Daniel Aggeler / ABB Switzerland Ltd. Corporate Research September 28th 2015

ATV - Meeting

Mobile and stationary battery energy storage solutions – status and trend

Application of BESS for integration of RES
Presentation outline

Introduction

Utility grid and none grid applications

Application fit of storage technologies

Integration of renewable energy sources

Real example

Source: EKZ Smart Grid Labor / www.ekz.ch

1MW, 500 kWh Lithium-ion battery energy storage system (BESS) at Elektrizitätswerke des Kantons Zürich (EKZ) headquarters in Switzerland

Changing power industry sector landscape
Energy Storage may become next «Big Thing»

Government concerns:

- Environment and climate
- People safety and quality of life
- Energy independence

Industry trends:

- Fast growing variable renewable generation: central and distributed
- «Green» transportation

Grid challenges:

- Stochastic in-feed
- Power and energy balance
- Insufficient T&D capacity

Technology options:

- Interconnectors
- Flexible generation
- Flexible demand
- Energy storage

Energy storage is a growing business area with an increasing gov't support in form of subsidies and legislations

All stakeholders need understanding of key technologies, applications, markets and legislations

Key elements of energy storage system
From primary storage to grid connection

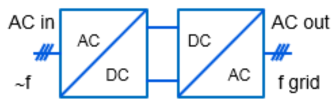




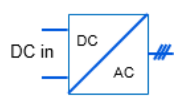


Underlying Storage Technology | Power Conversion | Control and Protection | Grid Connection

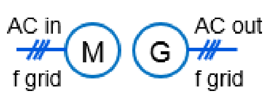
- Pumped Hydro
- Flywheel



- Batteries
- Supercapacitor



- Thermodynamic (CAES, ETES)



- H2 & Fuel Cells

Each system needs:

- Consulting
- Financing
- Design
- Commissioning
- Integration
- Service

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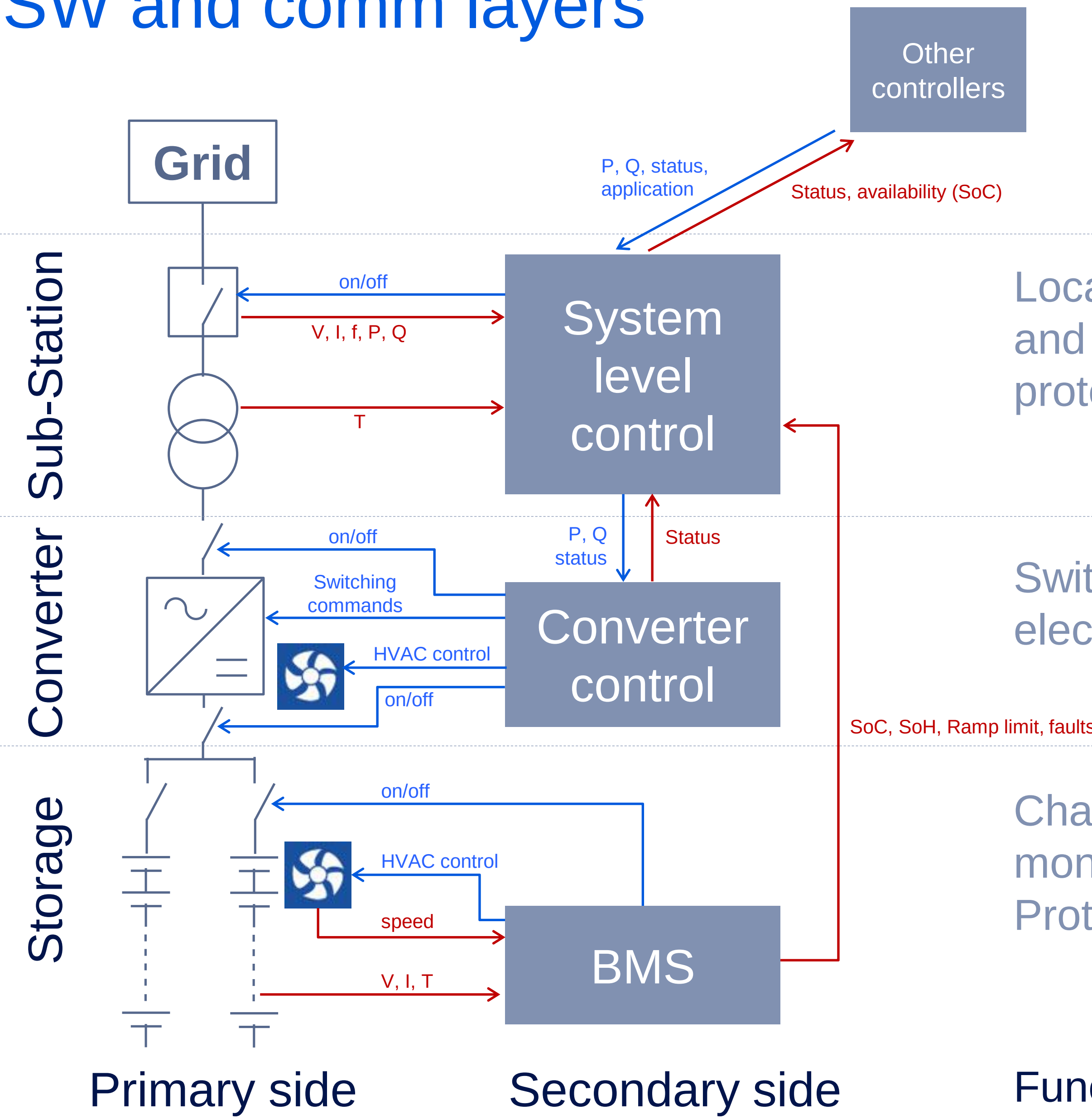
Key elements of energy storage system
HW, SW and comm layers



Local applications and ESS protection

Switching of power electronics

Charge and health monitoring Protection

Functionality

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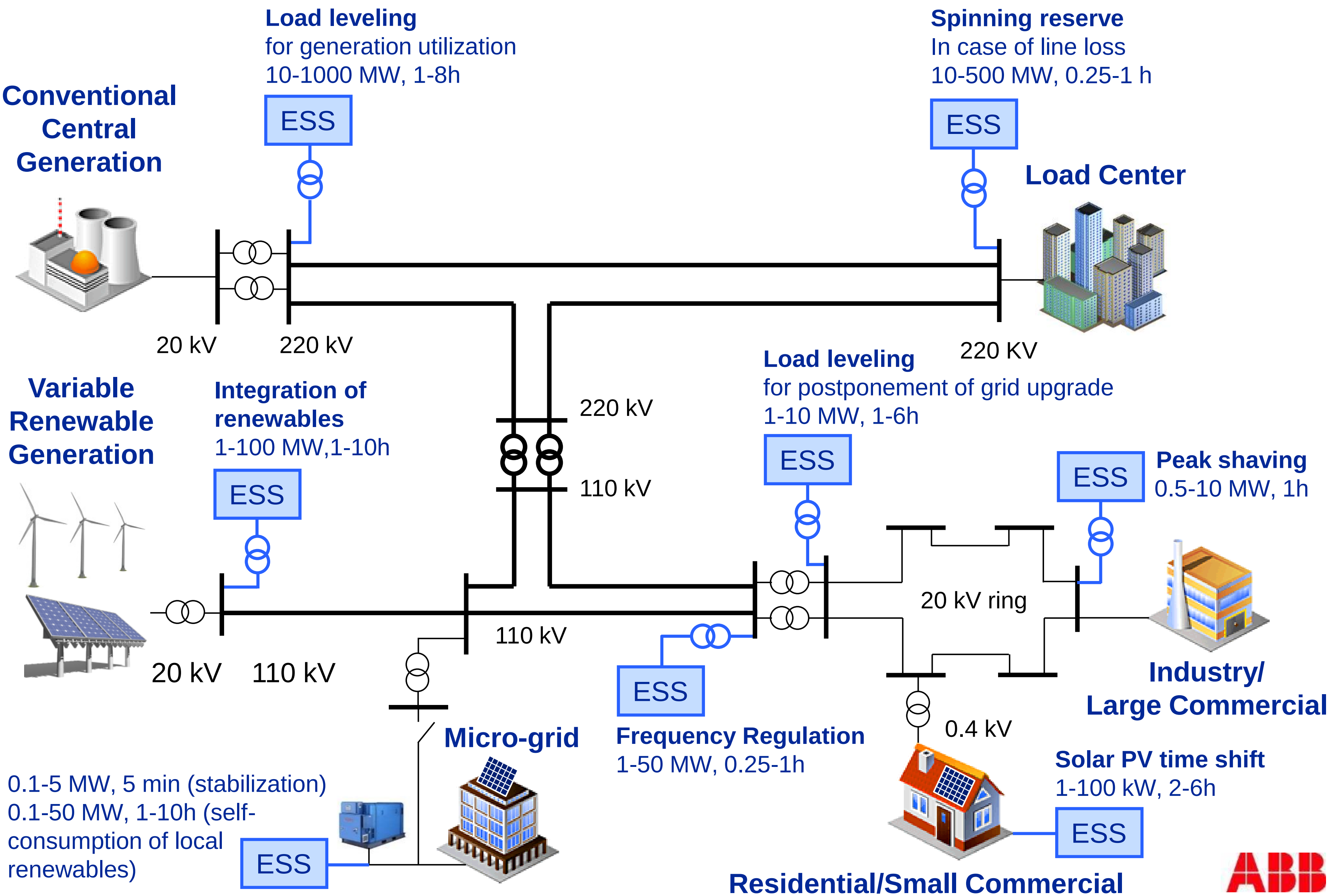
Energy storage applications: Electric grid



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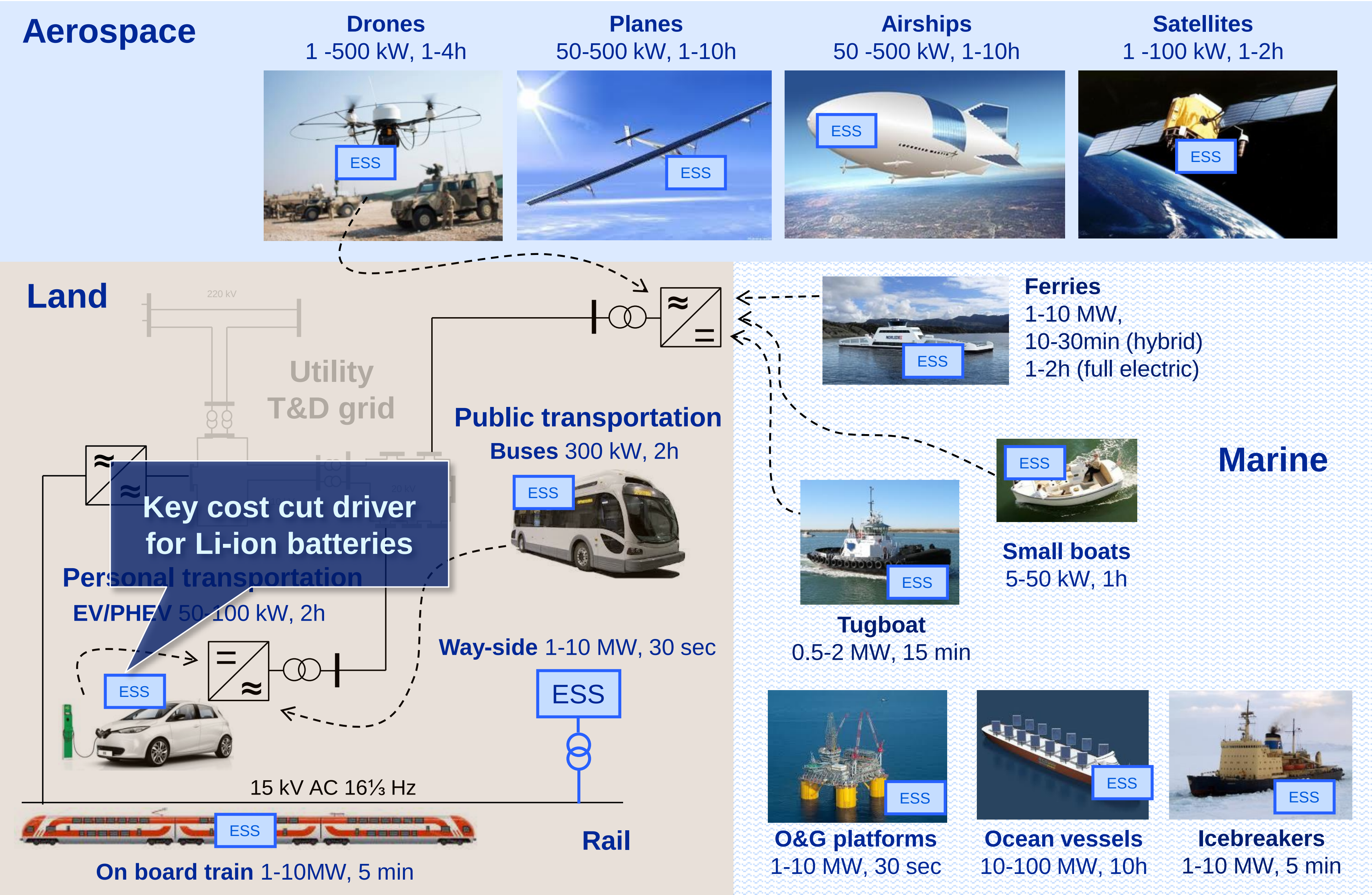
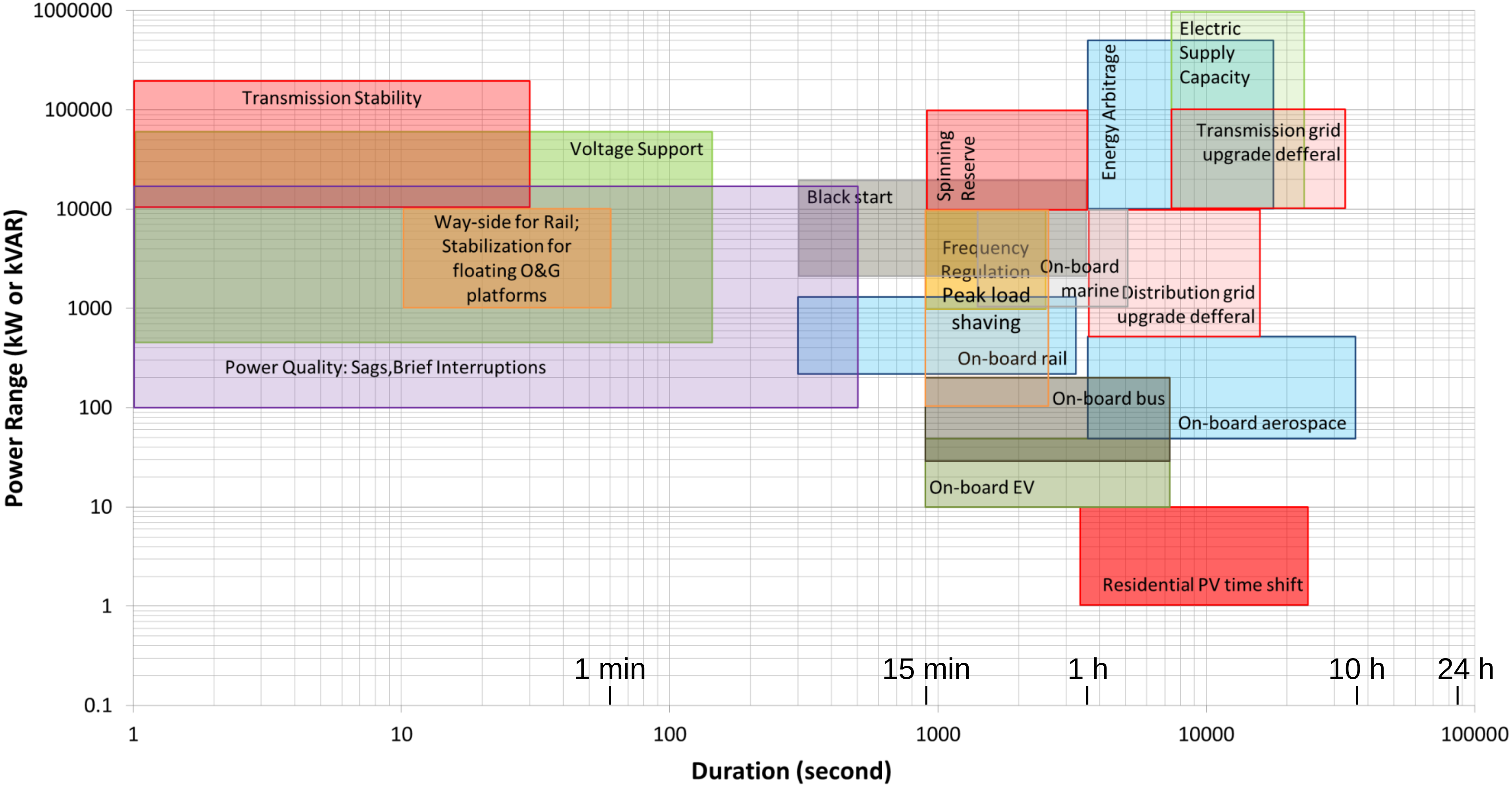
Energy storage applications: Mobility

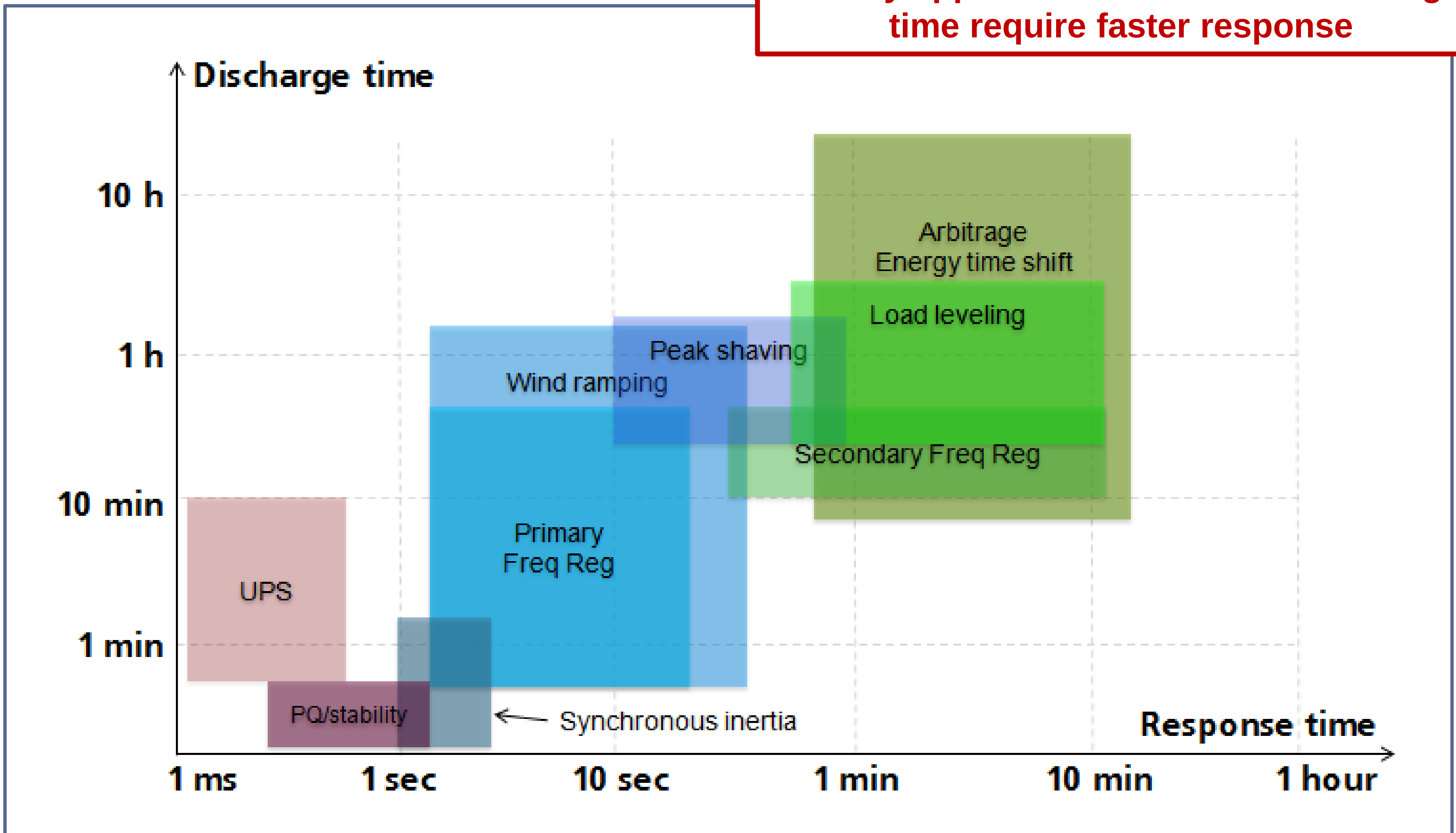


Energy storage application requirements



Energy storage application requirements

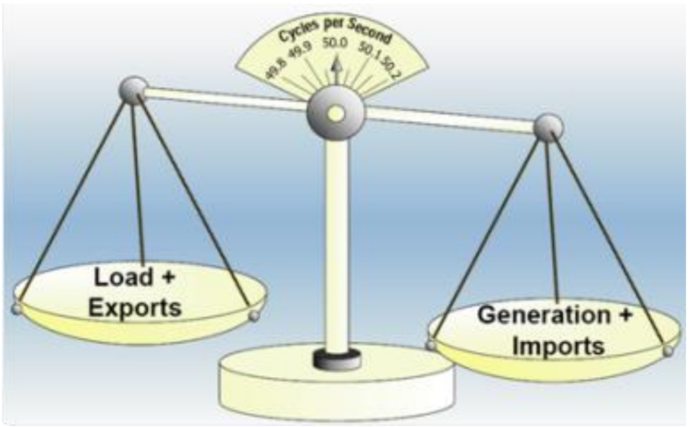
Usually applications with short discharge time require faster response

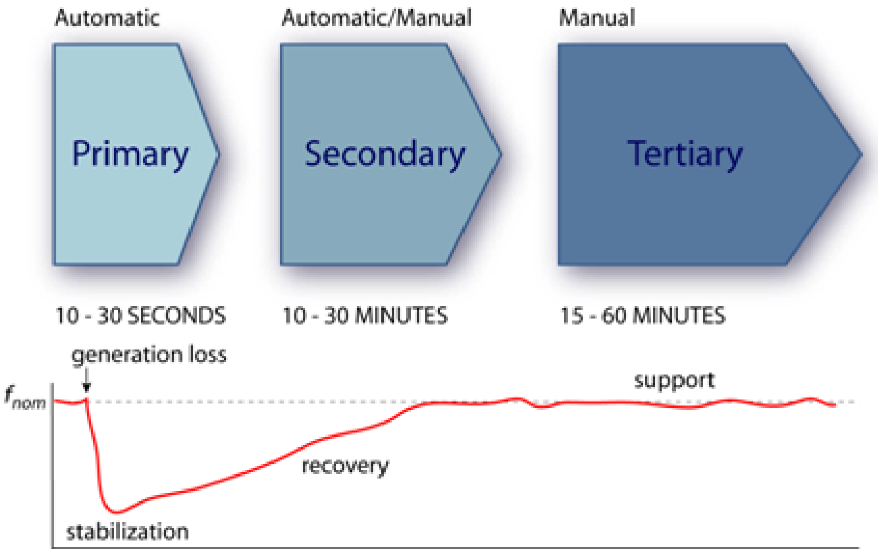


- In case of frequency regulation and PQ application response time vary in different regions according to local regulations, standards and market rules

Frequency regulation
A bulwark of system stability

- TSOs have the task of keeping the equilibrium between electricity generation and demand at all times
- To do so a TSO needs different types of frequency control reserves which differ according to volume, speed of activation, and duration
- The fastest reserve is automatically called immediately after a frequency deviation detection
    - ✓ E.g. in CE ENTSO-E zone a primary reserve is activated immediately after a detection of frequency deviation and reaches 100% level in 30 sec





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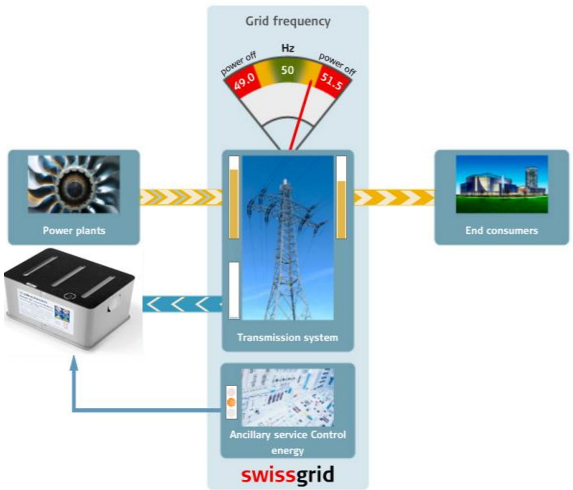
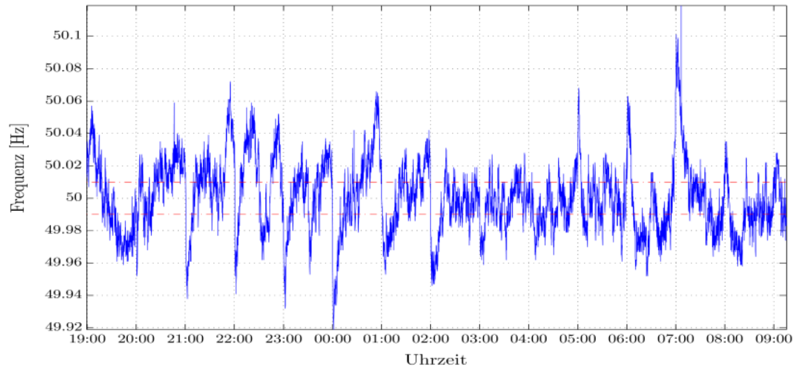
Frequency regulation (CH)



Source: adjusted graph by Swissgrid.ch

Typical frequency profile in ENTSO-E area



Prices for primary frequency control reserves in 2014 ($/MW per h)

- Denmark 20
- Switzerland 30
- NYISO 40
- PJM 50

	Case 0: EKZ case 2011 values	Case 1: Today's prices	Case 2: 2020 prices
BESS capacity (EKZ example)	1 MW 500 kWh	1 MW 500 kWh	1 MW 500 kWh
Primary control reserve offered	± 1 MW	± 1 MW	± 1 MW
Primary control reimbursement	30 (CHF/MW/h)	30 (CHF/MW/h)	50 (CHF/MW/h)
Li-ion battery cost (CHF/kWh)	1200	700	500
Total system cost (mio CHF)	2.2	1.65	1.35
Payback time w/out discount, (years)	8.4	6.3	5

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Energy storage technologies comparison

Levelized Cost of Storage
Lower — Higher

Power → Energy

Power / Energy

Technology	1 min	15 min	1 h	10 h	1 month	Technology Risks	Comments
	Levelized Cost of Storage						
Flywheel			NA	NA	NA	Mech	Low maintenance, no big changes anticipated
Supercapacitor			NA	NA	NA	Fire	Mature, asymmetric caps R&D is ramping up
Li-ion					NA	Fire Cnt	Rapid tech & cost improvement driven by automotive industry
Lead-acid					NA	Fire Cnt	Widely available at moderate cost Limited cycle life
Na-NiCl					NA	Fire Cnt	Limited field experience, only 2 OEM supplier
NaS					NA	Fire Cnt	Large installed base, single supplier, can be wiped by Li-ion
Pumped Hydro	NA					Visual Mech	Technically proven and lowest energy cost, limited geography
Flow battery (VRB)	NA					Leak Cnt	Can be fully discharged, still under development
H_2 & Fuel Cell	NA	NA				Leak Mech Fire	Can be used as transportation fuel, low round trip eff, scalability
ETES	NA	NA				Mech	Scalability must be proven

VRB – Vanadium Redox Battery; ETES – Electro Thermal Energy Storage
Technology Risks: Cnt - Contamination, Mech - Mechanical, Leak - Leakage

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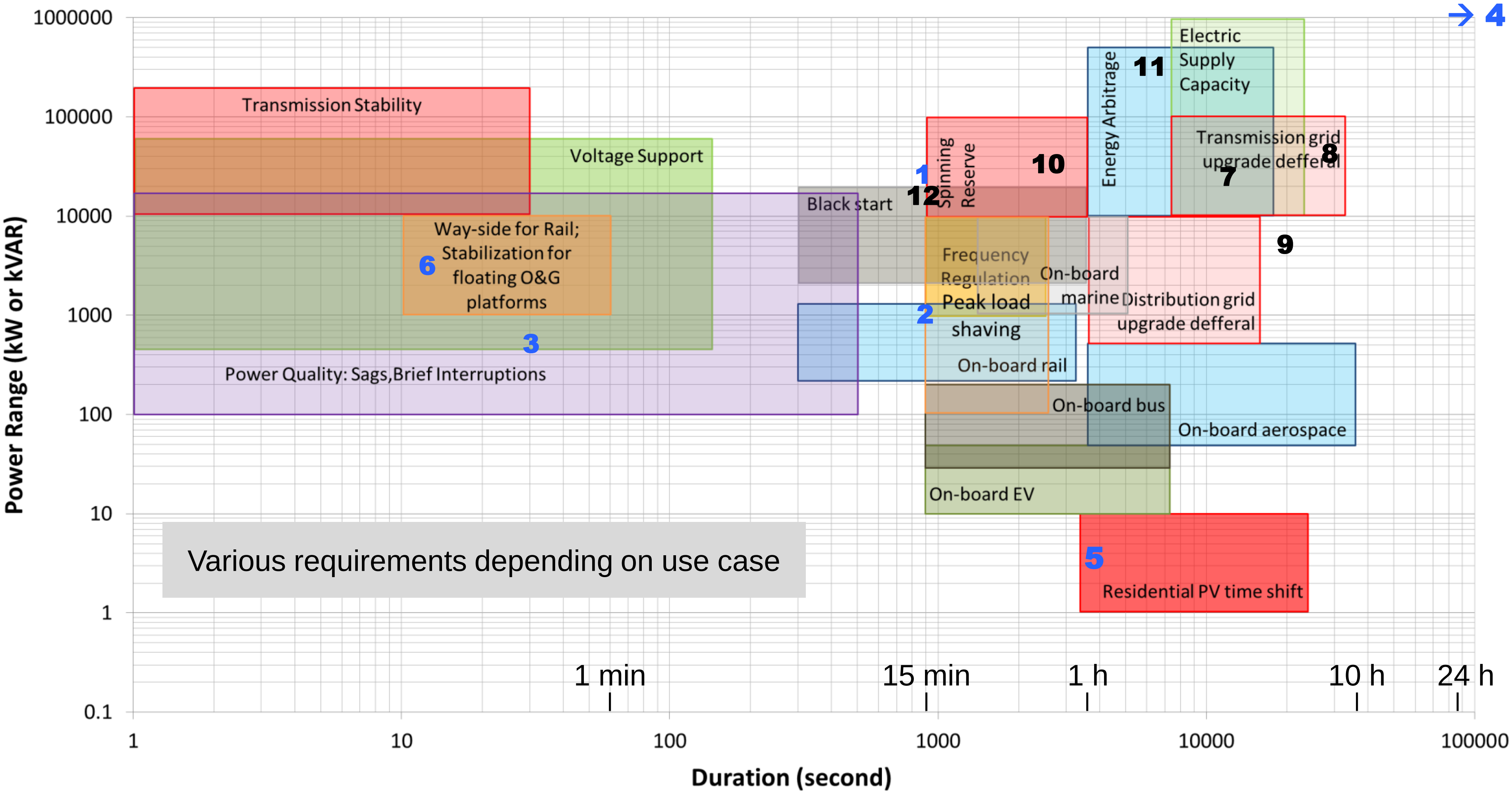
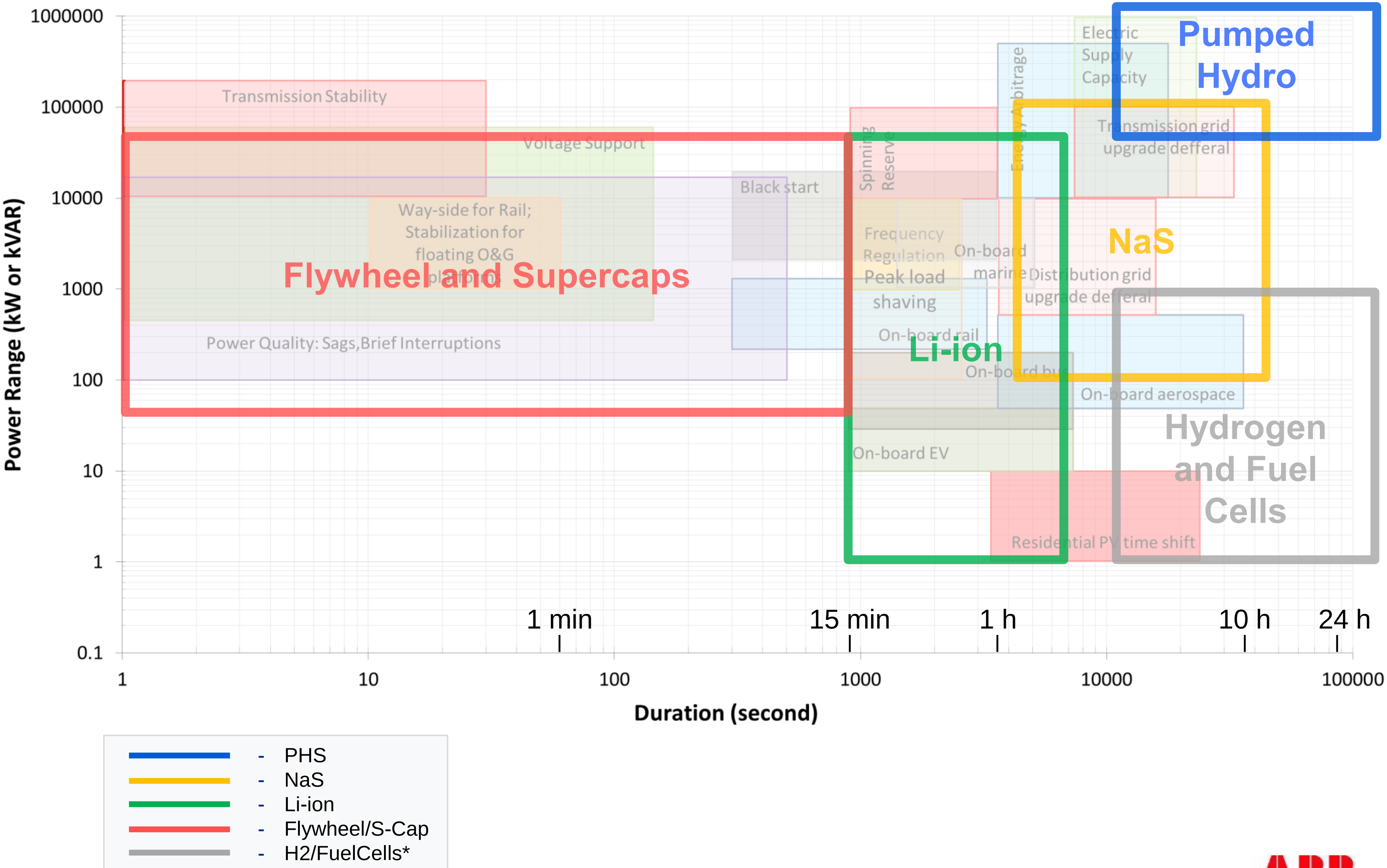
Energy storage application requirements



1. ABB for GVEA, Alaska, US	NiCd	27 MW / 15 min
2. ABB for EKZ, CH	Li-ion	1 MW / 15 min
3. ABB for Horizon Power, AU	Flywheel	500 kW / 0.5 min
4. ABB for Linthal, CH	PHS	1000 MW / 120 h
5. ABB PowerOne	Li-ion	4.6 kW / 1h
6. ABB for metro Warsaw, PL	S-Cap	3.3 MW / 12 s

7. Primus Power, USA	Flow bat	25 MW / 3 h
8. Rokkasho, JP	NAS	34 MW / 7.5 h
9. Zhangbei, China	Li-ion	6 MW / 6 h
10. Xtreme, Duke Energy, US	Lead-Acid	36 MW / 40 min
11. Huntorf, DE	CAES	321 MW / 2 h
12. Beacon Power, NY, US	Flywheel	20 MW / 15 min

Technology / Application mapping today



*) potential area in the future if cost will reduced

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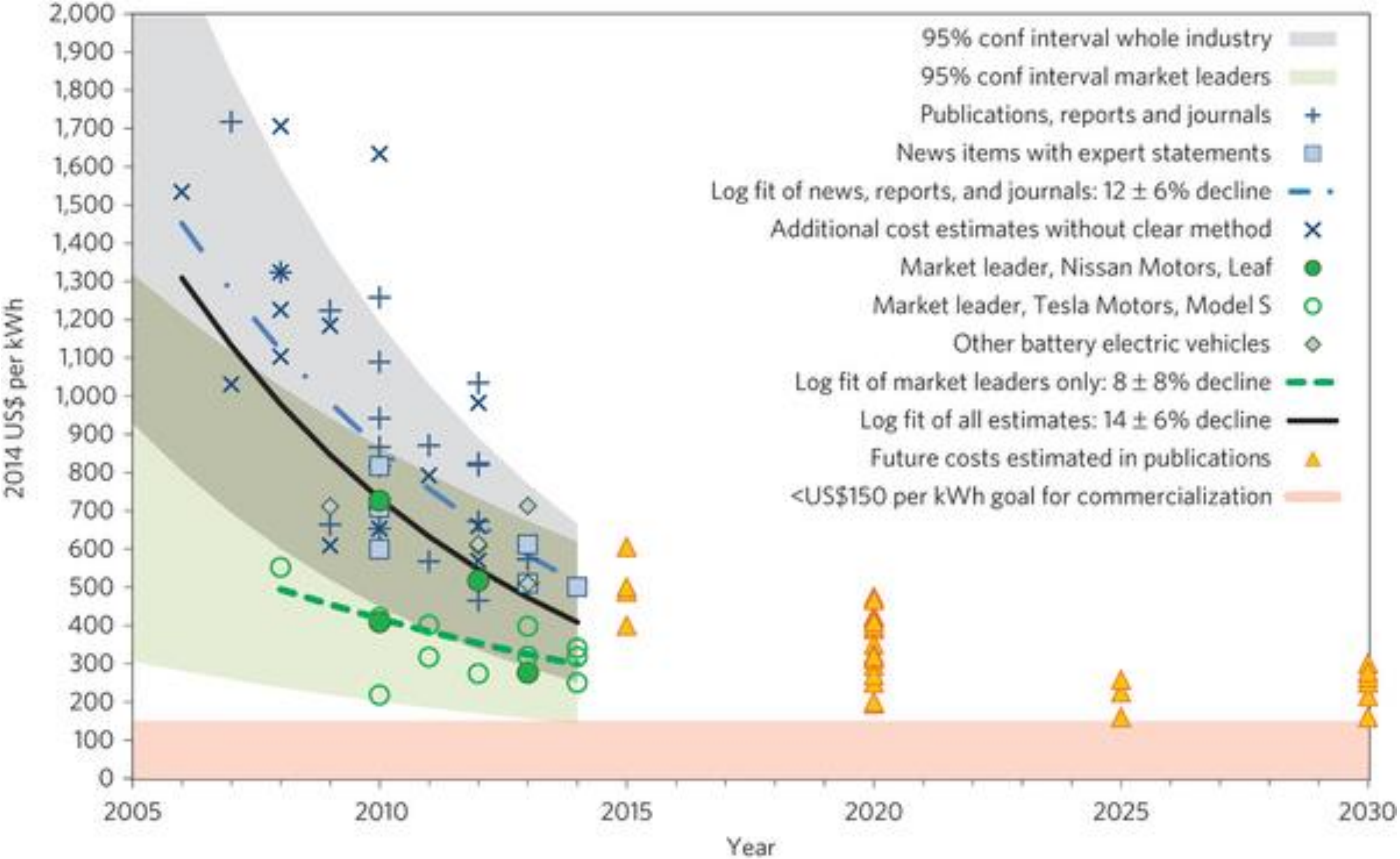
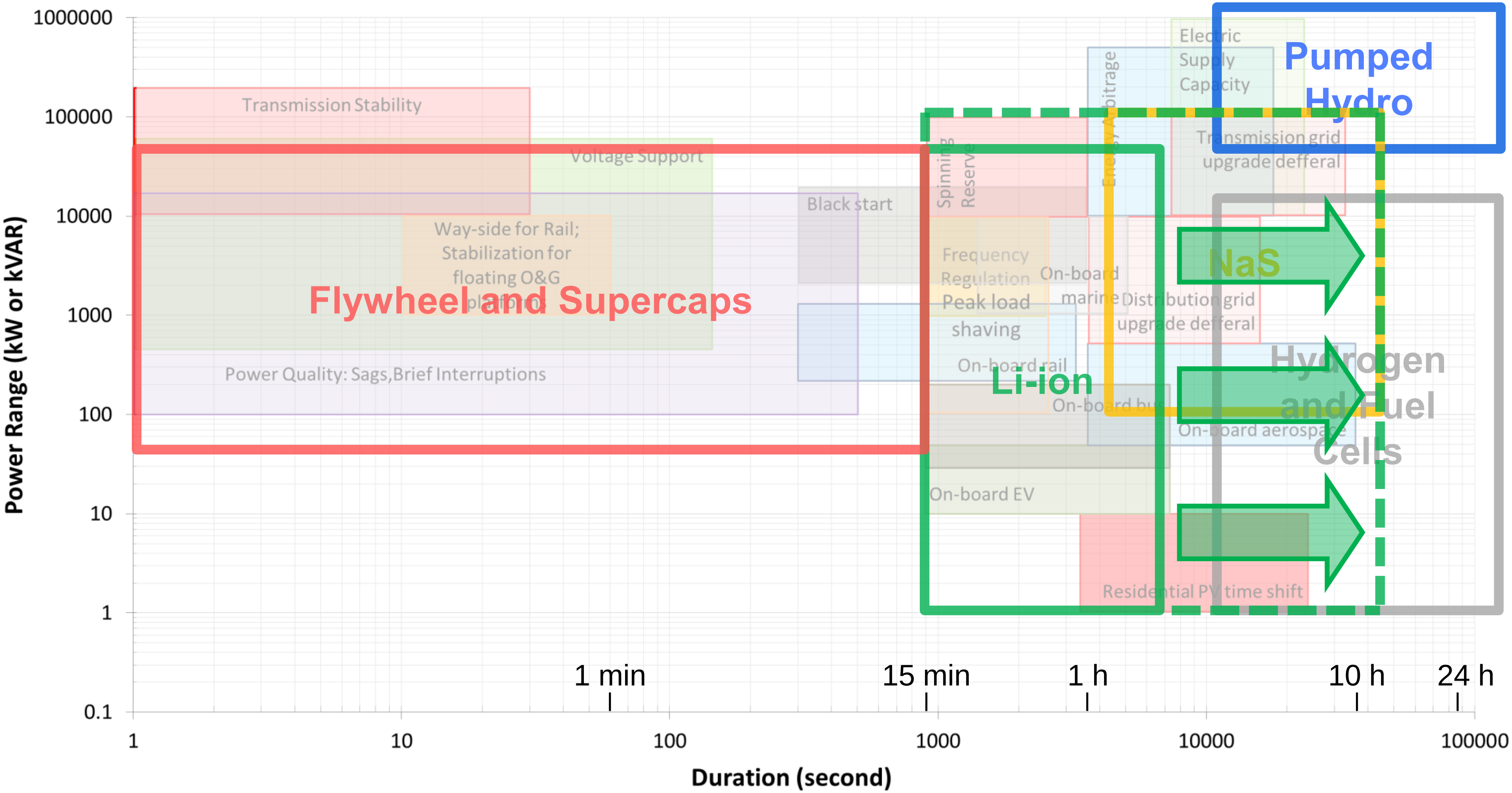
Cost is the biggest challenge to BESS adoption
Projected cost reductions of LIB ($/kWh)



*Source: Nykvist, B. and Nilsson, M., Nature Climate Change, 23 March 2015

Technology / Application mapping in 2025



PHS	- PHS
NaS	- NaS
Li-ion	- Li-ion
Flywheel/S-Cap	- Flywheel/S-Cap
H2/FuelCells*	- H2/FuelCells*

In terms of volumetric energy density both Li-ion and NaS show similar performance: 200-400 kWh/m3 and 170-270 kWh/m3 respectively

*) potential area in the future if cost will reduced

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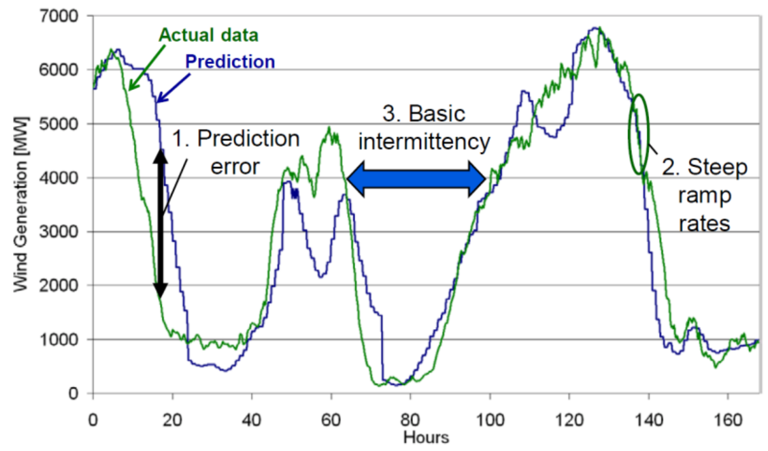
Variability of wind and solar generation

- RES such as wind and solar have a potential to reduce dependence on fossil fuels and greenhouse gas emissions but have variable and uncertain output

Classification criterion	Fossil fuel	Nuclear	Hydro	Wind solar
CO_2 and other air pollutants	-	+	+	+
Safety	+	-	+	+
Geographic constraints	+	+	-	+
Variable and uncertain output	+	+	+	-

- Wind and solar generation both experience intermittency, a combination of non-controllable variability and partial unpredictability



Source: I. Perez-Arriaga, MITEI Symposium on Managing Large-Scale Penetration of Intermittent Renewables, Cambridge/USA, 2011

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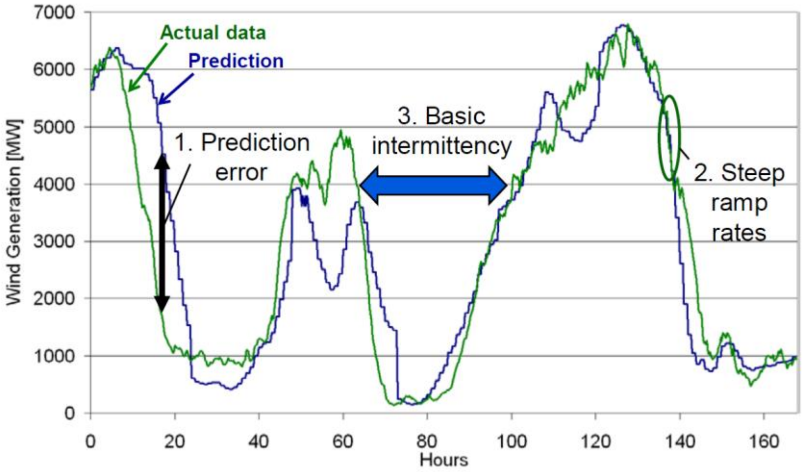
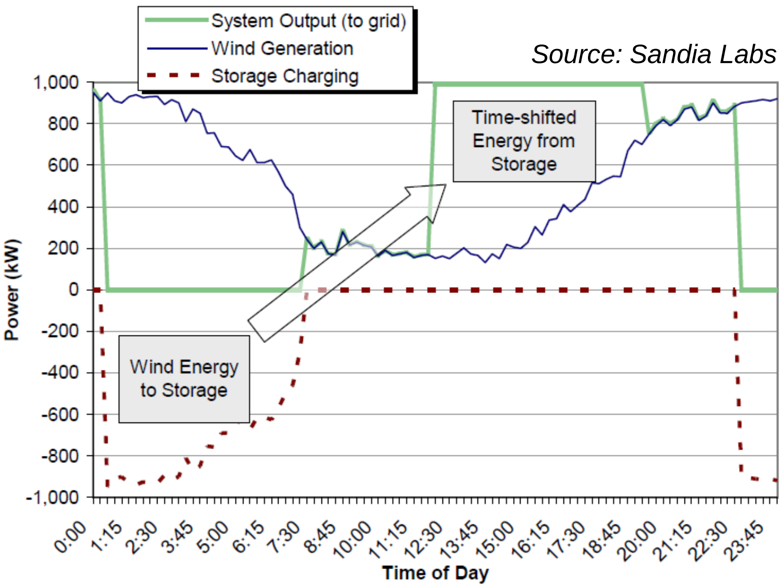
Application of BESS for integration of RES
Power and Energy based applications

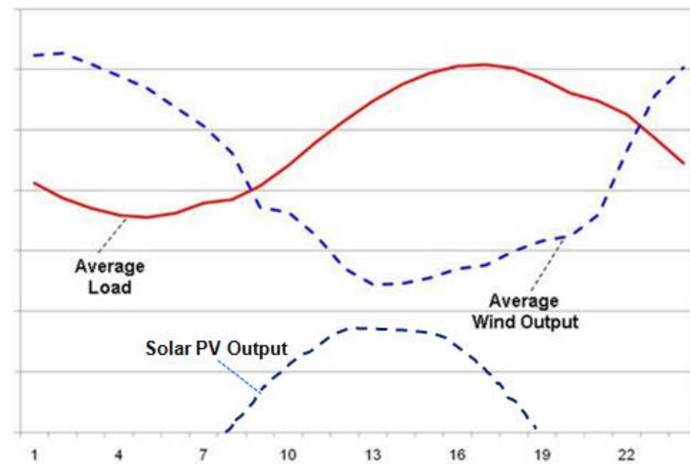
- Two applications are considered:
  - Shifting renewable energy in time
  - Smoothing an output of a renewable plant
- First application is primarily commercial and so the value of storage is dependent upon the market situation
- Second application is driven by a compliance with local regaulations



Application of BESS for integration of RES
Renewable energy time shift

- ES is charged using a low-value energy (e.g. generated off-peak at night) from the RES and sell it when it is more valuable (usually on-peak demand) via the wholesale or ‘spot’ market
- Typically, the storage discharge duration needed for a daily energy time-shift ranges from 4 to 6 hours, depending on
  - the duration of the region’s off-peak and on-peak periods
  - the on-peak vs. off-peak energy price differential





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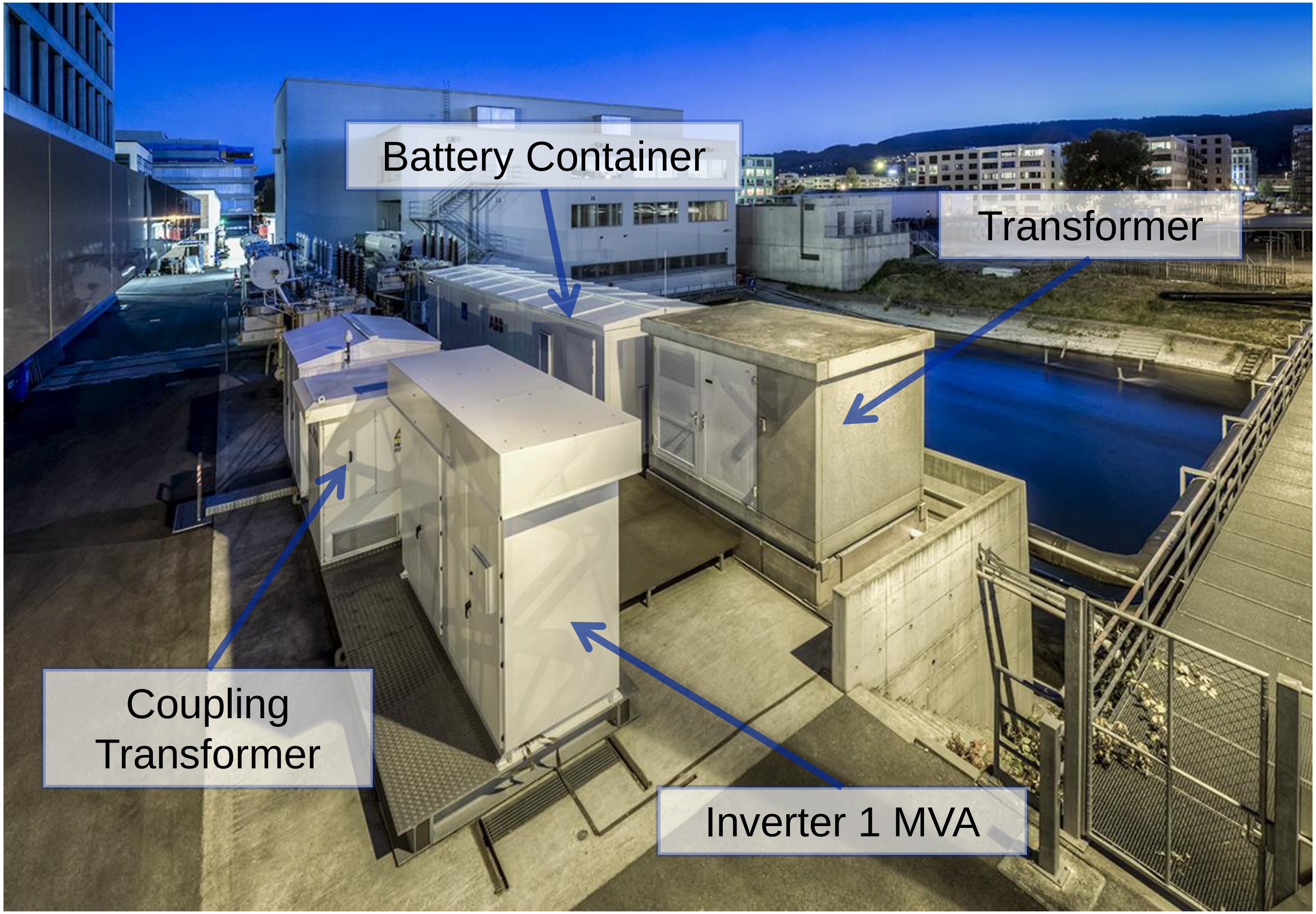
EKZ 1 MW BESS
System Overview



Source: EKZ

EKZ 1 MW BESS
System Components

Battery modules

Battery container

Inverter

SCADA

Source: EKZ

EKZ 1 MW BESS
System Properties

Property	Value	Notes
Power	1 MW	charging and discharging
Capacity	580 kWh	250 kWh @ 1 MW
System Integrator	ABB	
Battery Manufacturer	LG Chem	
Cell Type	Li-Ion	
Number of Cells	10368	
Lifetime[1]	3500 Cycles	2 Cycles/day, 250 kWh
System Costs[2]	~2 Mio EUR	~500k Battery

[1]Warranty, real lifetime most likely higher.
[2] Reflecting costs of procurement in 2011

Source: EKZ

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