ENERGY STORAGE FOR RENEWABLE POWER SUPPLY SYSTEMS

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Izmir, 17th of October 2019

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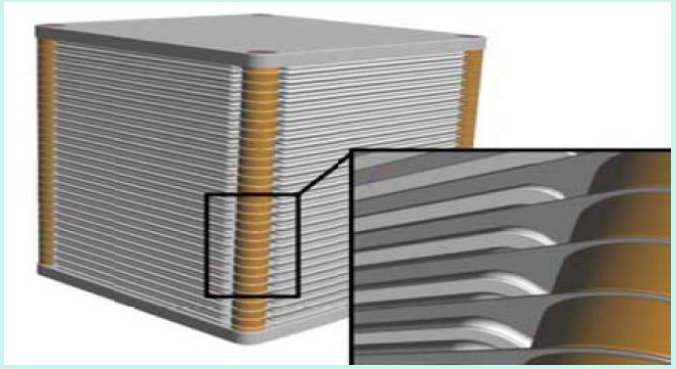
AGENDA

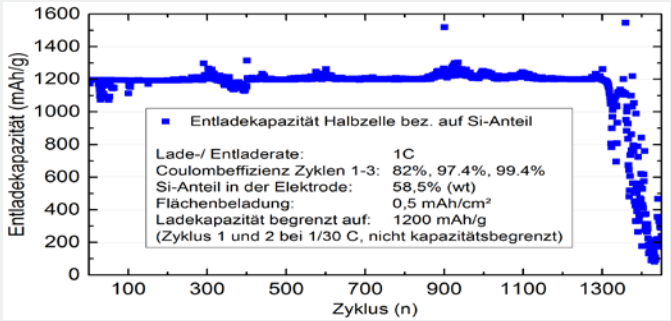
- Introduction to battery R&D of Fraunhofer ISE
- Market segments of stationary battery storage
  - Examples of transmission level
  - Examples of distribution level
  - Examples of customer level
- Key factors affecting bankability and insurability of PV + storage projects
- Conclusions

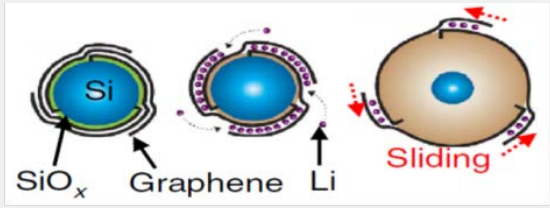
Battery cells
Current focus topics of Fraunhofer ISE

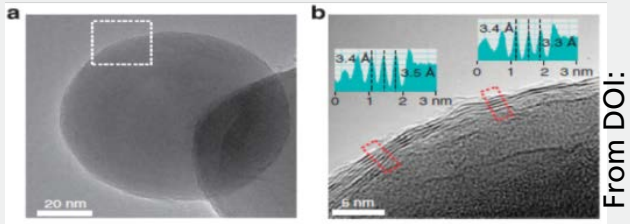
Aqueous batteries for stationary applications



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

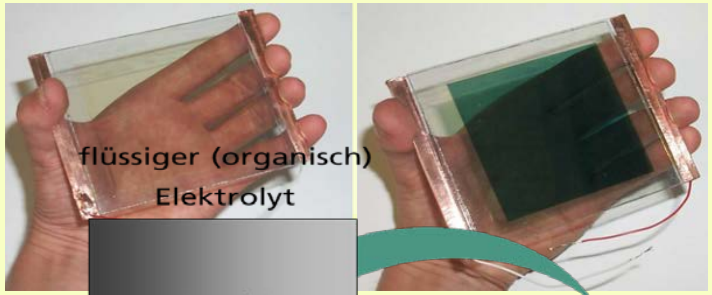






From DOI: 10.1038/ncomms8393

New materials and process technology for *solid state* batteries

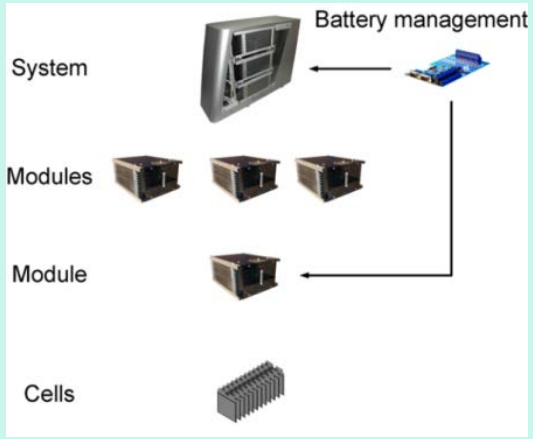


Up to 300 Wh/kg
Up to 850 Wh/l

~ 650 Wh/kg
~ 1700 Wh/l

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

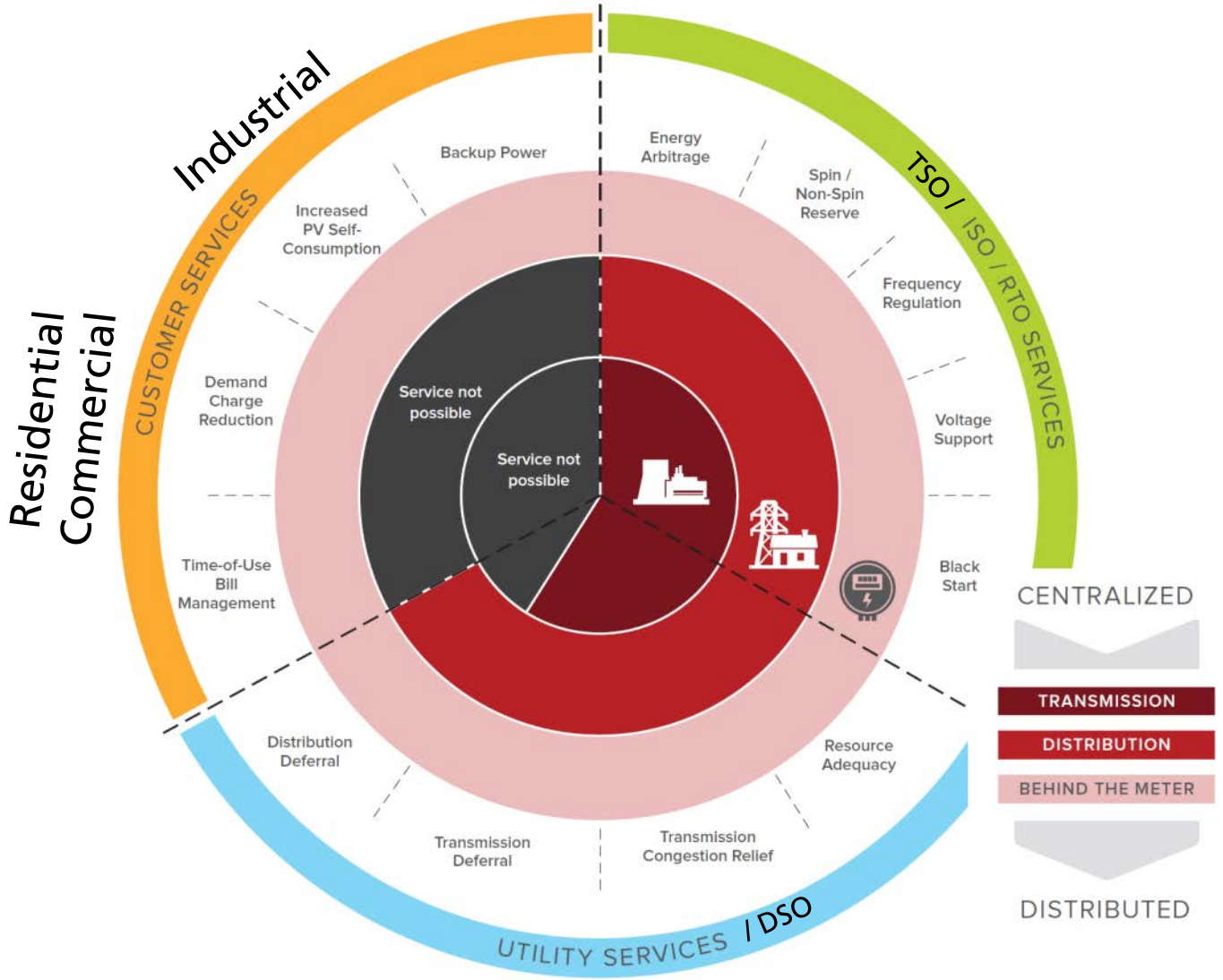
- Consultancy during planning phase
- System design and analysis
- Simulation based storage sizing
- Elaboration of specifications
- Energy management systems
- Site inspections and testing
- Monitoring

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.

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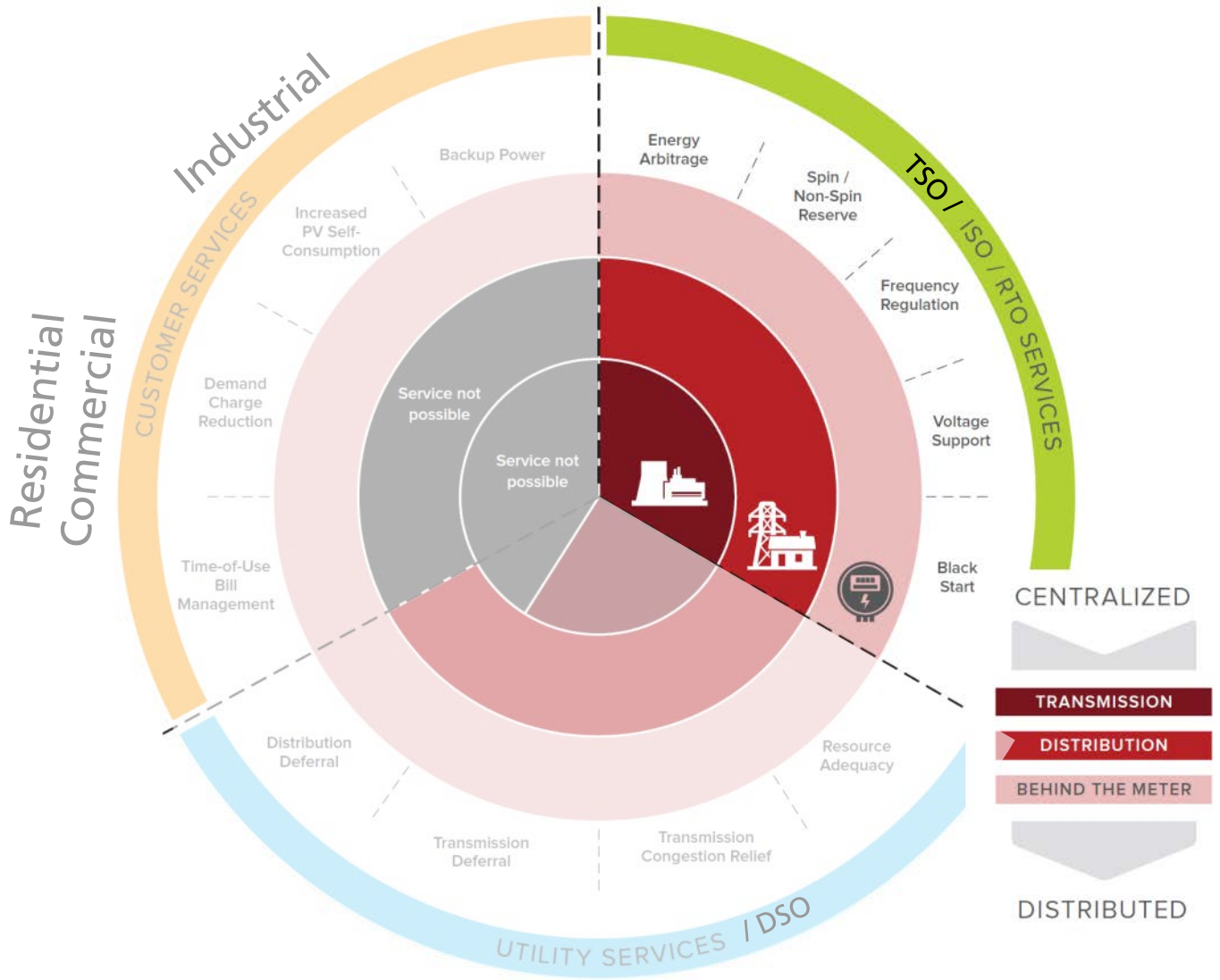
Market segments of stationary battery storage

Transmission level

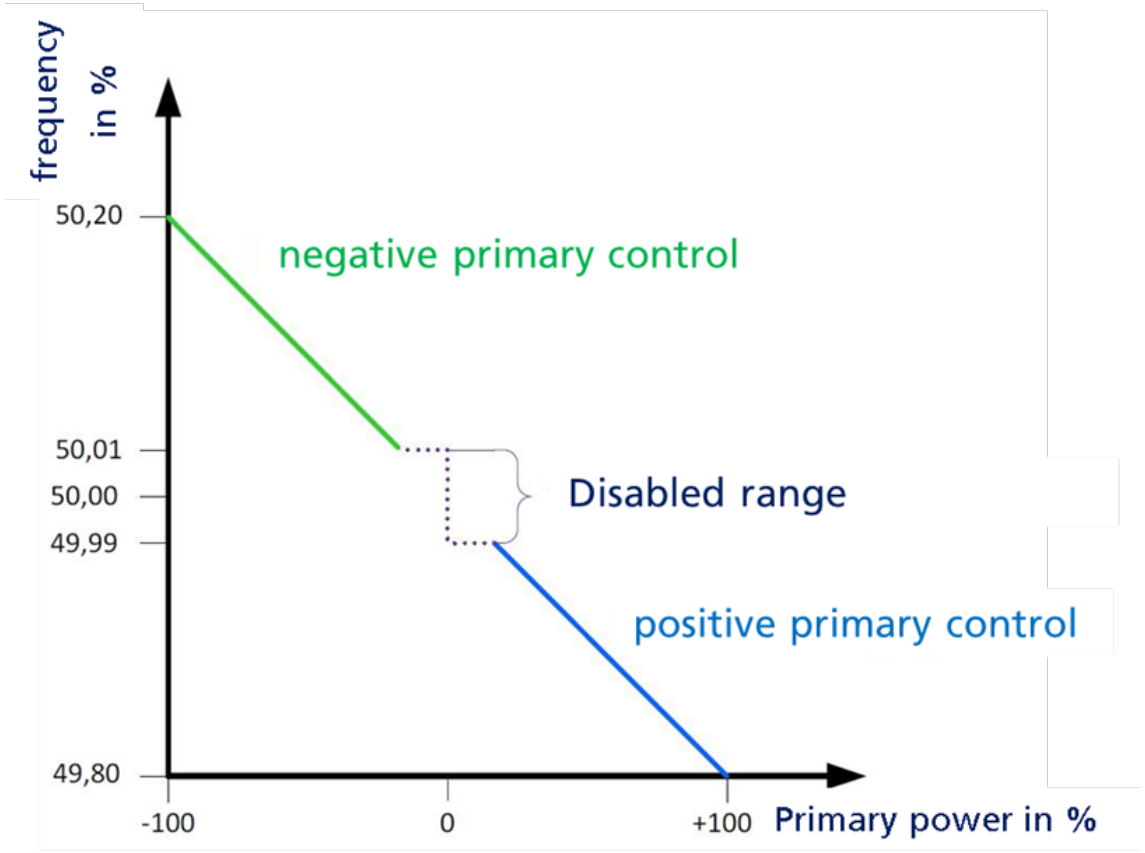
Batteries can provide up to 13 services to three stakeholder groups

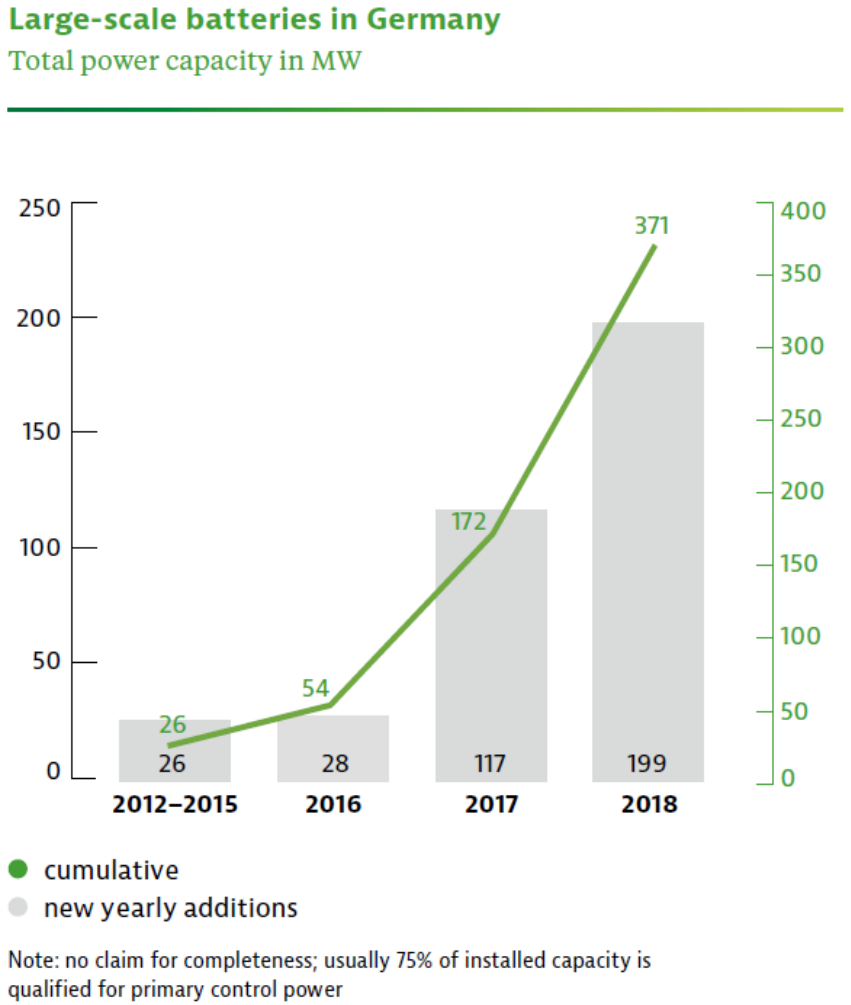


Source: F. Garrett, The Economics of Battery Energy Storage, Rocky Mountain Institute, September 2015.

Market segments of stationary battery storage

Transmission level – Example: Primary control power in Germany





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

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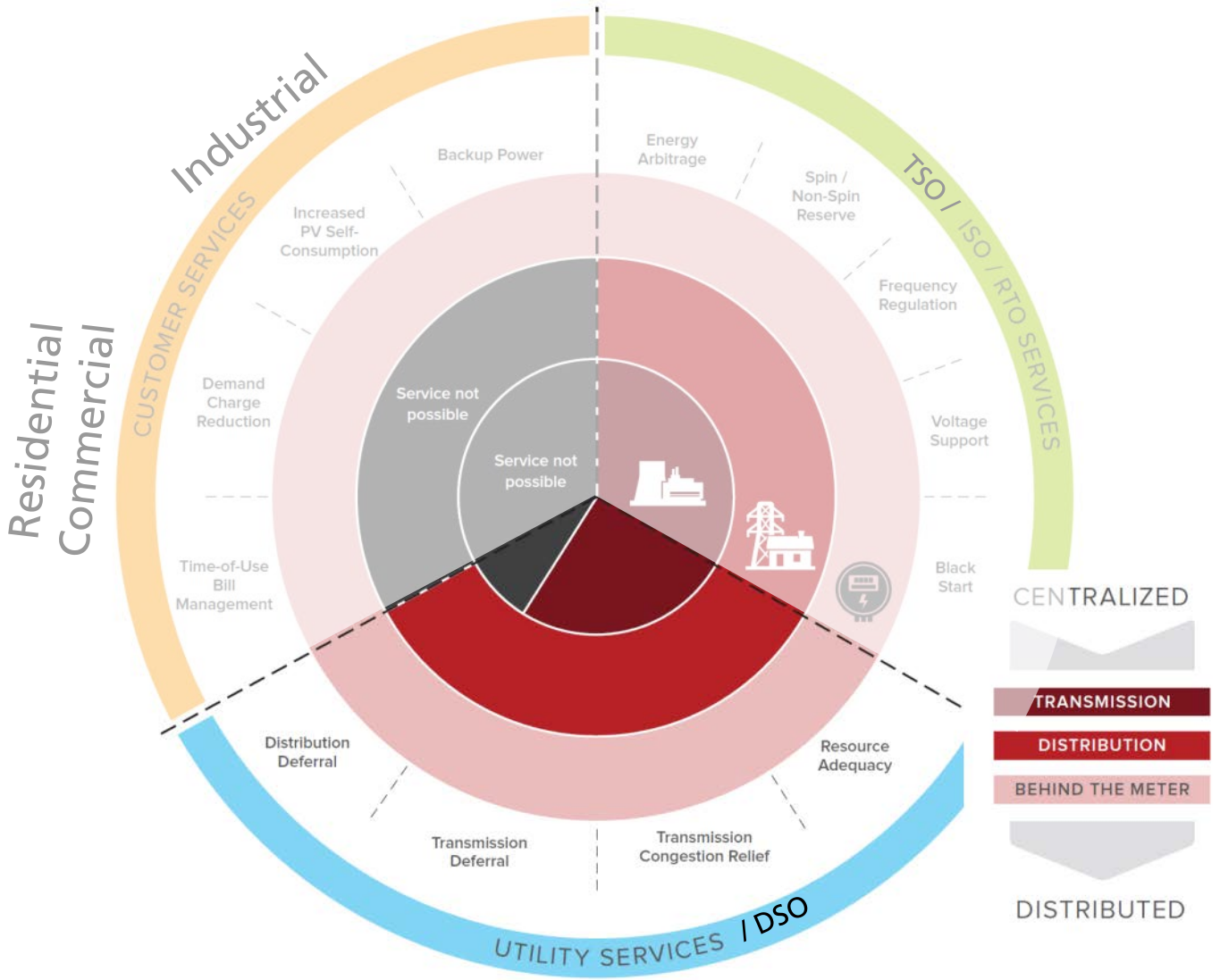
Market segments of stationary battery storage

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.

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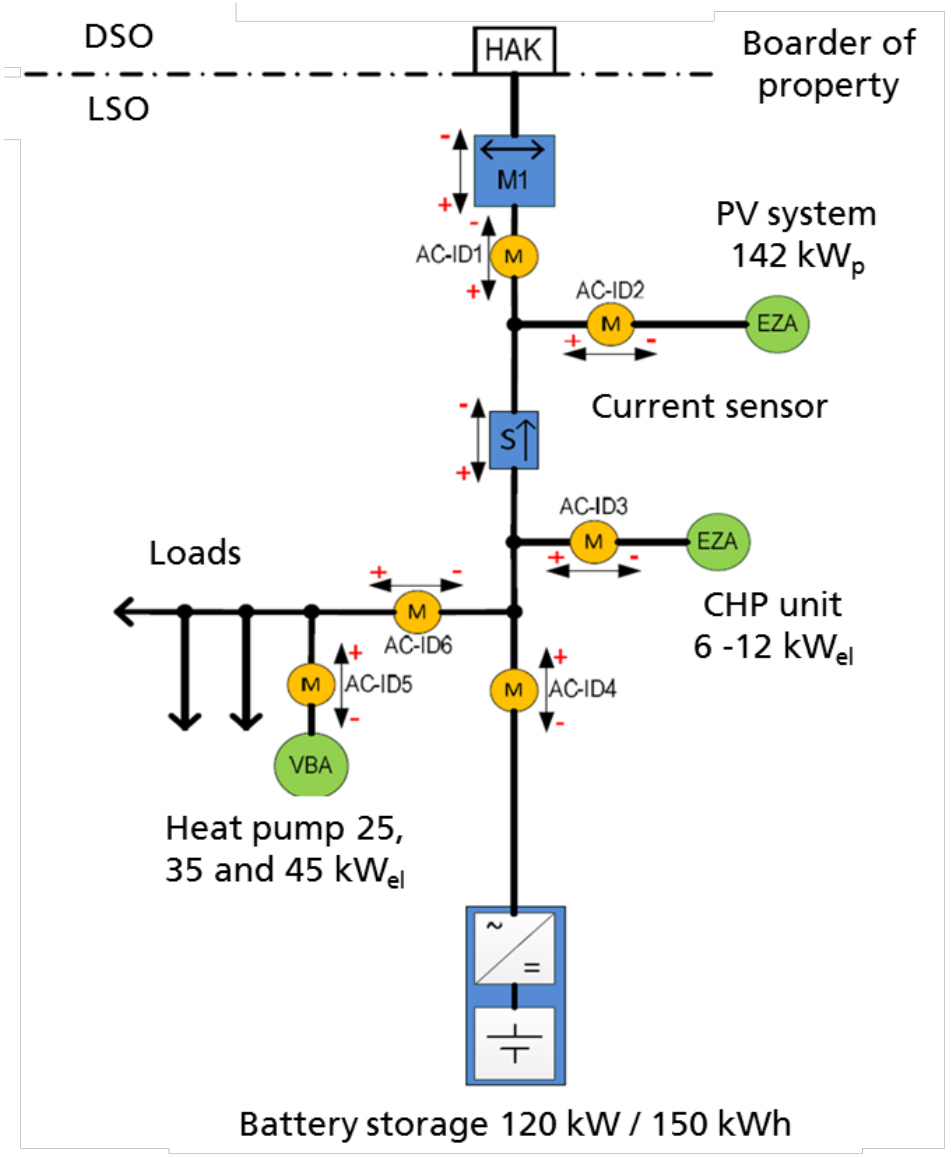
Market segments of stationary battery storage

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

Optimization criteria:

Minimization of grid dependency –

Physically not only accumulated



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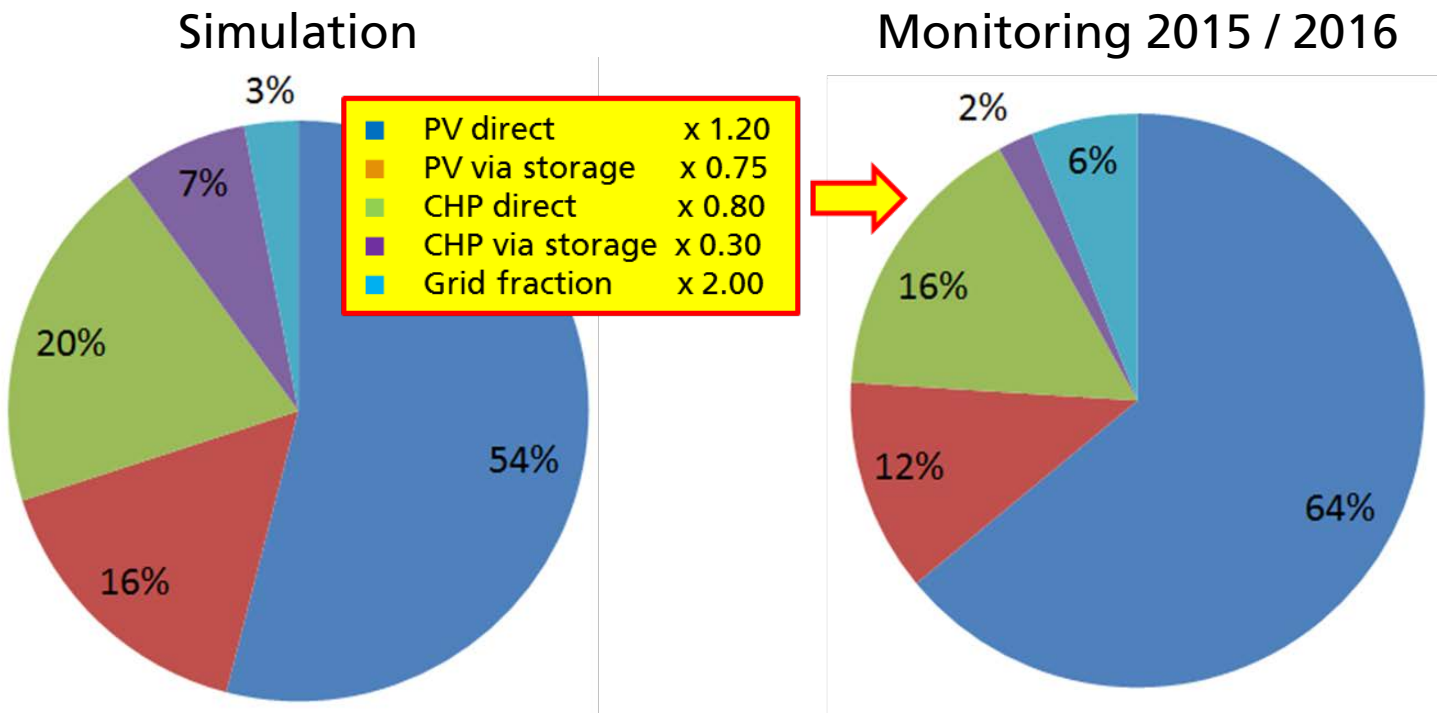
Market segments of stationary battery storage

Distribution level – Example: Smart district “Weinsberg” in Germany

Accumulated annual electrical energy quantities



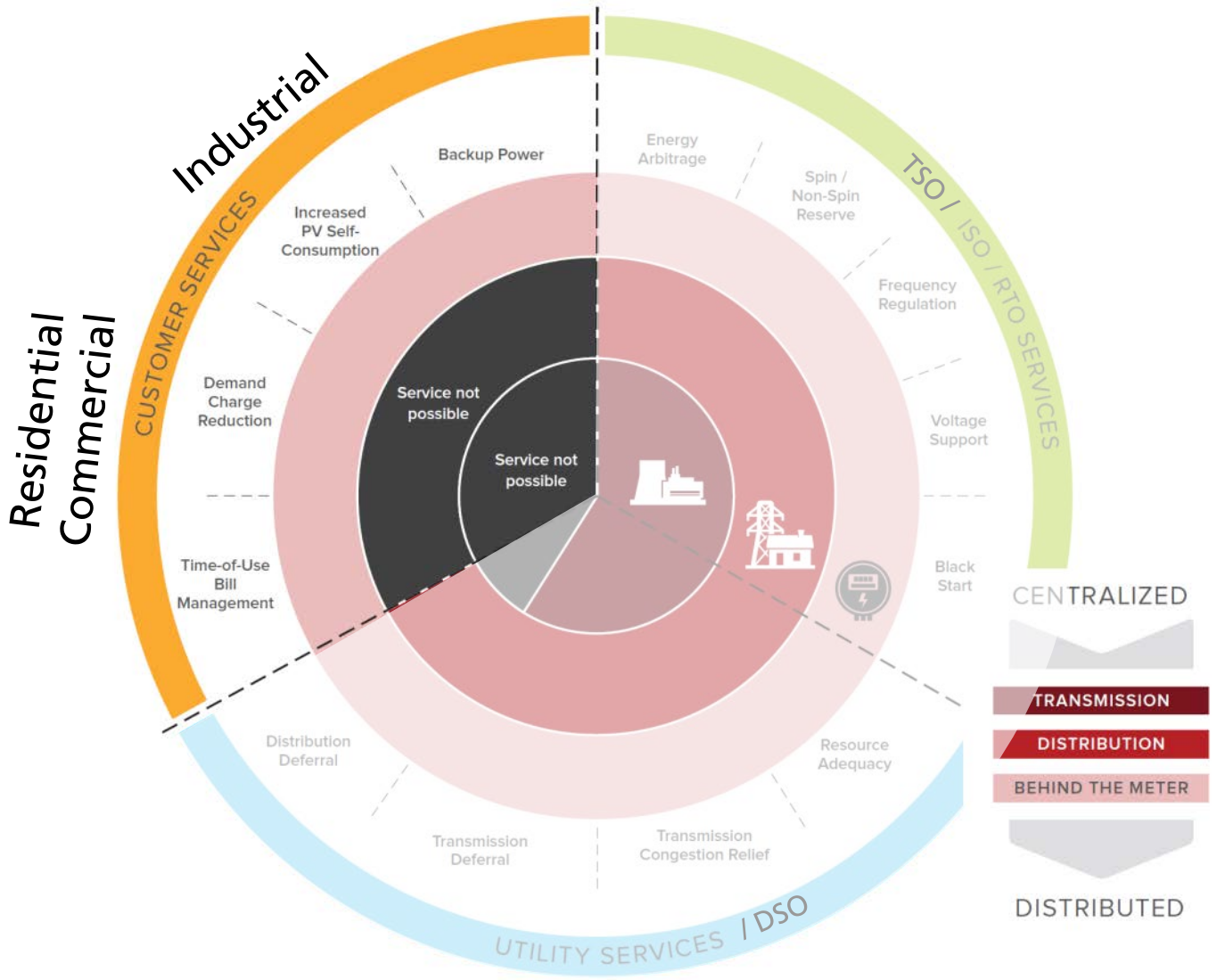
Reasons for differences:

- 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

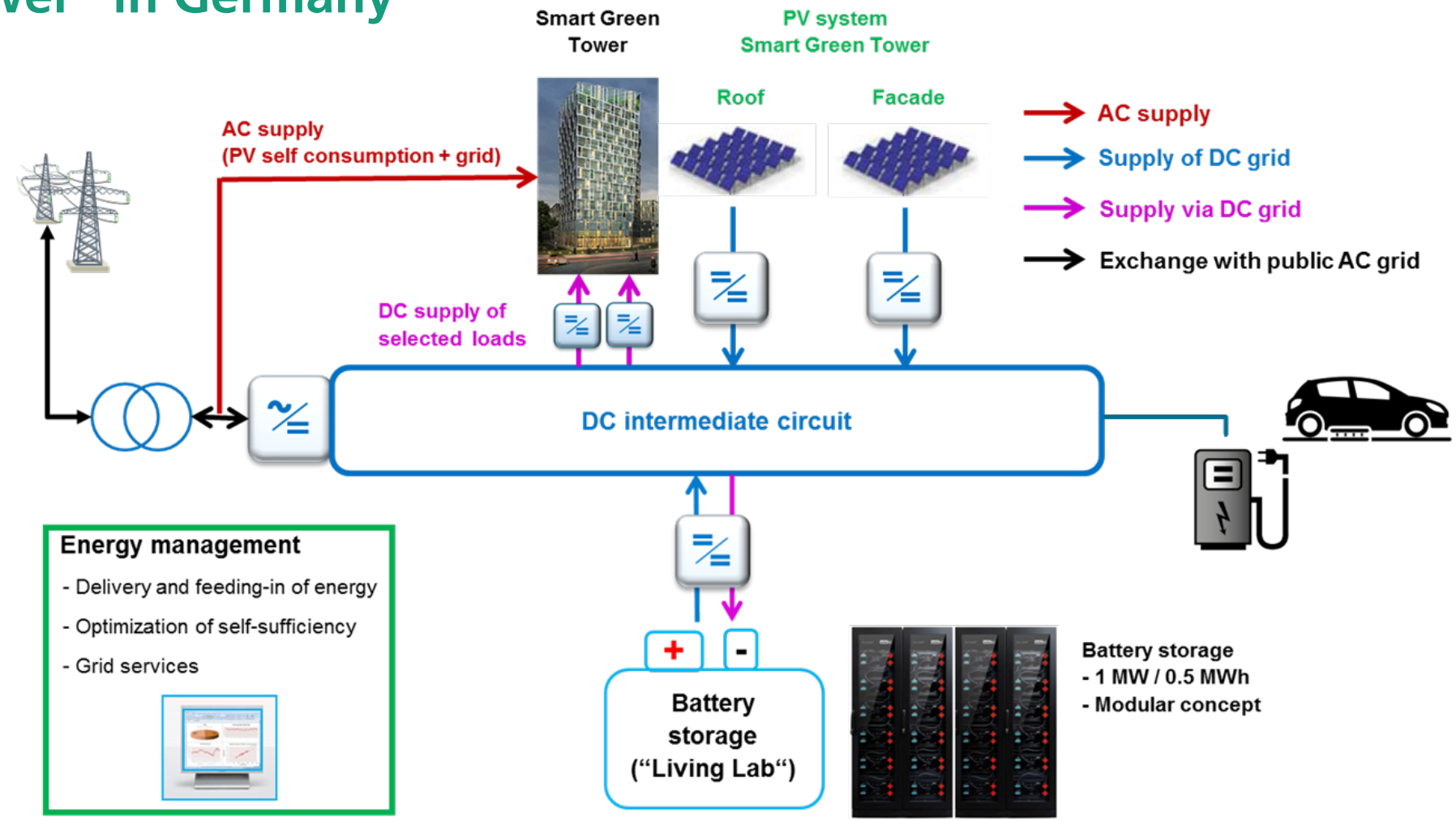
Batteries can provide up to 13 services to three stakeholder groups



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



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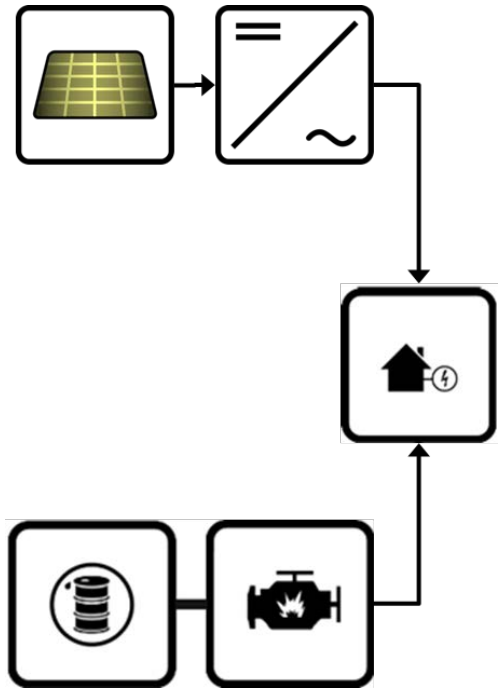
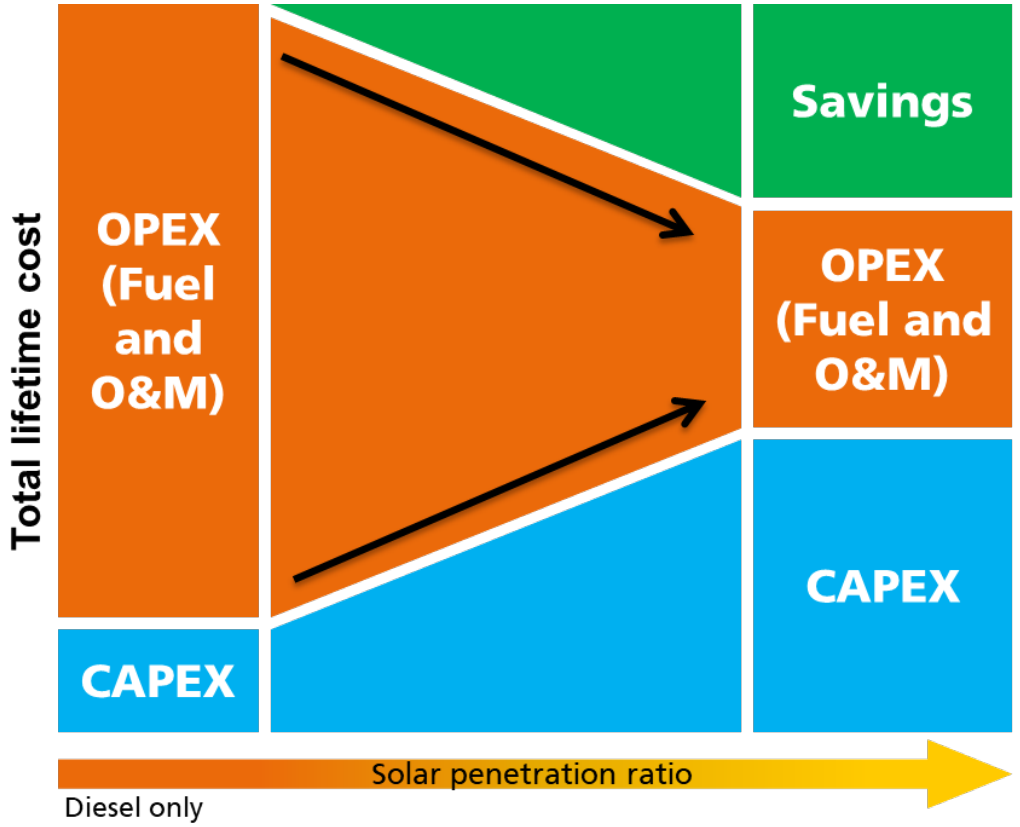
Market segments of stationary battery storage

Customer level – Example: PV mini-grids

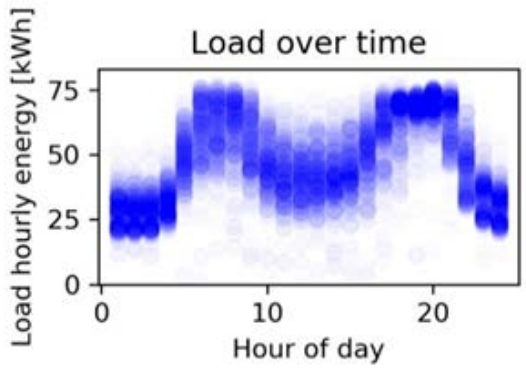
The business case of PV integration in Diesel powered mini-grids





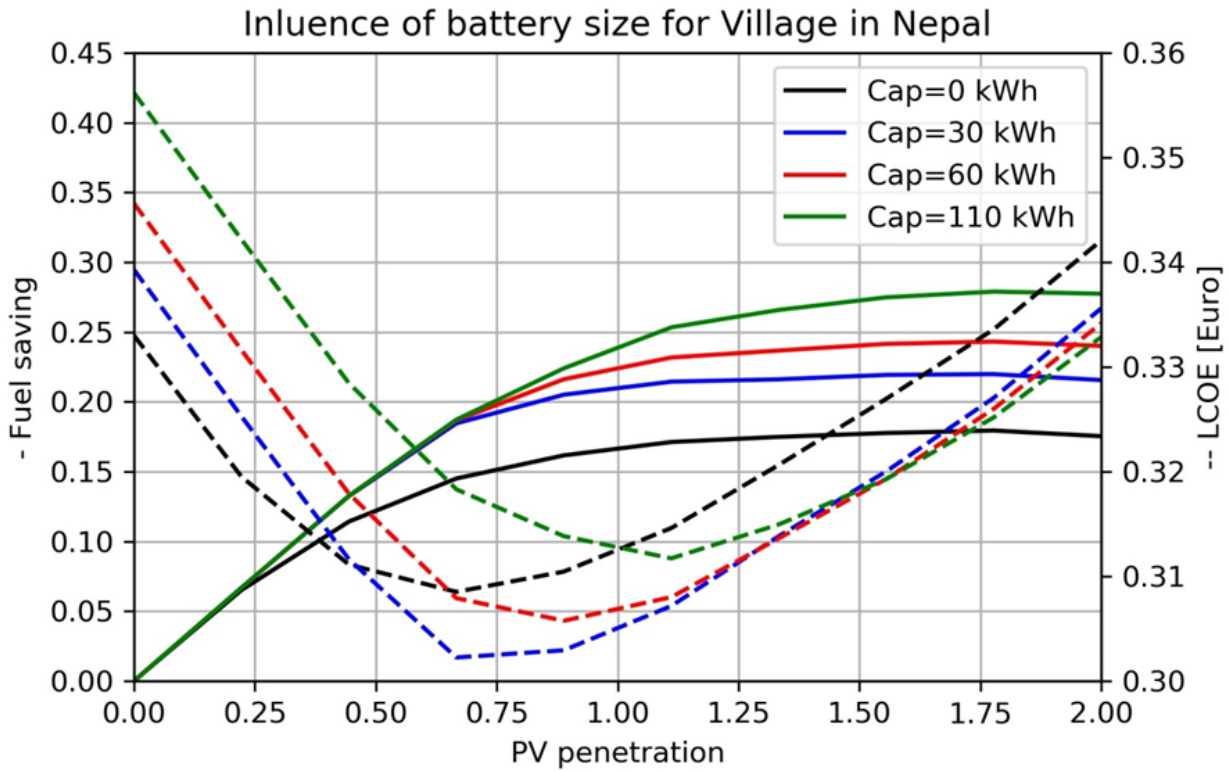
Market segments of stationary battery storage

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

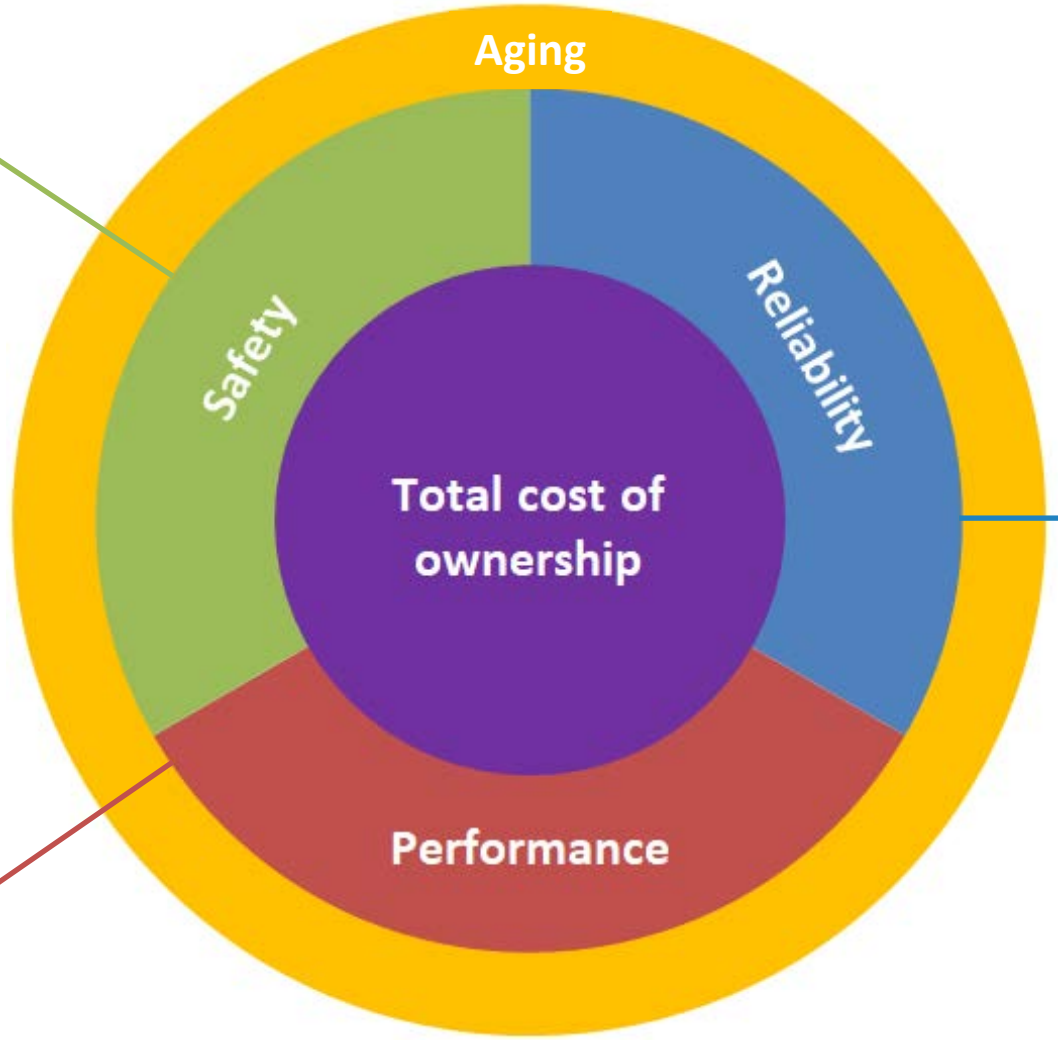
Customer level – Example: PV mini-grid for SKA1 low radio telescope in Australia

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

Key factors affecting bankability and insurability of PV + storage projects

- Component and system level
- Functional safety



- Component and system level
- Operating conditions

- System efficiency
- System effectiveness

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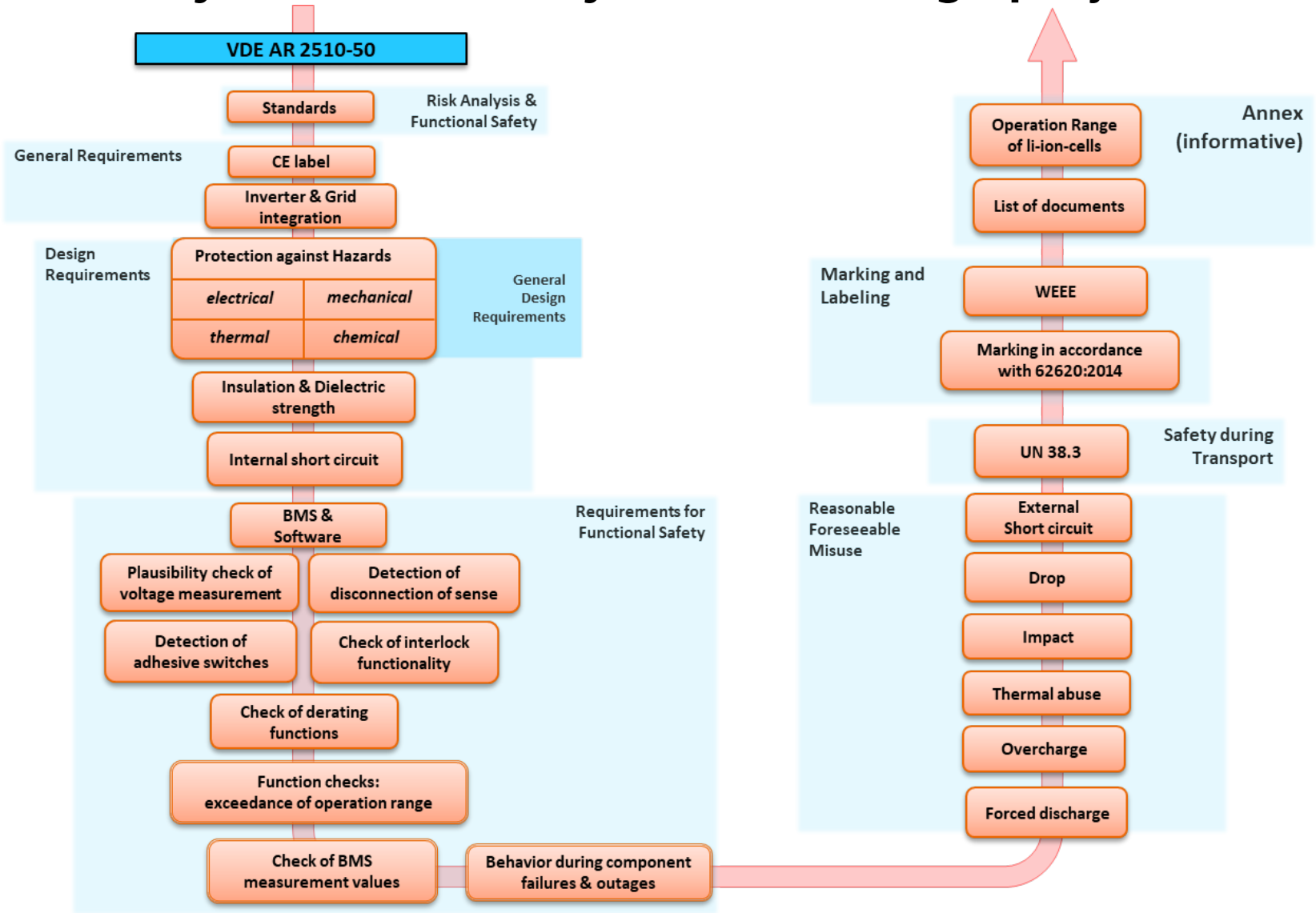
Key factors affecting bankability and insurability of PV + storage projects

Safety

- Example VDE application rule VDE AR 2510-50:

  Stationary energy storage systems with lithium batteries – Safety requirements



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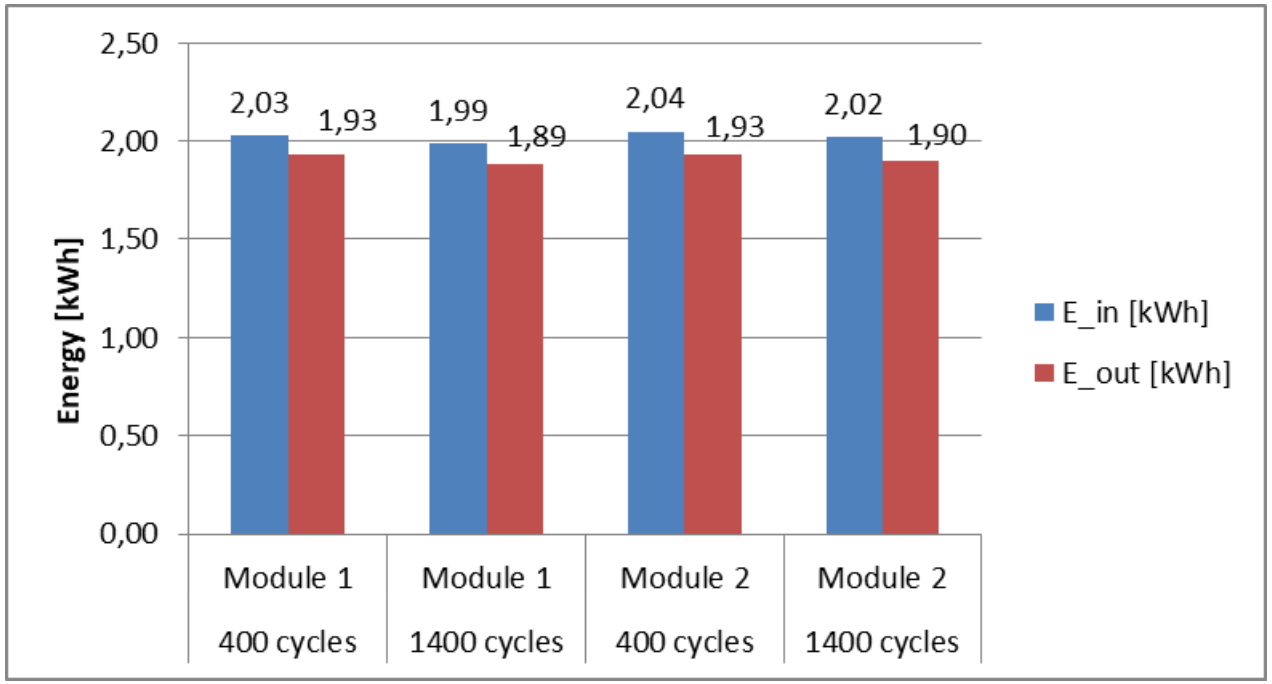
Key factors affecting bankability and insurability of PV + storage projects

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



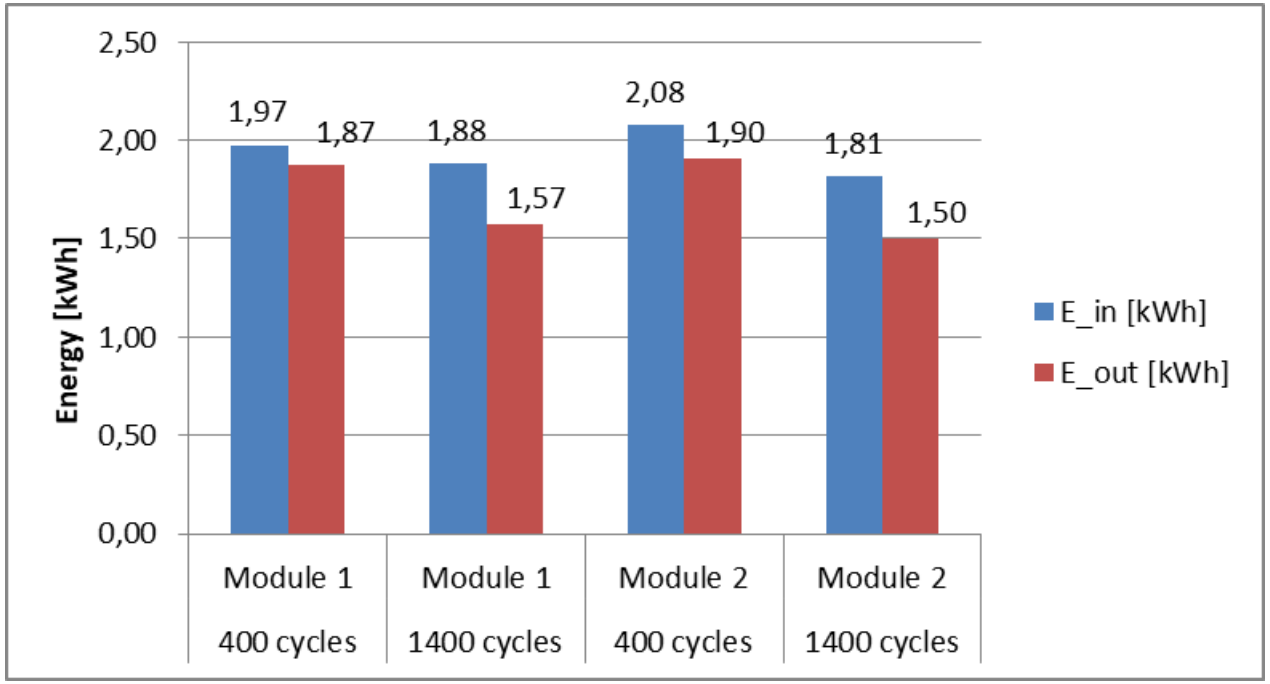
n	400	1400	400	1400
	module 1	module 1	module 2	module 2
E_in [kWh]	2.03	1.99	2.04	2.02
E_out [kWh]	1.93	1.89	1.93	1.90
Efficiency	95.30%	94.91%	94.57%	94.04%
Capacity loss		2.44%		1.85%
Efficiency loss		0.39%		0.53%

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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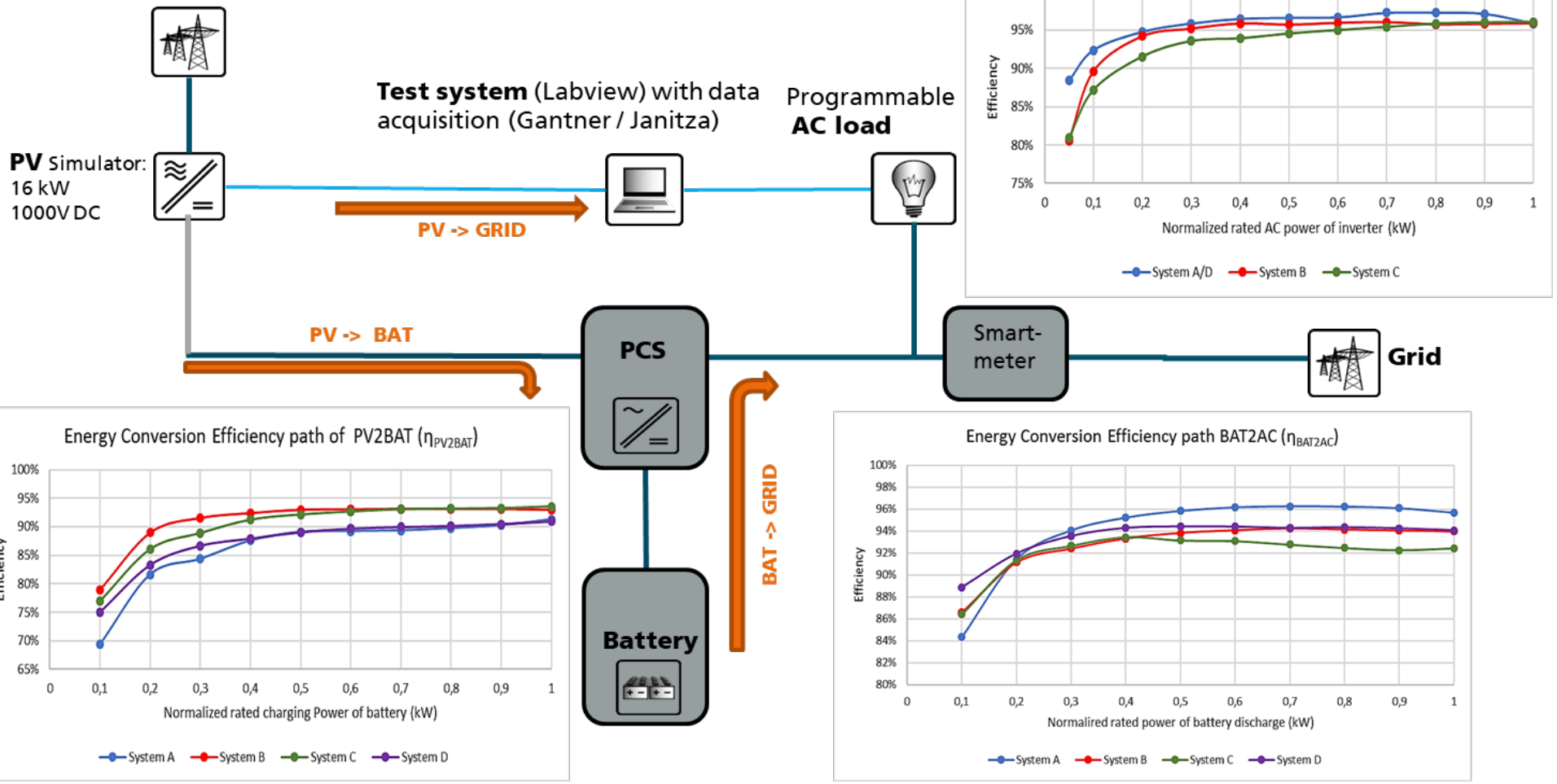
Key factors affecting bankability and insurability of PV + storage projects

Performance – Efficiencies: Examples of PV home storage systems



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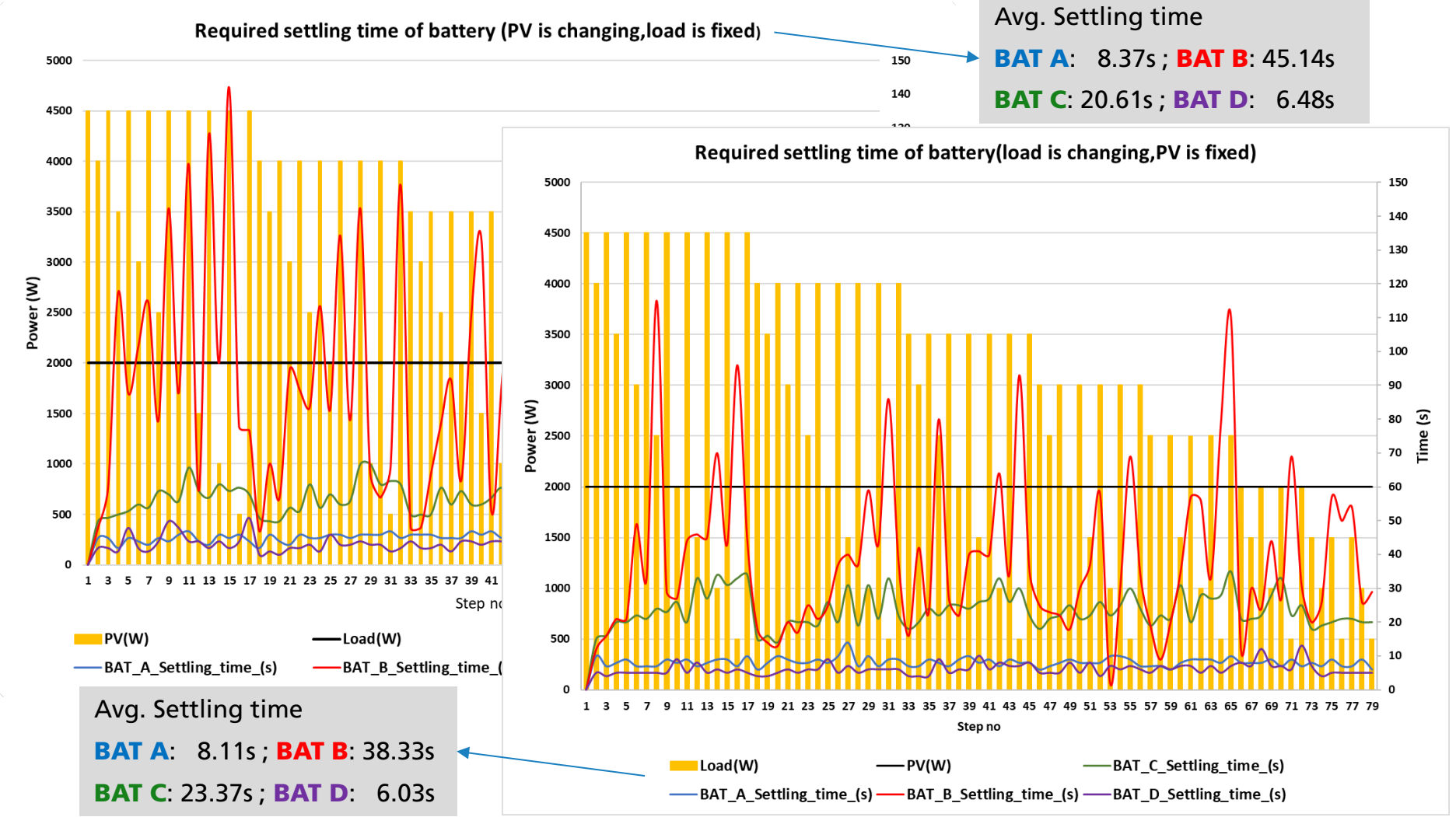
Key factors affecting bankability and insurability of PV + storage projects

Performance – Effectiveness: Examples of PV home storage systems

- Settling times



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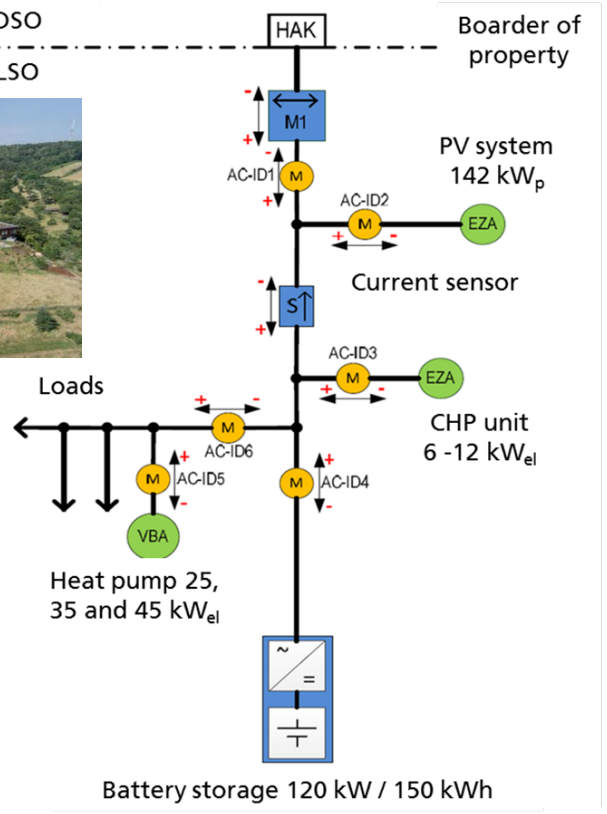
Key factors affecting bankability and insurability of PV + storage projects

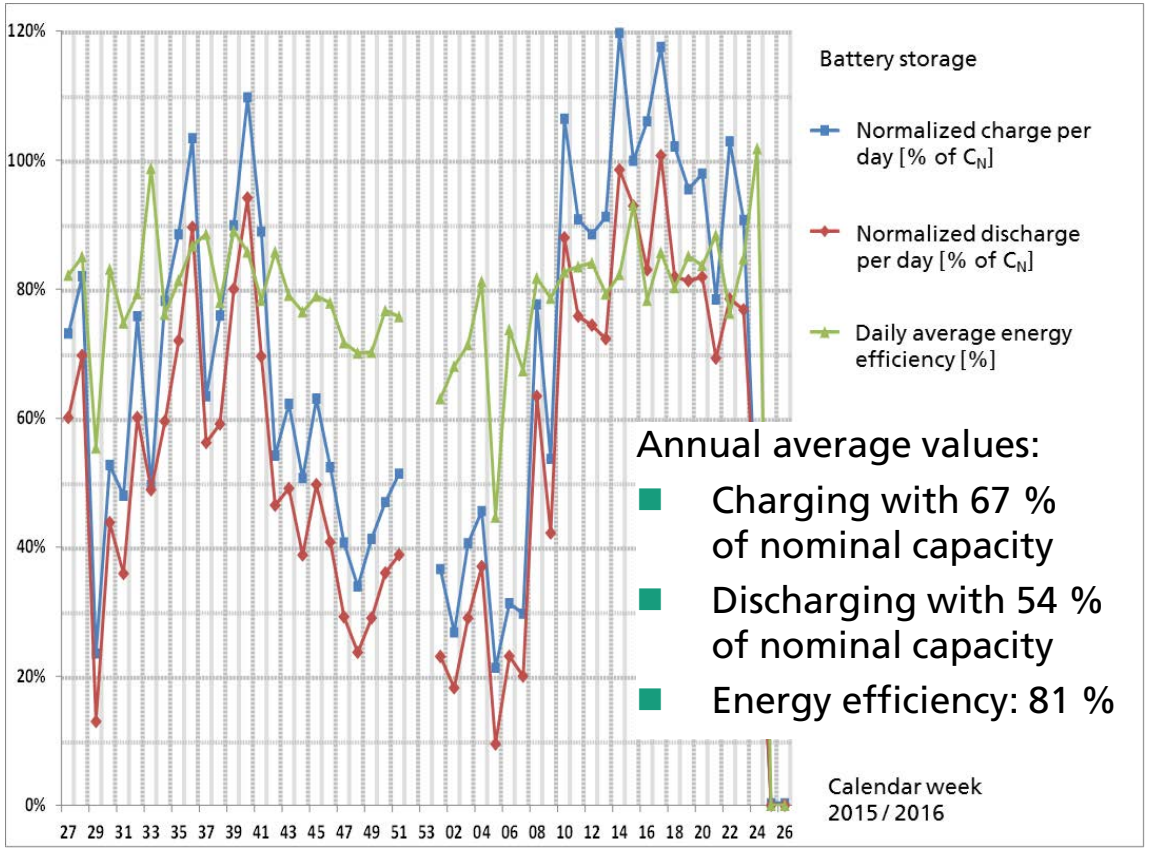
Performance – Efficiency: Example of smart district “Weinsberg”

- Results of measurement campaign

System concept of district power supply



Analysis of battery storage operation



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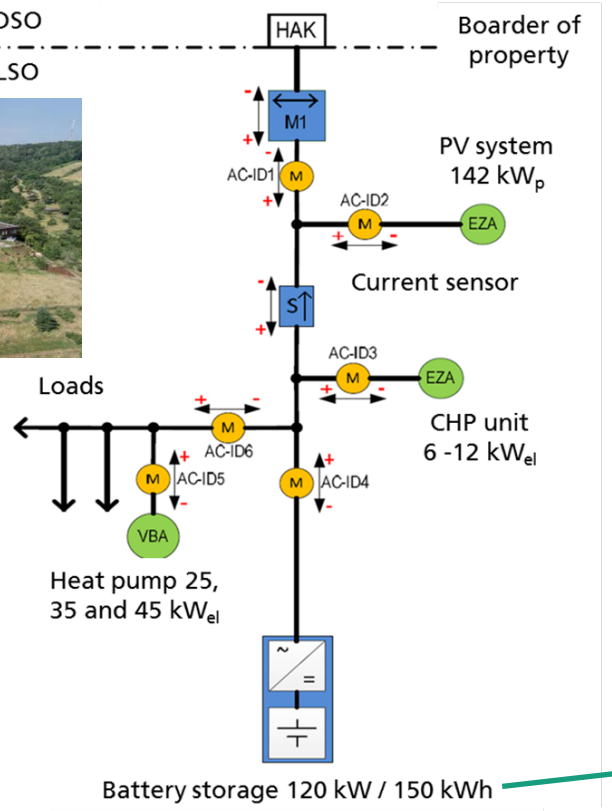
Key factors affecting bankability and insurability of PV + storage projects

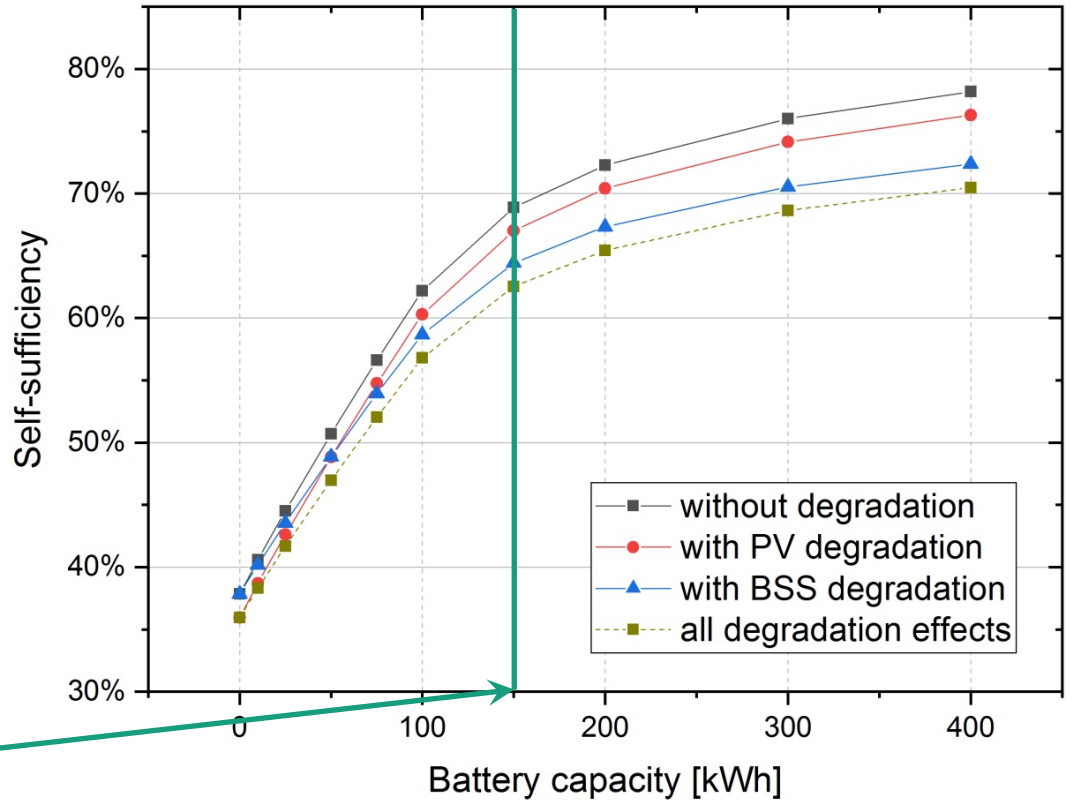
Performance – Effectiveness: Example of smart district “Weinsberg”

- Simulation based analyses

System concept of district power supply



Reduction of self-sufficiency over time

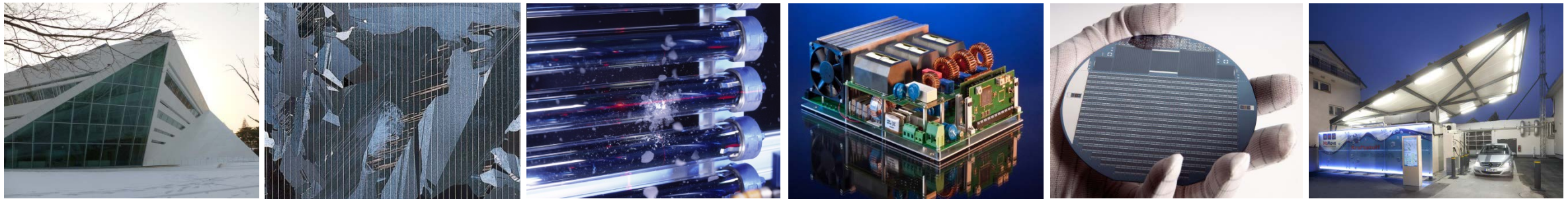


Source: L. Millet et al.: Extensive analysis of photovoltaic battery self-consumption: Evaluation through an innovative district case-study; Applied Physics Reviews, 2019.

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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