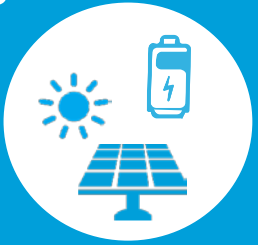
ENERGY

Energy storage in practice: issues and experiences

SEEEI International Annual Conference, 8-11-2017



Dr. Martijn Huibers, Business Leader Energy Storage

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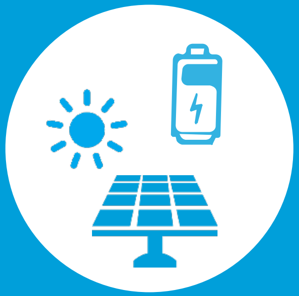
Content

1. Global status of energy storage market
2. Examples from Europe / specifically the Netherlands
3. Project realisation and risk mitigation
4. Key take-aways

Global status of energy storage market

Projects and applications



Flexibility instruments to enable high RES penetration

Flexible power

Demand side management

Energy storage

Supergrids / interconnectors

Storage technologies – high-power and high-energy options

Energy / power ratio ≥ 1 hour

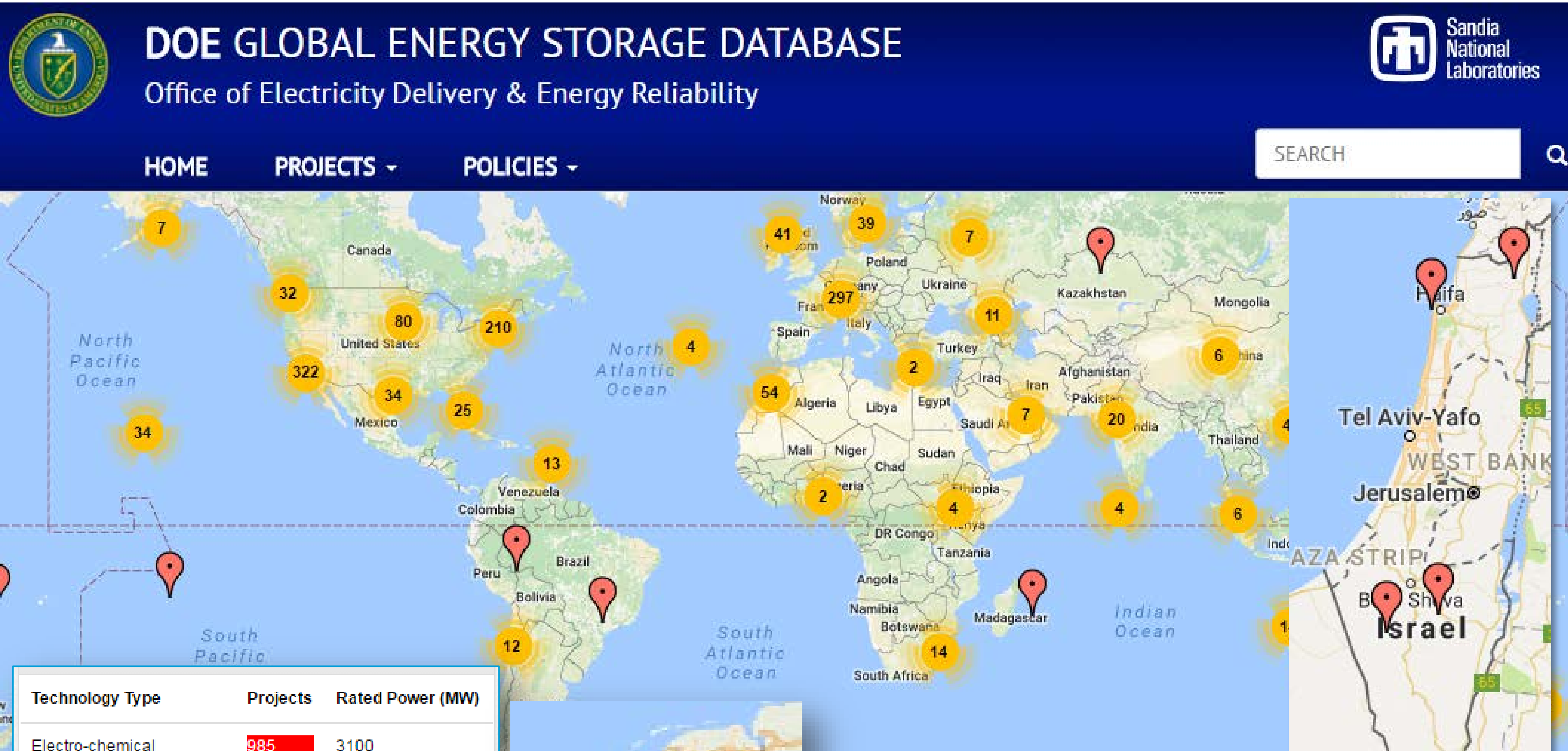
Energy / power ratio < 1 hour

- Pumped storage
- Compressed air energy storage
- Sodium sulfur (NaS) battery
- Vanadium redox flow battery

- Advanced lead acid batteries
- Zinc bromine flow battery
- Sodium nickel chloride battery
- Li-ion – high energy

- Li-ion – high power
- Flywheels
- Double layer capacitors (supercapacitors)

Global status projects: booming, strong regional differences



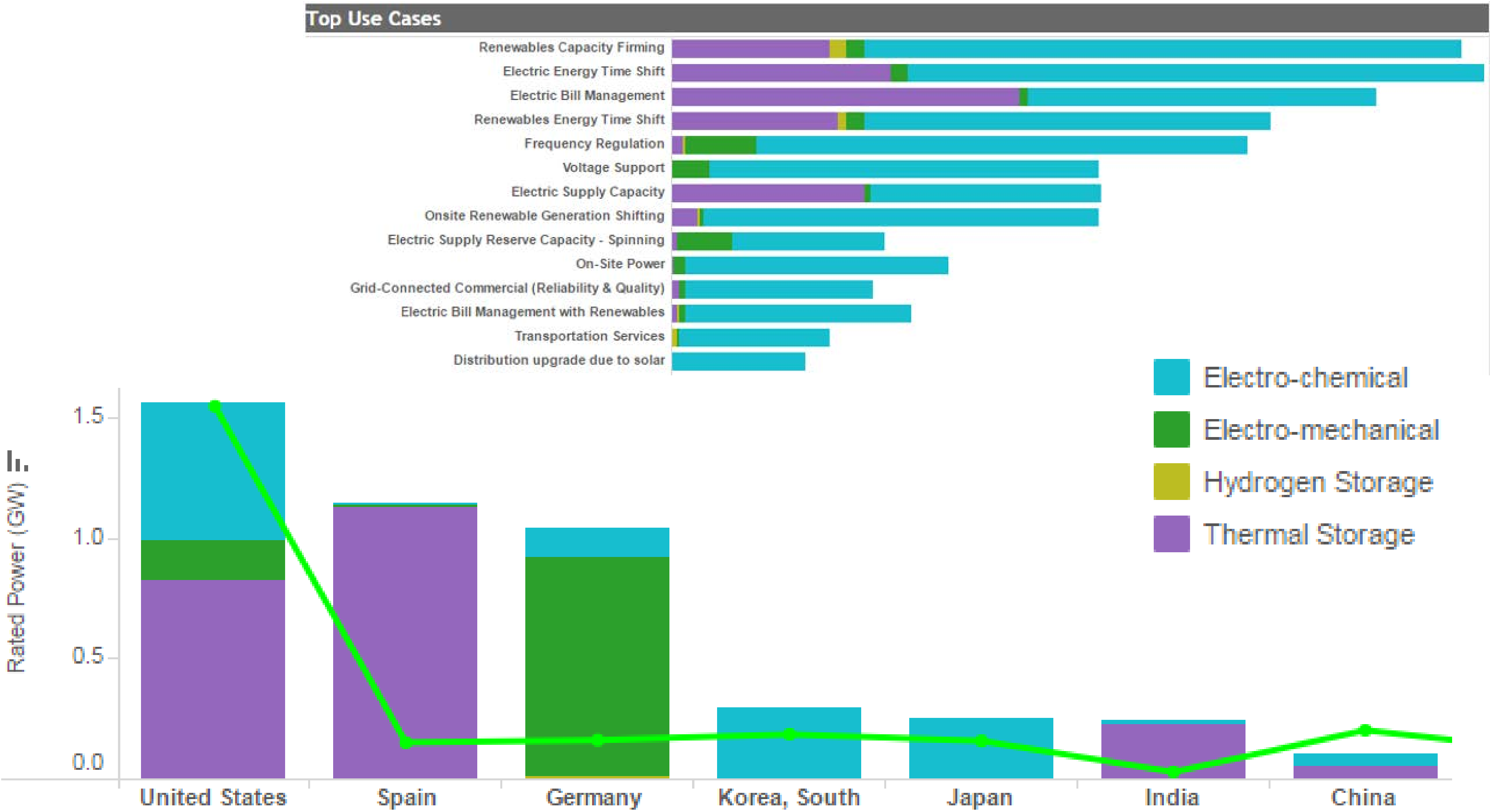
Technology Type	Projects	Rated Power (MW)
Electro-chemical	985	3100
Pumped Hydro Storage	352	183800
Thermal Storage	206	3622
Electro-mechanical	70	2616
Hydrogen Storage	13	18
Liquid Air Energy Storage	2	5

Gilboa Pumped Storage Plant (300 MW)

Ashalim CSP Molten Salt Thermal Storage (121 MW)

Enstorage Tech Demo Flow Battery (50 kW)

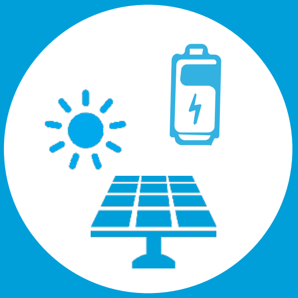
In comparison: the top 7 countries (installed capacity)



- *Source: DOE database*

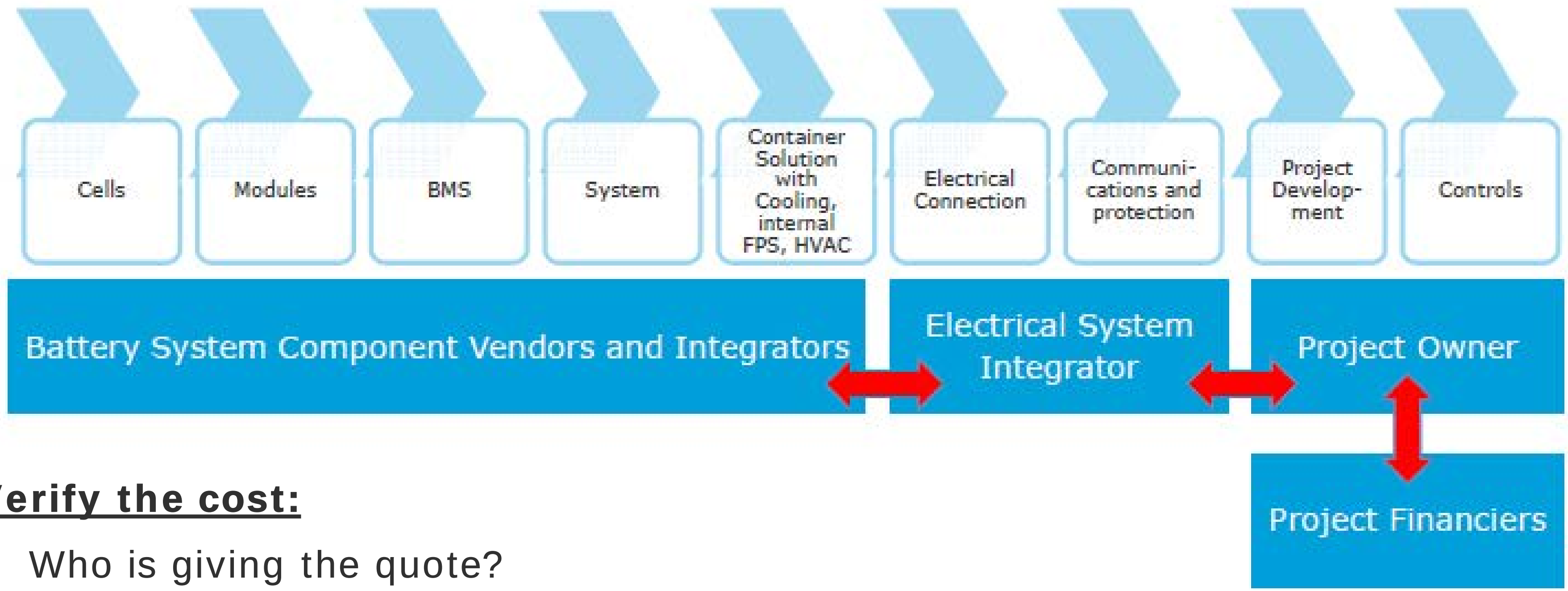
Global status of energy storage market

Economics – Li-ion



Capital Cost

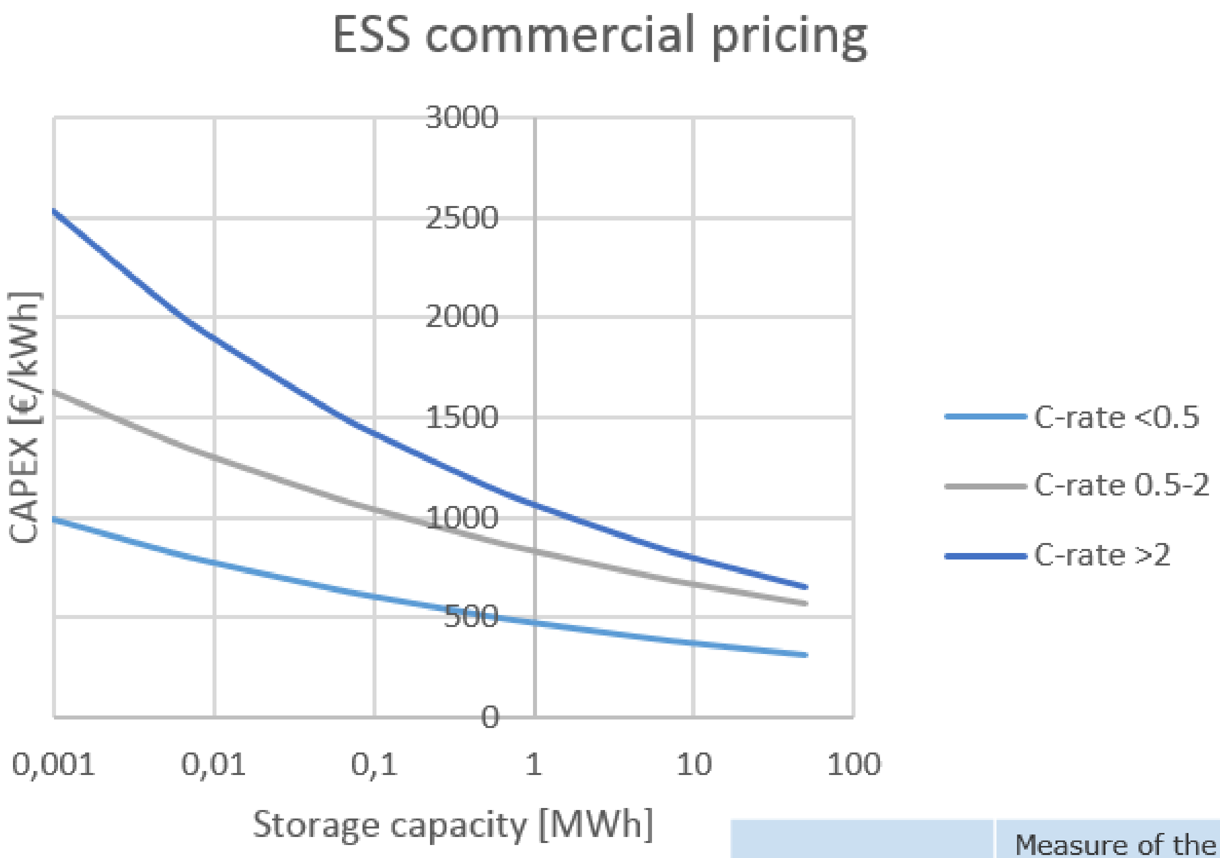
€125-300/kWh → €300-2500/kWh



Verify the cost:

- Who is giving the quote?
- Is it turnkey?
- Who else is involved?

This is real: projects are being bid in 2017 for <€300/kWh installed



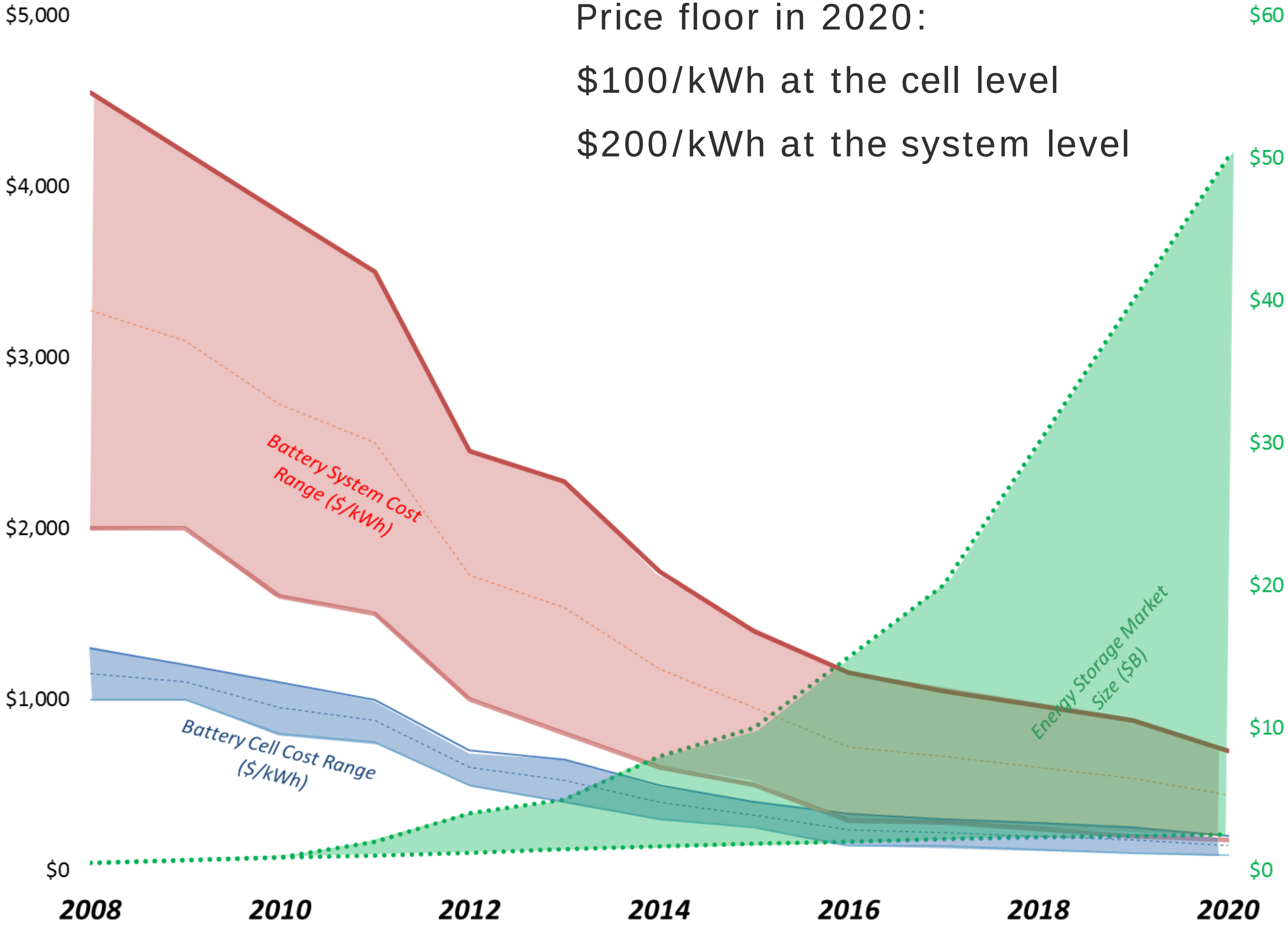
C-Rate	Measure of the rate at which a battery is discharged relative to its maximum capacity. The ratio between the power and energy (W:Wh) A High C-Rate = High Power

Projected costs

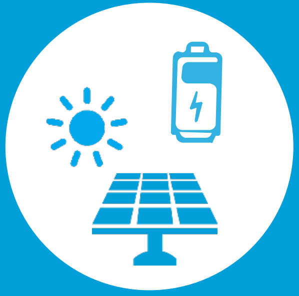
Price floor in 2020:

$100/kWh at the cell level

$200/kWh at the system level



Energy storage in Europe - examples



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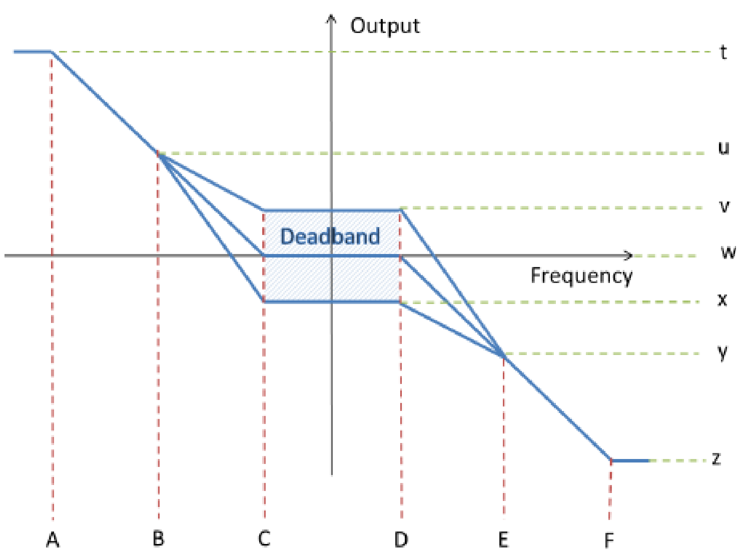
UK - Enhanced Frequency Response (EFR)

- 100% capacity must be supplied for 15 minutes
- Symmetrical capacity, 200MW tendered
- Payment based on Service Performance
- Required ramp rates depend of frequency and rate of change of frequency
- First tender round closed on July 15th 2016 (service 1, wide deadband service, service 2, narrow deadband service)



Reference Point	Service 1 (Hz)	Service 2 (Hz)
A	49.5	49.5
B	49.75	49.75
C	49.95	49.985
D	50.05	50.015
E	50.25	50.25
F	50.5	50.5

Table 1

Reference Point	Service 1 (%Capacity)	Service 2 (%Capacity)
t	100%	100%
u	44.44444%	48.45361%
v	9%	9%
w	0%	0%
x	-9%	-9%
y	-44.44444%	-48.45361%
z	-100%	-100%

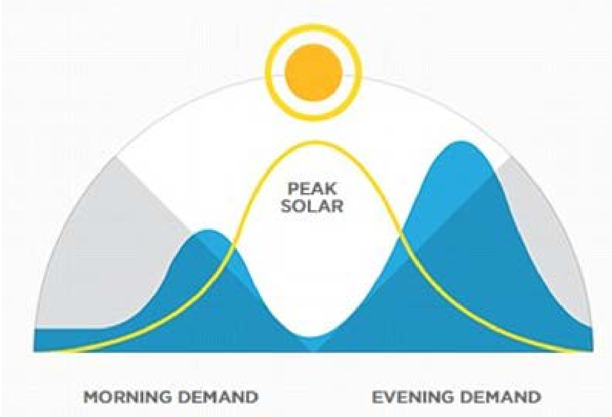
Source: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589935426, accessed March 2017
Source: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589934901, accessed March 2017

Germany and Norway

- **Home storage market in Germany**
  – Large installed capacity PV
  – Feed-in tariff, decreasing (new systems 2015: €0.09 - 0.12 / kWh)
  – Business cases may be difficult; emotional arguments play a role
  – Storage system not fully utilized, possibility for ancillary services (benefit stacking)
  – CAPEX support introduced for storage, now 25,000+ domestic storage devices

German 'solar storage' system SENEC.HOME

- **Norway**
  – >60% of Europe's PHS potential
  – Remote locations, lines (no cables)
  – Storage for resilience

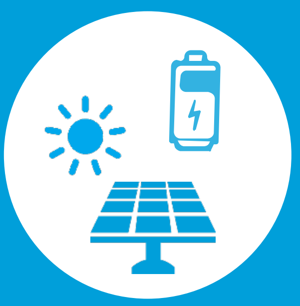


Examples of European regulatory issues (non-exhaustive list)

- Definition energy storage: still generation asset? But ownership clarified
- Incentives for renewable energy production
  - Differences in schemes across Europe, but in general variations on feed-in tariffs or net metering.
  - Barrier to storage
- Lack of dynamic retail tariffs (in general merely peak / off-peak prices)
  - Not reflecting differences in the value of electricity over time, which storage can bridge.
  - (But smart meter roll-out about to be finished 2020)
- Double charging/taxation
- Some more specific issues:
  - Technical requirements / codes
  - Market rules
  - Environmental legislation (e.g. transport of Li-ion batteries)

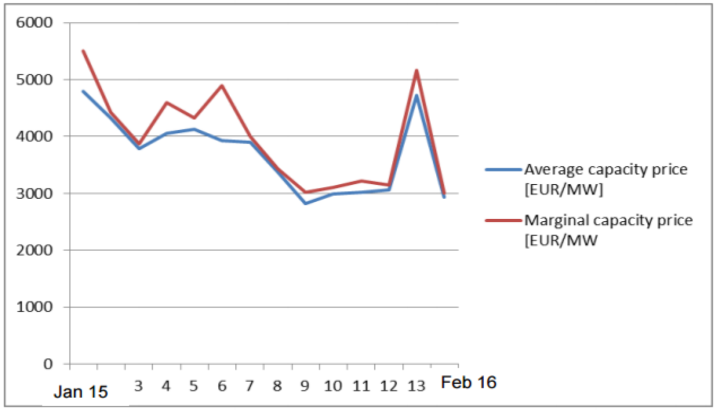
Regulation can differ widely per country

Project realisation in the Netherlands



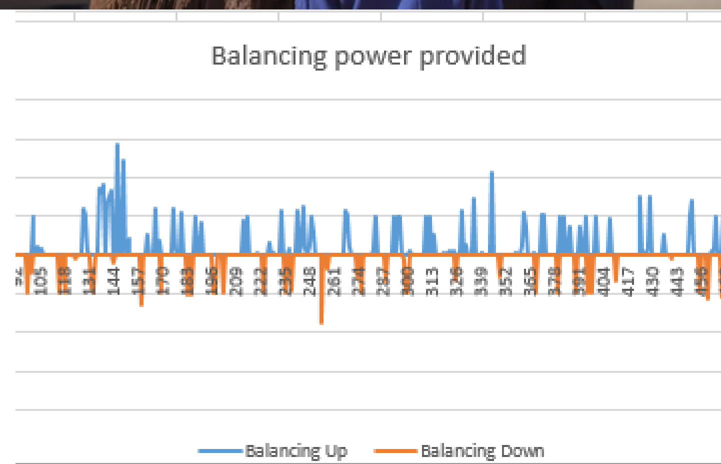
Frequency Containment Reserve – AES

- 10 MW of interconnected advanced, battery-based energy storage
- First deployment of AES' Advancion solution in continental Europe
- First battery project in the Netherlands for Frequency Containment Reserve purposes
- 45.000 lithium ion batteries



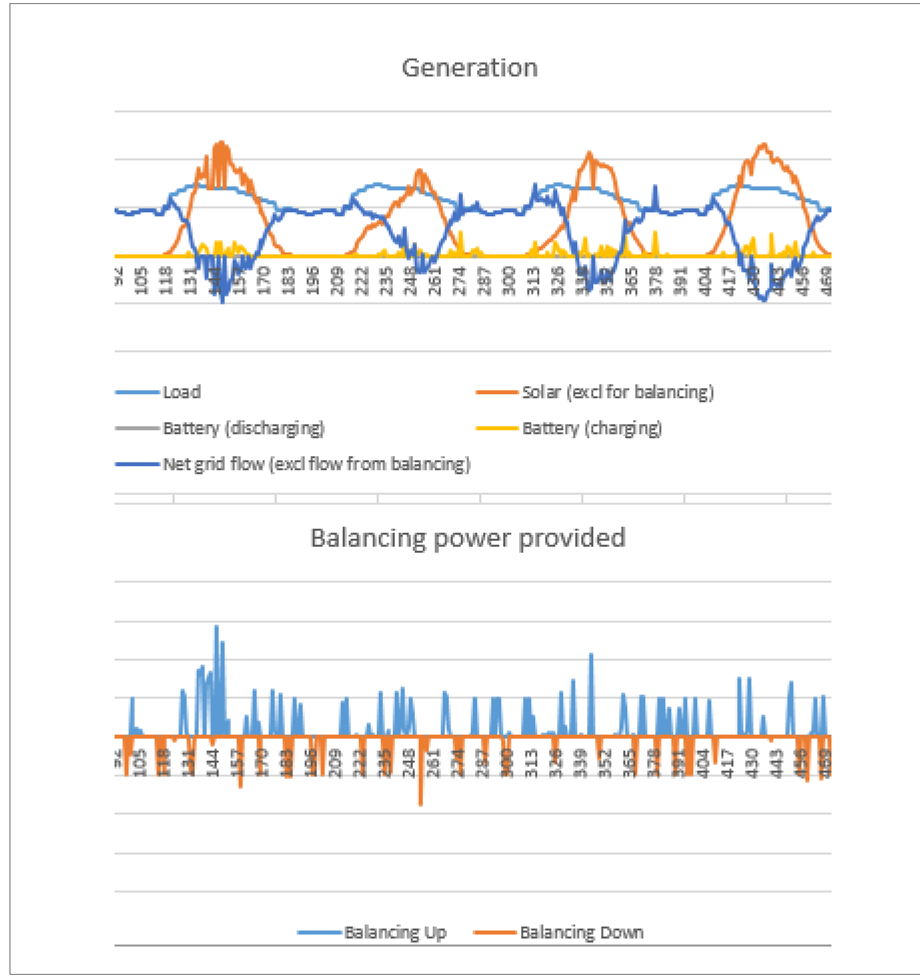
Energy storage for Alexia wind farm - Nuon

- Currently balancing and FCR
- Storage system 3MW to expand to 12MW
- Prinses Alexia Windpark (122 MW), Zeewolde
- Car batteries
- Alfen as system integrator



Solar+storage at a farm in Odoorn for multiple applications

- Solar + storage
- Balancing, self-consumption, peak-shifting
- At farm ‘De Jong en Bos’
- 294 kWh system
- ATEPS, Jules Energy, GroenLeven



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Community storage / De Buurtbatterij

Etten-Leur

- Enexis
- Smart Storage Unit
- Economically most attractive rev.
- 100kW-400kW / 240 kWh
- Jouw Energie Moment

Haarlemmermeer

- Alliander
- 120kW / 120kWh
- Rijsenhout
- Distribution grid services
- Market services
- Solar storage

Buurtbatterij

Behind the meter

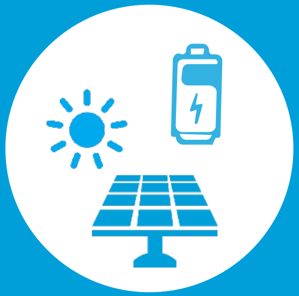
CrowdNett

- 400 Powerwalls = 1 MW_{FCR}. In NL by Q1 2017.Then scaling up in NL and starting in BE.
- Eneco aggregates capacity for FCR application at first instance
- Additional value streams at later stage (e.g. post-net metering)

Jouw Energy Moment

- Meulenspie in Breda
- 39 Tesla Powerwalls
- Testing flexible tariffs
- For trading and avoiding grid congestion

Project realisation and risk mitigation



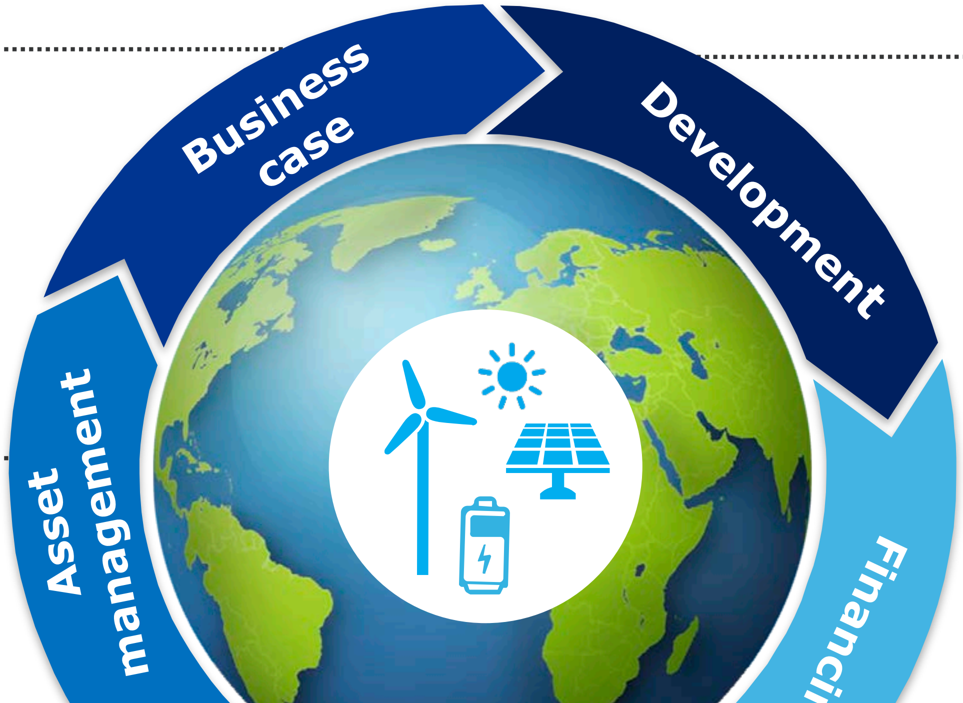
Typical elements of storage project life cycle

Business case

Market assessment
Application feasibility
Economic analysis (modeling benefits)

Development

Design engineering
Hardware and supplier vetting
Permitting, interconnection and regulatory compliance



Asset management

Monitoring, operations and maintenance
Term conversion and refinancing

Financing

roject bankability
deal structure)
revenues identified)
real estate)
partners secured)

Construction

EPC contracted supplier
Agreements construction
Monitoring project commissio

Risks in all phases for any asset, but more relevant for EESS due to:

- Technology / market maturity
- Stakeholder inexperience
- Integrated systems
- Project-specificity

Real-life examples of materialised risks

Feasibility risks

- System dimensioned on minimum CAPEX instead of TCO
- Market saturation not taken into account
- Sub-optimal combination of technology and applications

Performance risks

- Cycle life data under different conditions (DoD, temperature, C-rate)
- Standby losses not taken into account

Contract risks

- Conditions warranty and guarantees unclear
- System boundary unclear – e.g. safety responsibility

Regulation / certification risks

- System specification not in line with market regulation / grid code
- Systems not meeting standardisation

Commissioning risks

- FAT / SAT testing inadequate
- Handover unclear

Safety risks

- Fire suppression for li-ion batteries
- No FMEA analysis, no adequate measures and training
- Cyber safety

Methodology for de-risking energy storage: GRIDSTOR

DNV GL issued a Recommended Practice (DNVGL-RP-0043) on grid-connected energy storage

- Guidelines and methods to evaluate, assess and test safety, operation and performance of grid-connected ES
- Referencing ISO, IEC and IEEE standards if possible, enhancing where needed
- Industry supported: created by consortium of 7 parties, 36 parties involved in review process
- Comprehensive
- Free to use

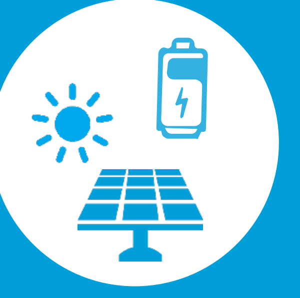
SAFETY	OPERATION	PERFORMANCE
FMEA/Bowtie analysis	Monitoring	Definitions
Risks and mitigation	Control	Conditions
Design consequences	Grid connection	Measurement
Procedures & documentation	Environmental analysis	Life cycle costs

GRIDSTOR Update!

- New technologies (CAES, ultra-caps, inorg. Li-ion)
- Cybersecurity
- Communication protocols
- Decommissioning
- Warrantees, guarantees
- Contracting aspects
- Bankability
- LCoS
- Residual value assessment
- Procurement
- Inverter aspects
- …and more…

For more information, see www.dnvgl.com/services/gridstor-recommended-practice-for-grid-connected-energy-storage-52177 and rules.dnvgl.com/docs/pdf/DNVGL/RP/2015-12/DNVGL-RP-0043.pdf

Key take-aways



Key take-aways

2016-2017 are breakthrough years for storage in many markets	Costs becoming commercially attractive, but depending on many aspects	Various projects in several countries, especially in maturing markets in UK, US, DE.	As a relatively new and complex item, various examples of materialised risks	GRIDSTOR Recommended Practice as the technical framework for risk analysis

Training courses grid-connected energy storage (worldwide)

ENERGY ACADEMY

TRAINING COURSE GRID-CONNECTED ENERGY STORAGE

Increase your understanding of the technical, market and financial aspects as well as risks associated with grid-connected energy storage.

This two-day course on grid-connected energy storage is intended for professionals wishing to acquire a comprehensive overview of grid-connected energy storage and to have the latest technology, market conditions and issues clearly explained. The topics covered are: energy markets in relation to energy storage, the role of storage in providing flexibility to solve intermittency issues in the grid, business models, performance indicators, warranties, safety, risks and risk mitigation, and more.

DNV GL will provide you with international examples and present our view on best practices for grid connected energy storage using our industry-supported GRIDSTOR methodology.

Your benefits

After this course you will be able to:

- Identify opportunities and risks for grid-connected energy storage in your business.
- Understand the complexity of grid-connected energy storage projects, be able to make decisions and interact with stakeholders during the entire project life cycle.

Course topics

The following topics will be addressed:

- Roles of storage in the electricity grid
  - Electricity markets
  - Types of energy storage systems (e.g. Li-ion, vanadium redox flow batteries, etcetera)
  - Components of energy storage systems
- Essential elements - life cycle phases and planning
  - Performance indicators/reliability
  - Sizing
  - FAT/SAT
  - Warranty/safety items
  - Contracting, actors and responsibilities
- Business models
  - Value of flexibility
  - Levelised cost of storage (LCOS)
  - Technology/market combinations
  - Examples/case studies
- Risk in energy storage
  - Risks & risk mitigation
  - Safety, health and environmental aspects
  - Design FMECA/operational FMECA
  - Standards

Thank you.

Questions → DNV GL booth

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Comparison of Li-ion batteries

Criteria	Graphite/Lithium Iron Phosphate	Graphite/Nickel Cobalt mixed oxides (NMC, NCA)	Graphite/ Lithium Manganese oxide	Lithium Titanate Oxide/Lithium Manganese oxide/Nickel Cobalt mixed oxides	Lithium Titanate Oxide/Lithium Iron Phosphate
Energy density (Wh/kg)	▪ 120	▪ 150	▪ 120	▪ 80	▪ 50
Safety	▪ Good	▪ Medium	▪ Medium	▪ Very good	▪ Very good
Calendar life (years)	▪ 15	▪ 10	▪ 10	▪ 20	▪ 25
Cycle count at 100% (DOD)	▪ 2000-3000	▪ 1500-2000	▪ 2000-3000	▪ 15000	▪ 20000 +
Initial capex per kWh (%)	▪ 30%	▪ 35%	▪ 30%	▪ 70%	▪ 100%
Stored cost of kWh comparison (%)	▪ 60%	▪ 100%	▪ 60%	▪ 23%	▪ 25%
Advantages	✓ Safety and power	✓ High energy density	✓ Good power and low costs	✓ Safest and highest cycle count	✓ Potentially the longest lasting
Disadvantages	× Degradation at higher temperatures	× Low cycle count × Lower safety	× Rapid degradation at temperatures above 40ºC	× Low energy density and high initial cost	× High cost × Gassing problems that limit usable lifetime

Ref: Leclanché