BATTERY STORAGE IN STATIONARY APPLICATIONS
MARKETS, TECHNOLOGIES AND KEY FACTORS

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Solar Power Africa Virtual Conference

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AGENDA

- Introduction to battery research, development and services at Fraunhofer ISE
- Stationary battery storage – Mission
- Stationary battery storage – Market developments
- Stationary battery storage – Market segments and examples
- Stationary battery storage – Technology targets and new developments
- Key factors for battery storage product and project evaluation
- Conclusions

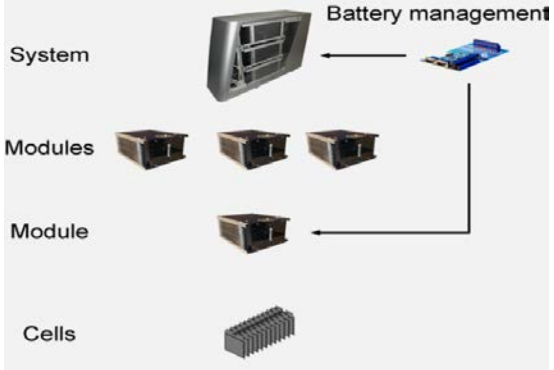
Department Electrical Energy Storage

Overview – Research, Development and Services

Battery Cell Technology
materials, architecture, production

- Development and characterization of materials and battery cells
- Development of process technologies
- Aqueous systems for stationary energy storage
- Lithium ion battery cells
- Solid state battery cells
- Technical and economical analysis
- Life cycle analysis

Battery Engineering
from cells to systems



- Cell formation
- Cell and system characterization
- Ageing and performance scrutiny
- System design and engineering
- Thermal management
- Battery management
- Algorithms for state estimation and life time prediction
- Optimized charging and operating control strategies

Applied Storage Systems
system design, integration and quality assurance

- Realization of lighthouse projects
- Business case development
- Consulting during complete life cycle of storage projects
- System modelling, analysis and optimized system design
- Simulation based storage sizing
- Energy management systems
- Technical due diligence: Site inspection, testing and monitoring

TestLab Batteries
electrical, thermal, mechanical testing

- Ageing: calendric and cyclic
- Safety: components and systems including functional safety
- Reliability: consideration of operating conditions and system behavior with aged components
- Performance: efficiency and effectiveness
- End-of-line quality control for cell production

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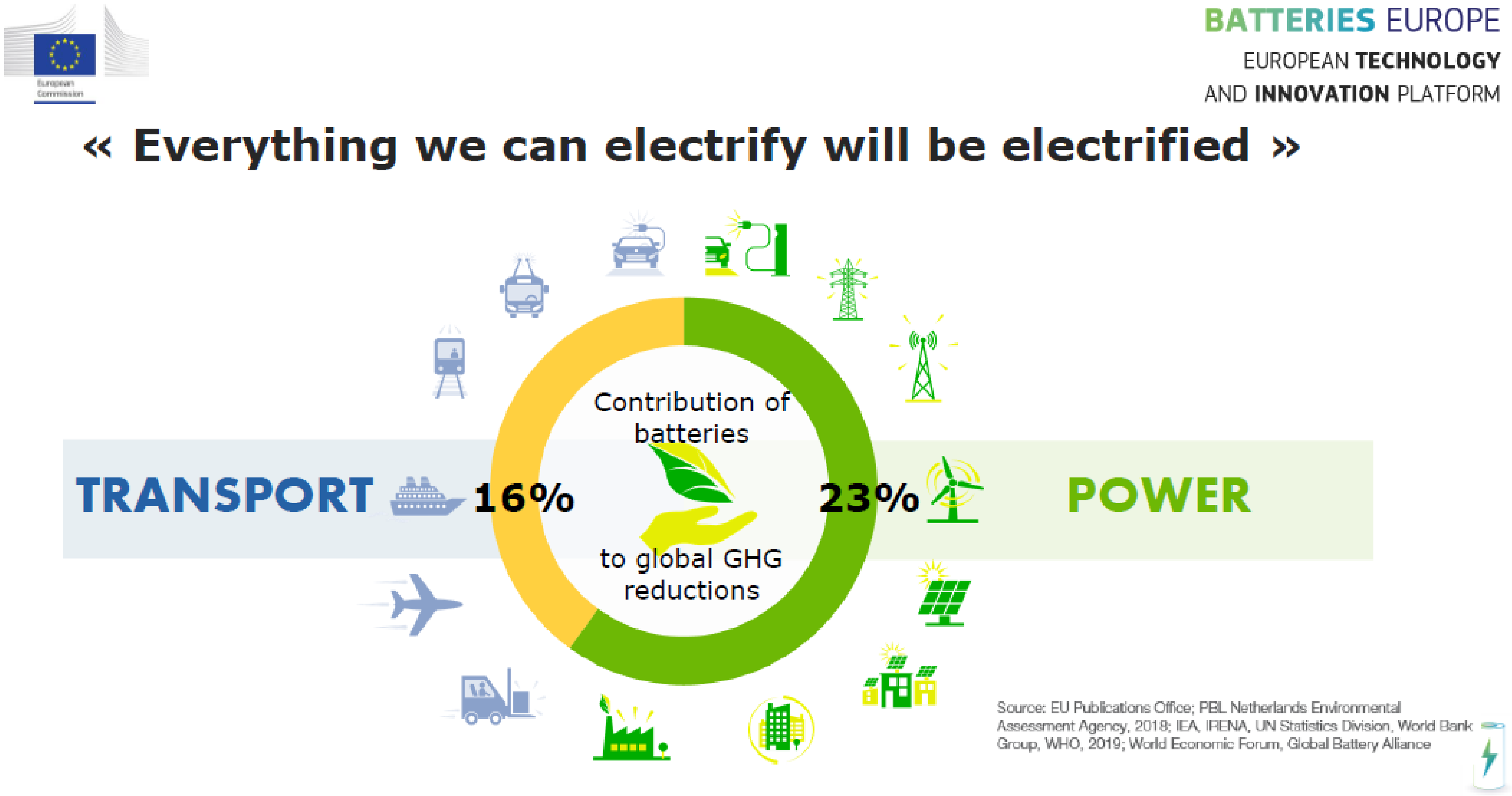
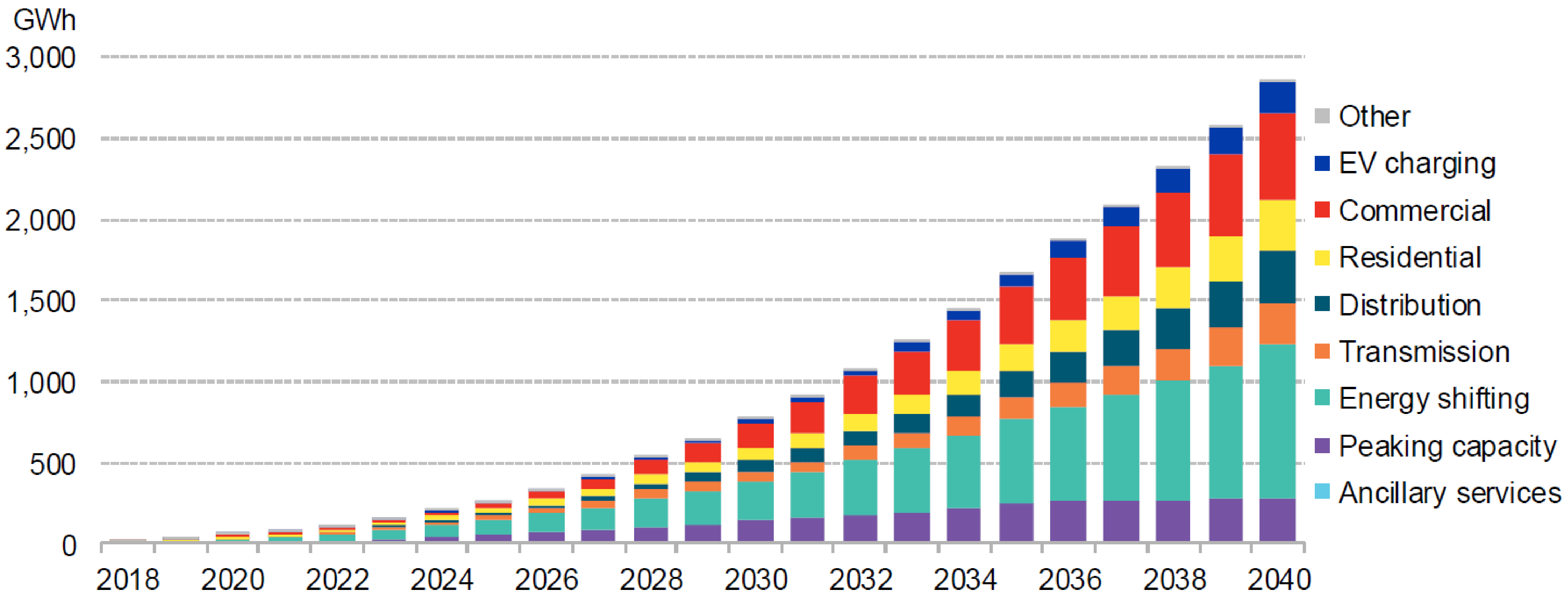
Stationary battery storage – Mission

Batteries Europe: Strategic Research Agenda – Extract



Source: E. Sheridan: Batteries Europe, European Technology and Innovation Platform – Overview of Strategic Research Agenda, Batteries Europe Webinar, 28th of October 2020.

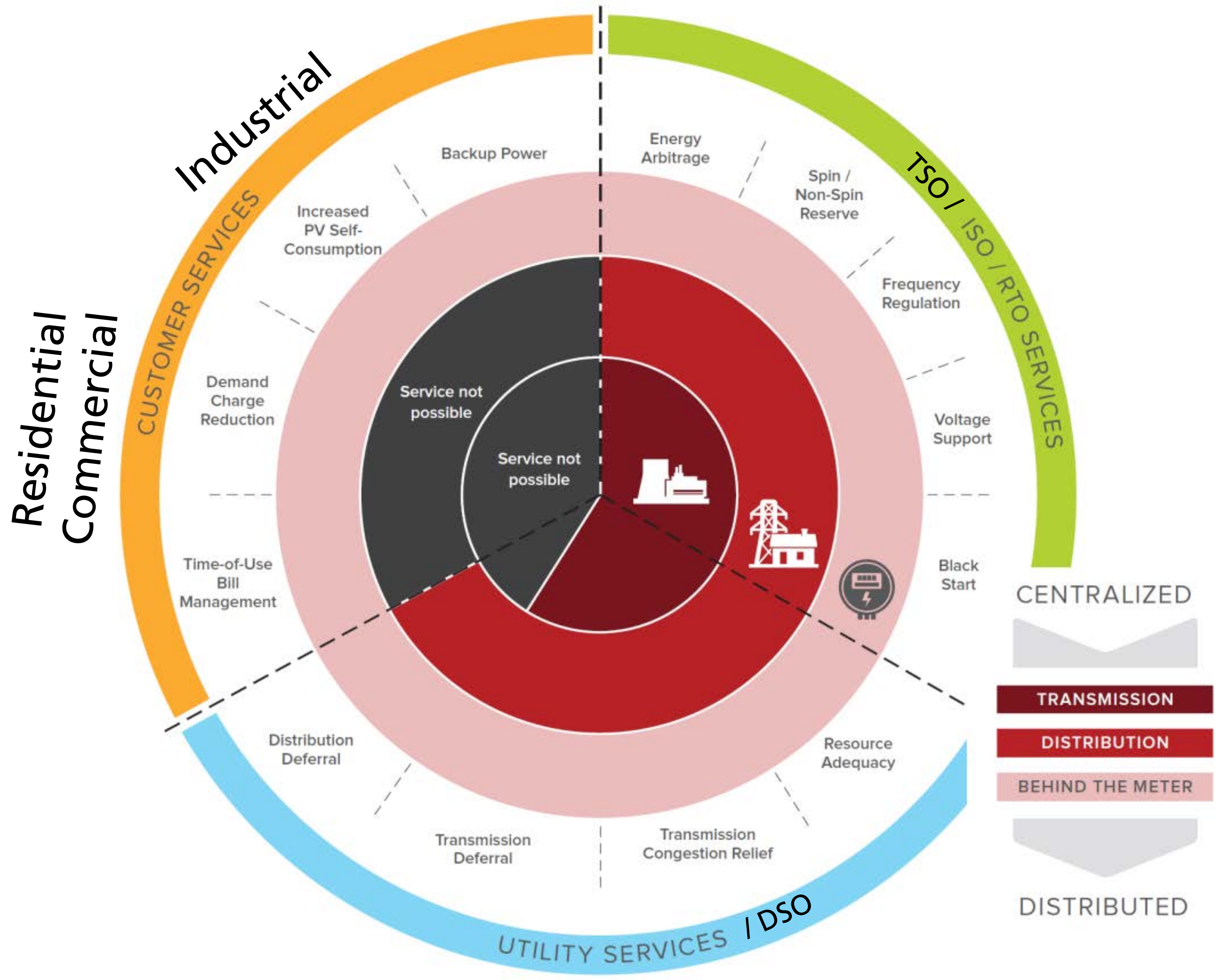
Stationary battery storage – Market developments
Prognosis for global cumulative deployments



Source: BloombergNEF, 2019.

Stationary battery storage – Market segments

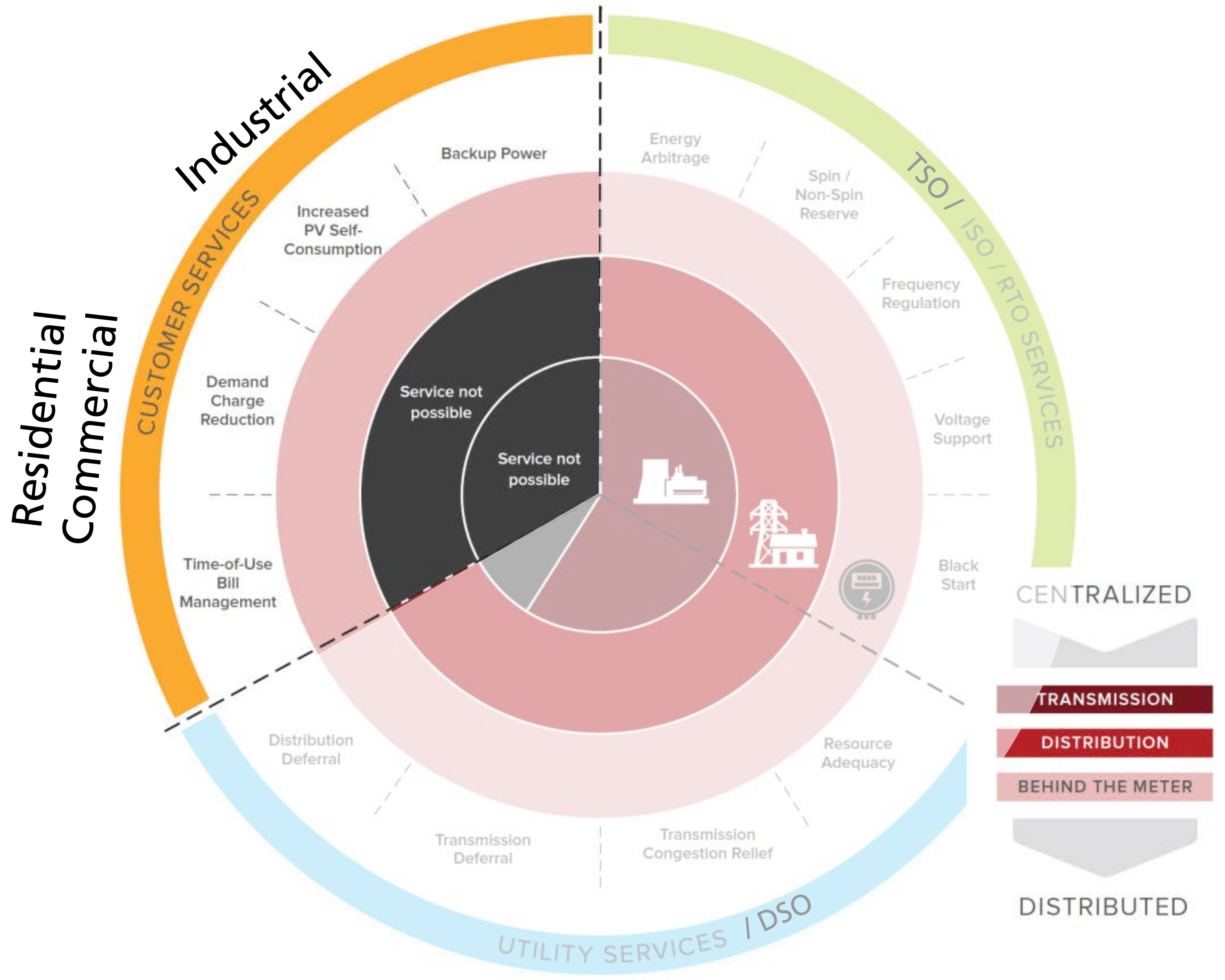
Provision of services to three stakeholder groups



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

Stationary battery storage – Market segments
Customer level

Provision of services to
three stakeholder groups



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

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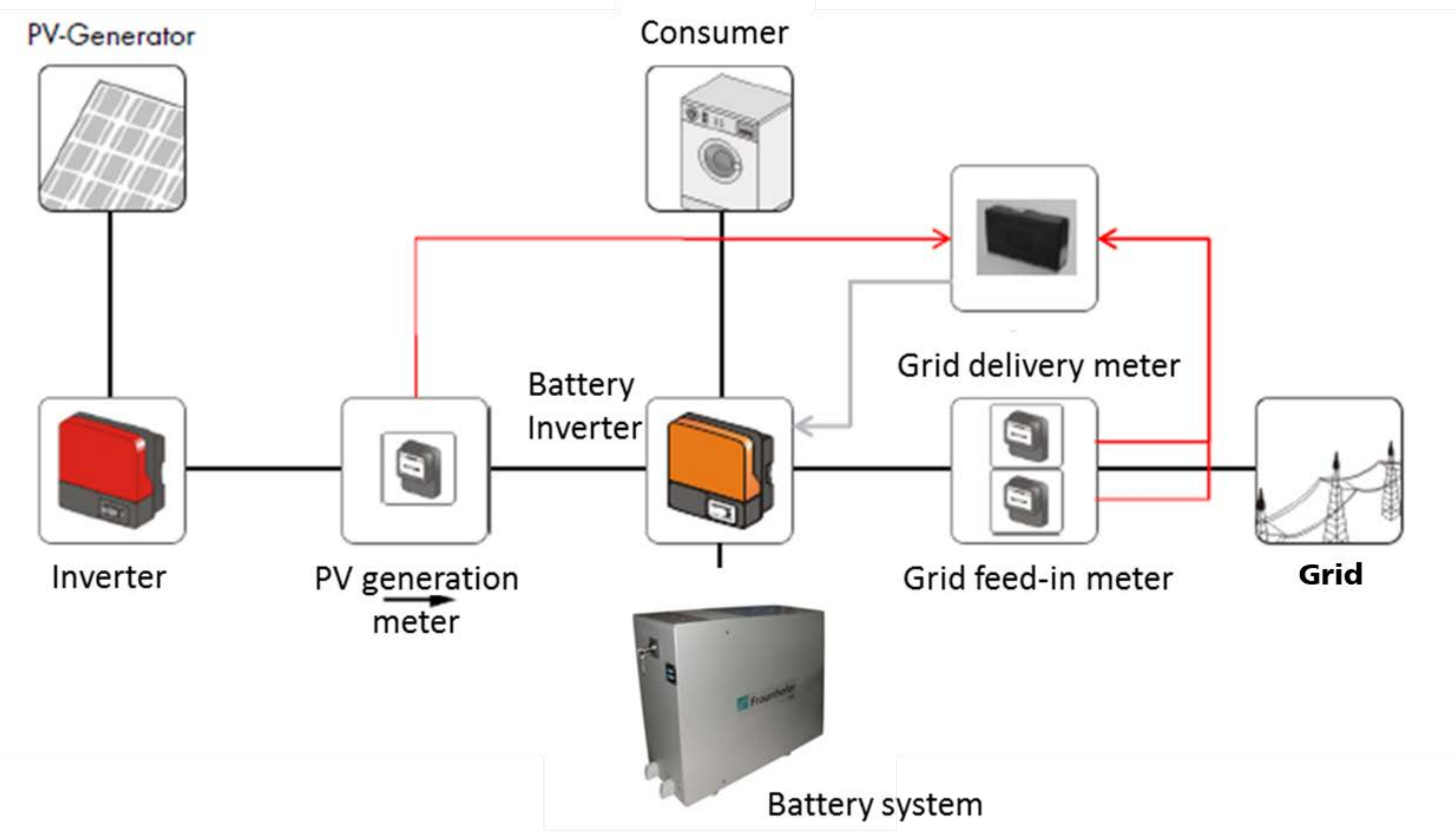
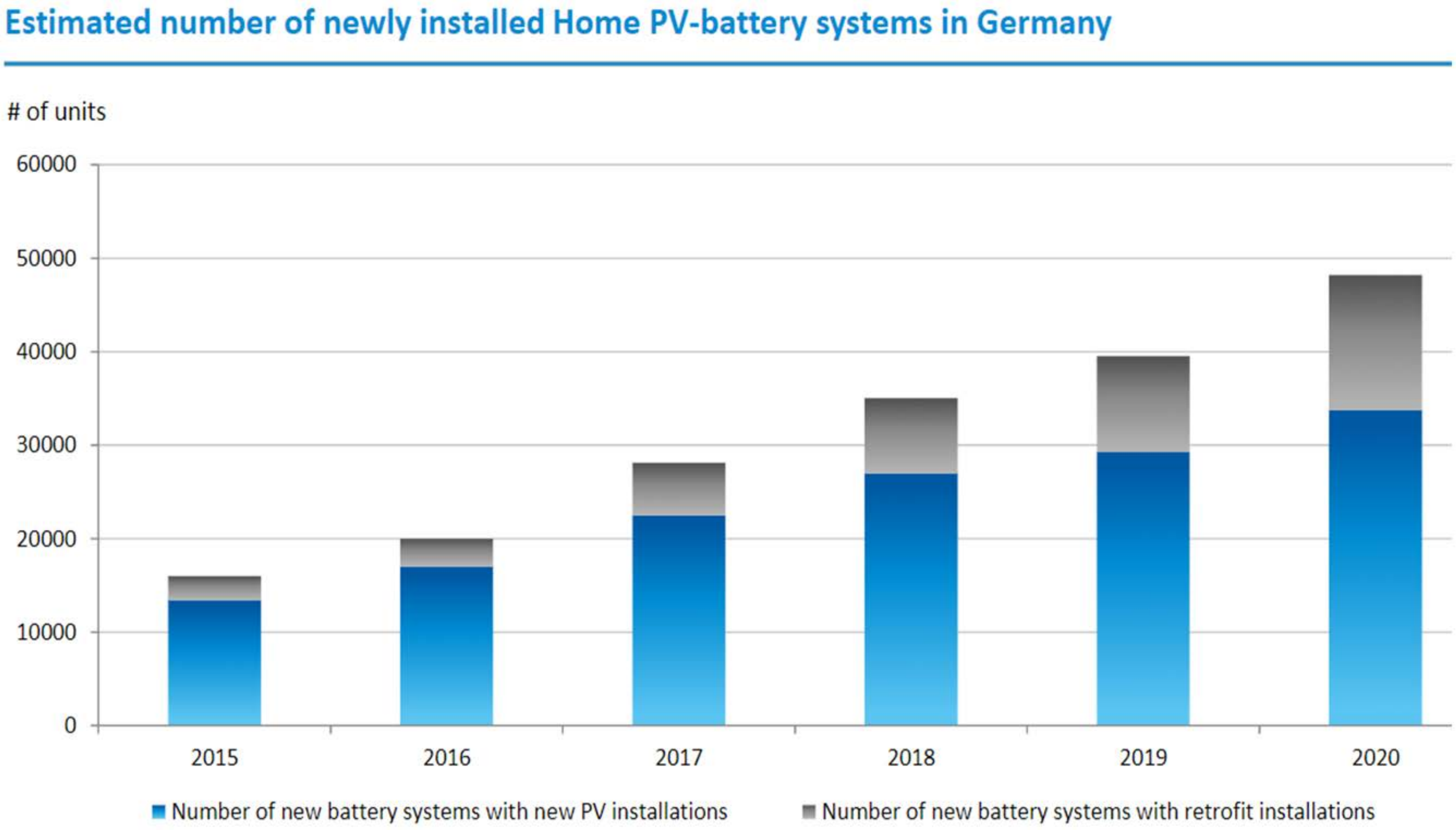
Stationary battery storage – Market segments
Customer level – Example: Residential PV battery systems



Source: SMA

Stationary battery storage – Market segments

Customer level – Example: Residential PV battery systems in Germany



Source: GTAI, 2019.

Stationary battery storage – Market segments

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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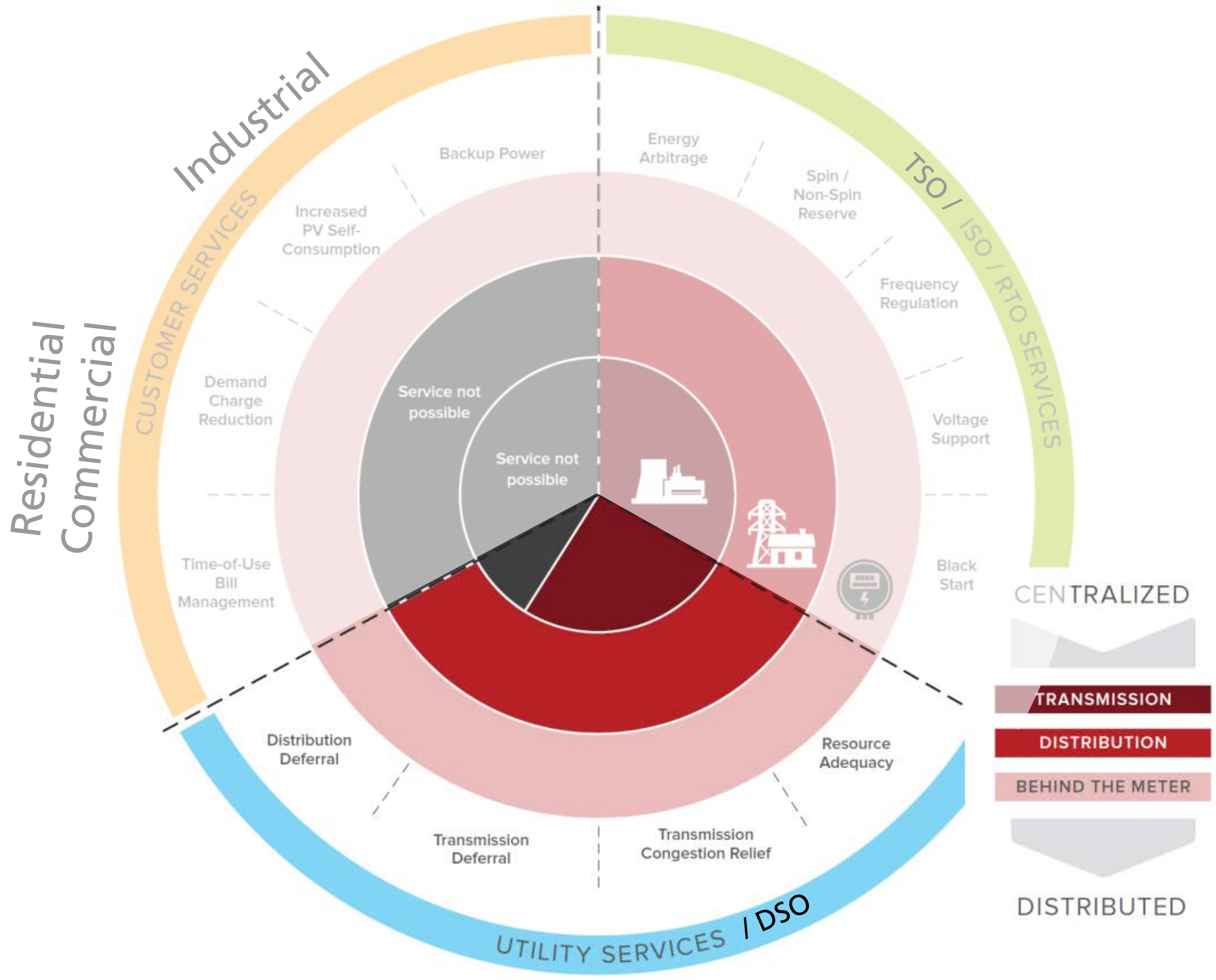
Stationary battery storage – Market segments
Distribution level

Provision of services to three stakeholder groups



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

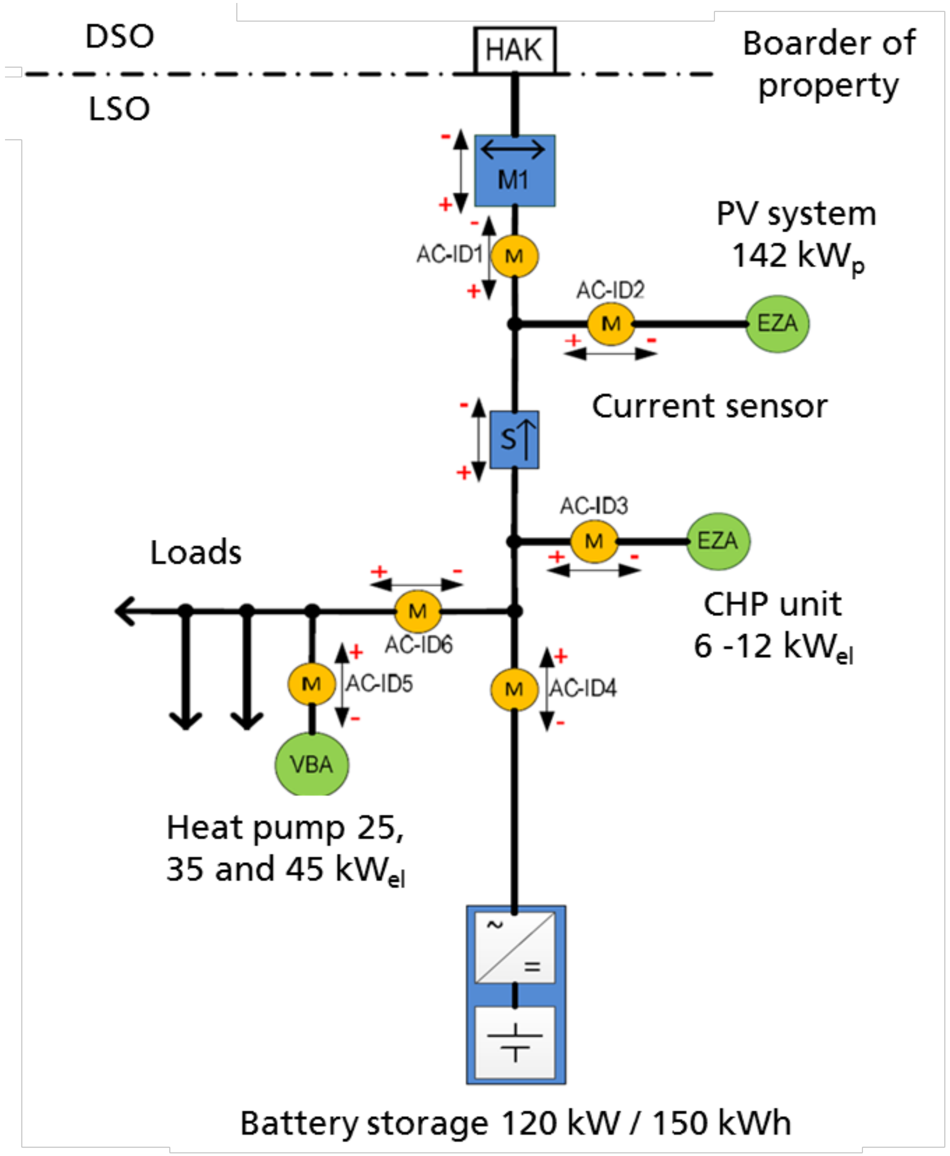
Stationary battery storage – Market segments

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

Optimization criteria:

Minimization of grid dependency –

Physically not only accumulated



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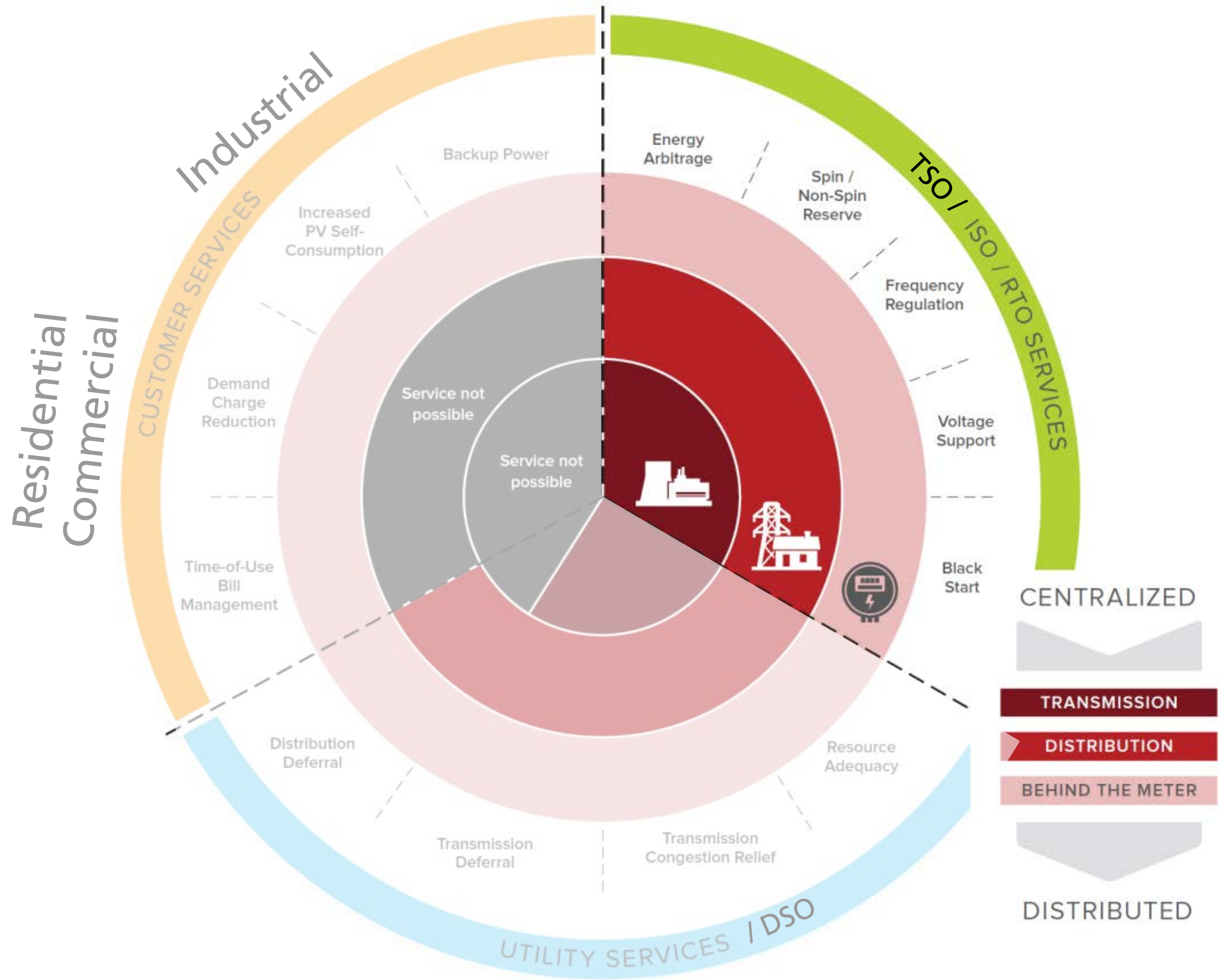
Stationary battery storage – Market segments
Transmission level

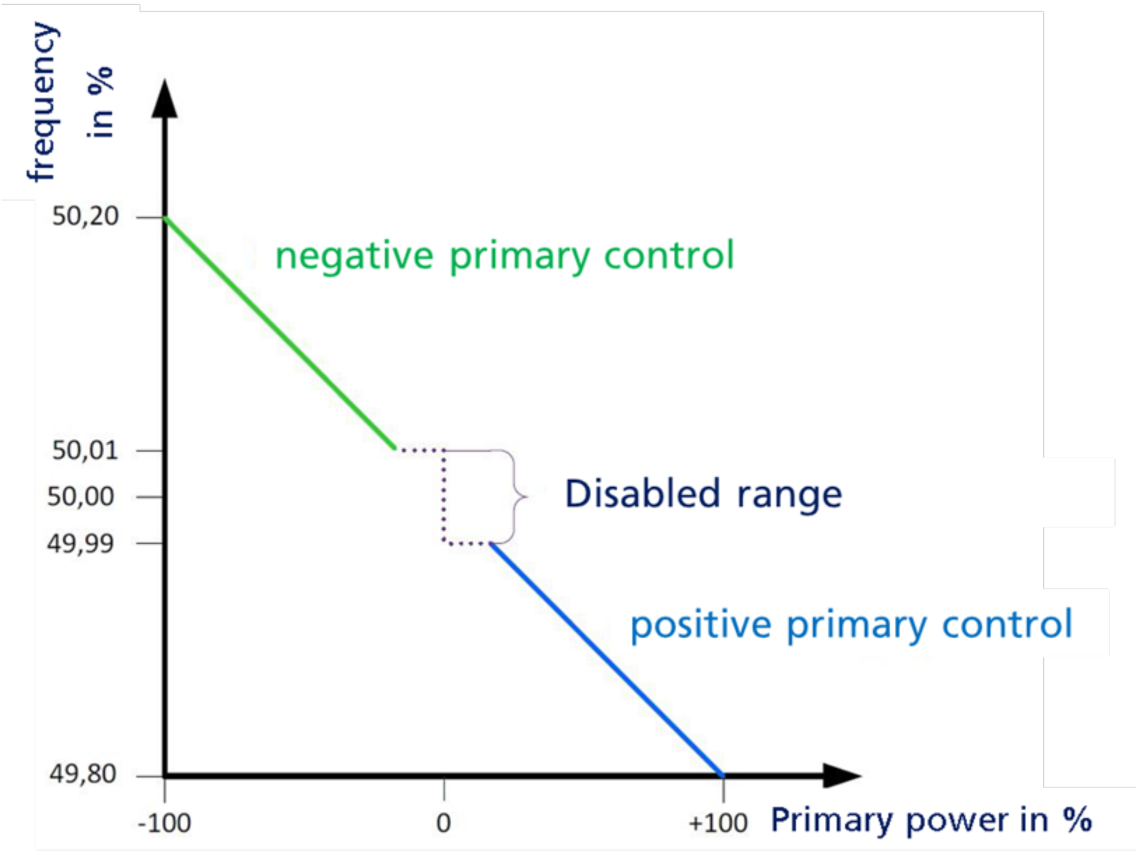
Batteries can provide up to 13 services to three stakeholder groups

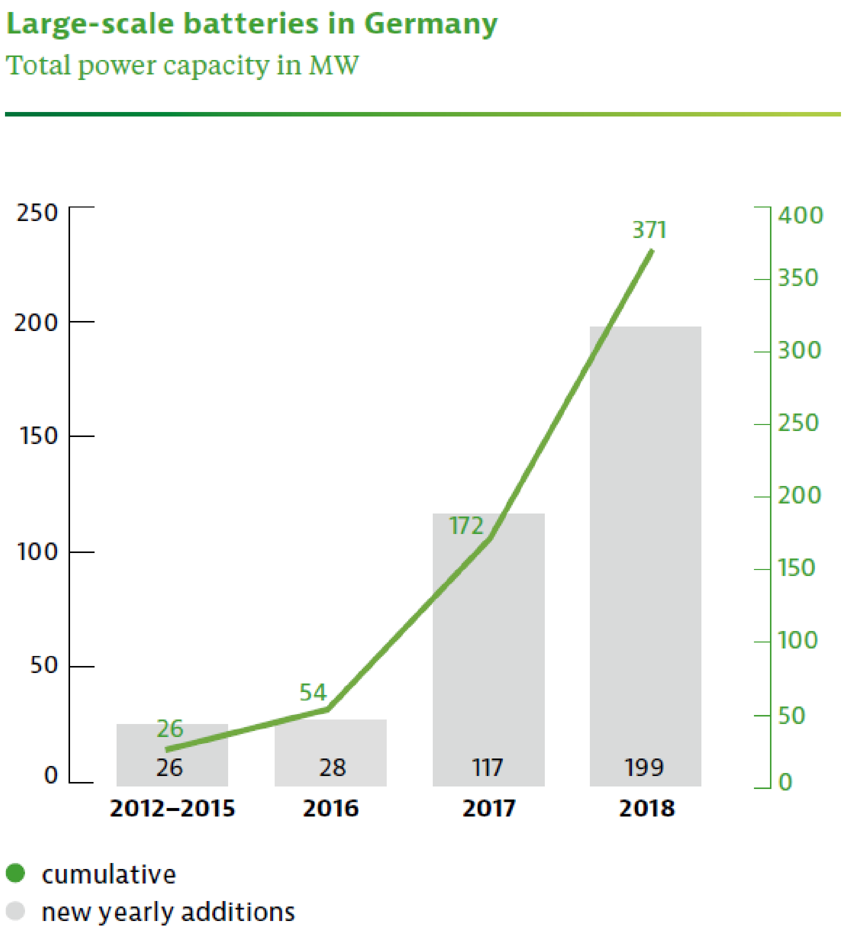


Source: F. Garrett, The Economics of Battery Energy Storage, Rocky Mountain Institute, September 2015.

Stationary battery storage – Market segments

Transmission level – Example: Primary control power in Germany





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.

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Stationary battery storage – Technology targets and new developments

Batteries Europe: Strategic Research Agenda – Extract

BATTERIES EUROPE
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

Batteries for Stationary storage

Innovative technologies and components to decrease battery cost for stationary applications, improve calendar and cycle life and ensure optimal performance

Full Equivalent Cycle life for stationary applications depending on the application,

increased to 15,000 cycles or calendar life increased to 30 years, For power-orientated services C rate capability up to 8C, self-discharge 0,1% of SoC per month, discharge duration +10 hours

Technologies, methodologies and tools to enhance safety in stationary electrical energy storage systems

Open access and interoperable advanced Battery Management Systems

Support the creation and up-take of second-life applications market for EV batteries, so contributing to sustainability and competitiveness of batteries…will also facilitate hybridisation for smart energy integration

…stationary storage will contribute to the security of electricity supply in Europe while improving grid flexibility and allowing further RES penetration… "

Source: E. Sheridan: Batteries Europe, European Technology and Innovation Platform – Overview of Strategic Research Agenda, Batteries Europe Webinar, 28th of October 2020.

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Stationary battery storage – Technology targets and new developments

Batteries Europe: Strategic Research Agenda – Extract: Lithium batteries

- Lithium-ion "evolution"
- Solid state "revolution"

→ Lithium dominates the current decade

→ Technology targets are mainly driven by the transport sector !

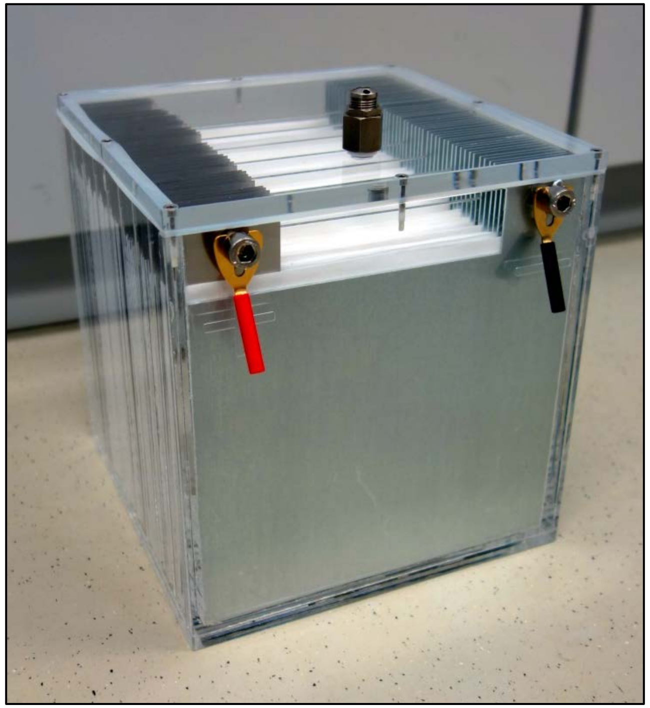
Battery Generation	Electrodes active materials	Cell Chemistry / Type	Forecast market deployment
Gen 1	• Cathode: LFP, NCA • Anode: 100% carbon	Li-ion Cell	current
Gen 2a	• Cathode: NMC111 • Anode: 100% carbon	Li-ion Cell	current
Gen 2b	• Cathode: NMC523 to NMC 622 • Anode: 100% carbon	Li-ion Cell	current
Gen 3a	• Cathode: NMC622 to NMC 811 • Anode: carbon (graphite) + silicon content (5-10%)	Optimised Li-ion	2020
Gen 3b	• Cathode: HE-NMC, HVS (high-voltage spinel) • Anode: silicon/carbon	Optimised Li-ion	2025
Gen 4a	• Cathode NMC • Anode Si/C • Solid electrolyte	Solid state Li-ion	2025
Gen 4b	• Cathode NMC • Anode: lithium metal • Solid electrolyte	Solid state Li metal	>2025
Gen 4c	• Cathode: HE-NMC, HVS (high-voltage spinel) • Anode: lithium metal • Solid electrolyte	Advanced solid state	2030
Gen 5	• Li|O_2 – lithium air / metal air • Conversion materials (primarily Li|S) • new ion-based systems (Na, Mg or Al)	New cell gen: metal-air/ conversion chemistries / new ion-based insertion chemistries	>2030

Source: E. Sheridan: Batteries Europe, European Technology and Innovation Platform – Overview of Strategic Research Agenda, Batteries Europe Webinar, 28th of October 2020.

Stationary battery storage – Technology targets and new developments

Exemplary alternative for lithium-ion batteries: Zinc-ion technology

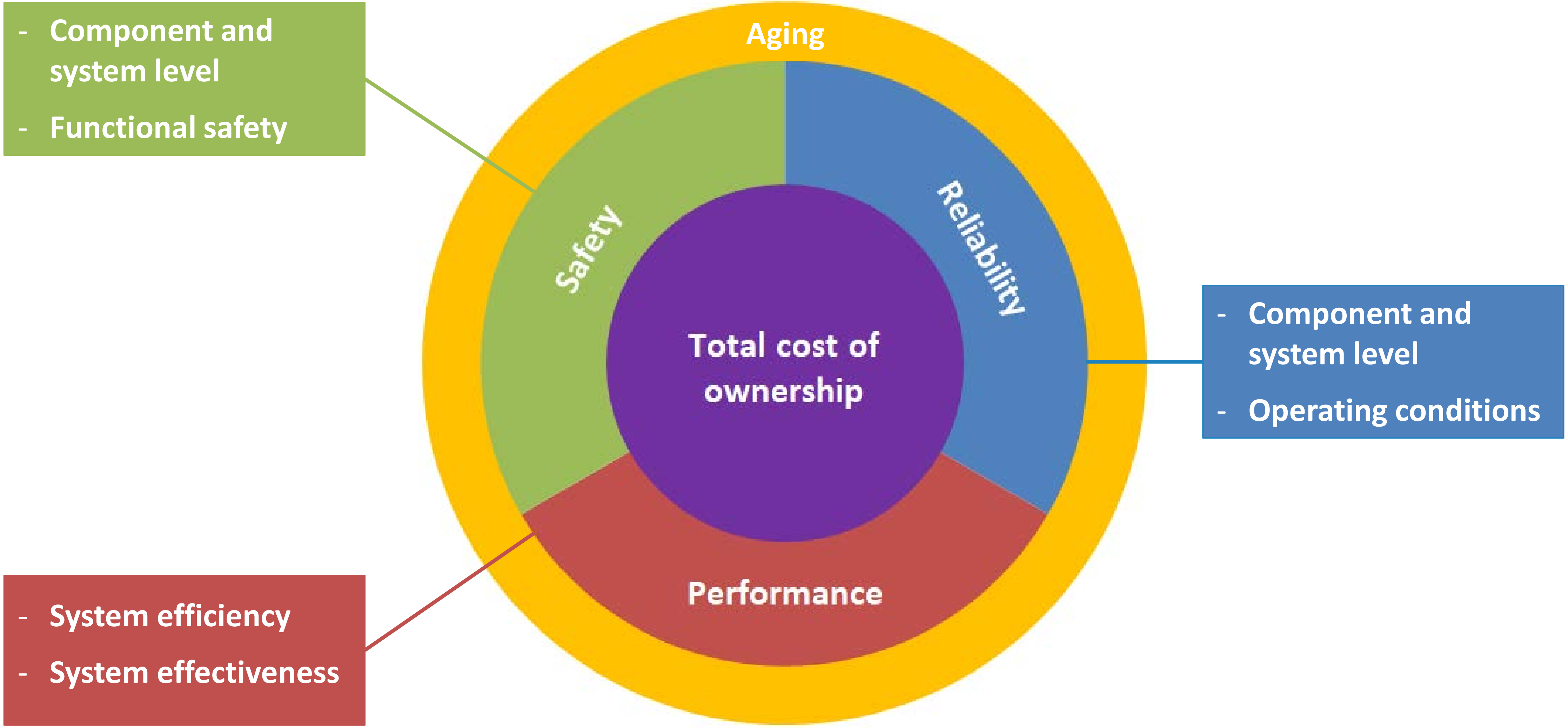
- Characteristics
  - Inherent safe
  - Cost-efficient
  - Environmentally friendly
- Status
  - Reaction mechanism of cell chemistry is still investigated *
- Demonstrator of Fraunhofer ISE
  - Voltage level: 12 V - 48 V
  - Volumetric energy density: ~ 45 Wh/l
  - Gravimetric energy density: ~ 50 Wh/kg
  - Degree of discharge: > 90%



Demonstrator stack with 6 cells, switched in series and a degassing valve.

* Source: Bischoff, Fitz et al. 2020, J. Electrochem. Soc. 2020, 167 (2), 20545. DOI: 10.1149/1945-7111/ab6c57.

Key factors for battery storage product and project evaluation



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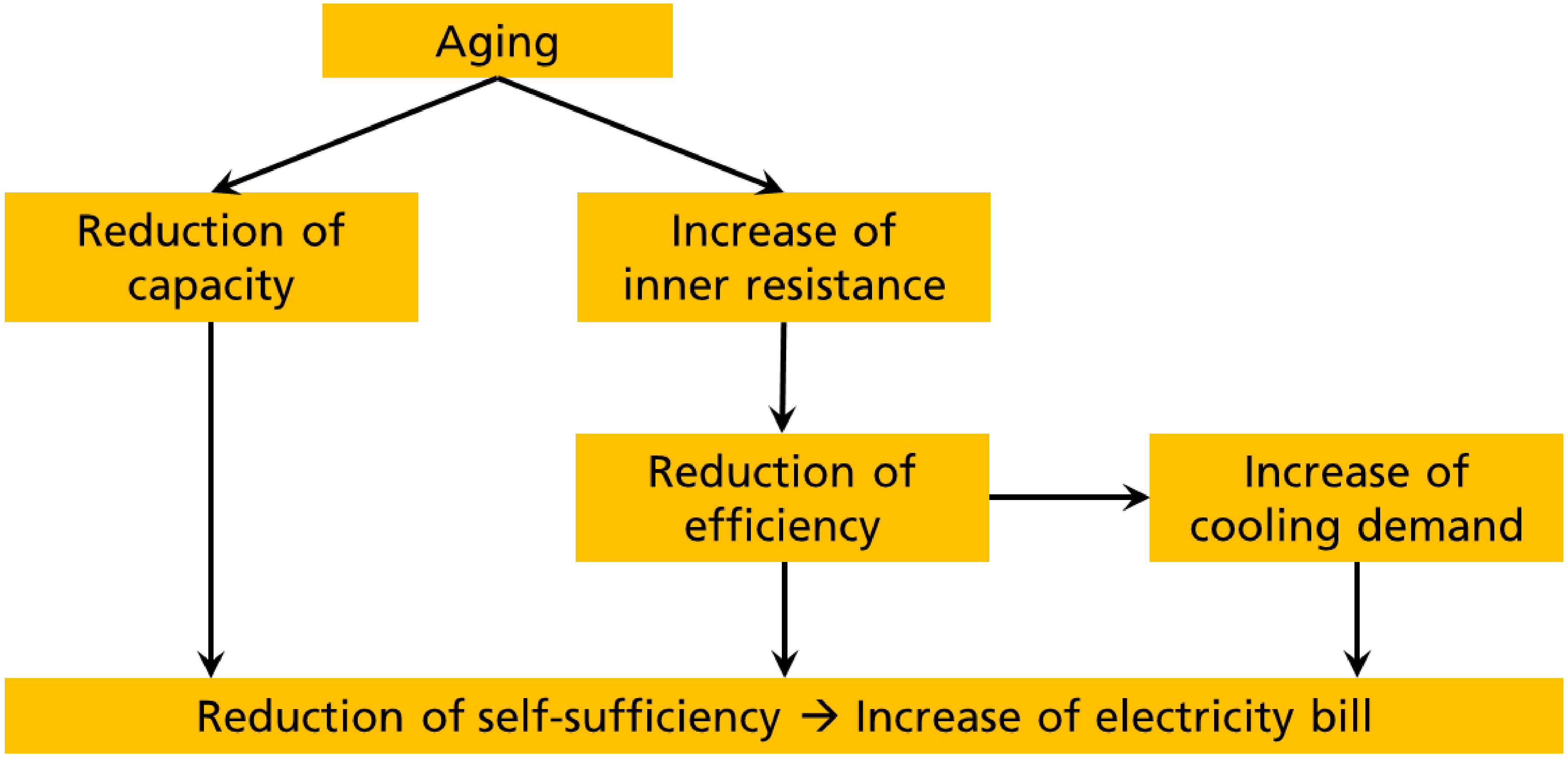
Aging of lithium-ion battery cells
Influence on system performance

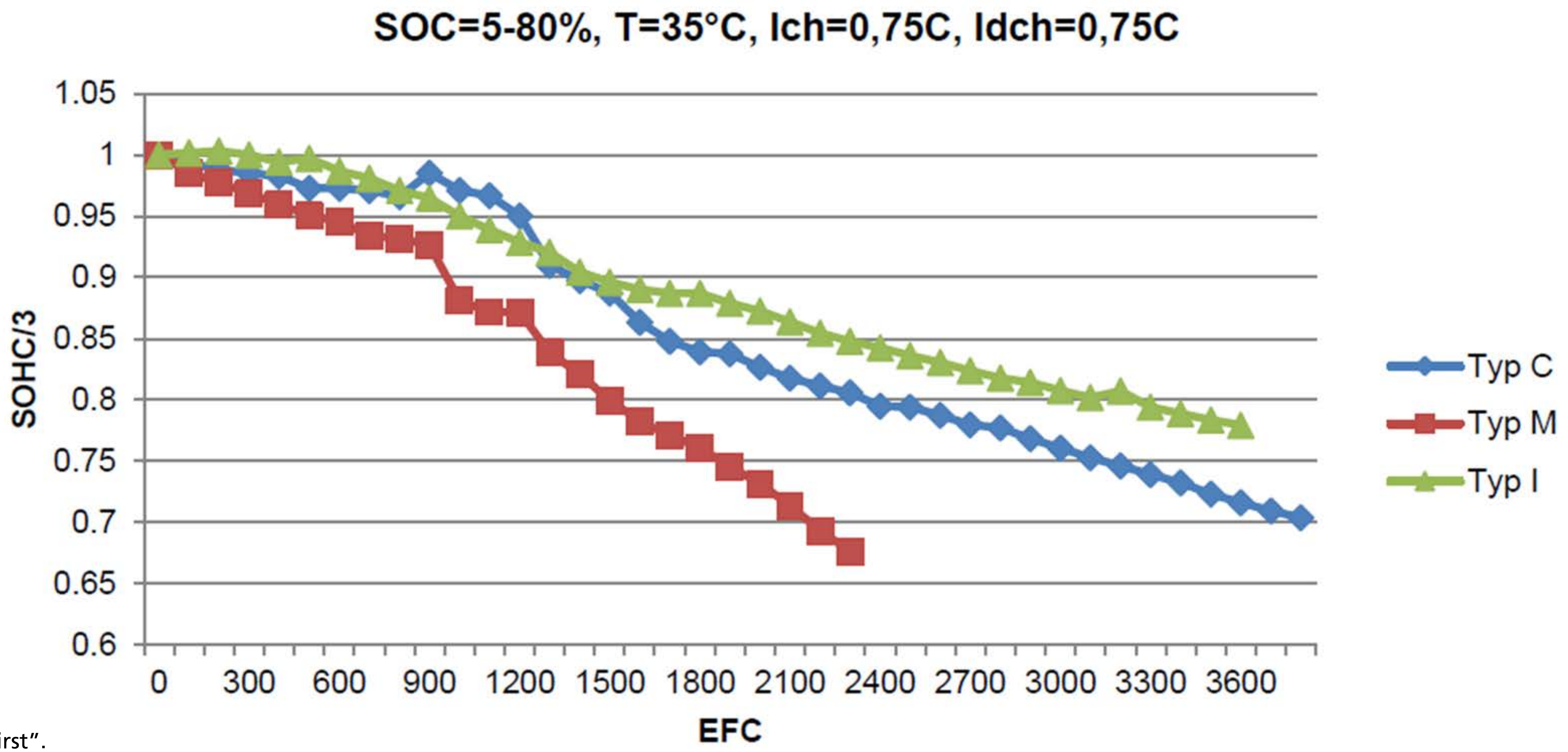
Example self-sufficiency of PV battery systems



Aging of lithium-ion battery cells

Examples of market available products (residential PV storage systems)

Cyclic aging – Capacity fade



Source: Final report project “SafetyFirst”.

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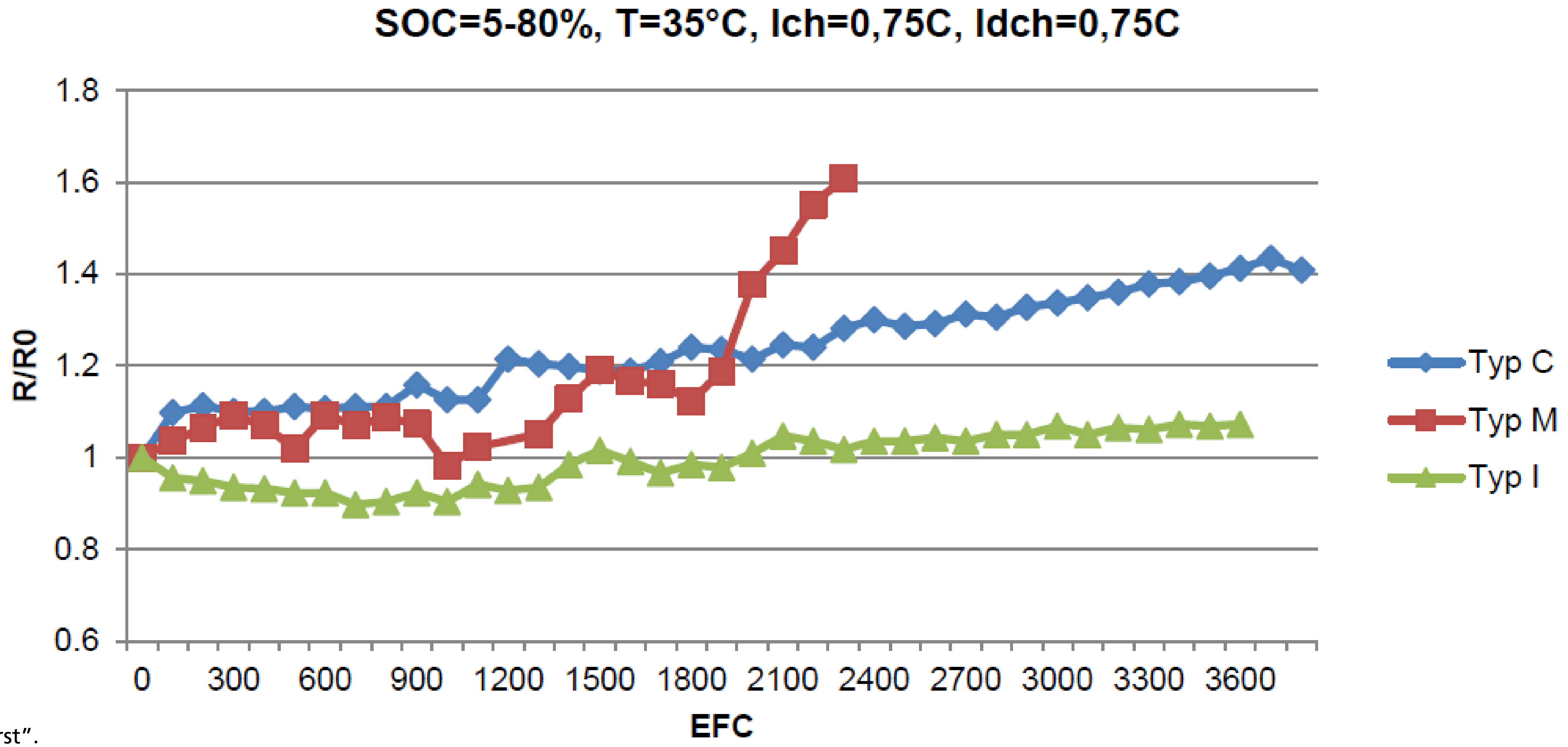
Aging of lithium-ion battery cells

Examples of market available products (residential PV storage systems)

Cyclic aging – Increase of inner resistance

Pulse test: 10 sec @ SOC = 50%



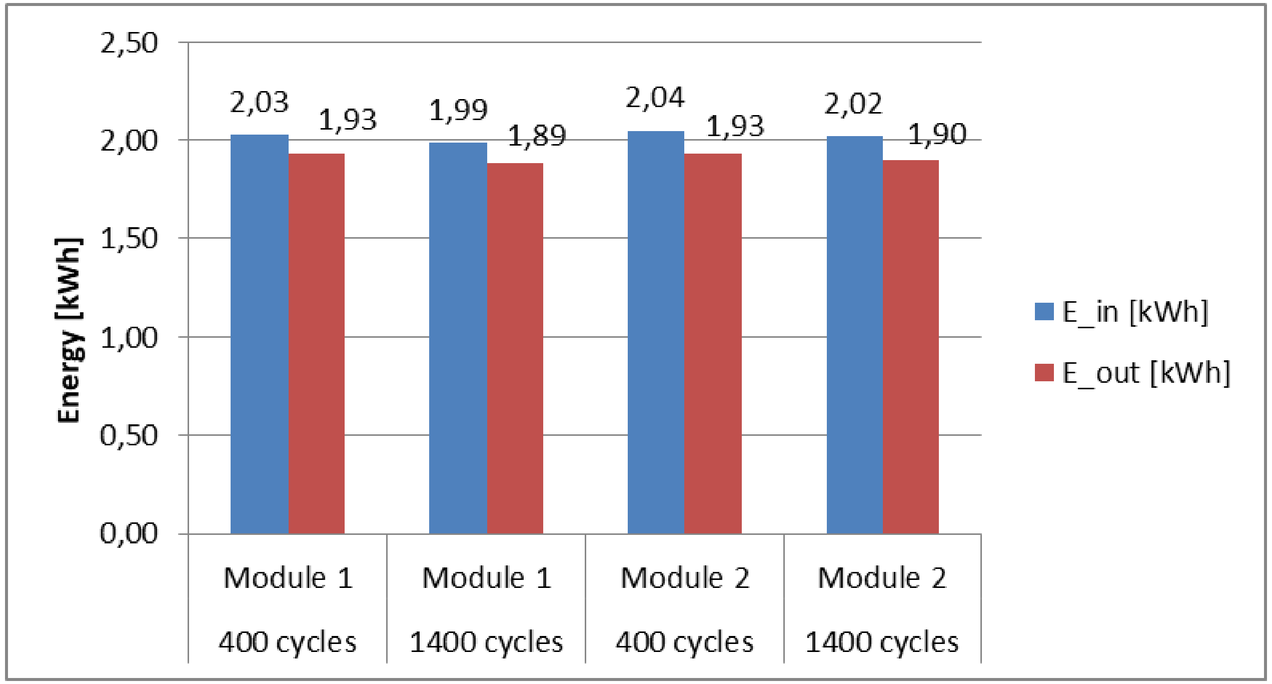
Source: Final report project "SafetyFirst".

Key factors for battery storage product and project evaluation

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



Number of cycles	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		0.39%		0.53%

Source: Final report project “SafetyFirst”.

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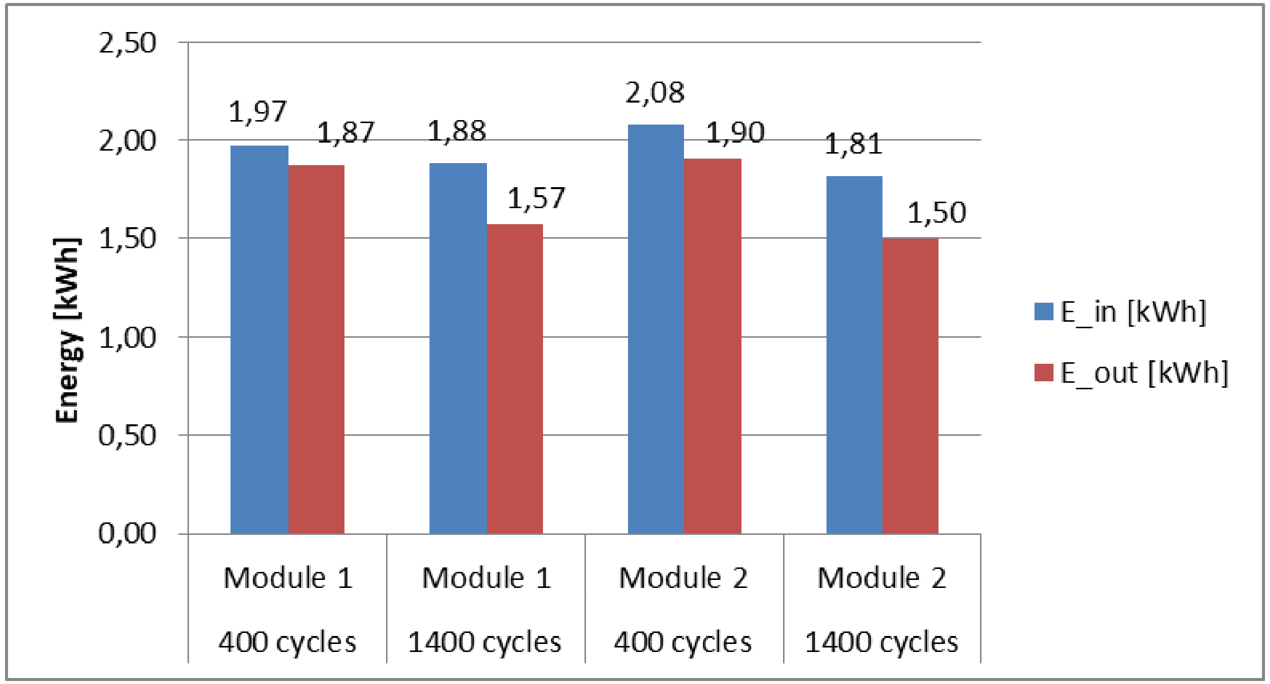
Key factors for battery storage product and project evaluation
Reliability – Example battery storage with aged battery modules

Battery storage product 2

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



Number of cycles	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		11.15%		9.01%

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

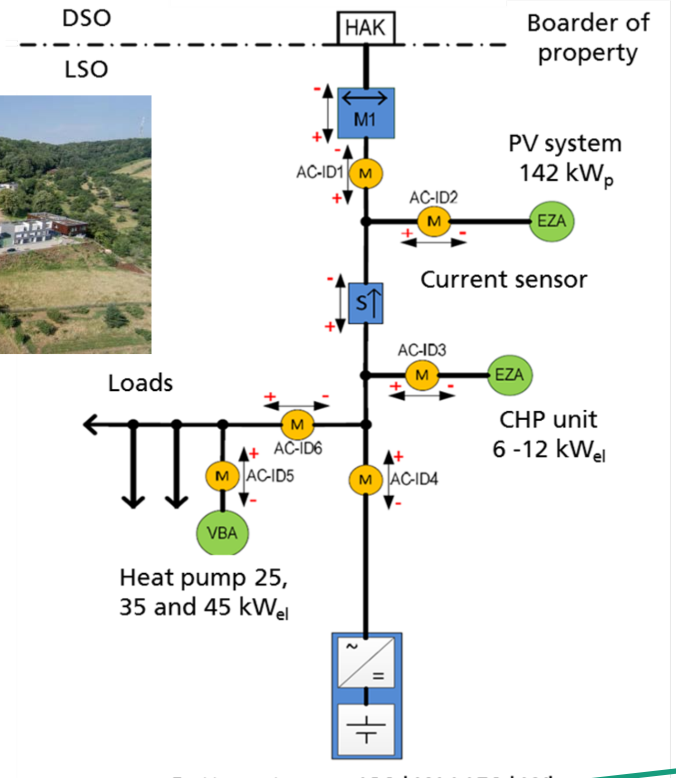
Source: Final report project "SafetyFirst".

Key factors for battery storage product and project evaluation

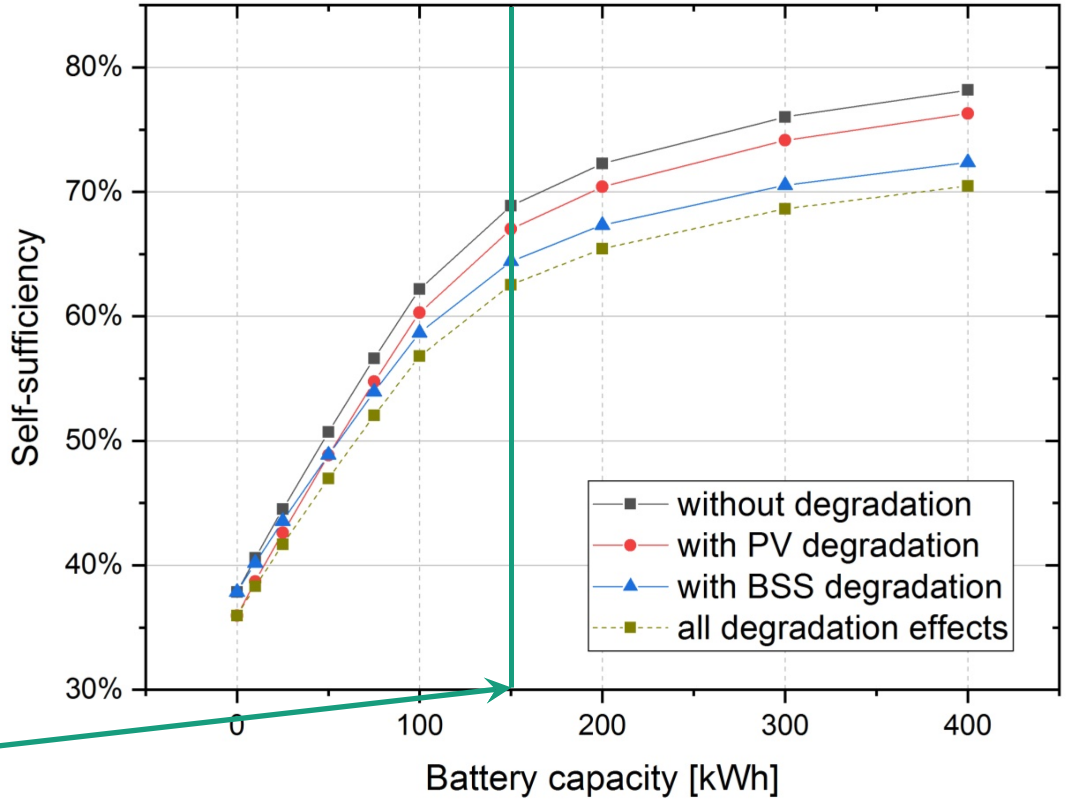
Performance – Effectiveness: Example of a district battery storage

- Simulation based analyses

System concept of district power supply



Reduction of self-sufficiency over time



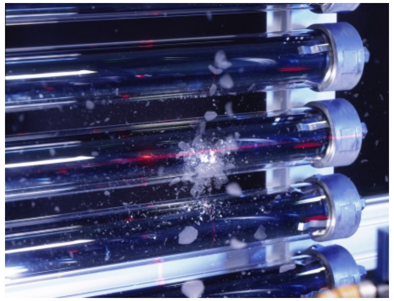
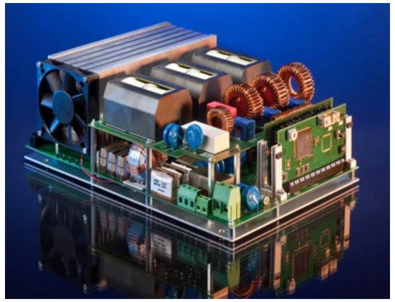
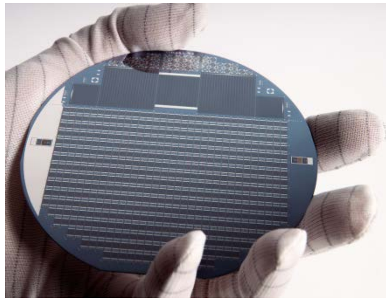
Source: L. Millet et al.: Extensive analysis of photovoltaic battery self-consumption: Evaluation through an innovative district case-study; Applied Physics Reviews, 2019.

Conclusions

- Large-scale system integration of fluctuating renewable energies and (fast) charging stations for the transport sector require storage
  - ➢ Technically → Reliability of power supply
  - ➢ Economically → Business models in post feed-in tariff times
  - → Accelerated market growth for stationary battery storage expected !
  - → Definition of ambitious targets for advanced battery technologies !
  - → But: Lack of long-term experiences with advanced battery technologies in the field !
- Key factors for storage product and project evaluation
  - ➢ 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 these factors
- Appropriate and holistic quality assurance measures have to consider all these topics

Thanks for your attention !!!

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