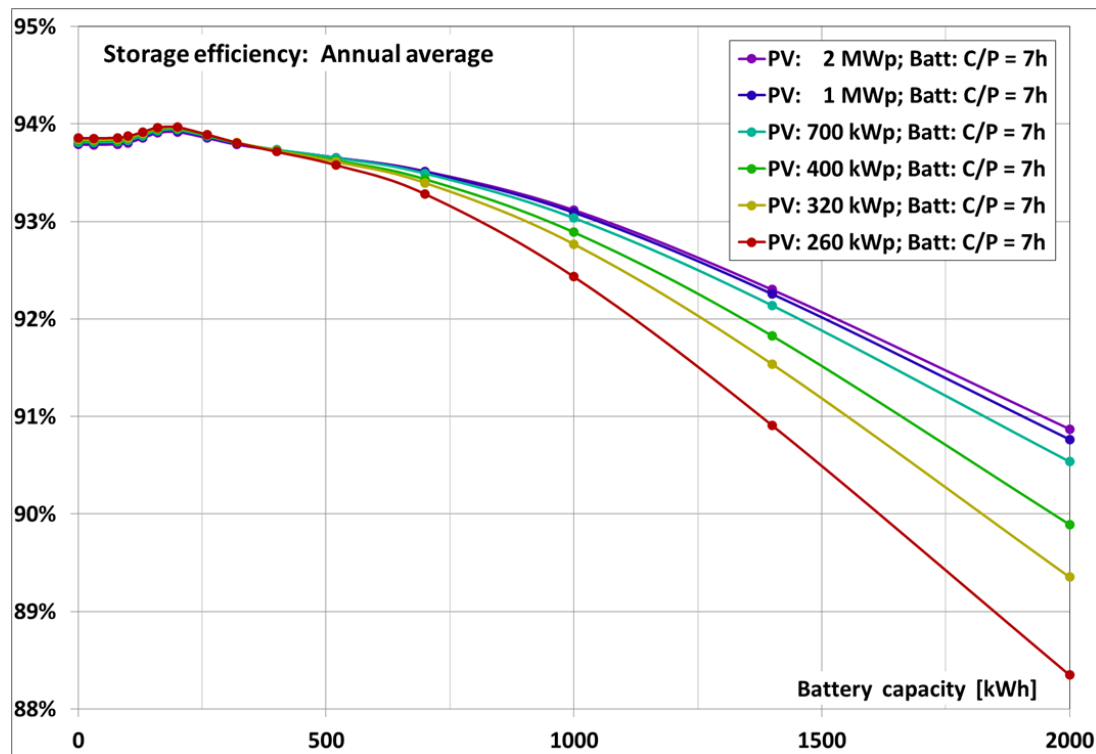
Levelized cost of consumed electricity



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 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



Project examples – System simulation and analyses

Techno-economical evaluation of a mini-grid in Uganda

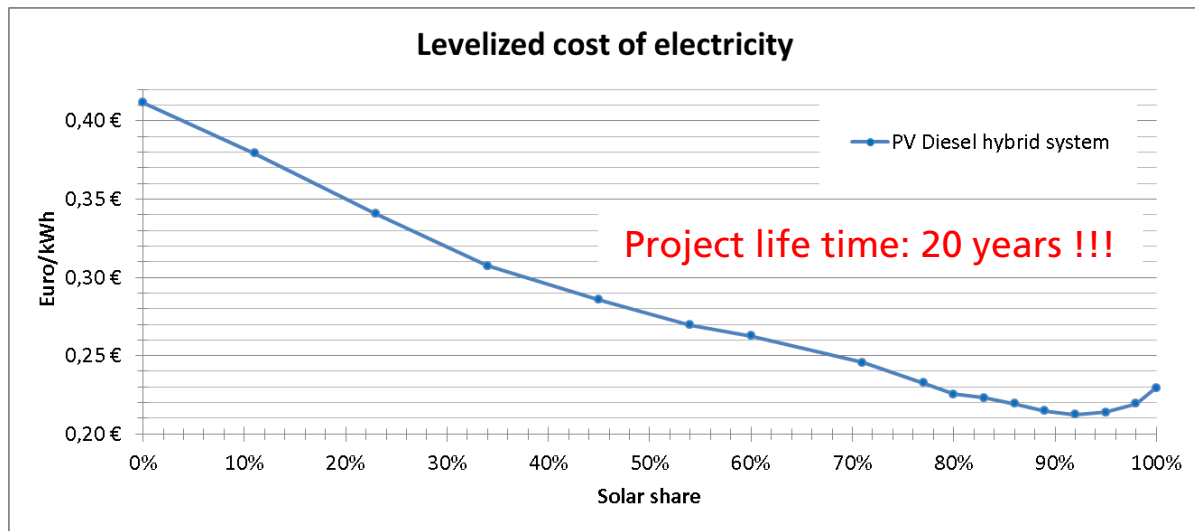
■ Example Uganda

■ Load:

- Peak load: 200 kW
- Annual consumpt.: 574 MWh

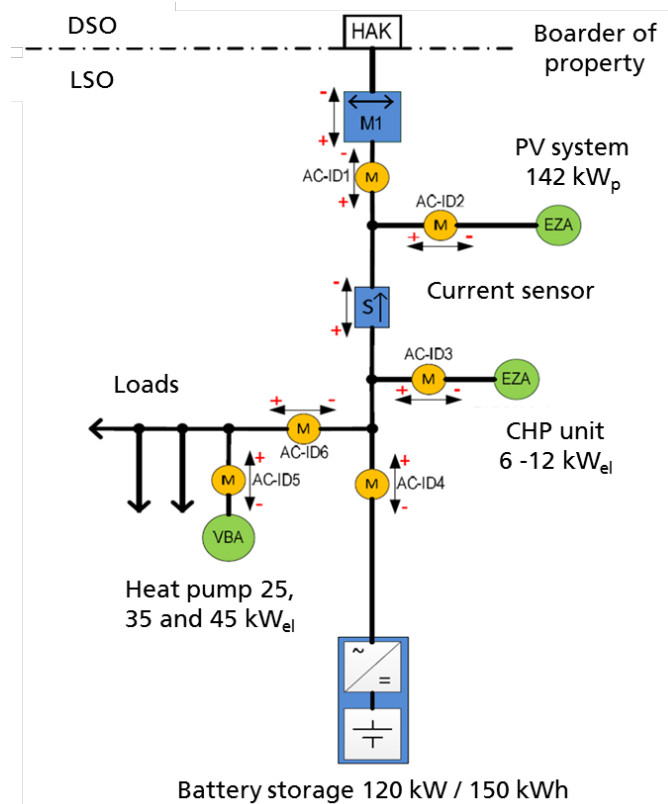
■ PV Diesel hybrid system:

- 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

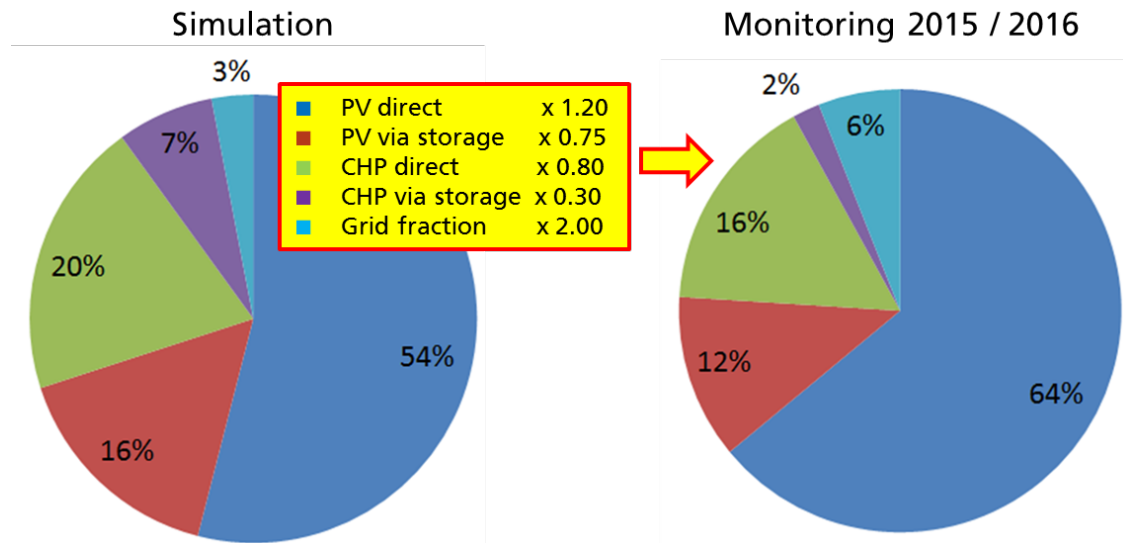
District storage system – “Weinsberg”



Project examples – Monitoring and system evaluation

District storage system – “Weinsberg”

Accumulated annual
electrical energy quantities



Reasons for differences:

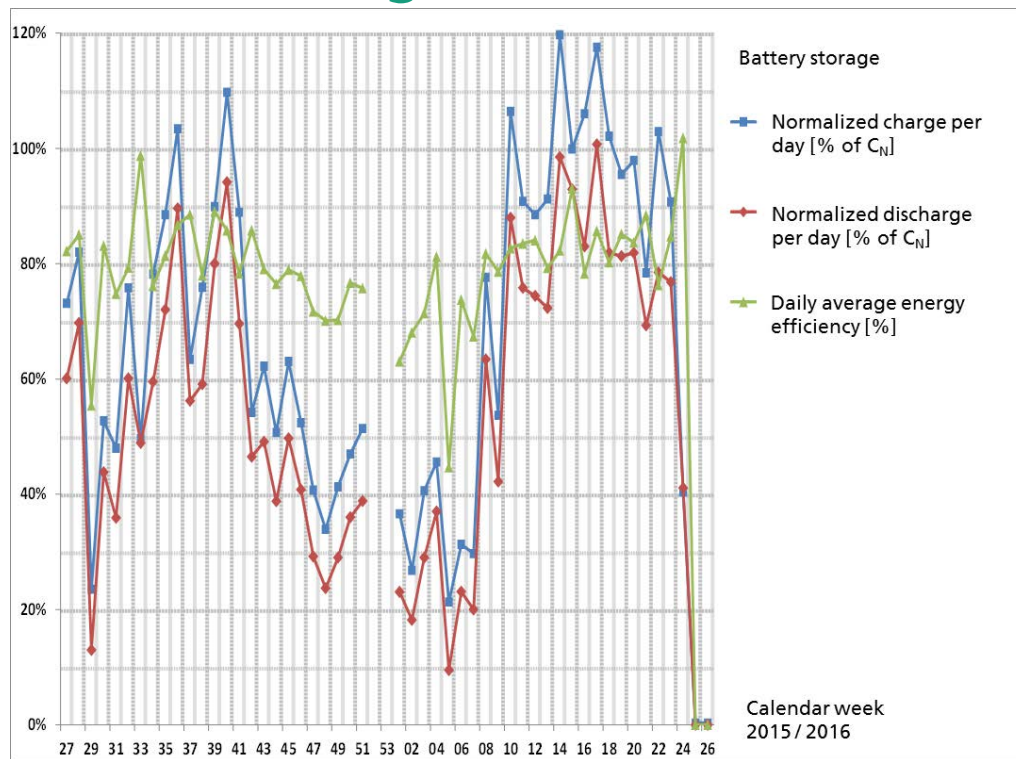
- Problems with air conditioning → To high temperatures in operation room → Shut-down of CHP unit and battery inverter
- Necessary maintenance interval of CHP unit in winter (!)
- End-users do not behave 100 % as predicted (!)

Project examples – Monitoring and system evaluation

District storage system – “Weinsberg”

Annual average values:

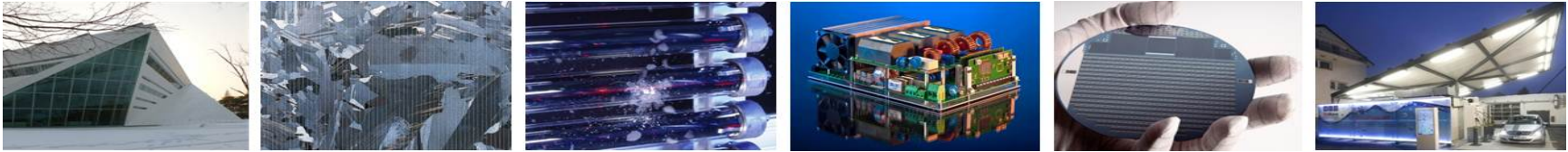
- Charging with 67 % of nominal capacity
- Discharging with 54 % of nominal capacity
- Energy efficiency: 81 %



Conclusions

- Large-scale integration of fluctuating renewable energies in power supply systems require storage (grid-connected and isolated mini-grid applications)
- 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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