ENERGY STORAGE – GENERAL OVERVIEW, APPLICATIONS AND BUSINESS MODELS

¿Son los sistemas de almacenamiento una solución para los desafios del mercado electrico?

Johannes Wüllner

Fraunhofer Institute for Solar Energy Systems ISE

International Seminar: STORAGE SYSTEMS IN THE ELECTRICAL SECTOR

Santiago de Chile, 8.1.2019

www.ise.fraunhofer.de

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AGENDA

- Brief introduction Fraunhofer
- Overview on energy storage technologies
- Applications / Business models
- Requirements for success
- Conclusion

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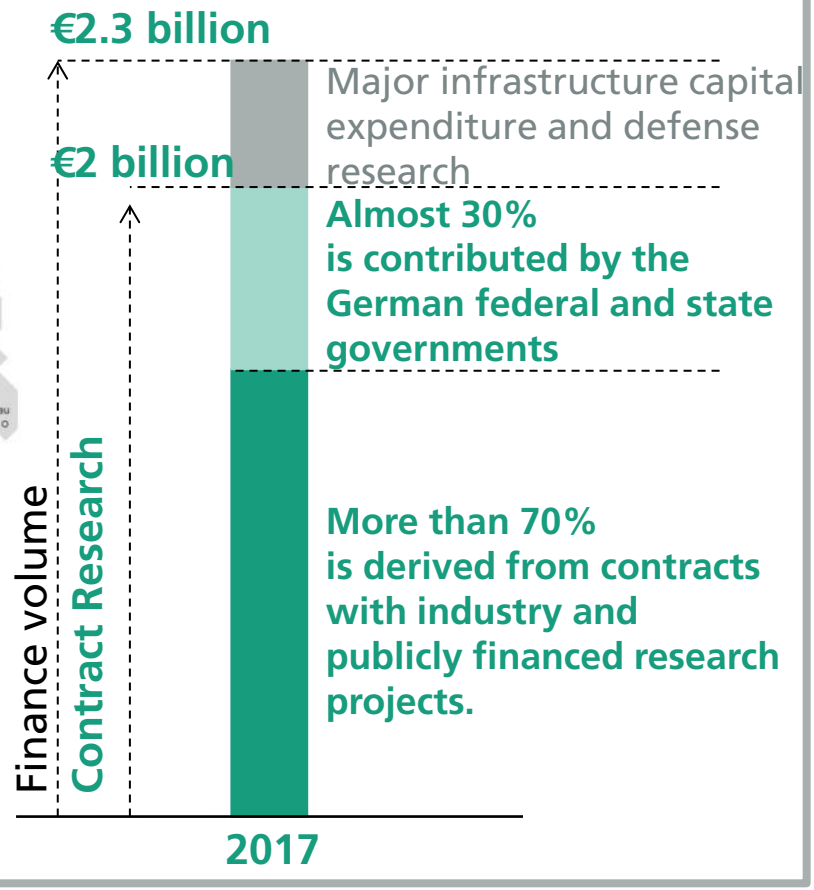
The Fraunhofer-Gesellschaft
At a Glance

25,327 staff

72 institutes and research units



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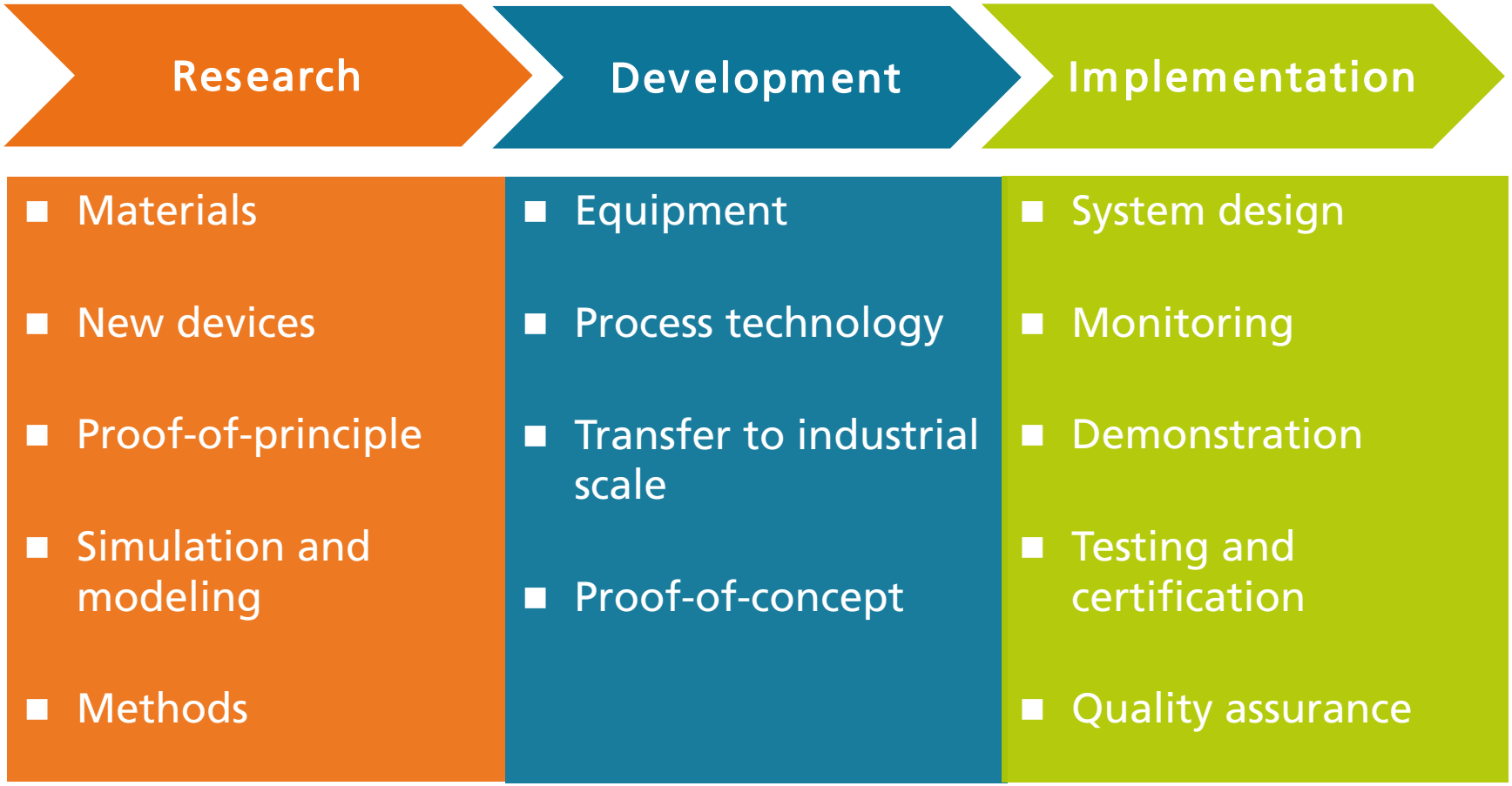
Fraunhofer
our Scope of Our Work: Applied Research



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Fraunhofer Institute for Solar Energy Systems - ISE
At a Glance

Institute Directors:
Prof. Dr. Hans-Martin Henning
Dr. Andreas Bett

Staff: ca. 1200

Budget 2017: €89.2 million

Established: 1981

Photovoltaics

Solar Thermal Technology

Building Energy Technology

Hydrogen Technologies

Energy System Technology

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Business Area Energy System Technology
Research Topics

Energy system technology, which aims to optimize the interaction between supplier and consumer, belongs to one of the most important research areas of the energy transformation.

- Power Electronics
- Smart Grid Technologies
- System Integration – Electricity, Heat, Gas
- Battery Storage for Stationary and Mobile Applications
- Energy System Analysis

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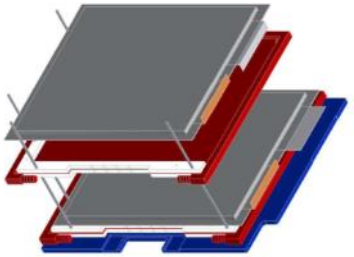
Department of Electrical Energy Storage

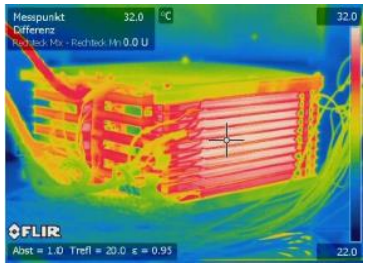
- Battery **Cell** Development
  - New cell materials
  - New cell types
  - Optimize production processes
- **Battery** Engineering
  - Development of battery systems
  - BMS Development
  - Thermal Management
- Applied Storage **Systems**
  - New business models
  - Lighthouse Projects
  - Applied research

Cell

Battery

Systems





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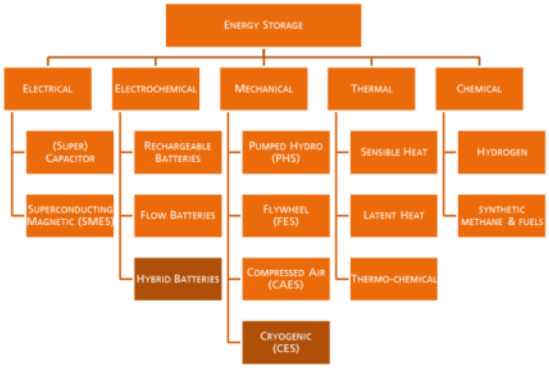
AGENDA

- Brief introduction Fraunhofer
- Overview on energy storage technologies
  - Overview
  - Range of Power vs. Energy
  - Current battery research
- Applications / Business models
- Requirements for a success
- Conclusion



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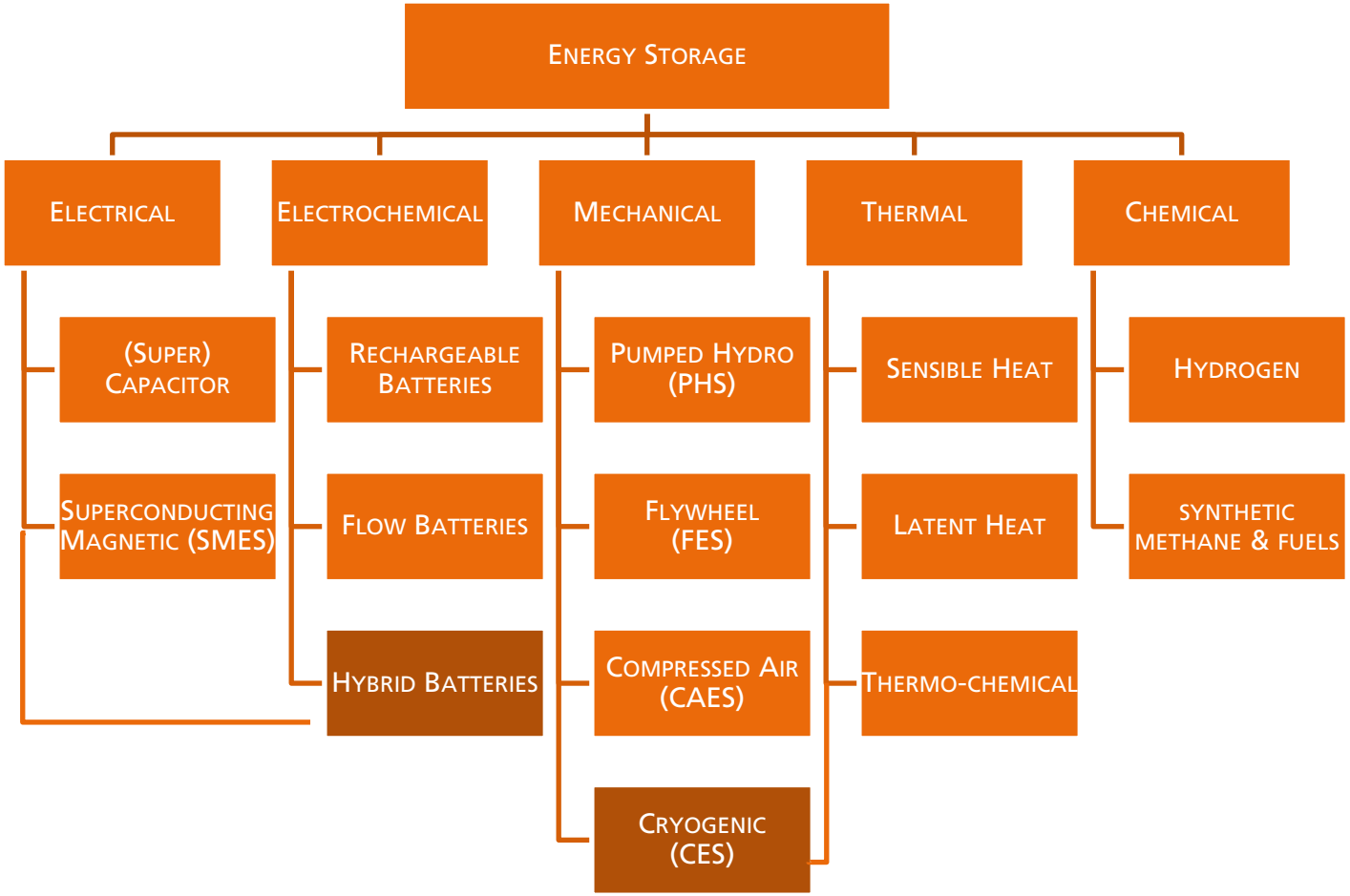
Overview on energy storage technologies



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Overview on energy storage technologies - examples

Source: A. Marrero Q. - *Gorona del Viento Wind Hydro Power plant*, IHPS workshop, Teneriffe, 2018

Source: CSIRO, Australia, 2018

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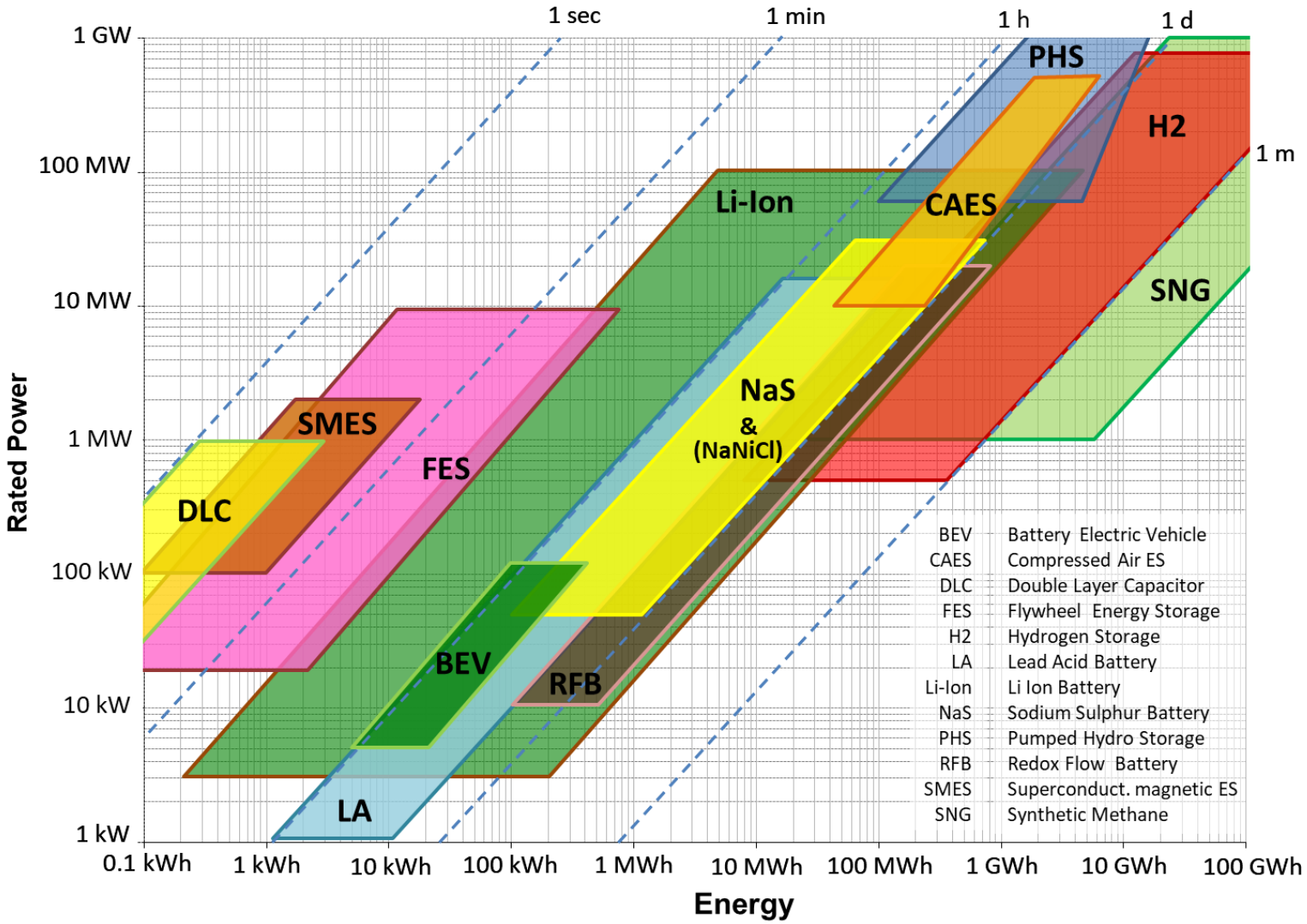
Range of energy storage - power vs. energy



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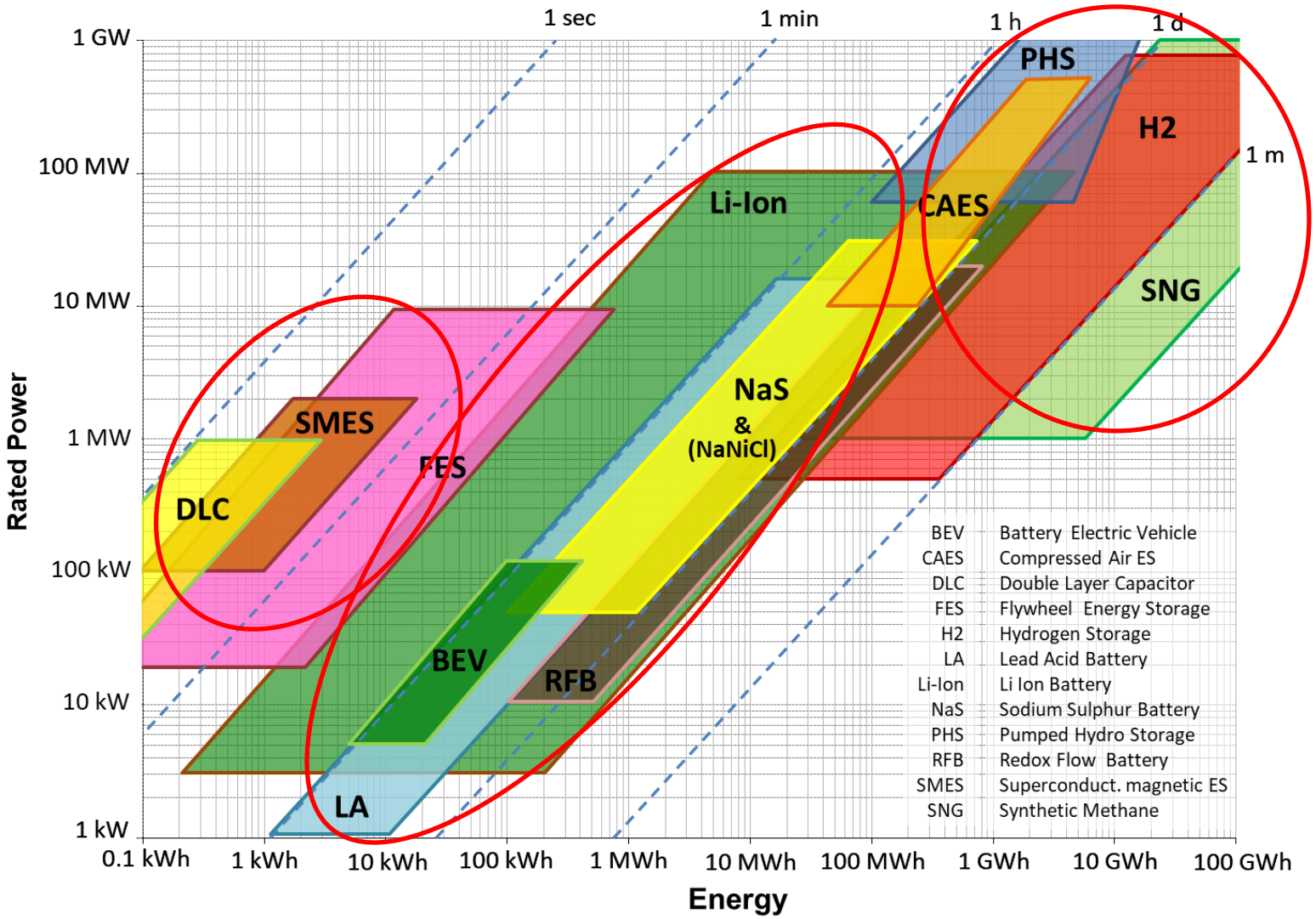
Range of energy storage - power vs. energy



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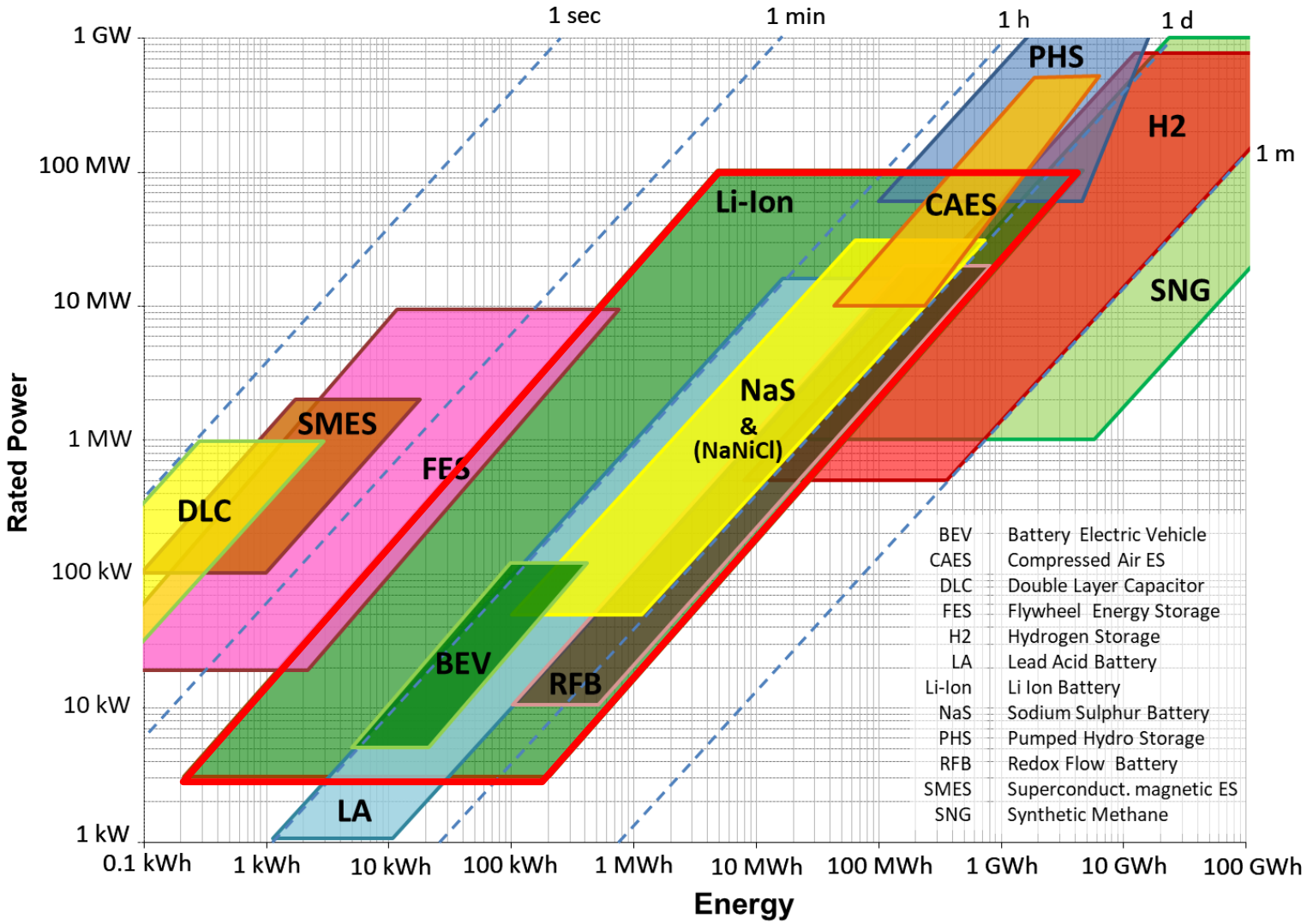

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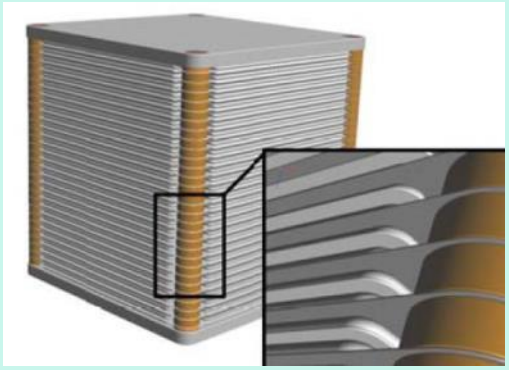
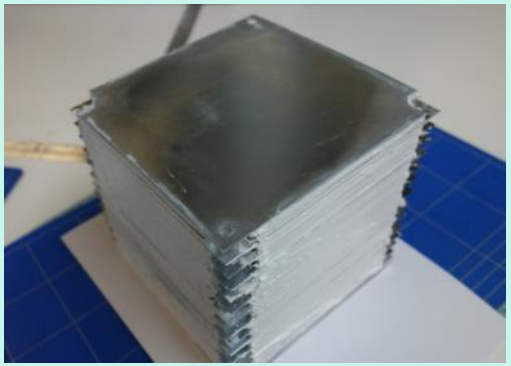
New Battery materials and cells research

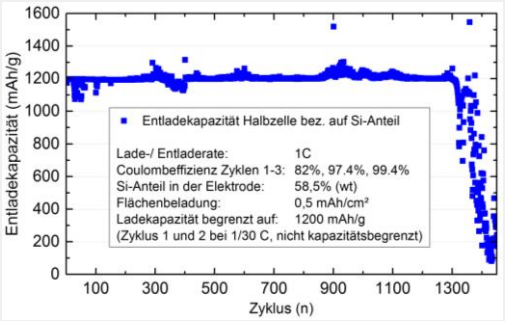
Current focused reserach topics of Fraunhofer ISE

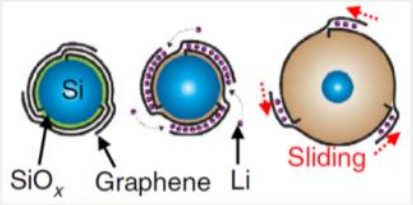
Aqueous batteries for stationary applications

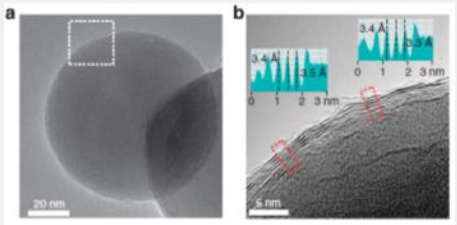




Silicon based anodes as *drop-in replacement* for lithium-Ion battery cells

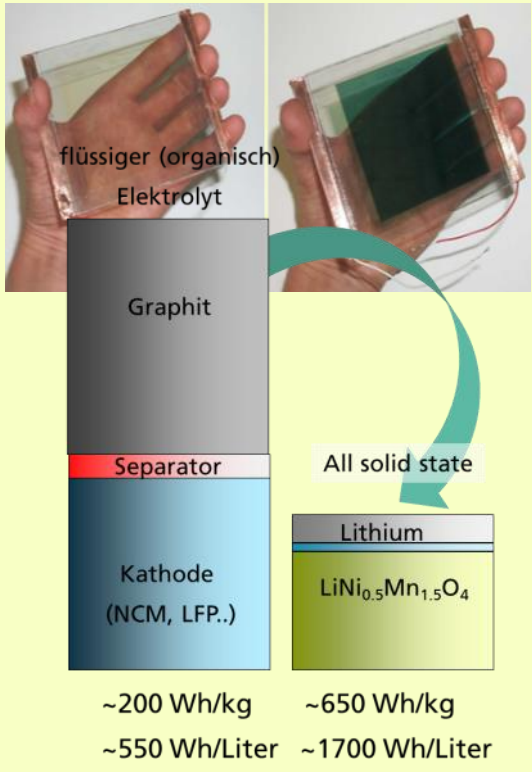






From DOI: 10.1038/ncomms8393

New materials and process technology for *solid state* batteries



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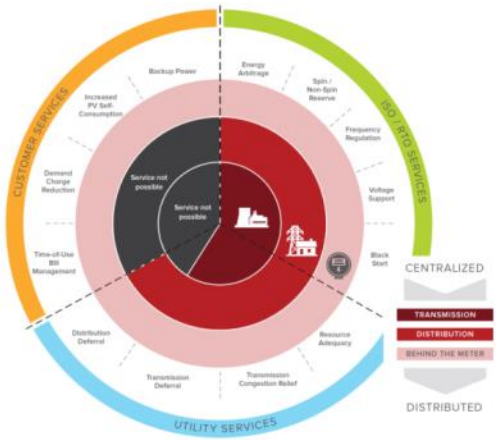
- Applications / Business models
  - Transmission level
  - Distribution level
  - Behind-the-meter
- Requirements for success
- Conclusion



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

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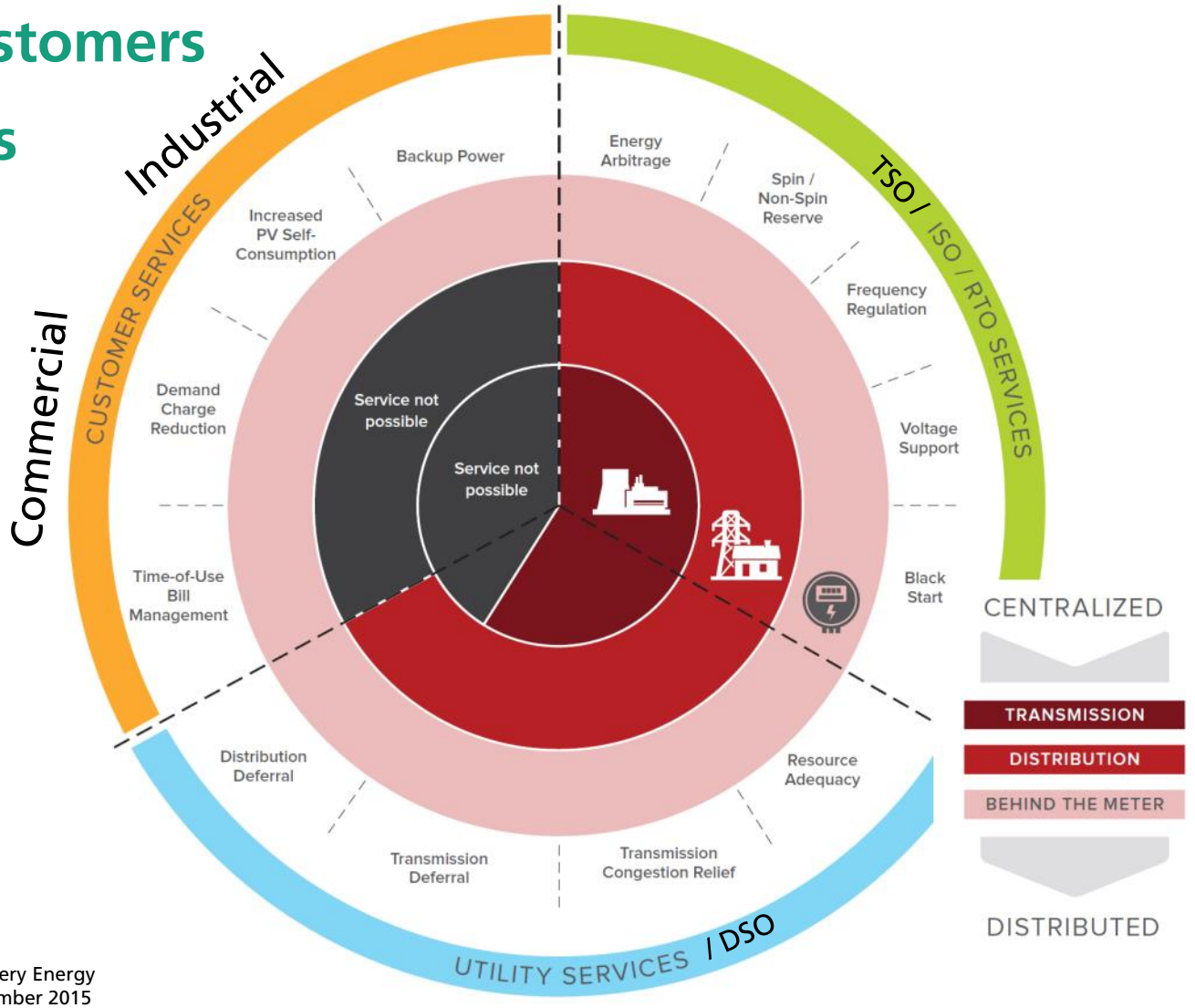
Applications and business models

Services to customers and grid levels

BATTERIES CAN PROVIDE UP TO 13 SERVICES TO THREE STAKEHOLDER GROUPS



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Applications and business models on transmission level

Services to customers and grid levels

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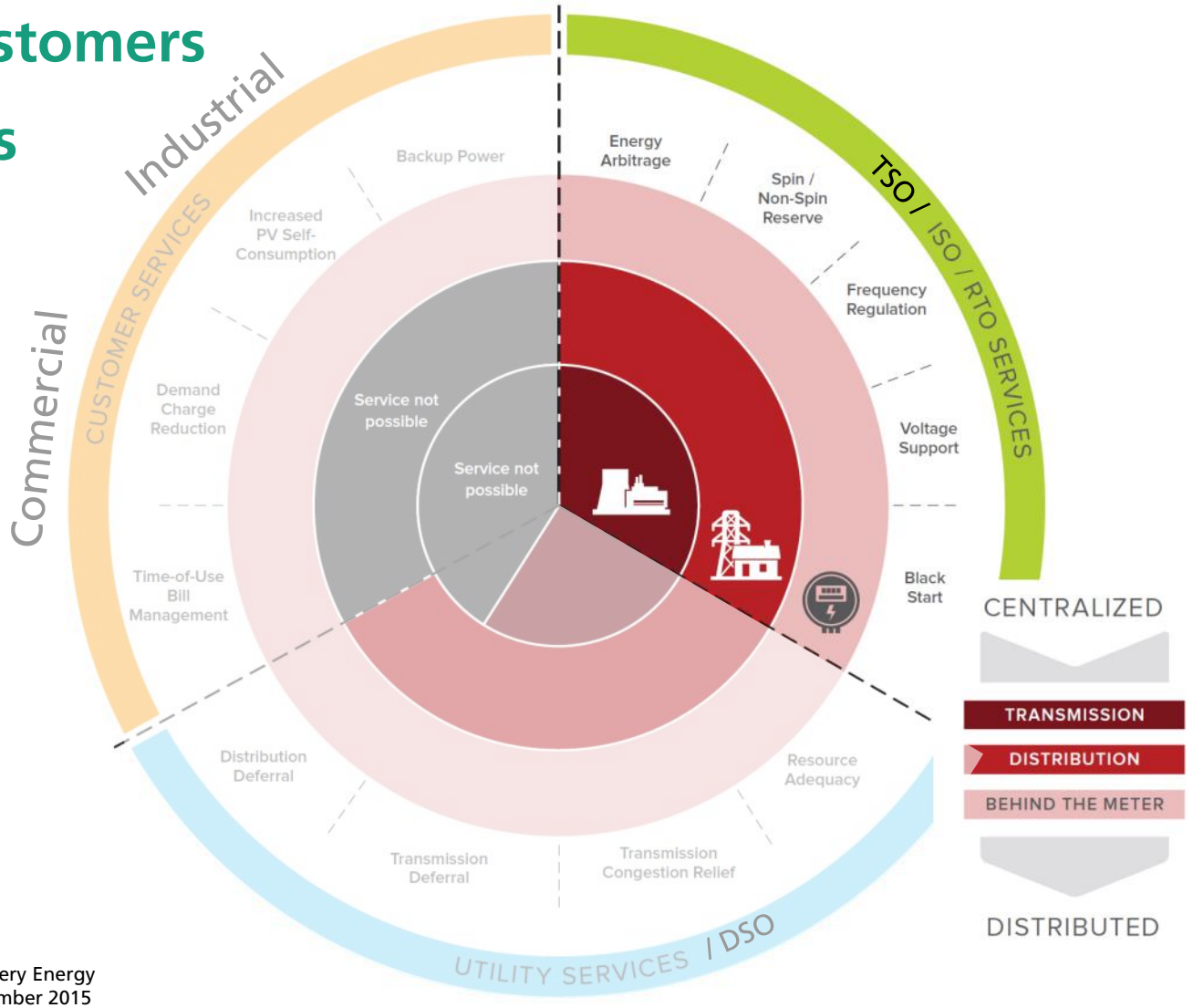

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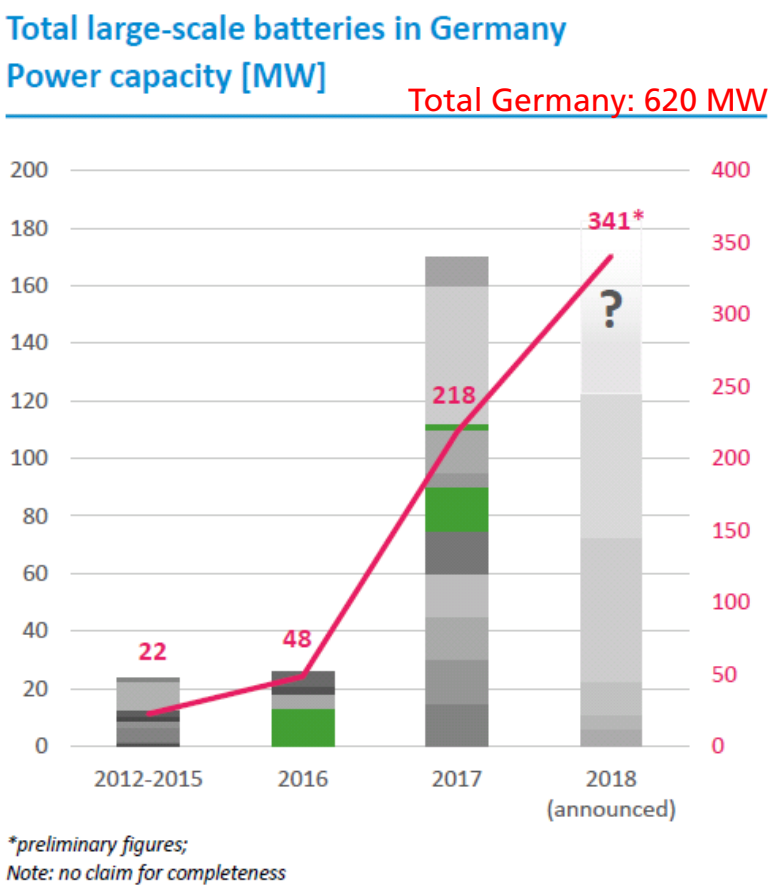
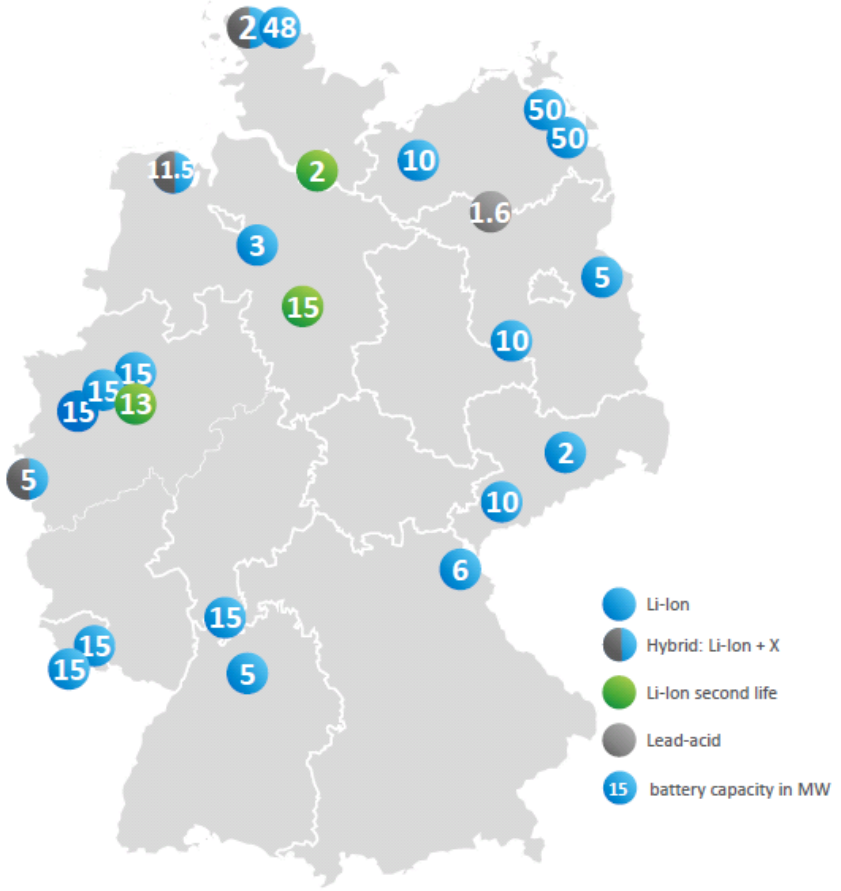
Applications and business models on transmission level

Example Germany: Primary control power





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

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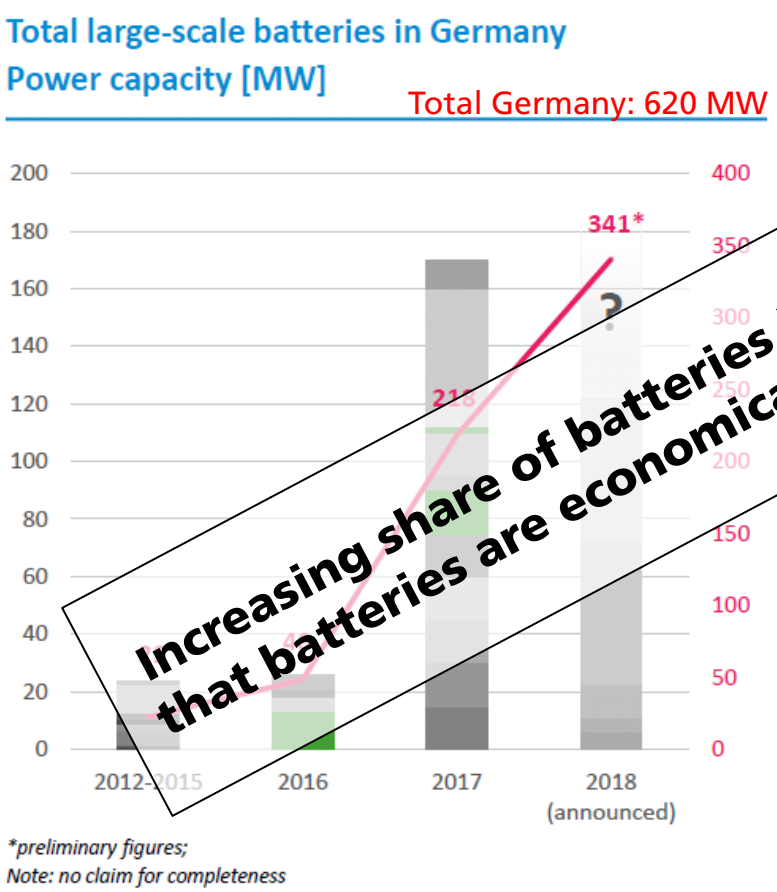
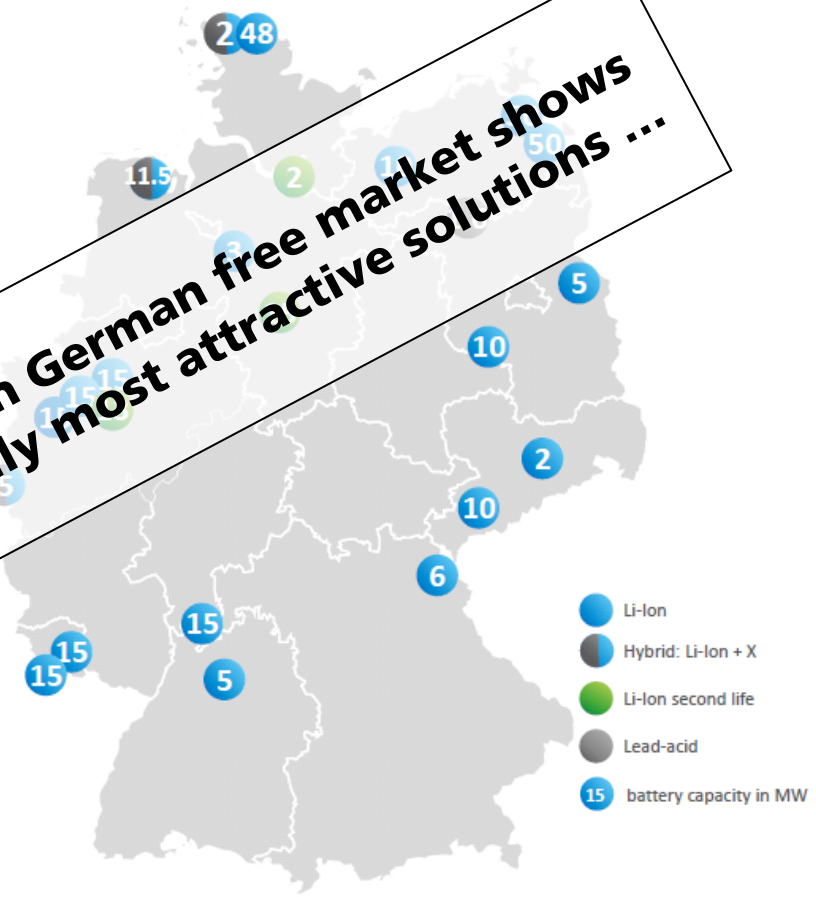
Applications and business models on transmission level

Example Germany: Primary control power



Increasing share of batteries in German free market shows that batteries are economically most attractive solutions …



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Applications and business models on transmission level

Example Italy: Batteries for grid support

The Context

Terna GROUP

Causes	Effects	Mitigating actions
• 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	• 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*	Optimize integration of RES and increase flexibility of national grid (i.e. smarter grid)

Solutions

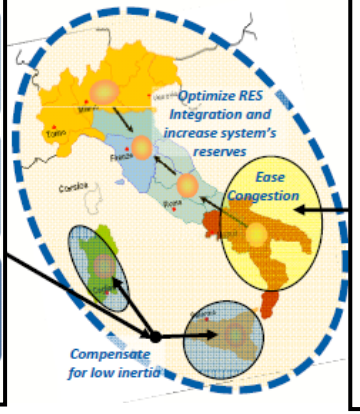
1st Phase Storage Lab

- Sardinia: 8 MW — Codrongianos
- Sicily: 8 MW — Ciminna
- Total to be deployed in 1st phase 16MW

2nd Phase

- Sardinia: 12 MW — Codrongianos
- Sicily: 12 MW — Casuzze
- Total to be deployed in 2nd phase 24MW

Cumulative ESS Deployment 40 MW



By mid 2015

- In the South of Italy on the 150 kV Backbone: *"Benevento 2 – Celle San Vito"* 12 MW — 12 MW Ginestra
- In the South of Italy on the 150 kV Backbone: *"Benevento 2 – Bisaccia 380"* 22,8 MW — 12 MW Flumeri; 10.8 MW Scampitella

Cumulative ESS Deployment 35 MW

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

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Applications and business models on transmission level

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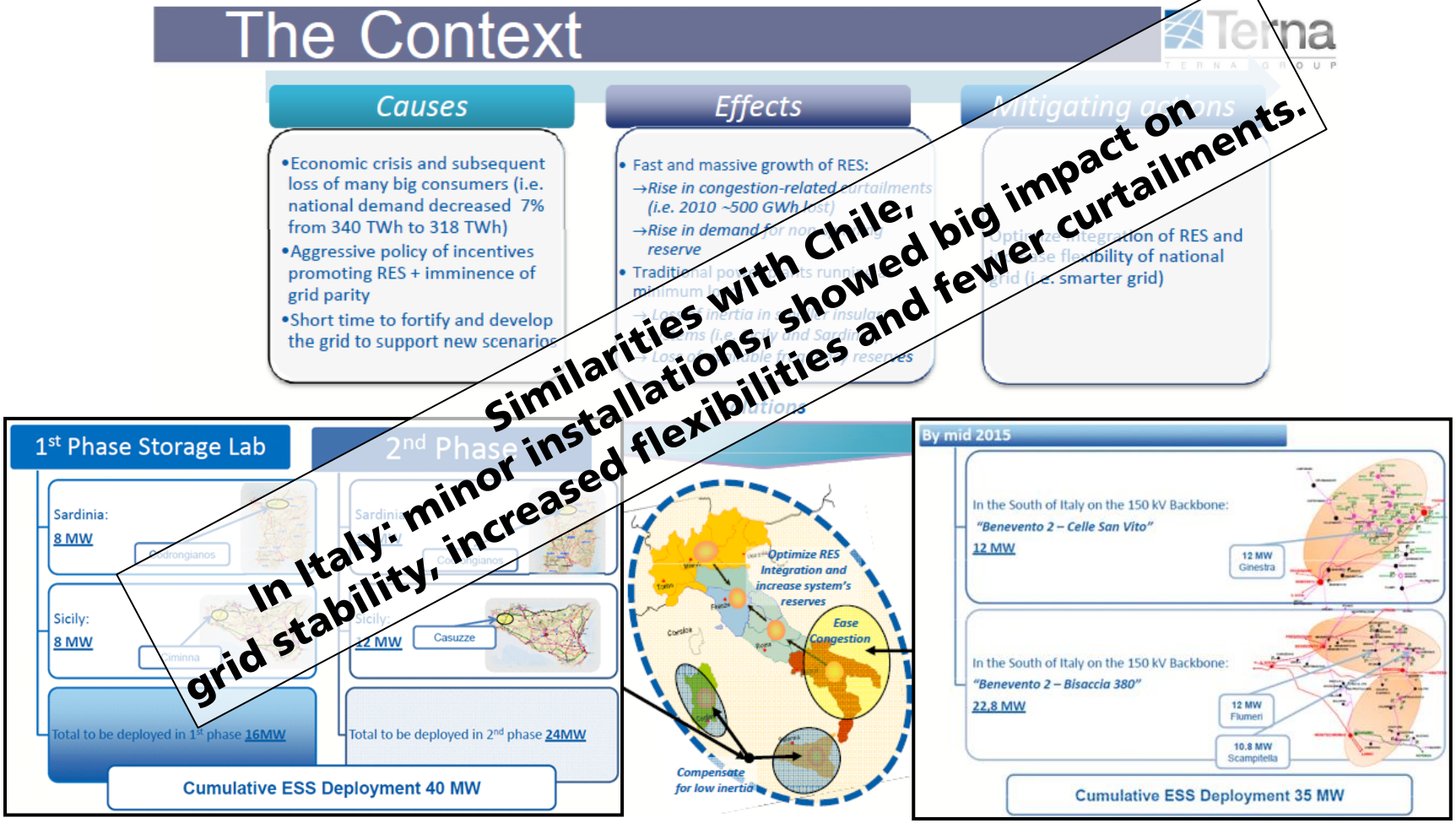

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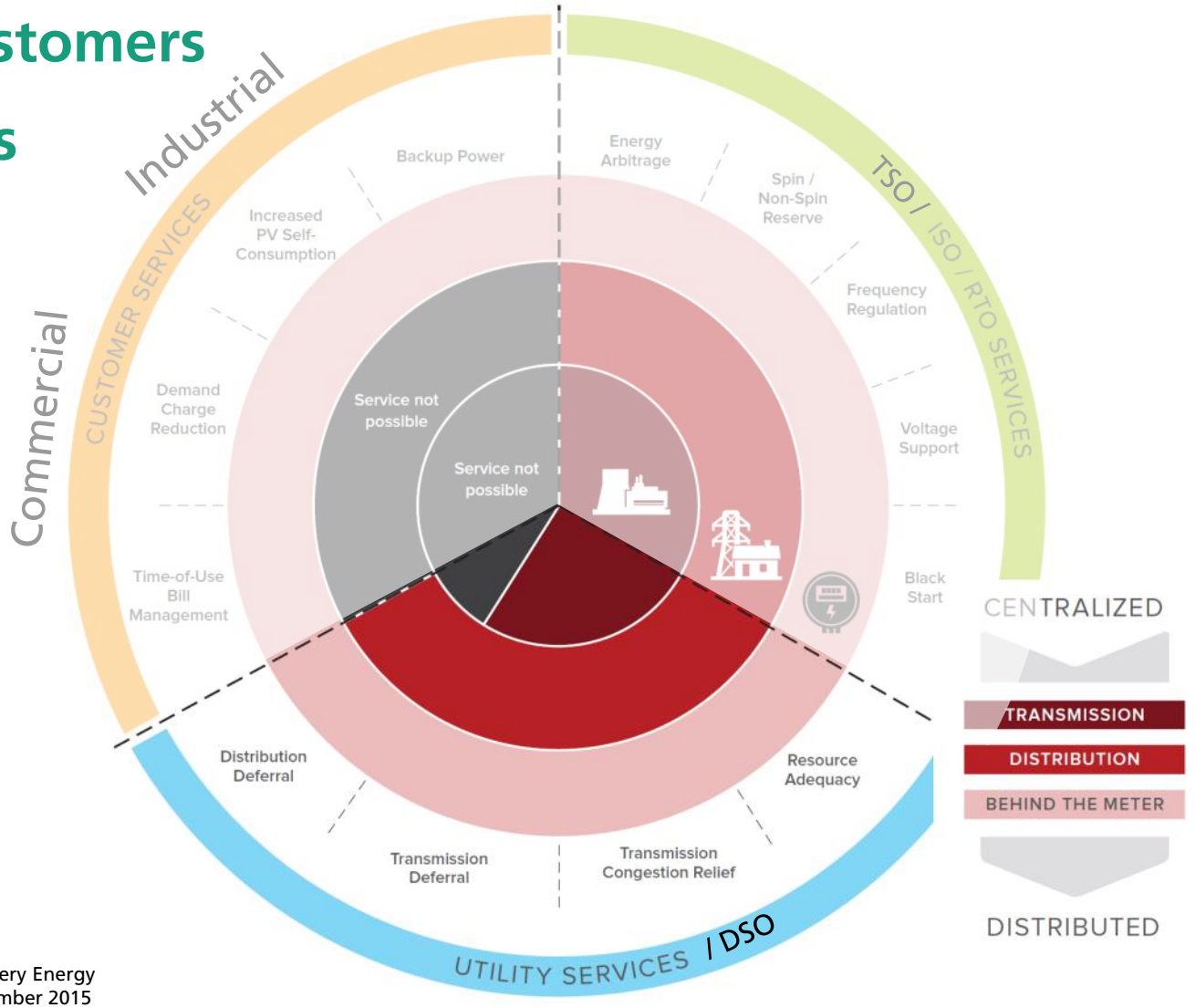
Applications and business models on distribution level

Services to customers and grid levels

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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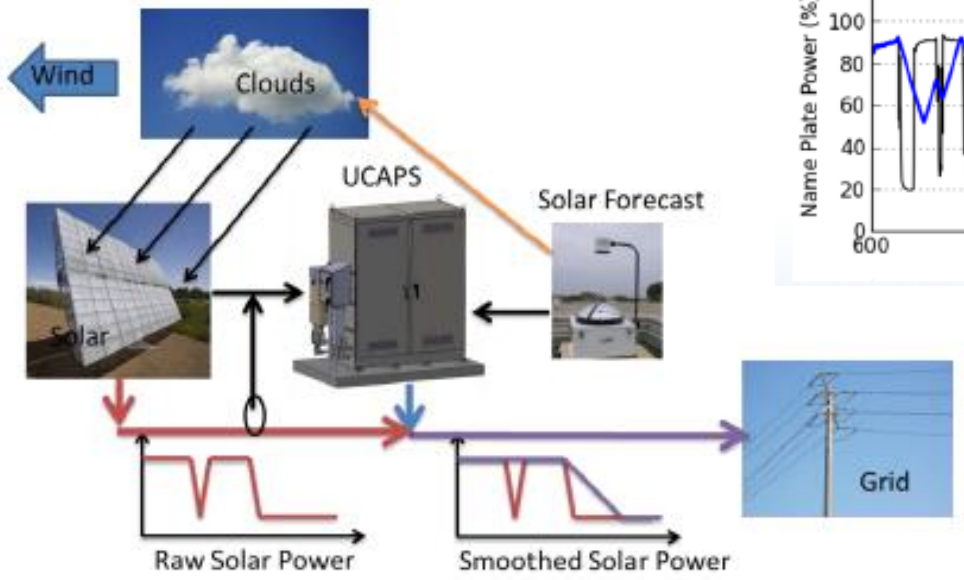
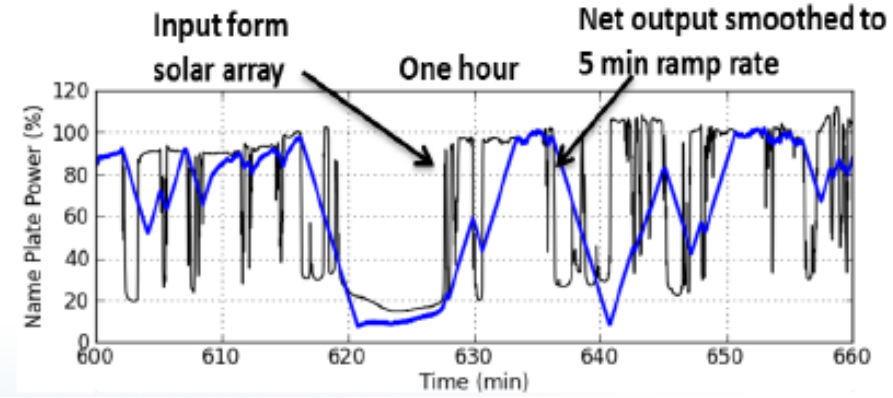
Applications and business models on distribution level

Example USA: Solar firming (PV power plants + storage)

- 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.

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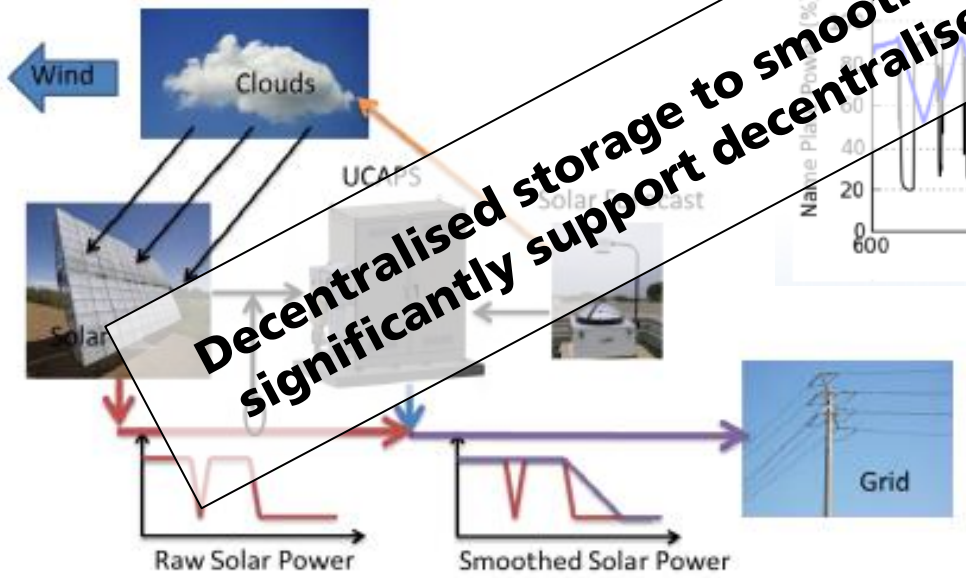
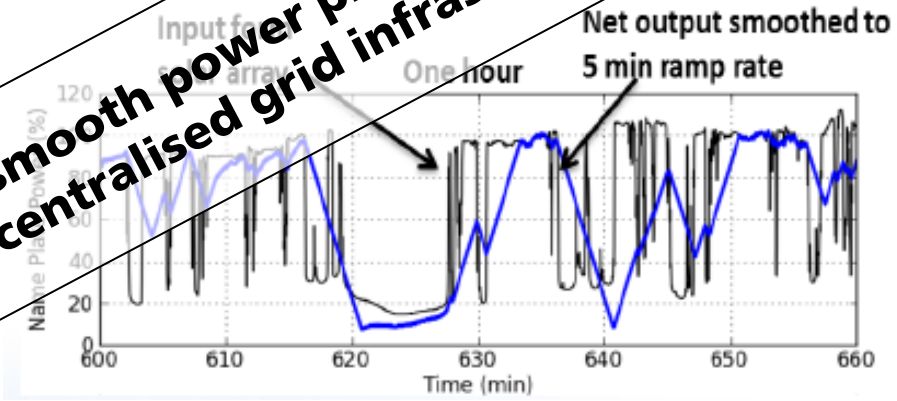


Decentralised storage to smooth power production can significantly support decentralised grid infrastructure



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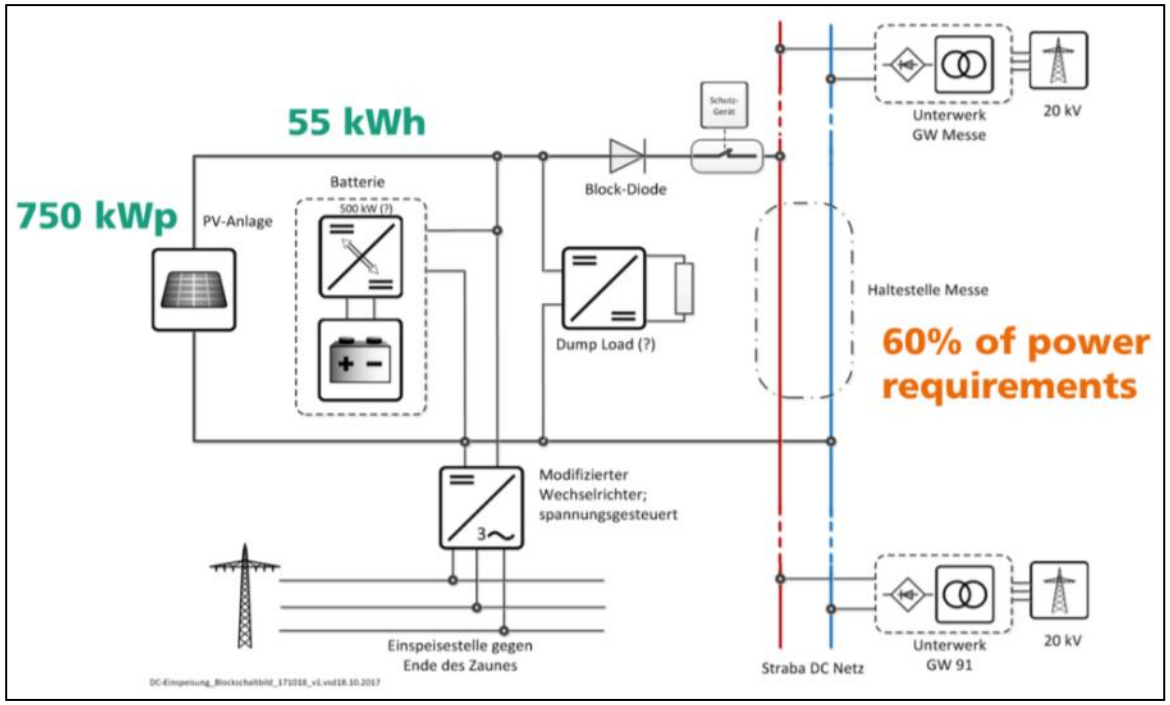
Applications and business models on distribution level

PV battery integration into light-rail system at new SC Freiburg soccer stadium

- Smart sector coupling
- Efficient DC integration of a PV battery system into the light-rail system of VAG
- Peak load:
  Up to 950 kW
- Energy consumption:
  ~ 1 MWh / day
- PV battery system:
  750 kW_p and 55 kWh can cover in average 60 % of required power
- Via direct marketing to VAG economics of the PV battery system can be improved



Gefördert durch den Innovationsfonds Klima- und Wasserschutz
badenova Energie. Tag für Tag
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Fraunhofer ISE

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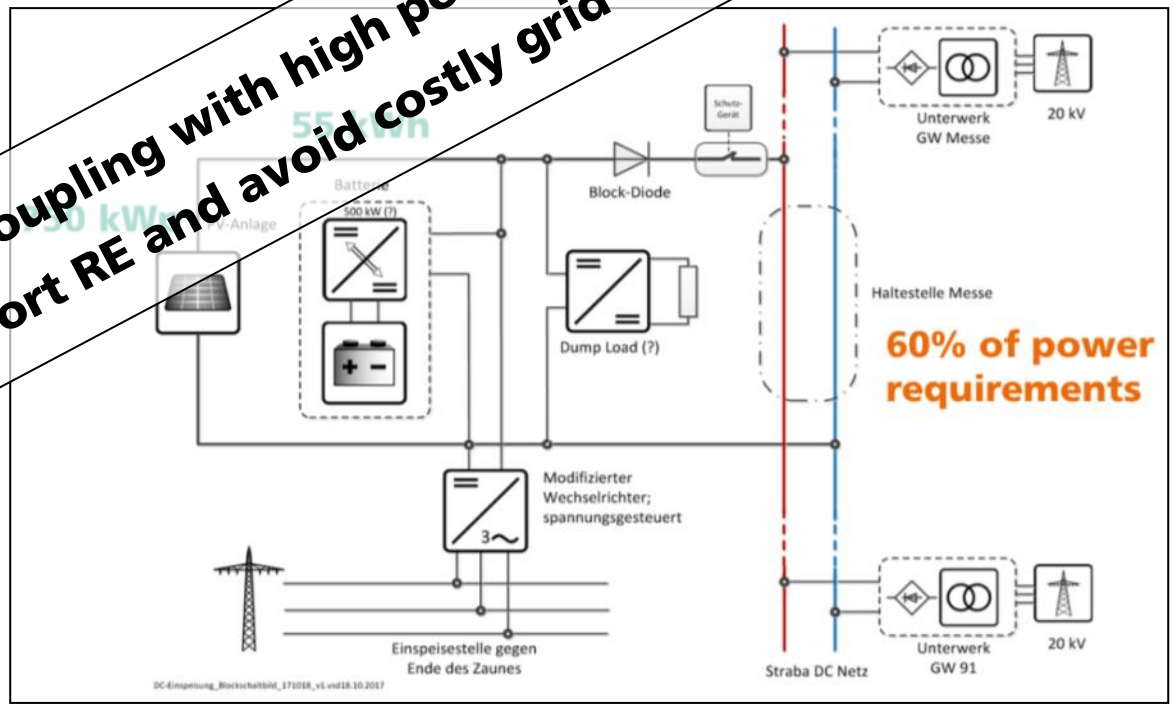
Smart sector coupling with high power energy storage can support RE and avoid costly grid extension



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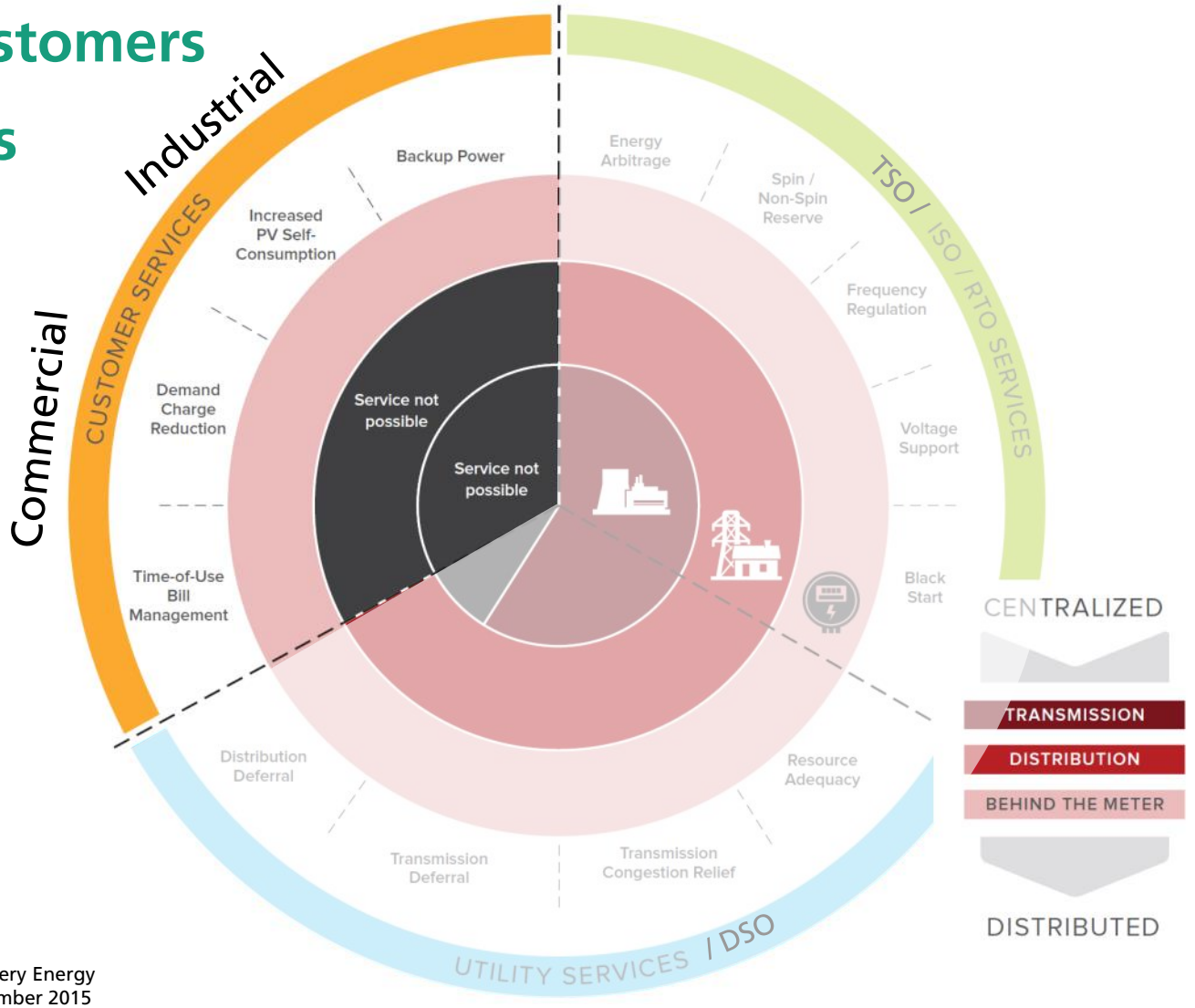
Applications and business models on customer level

Services to customers and grid levels

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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Applications and business models on customer level

Layout and sizing of a PV mini-grid for SKA1 low radio telescope

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 RPFs (distance from CPF > 10 km)
- LCOE: ~ 0.307 €/kWh

Source: CSIRO, Australia, 2018

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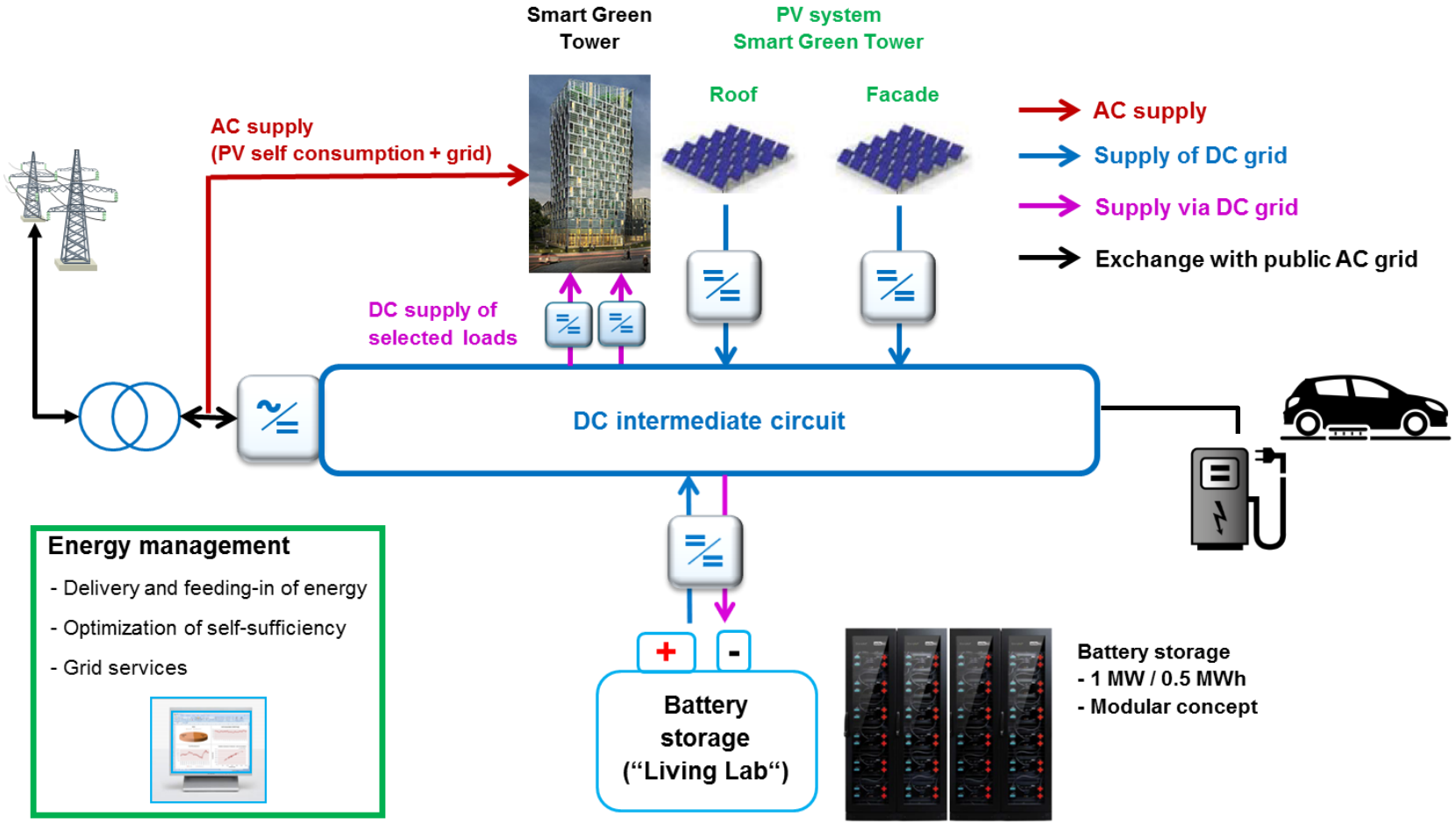
Especially in remote off-grid applications, energy storage can be the cheapest solution.

Source: CSIRO, Australia, 2018

CSIRO SKA Fraunhofer ISE

Applications and business models on customer level

Layout and sizing of “Smart Green Tower” in Freiburg



FREY ARCHITEKTEN

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Applications and business models on customer level

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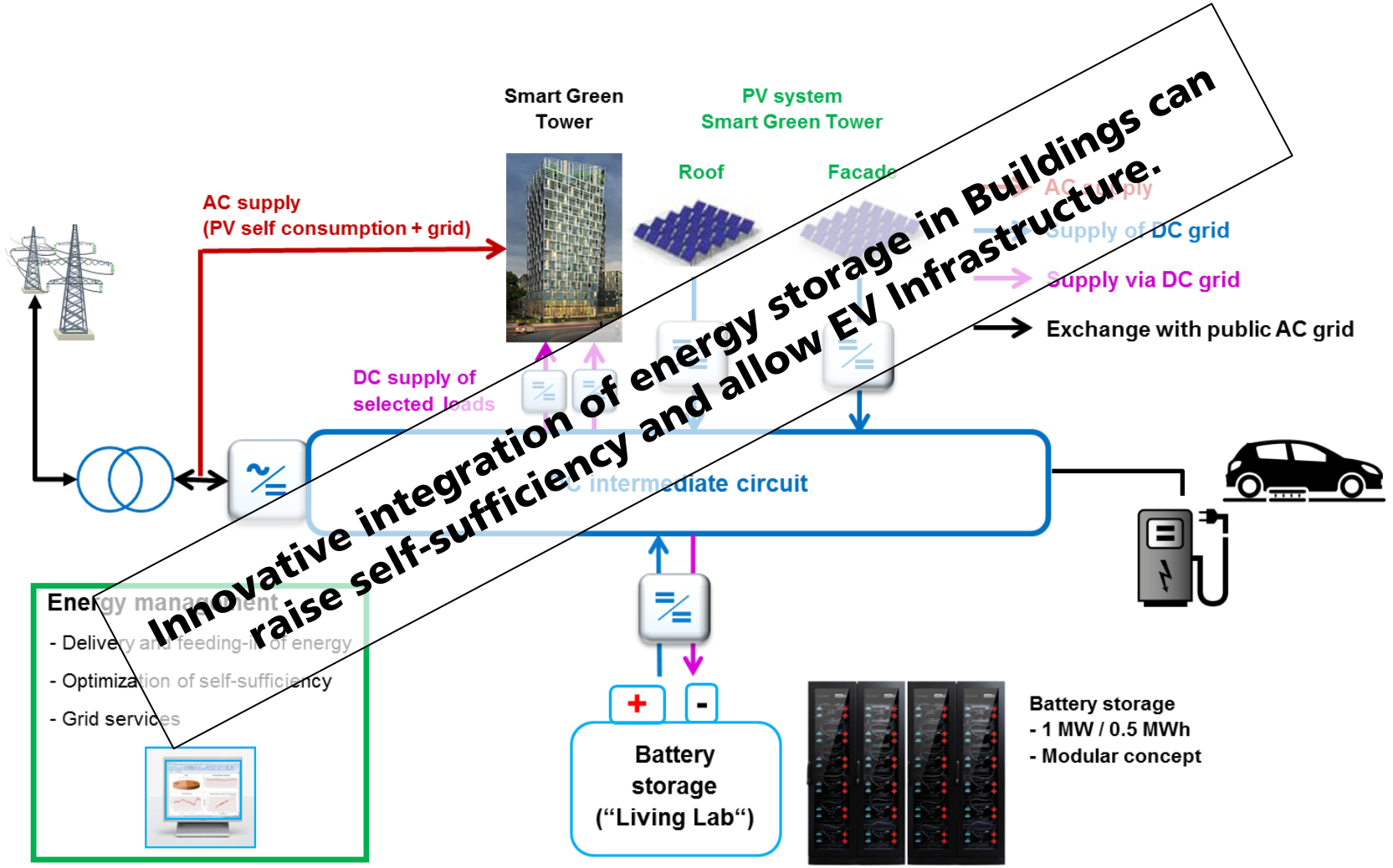

FREY ARCHITEKTEN

Fraunhofer ISE

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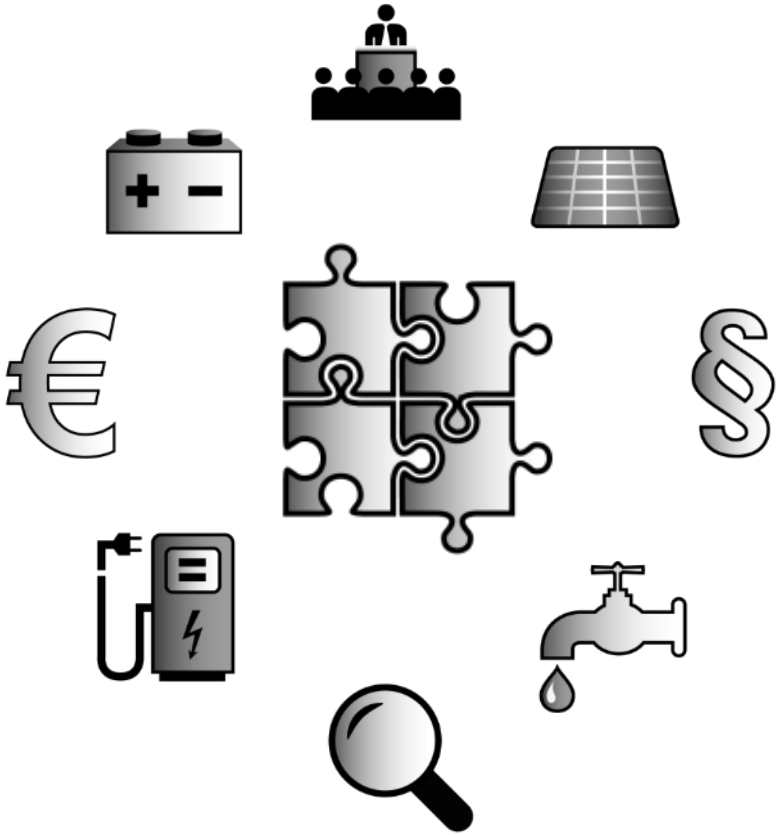
- Overview on energy storage technologies
- Applications / Business models
- Requirements for success
  - Supporting legislation and regulation
  - Research related support and services
  - Holistic quality assurance
- Conclusion

Supporting legislation and regulation
for integration of Renewable Energies (RE) and grid stabilizing infrastructure (EES)

Fraunhofer supports in

- Roadmaps and geographical potential analysis
- Development of legal and regulatory frameworks for RE / EES
- legal decision making and implementation to support RE and EES
- Education and development of curricula for RE / EES
- Quality assurance and standardisation for RE / EES



Source:Fraunhofer ISE, Germany

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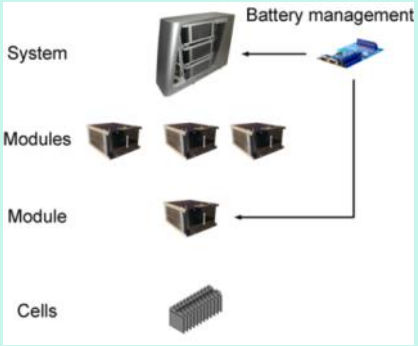
Research related support and services
applied R&D and services of Fraunhofer ISE

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

Research related support and services
applied R&D and services of Fraunhofer ISE

Battery system technology
From cells to systems

Development of stable, secure and high quality Products

- 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

Identification and demonstration of new business cases

- 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

Reliable quality assurance and certification

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

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Quality Assurance Services for energy storage systems
From product development to project implementation

Strategic partnership of Fraunhofer ISE and VDE Renewables

Product design and project planning	Testing and project development	Certification and implementation
■ Analyses of load profiles	■ Economic feasibility studies using simulation-based system analyses	■ Certification of whole energy storage systems
■ Technical advice with focus on product design and optimization	■ Characterization of components	■ System testing
■ Simulation-based system design and component dimensioning	■ Performance testing	■ Certification and compliance of grid interconnected components
■ Yield prediction	■ Lifecycle testing	■ Ongoing quality monitoring
■ Recommendations on component selection	■ Conformity testing	
	■ Electrical safety and EMC testing	
	■ Benchmark tests	
	■ Environmental simulation	
	■ Abuse tests	
	■ United Nations Transport Test	

Testing and certification for batteries and energy storage systems

From product development to project implementation

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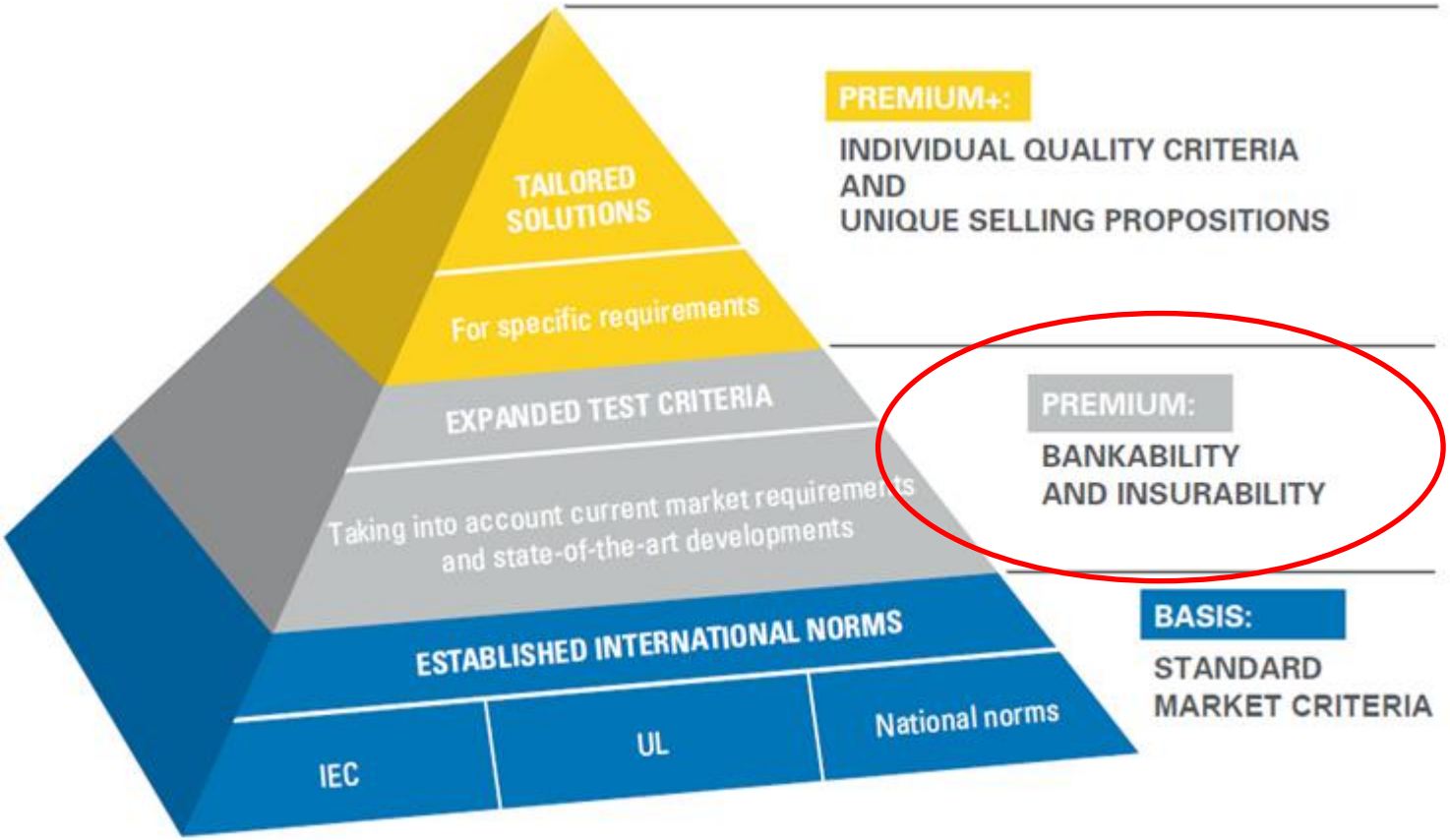
VDE RENEWABLES

The Pyramid of Quality Assurance Services

Path to bankability, investability and insurability



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AGENDA

- Brief introduction Fraunhofer
- Overview on energy storage technologies
- Applications / Business models
- Requirements for success
- Conclusion

Conclusion

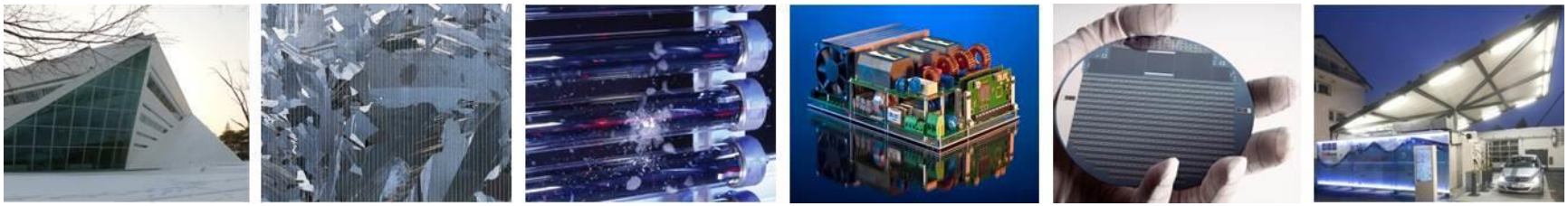
¿Son los sistemas de almacenamiento una solución para los desafios del mercado electrico?

- Yes! There is a technical storage solution for every grid challenge!
- There is a high technical variety of different storage solutions for every requirement

- Large-scale integration of fluctuating renewable energies in power supply systems requires energy storage
- Numerous applications in all grid levels proof functionality, increased stability and are economically viable

- There is the need of supporting legislation and regulation
- Large integration of RE and EES requires holistic quality assurance to secure grid stability and enabling bankable projects

Thank you for your attention!



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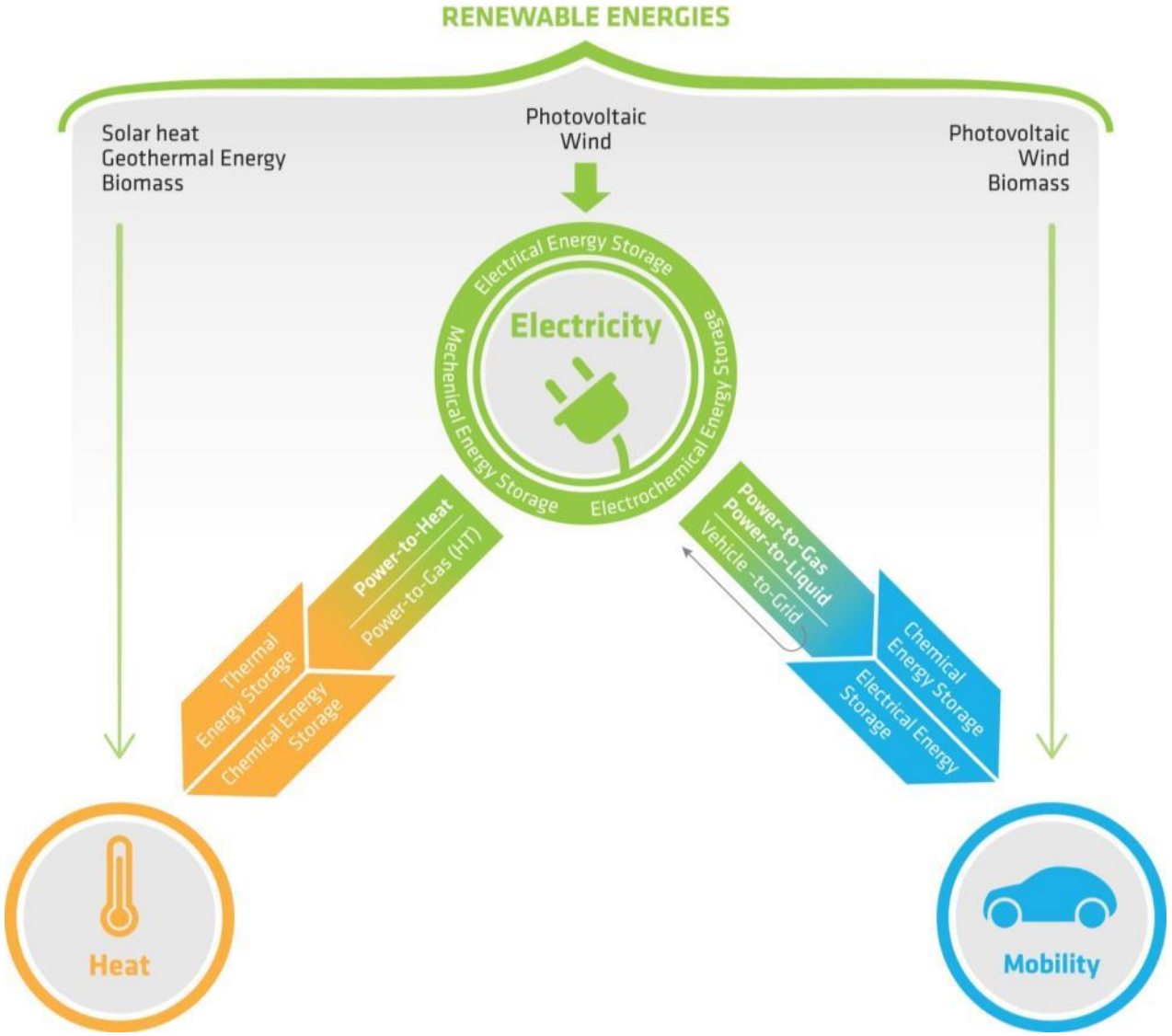
Sector coupling



BVES GERMAN ENERGY STORAGE ASSOCIATION

Source: BVES, Germany

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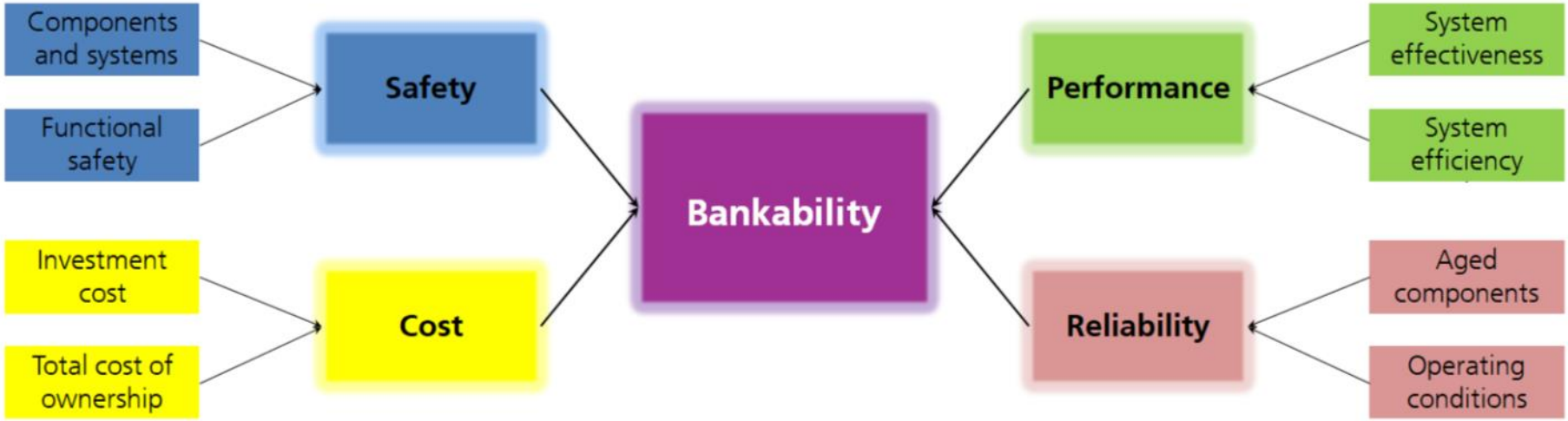
Quality Assurance Services for energy storage systems

Key factors affecting bankability and insurability



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