ENERGY STORAGE FOR RENEWABLE POWER SUPPLY SYSTEMS

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Izmir, 17th of October 2019

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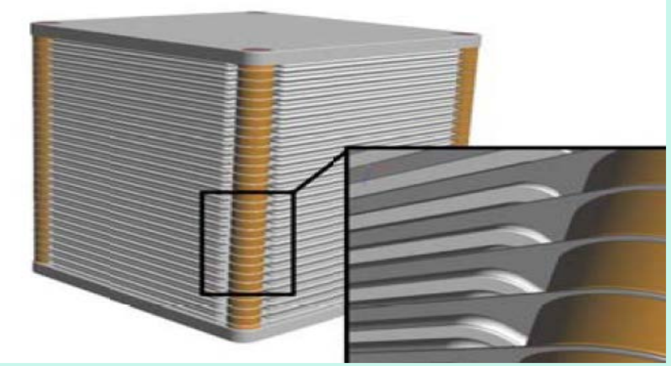
AGENDA

- Introduction to battery R&D of Fraunhofer ISE
- Market segments of stationary battery storage
  - Examples of transmission level
  - Examples of distribution level
  - Examples of customer level
- Key factors affecting bankability and insurability of PV + storage projects
- Conclusions

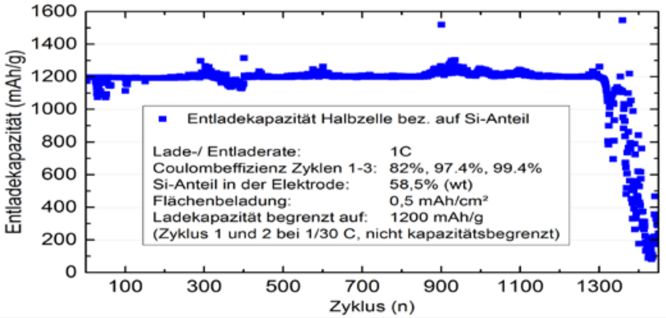
Battery cells

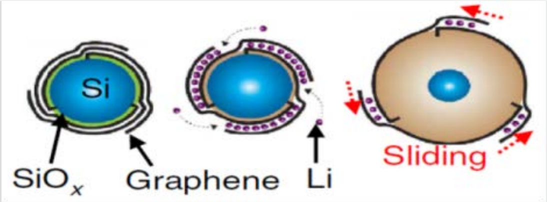
Current focus topics of Fraunhofer ISE

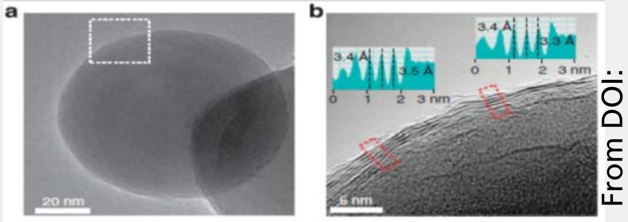
Aqueous batteries for stationary applications



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

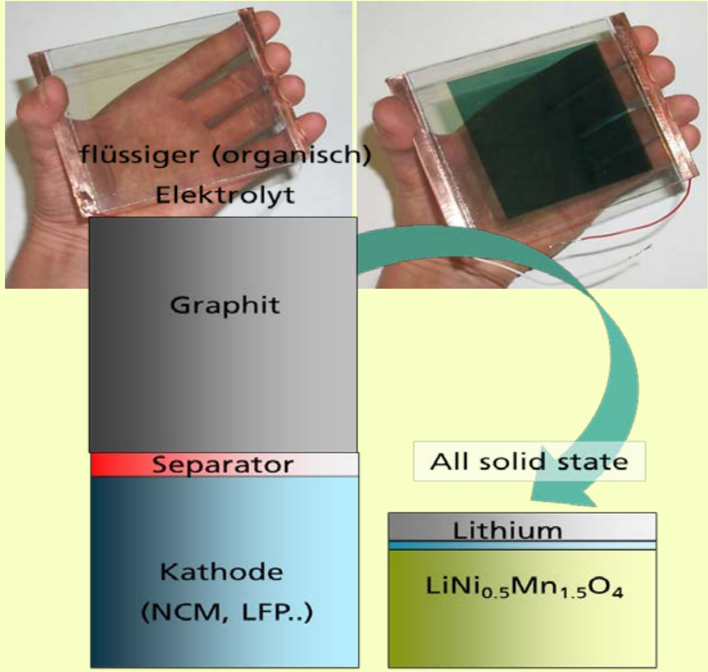






From DOI: 10.1038/ncomms8393

New materials and process technology for *solid state* batteries



Up to 300 Wh/kg	**~ 650 Wh/kg**
Up to 850 Wh/l	**~ 1700 Wh/l**

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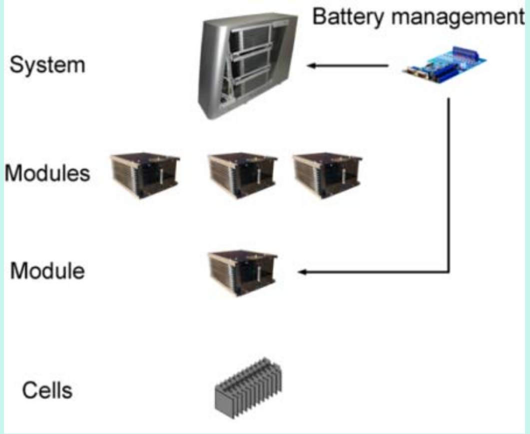
Battery systems and applications

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

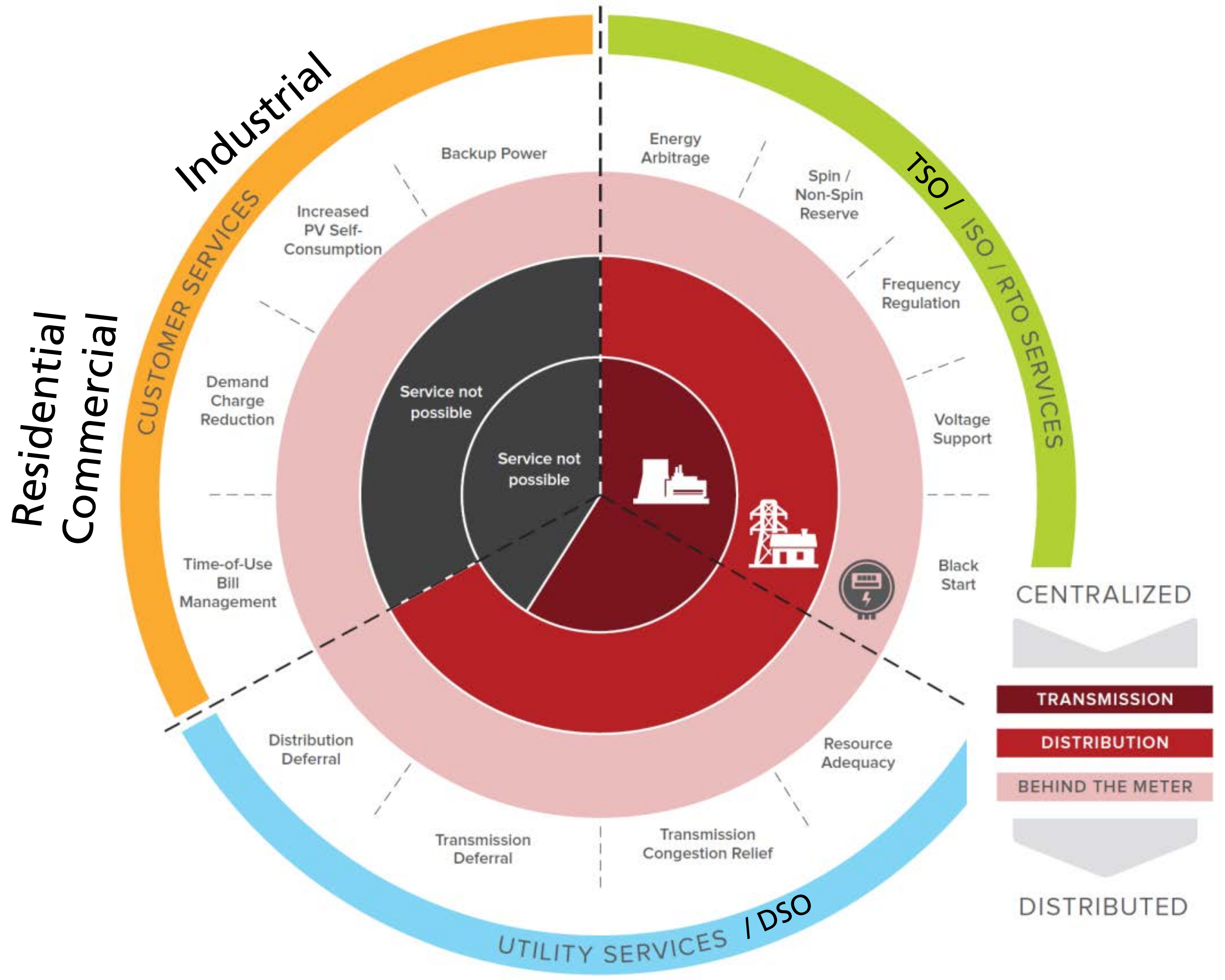
- Consultancy during planning phase
- System design and analysis
- Simulation based storage sizing
- Elaboration of specifications
- Energy management systems
- Site inspections and testing
- Monitoring

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

Market segments of stationary battery storage

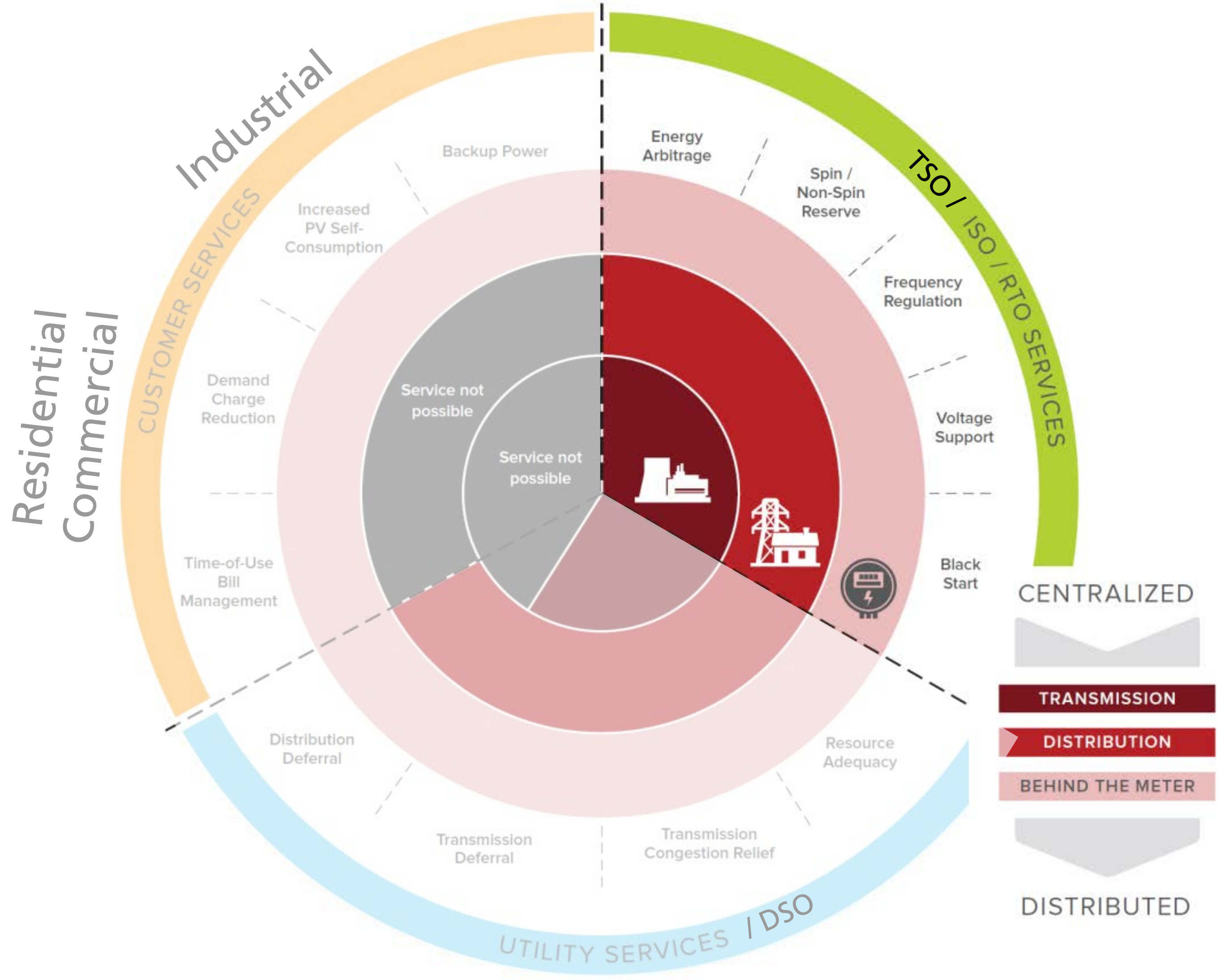
Batteries can provide up to 13 services to three stakeholder groups



Source: F. Garrett, The Economics of Battery Energy Storage, Rocky Mountain Institute, September 2015.

Market segments of stationary battery storage
Transmission level

Batteries can provide up to 13 services to three stakeholder groups



Source: F. Garrett, The Economics of Battery Energy Storage, Rocky Mountain Institute, September 2015.

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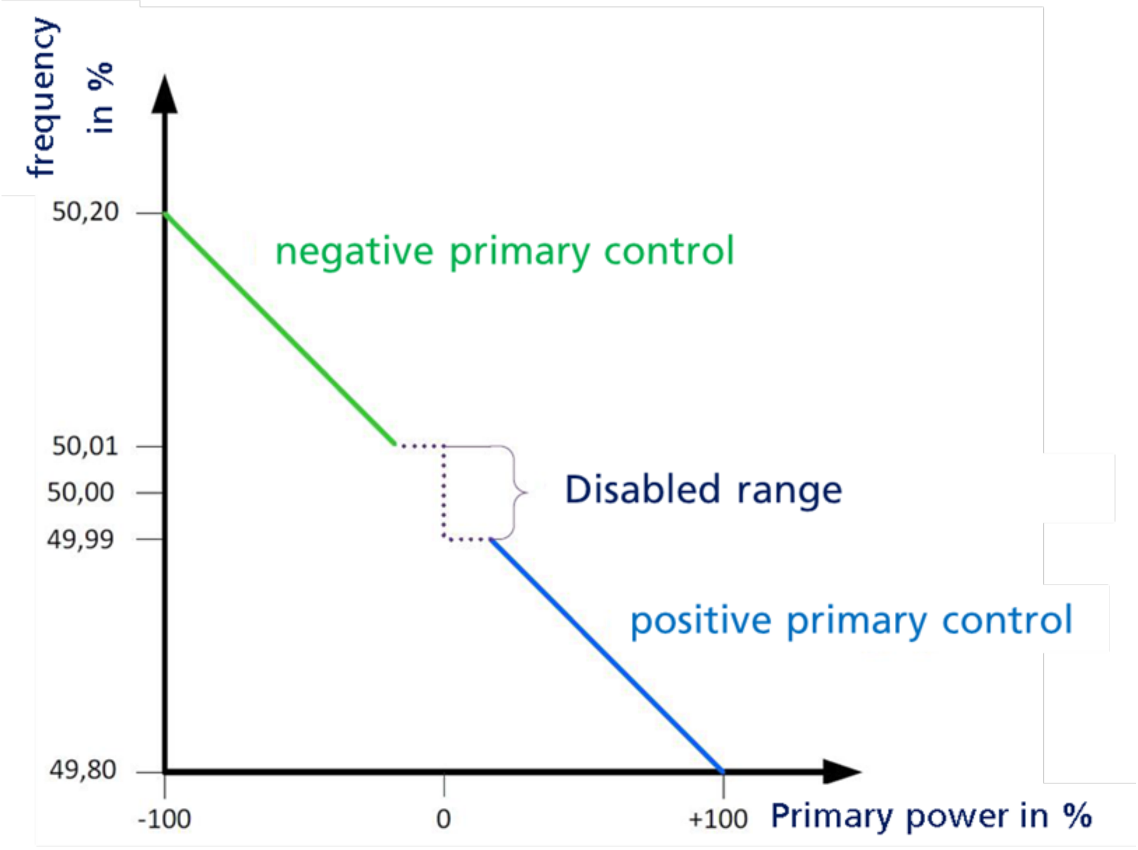
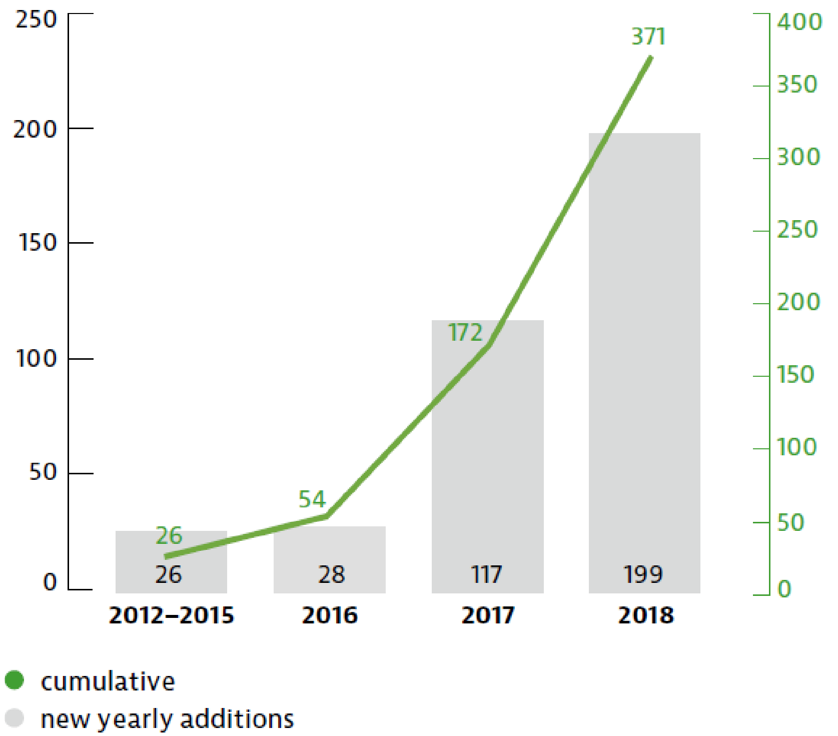
Market segments of stationary battery storage
Transmission level – Example: Primary control power in Germany



Large-scale batteries in Germany
Total power capacity in MW

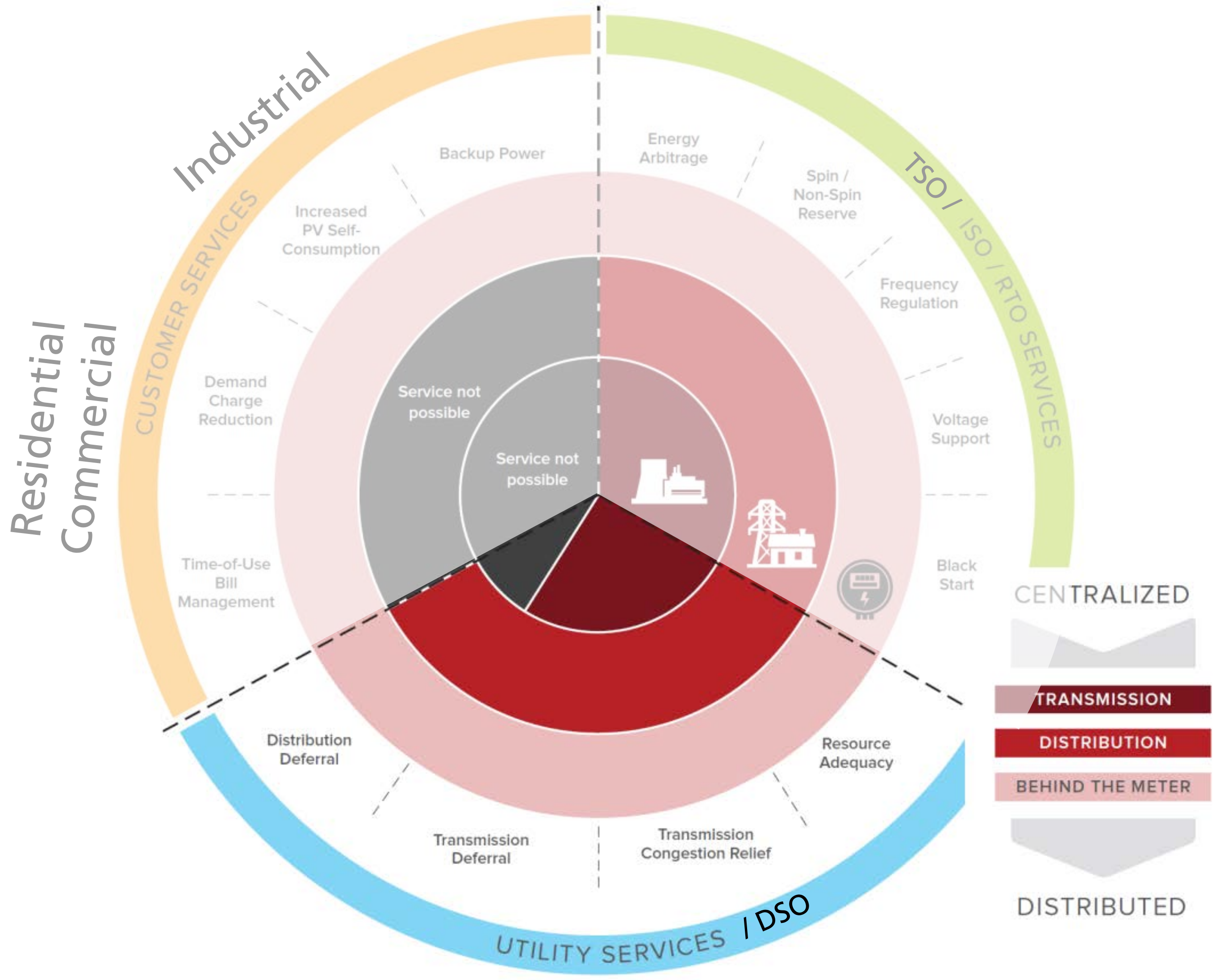


Note: no claim for completeness; usually 75% of installed capacity is qualified for primary control power

Source: German Trade and Invest: Fact sheet – The energy storage market in Germany; Issue 2019.

Market segments of stationary battery storage
Distribution level

Batteries can provide up to 13 services to three stakeholder groups



Source: F. Garrett, The Economics of Battery Energy Storage, Rocky Mountain Institute, September 2015.

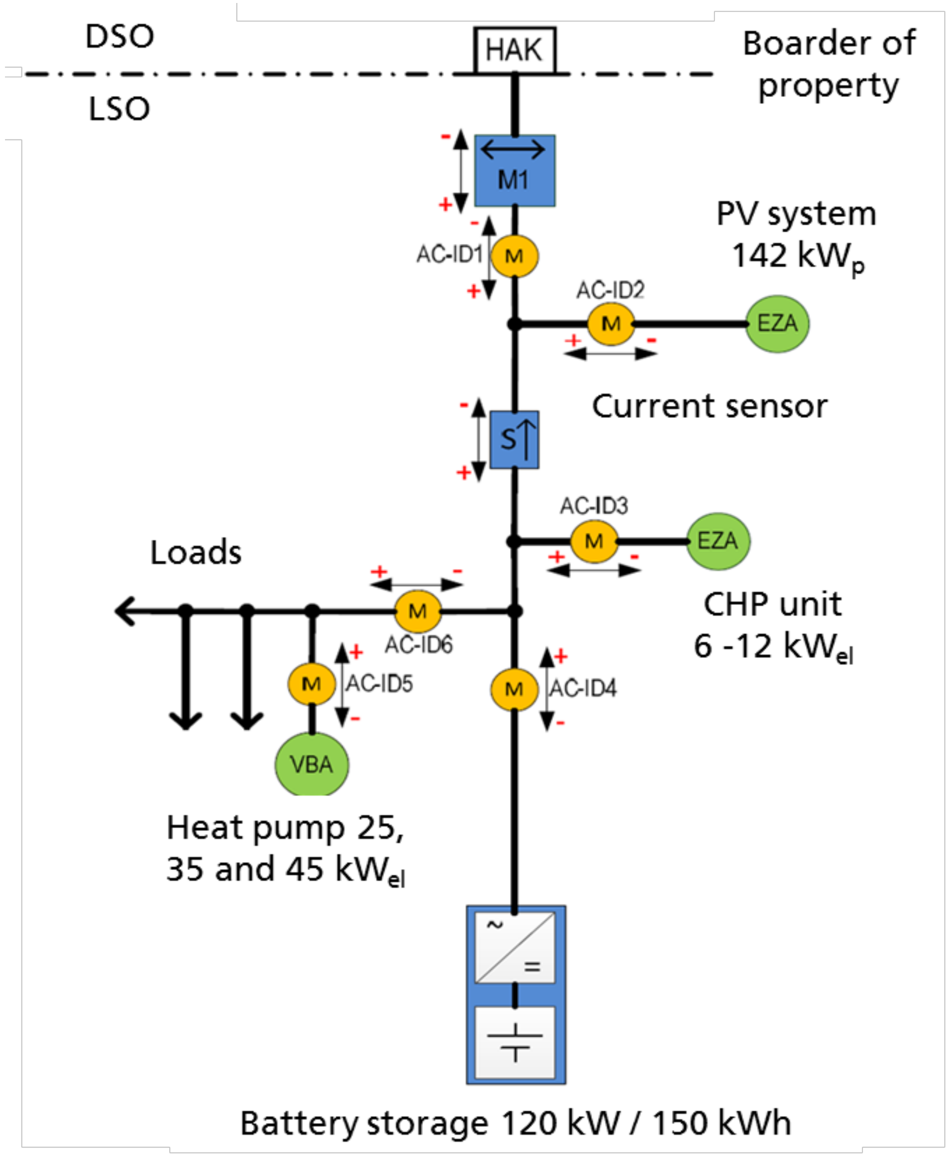
Market segments of stationary battery storage

Distribution level – Example: Smart district "Weinsberg" in Germany

Optimization criteria:

Minimization of grid dependency –

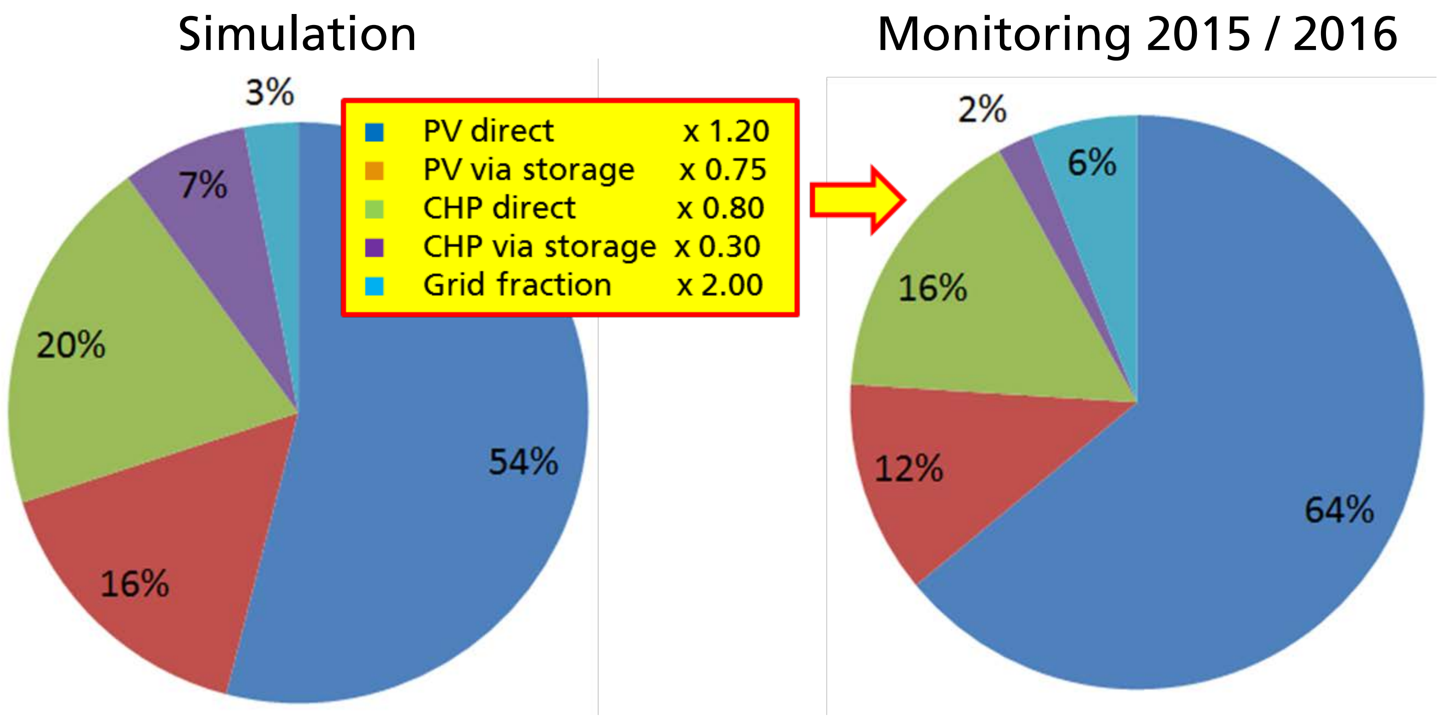
Physically not only accumulated



Market segments of stationary battery storage

Distribution level – Example: Smart district "Weinsberg" in Germany

Accumulated annual electrical energy quantities

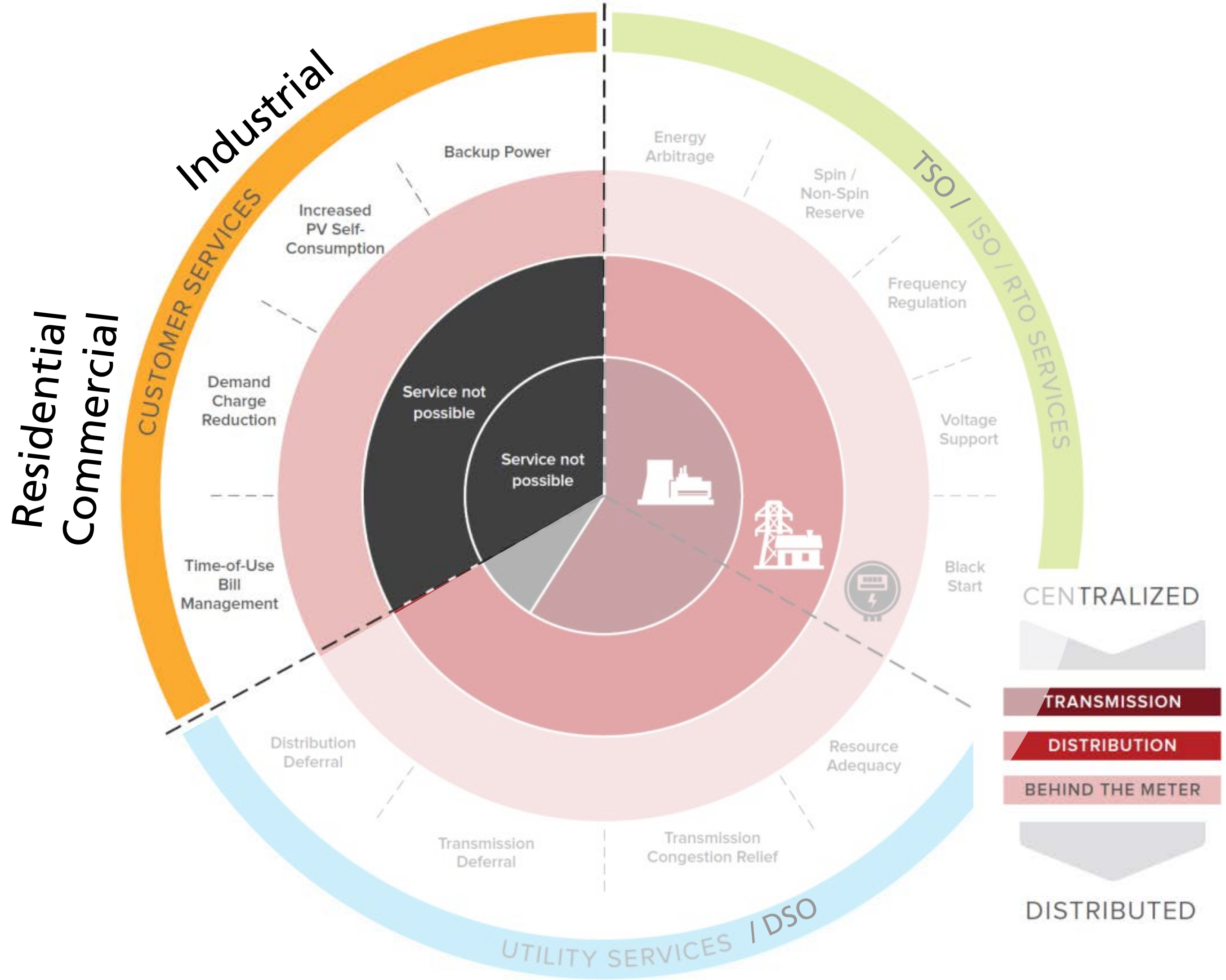


Reasons for differences:

- 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 (!)

Market segments of stationary battery storage
Customer level

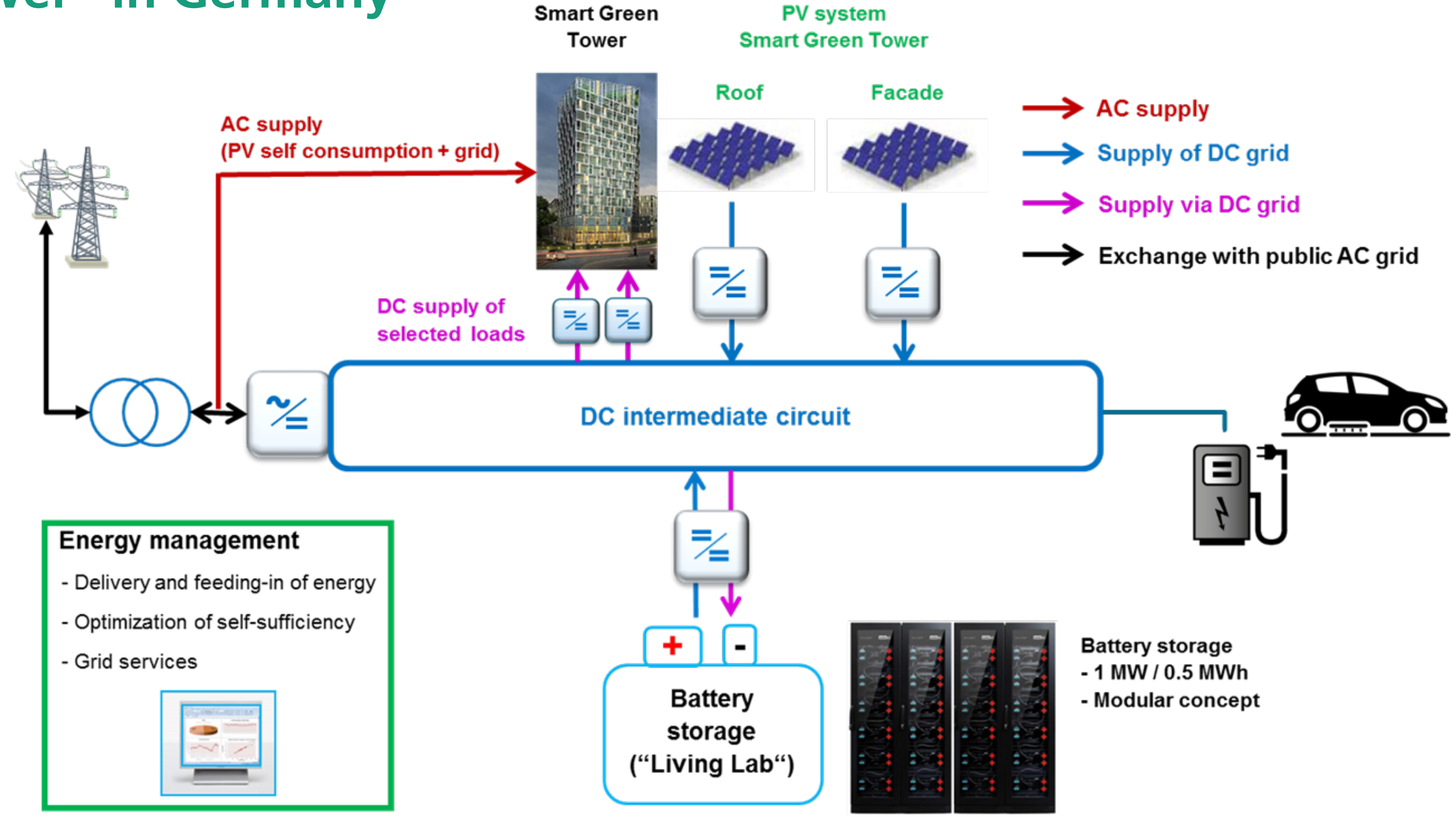
Batteries can provide up to 13 services to three stakeholder groups



Source: F. Garrett, The Economics of Battery Energy Storage, Rocky Mountain Institute, September 2015.

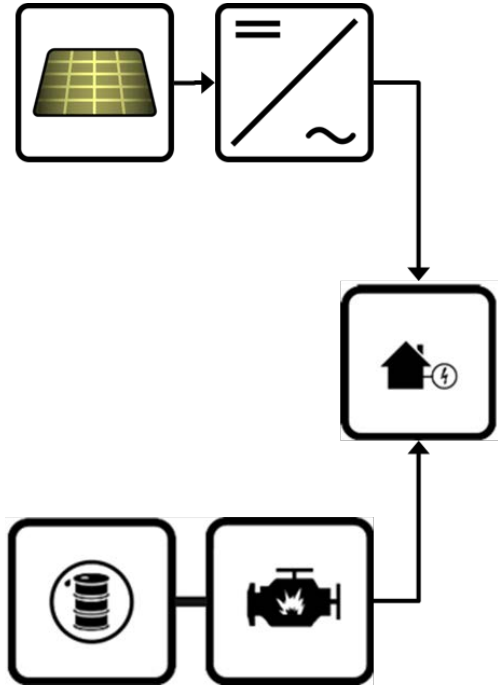
Market segments of stationary battery storage

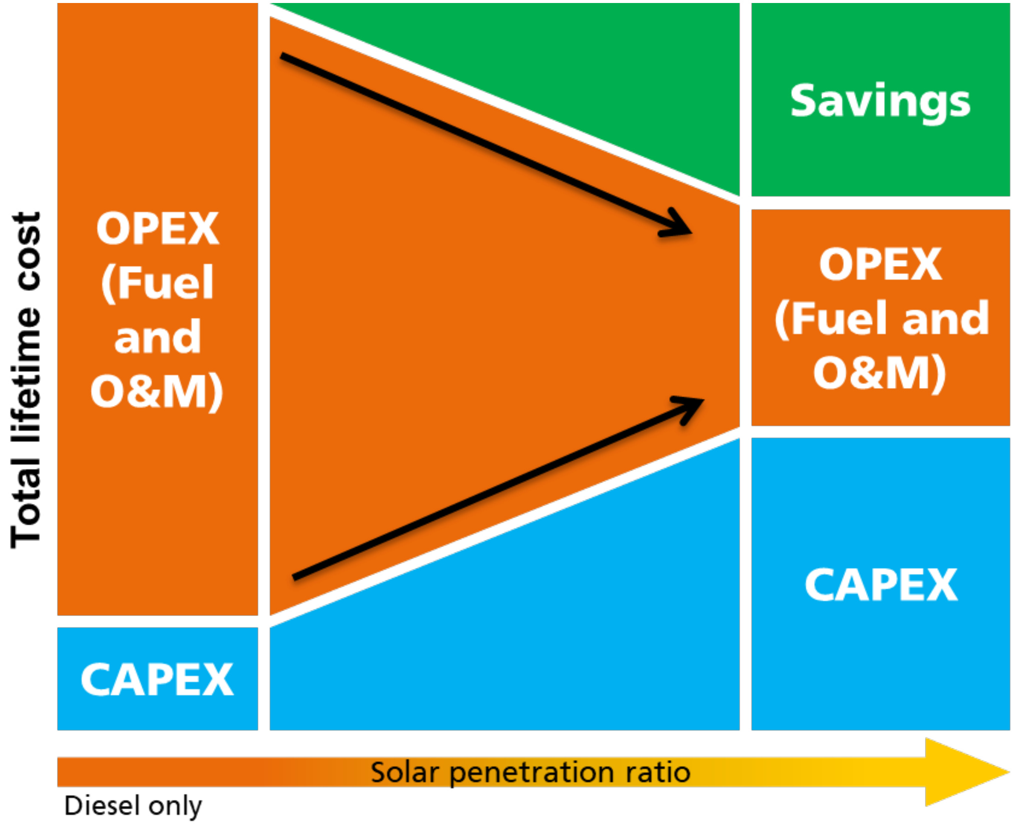
Customer level – Example: Mixed commercial and residential building "Smart Green Tower" in Germany



Market segments of stationary battery storage
Customer level – Example: PV mini-grids

The business case of PV integration in Diesel powered mini-grids





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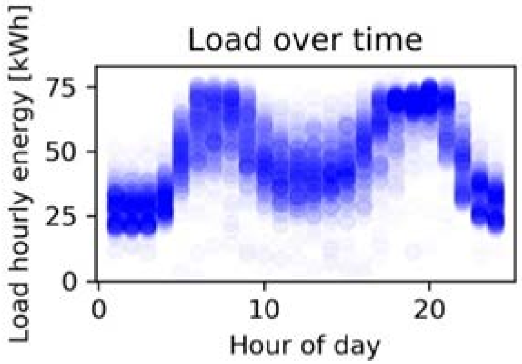
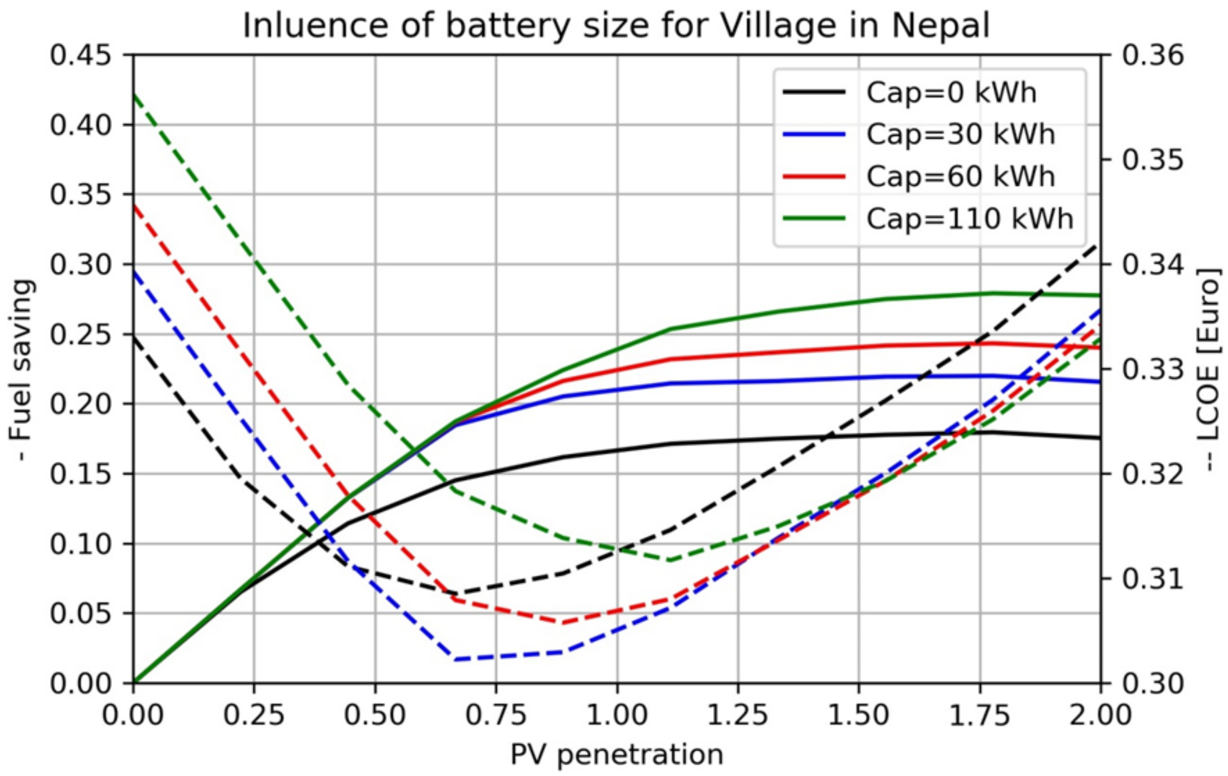
Market segments of stationary battery storage

Customer level – Example: Case study for a PV mini-grid in Nepal



The business case of PV integration in Diesel powered mini-grids

- Nepal case: Electricity demand and PV generation is not matching well
- With today's battery storage prices a reduction of the LCOE can be achieved already
- With "near" future battery storage prices the economics will look much better !!!
- With help of a battery storage the overall CO_2 emissions can be reduced



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Market segments of stationary battery storage
Customer level – Example: PV mini-grid for SKA1 low radio telescope in Australia

Developed 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 remote processing facilities (distance from central processing facility > 10 km)
- LCOE: ~ 0.307 €/kWh

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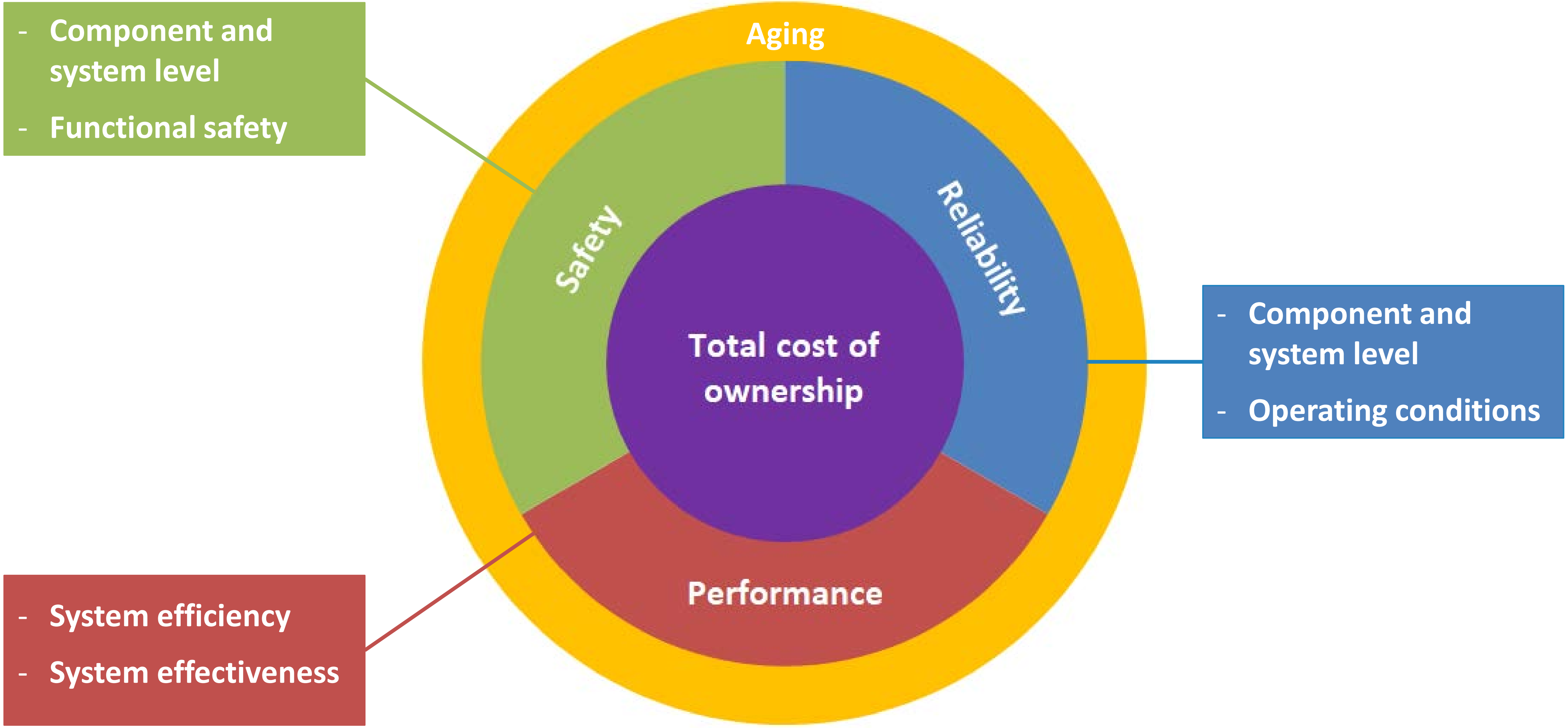
Key factors affecting bankability and insurability of PV + storage projects



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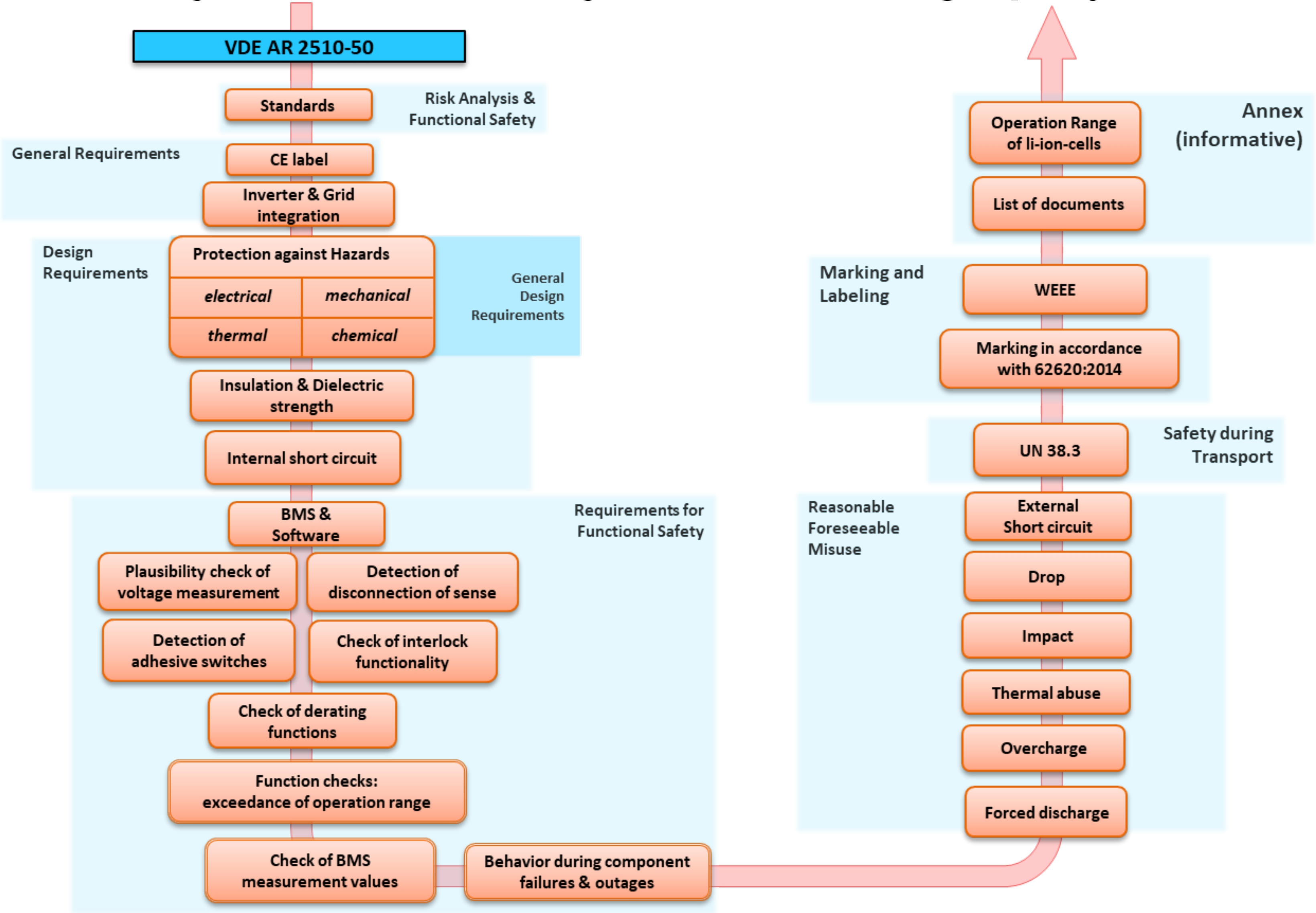
Key factors affecting bankability and insurability of PV + storage projects

Safety

- Example VDE application rule VDE AR 2510-50:

  Stationary energy storage systems with lithium batteries – Safety requirements



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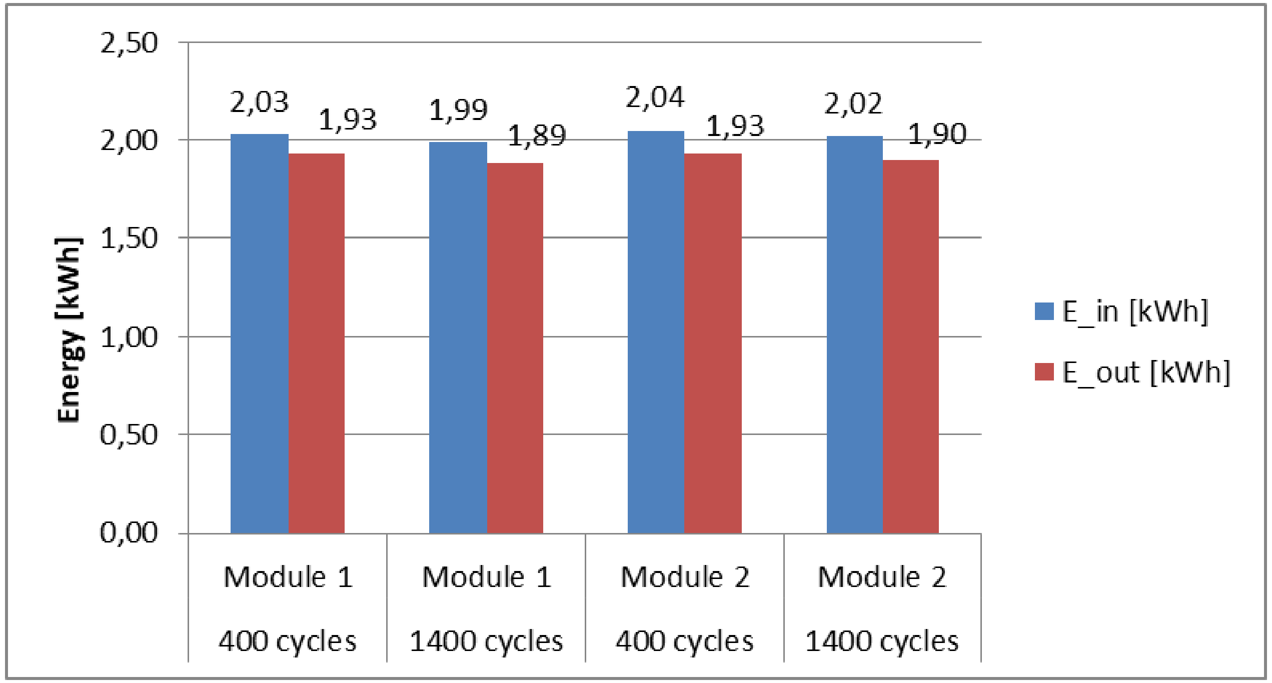
Key factors affecting bankability and insurability of PV + storage projects
Reliability – Example battery storage with aged battery modules

Battery storage product 1

- Little loss of capacity after 1400 cycles
- Loss of efficiency after 1400 cycles negligible
- Almost homogeneous aging behavior



n	400	1400	400	1400
	module 1	module 1	module 2	module 2
E_in [kWh]	2.03	1.99	2.04	2.02
E_out [kWh]	1.93	1.89	1.93	1.90
Efficiency	95.30%	94.91%	94.57%	94.04%
Capacity loss		2.44%		1.85%
Efficiency loss		0.39%		0.53%

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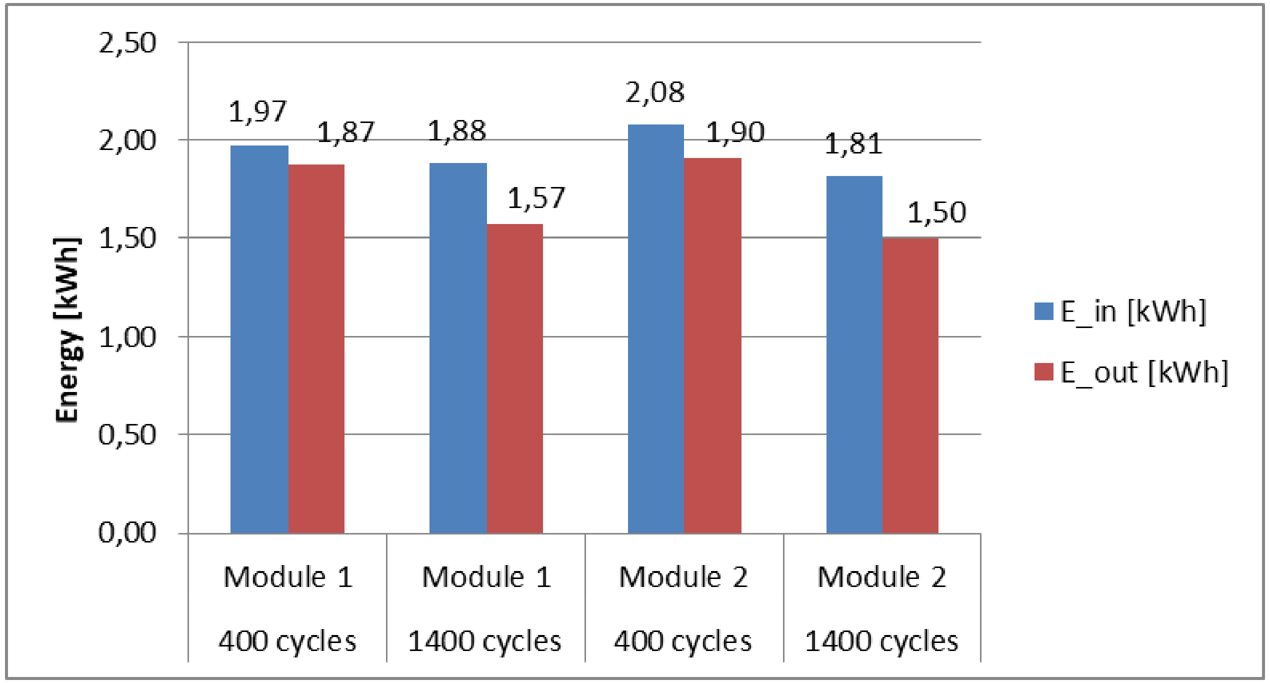
Key factors affecting bankability and insurability of PV + storage projects

Reliability – Example battery storage with aged battery modules

Battery storage product 2

- Huge loss of capacity after 1400 cycles
- Huge loss of efficiency after 1400 cycles
- Inhomogeneous aging behavior



n	400	1400	400	1400
	module 1	module 1	module 2	module 2
E_in [kWh]	1.97	1.88	2.08	1.81
E_out [kWh]	1.87	1.57	1.90	1.50
Efficiency	94.86%	83.71%	91.64%	82.63%
Capacity loss		15.99%		21.25%
Efficiency loss		11.15%		9.01%

→ Question of reliability:
Can the cooling system cope with the increasing heat generation of aged battery modules ???

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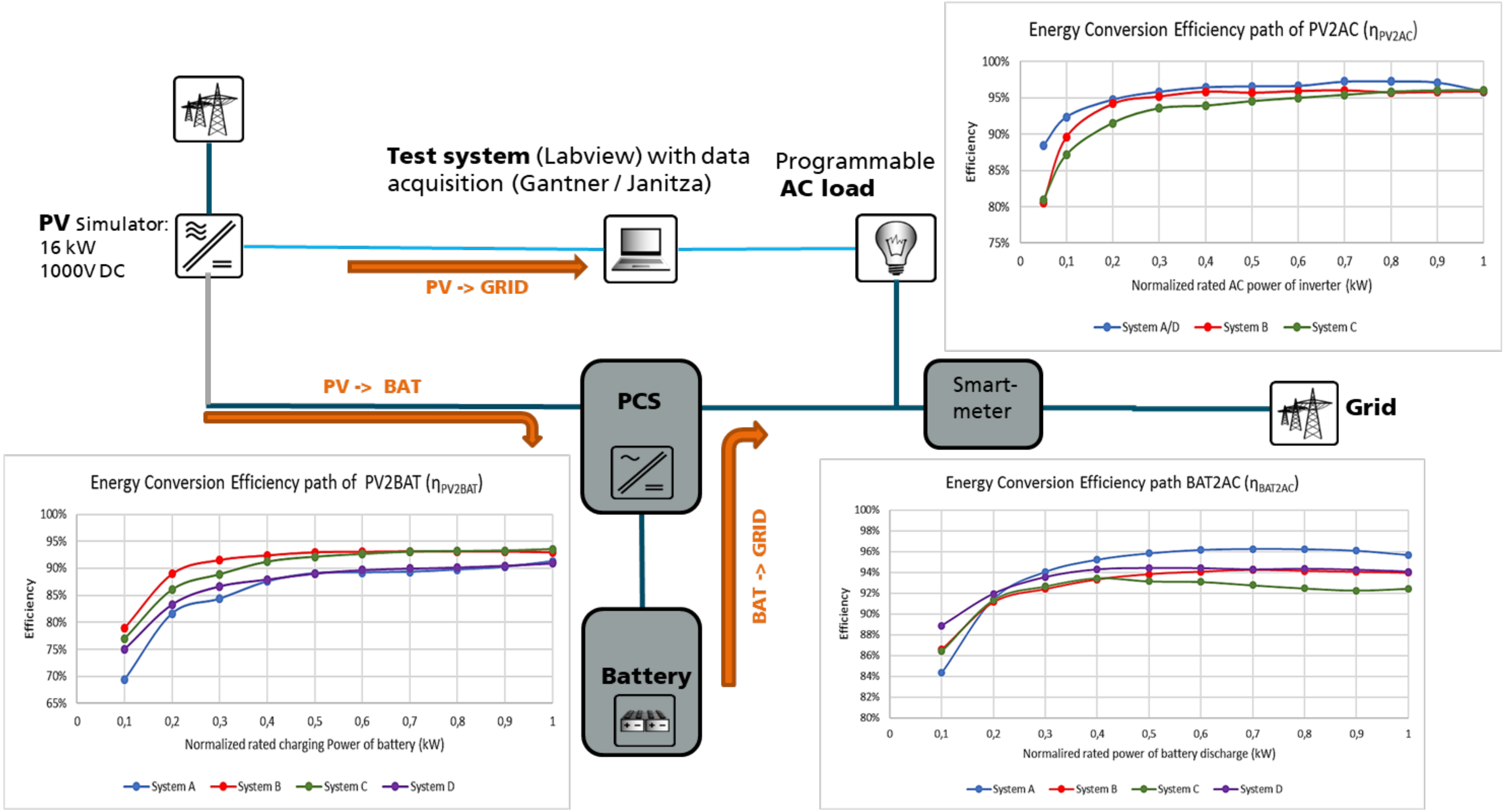
Key factors affecting bankability and insurability of PV + storage projects

Performance – Efficiencies: Examples of PV home storage systems



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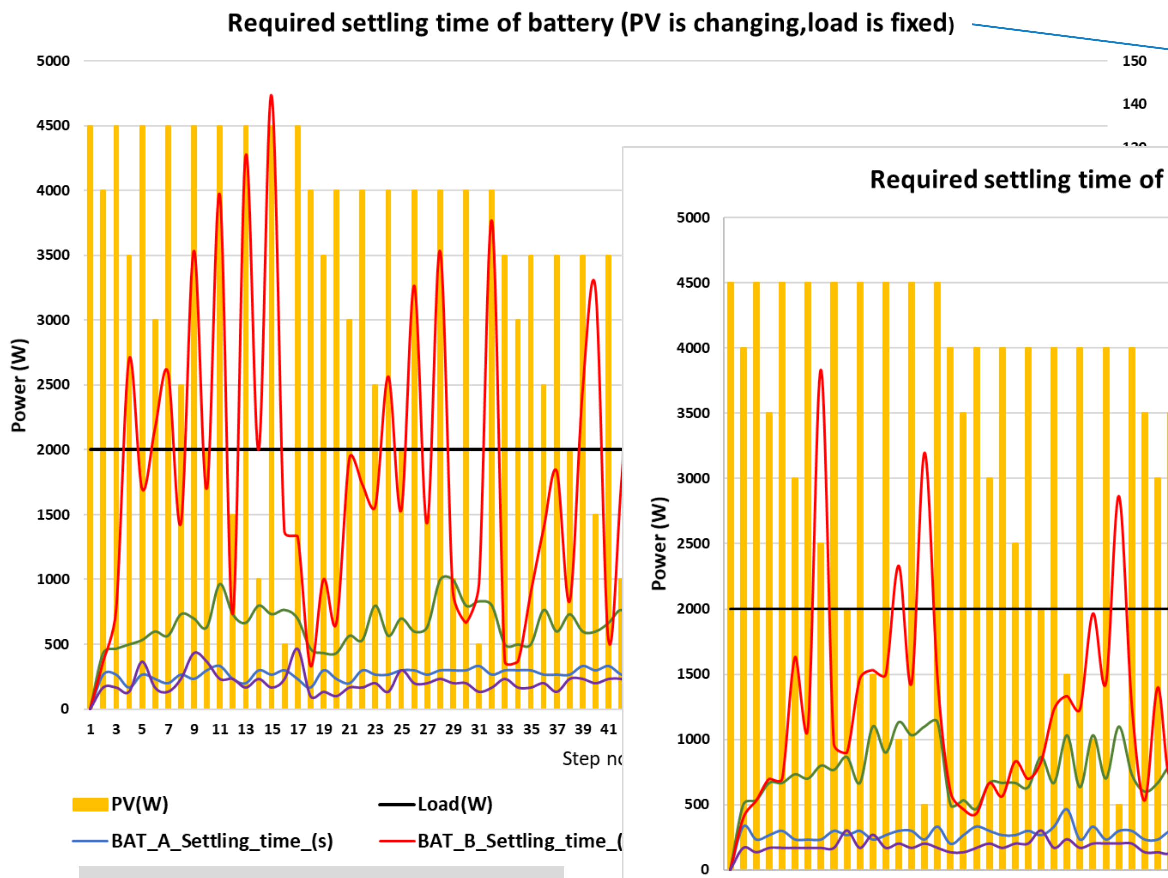
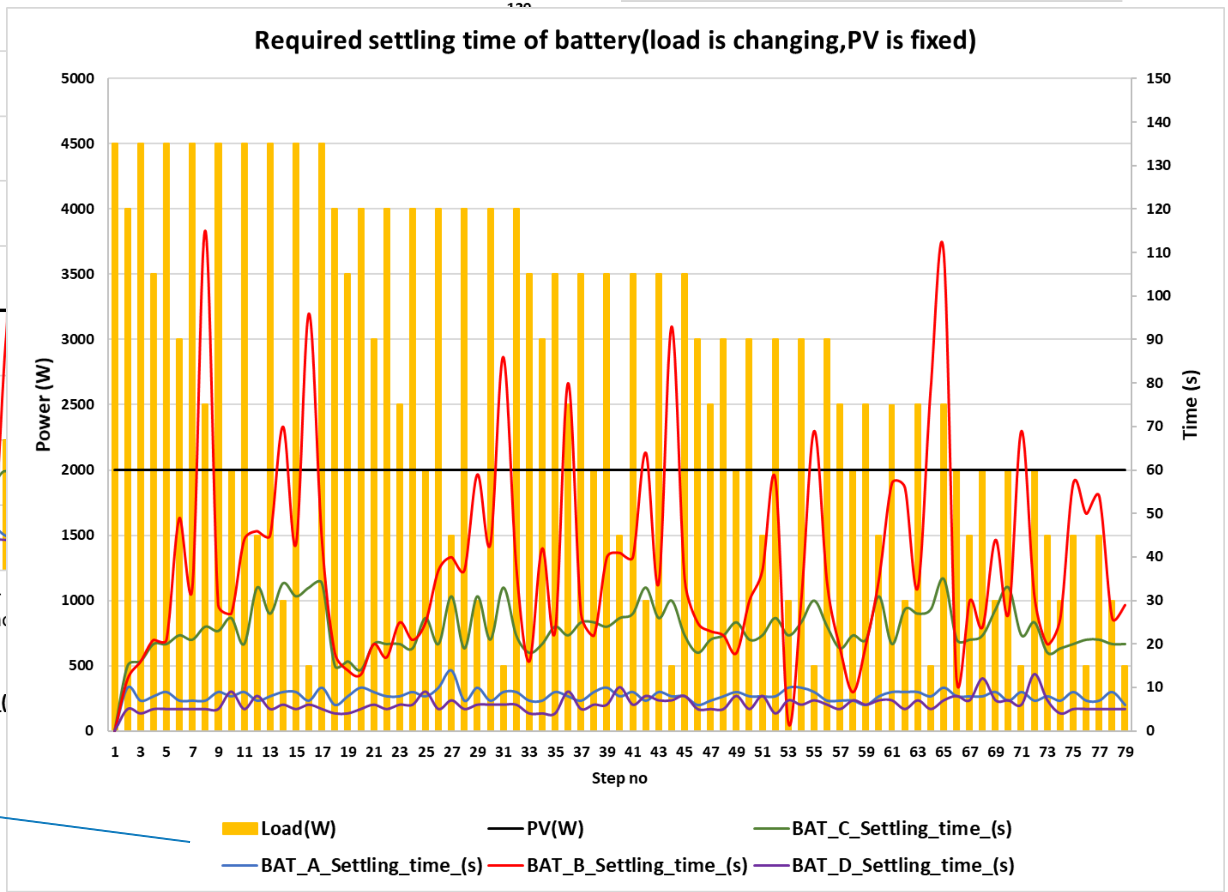
Key factors affecting bankability and insurability of PV + storage projects

Performance – Effectiveness: Examples of PV home storage systems

- Settling times



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



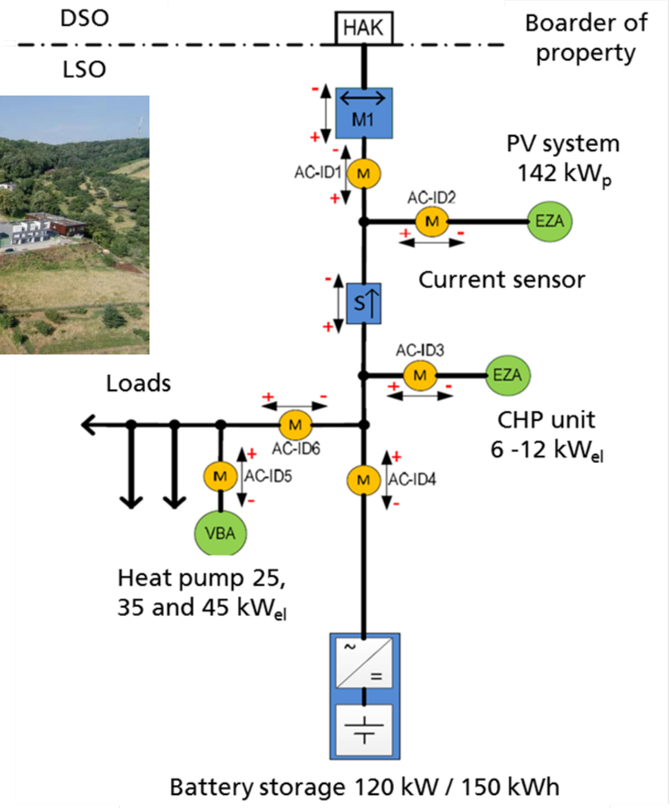
Avg. Settling time
BAT A: 8.11s ; **BAT B**: 38.33s
BAT C: 23.37s ; **BAT D**: 6.03s

Key factors affecting bankability and insurability of PV + storage projects

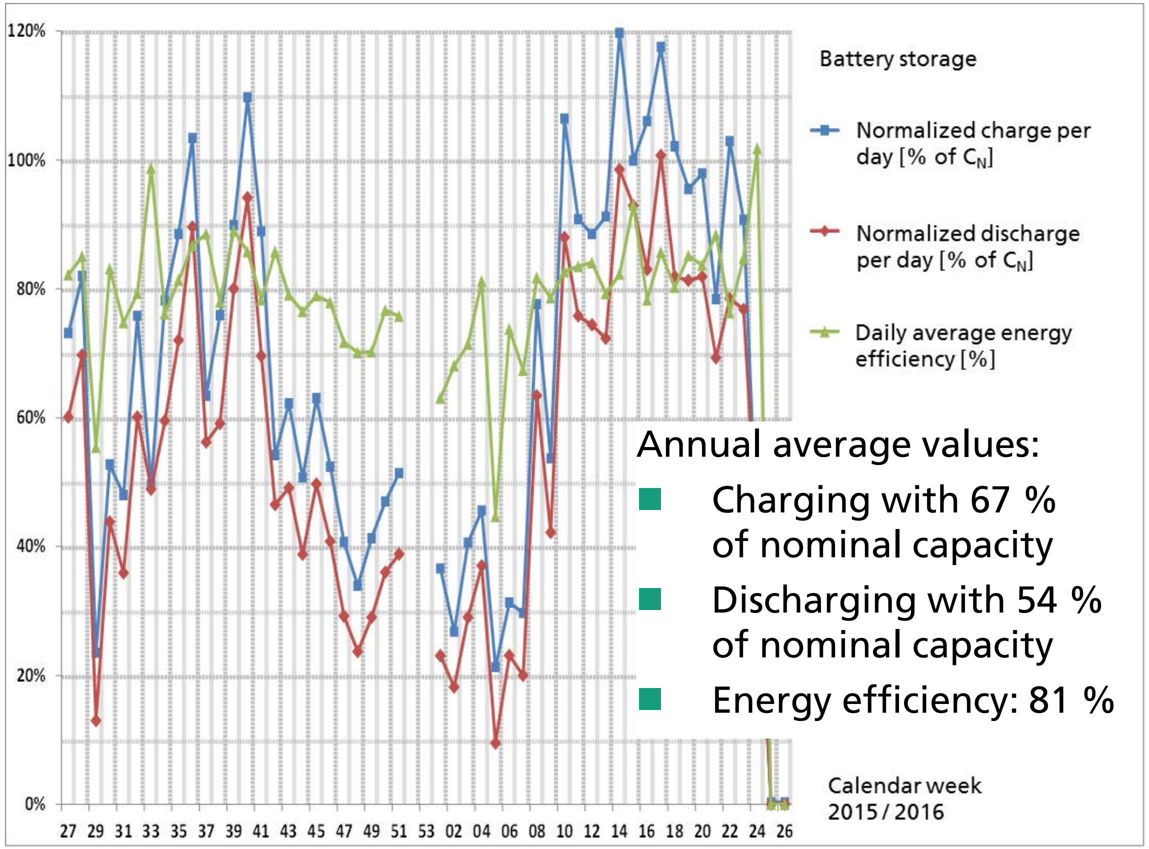
Performance – Efficiency: Example of smart district "Weinsberg"

- Results of measurement campaign

System concept of district power supply



Analysis of battery storage operation



Annual average values:

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

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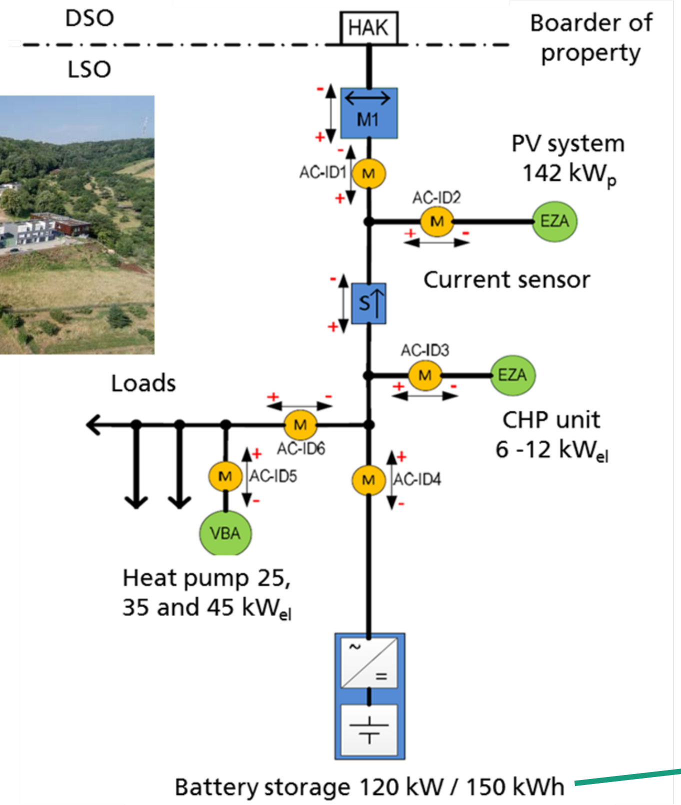
Key factors affecting bankability and insurability of PV + storage projects

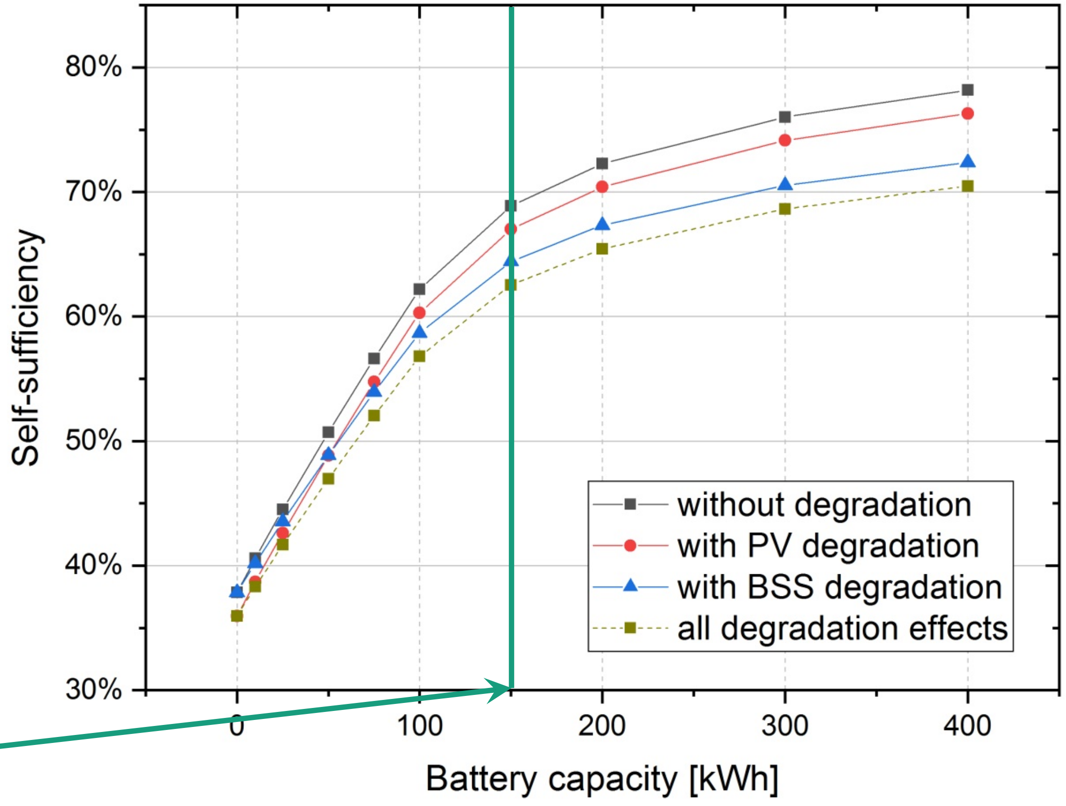
Performance – Effectiveness: Example of smart district "Weinsberg"

- Simulation based analyses

System concept of district power supply



Reduction of self-sufficiency over time



Source: L. Millet et al.: Extensive analysis of photovoltaic battery self-consumption: Evaluation through an innovative district case-study; Applied Physics Reviews, 2019.

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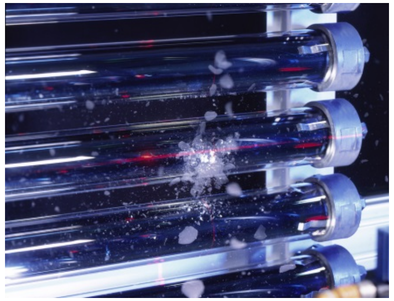
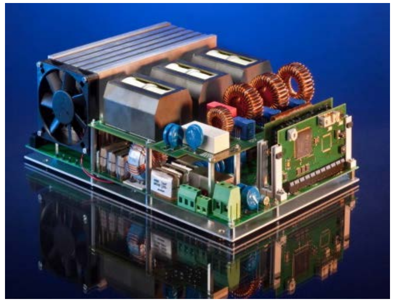
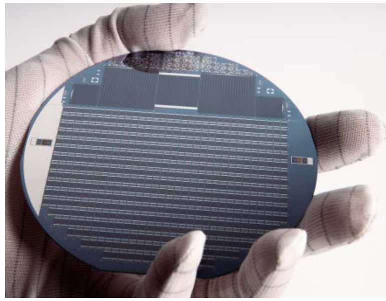
Conclusions

- Large-scale integration of fluctuating renewable energies in power supply systems require storage (grid-connected and isolated mini-grid applications)
  - ➢ Technically → Reliability of power supply
  - ➢ Economically → Business models in post feed-in tariff times
  - → Huge market growth for battery storage expected !
- Quality assurance has to address all relevant factors for enabling bankable projects:
  - ➢ Safety: Component and system level as well as functional safety
  - ➢ Reliability: Component and system level as well as consideration of operating conditions
  - ➢ Performance: System efficiency as well as system effectiveness
  - ➢ Aging: Has a strong influence on all relevant factors
- "Real world" projects with battery storage:
  - ➢ No long-term experience with "new" cell technologies
  - → Appropriate quality assurance measures are key for risk mitigation

Thanks for your attention !!!

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