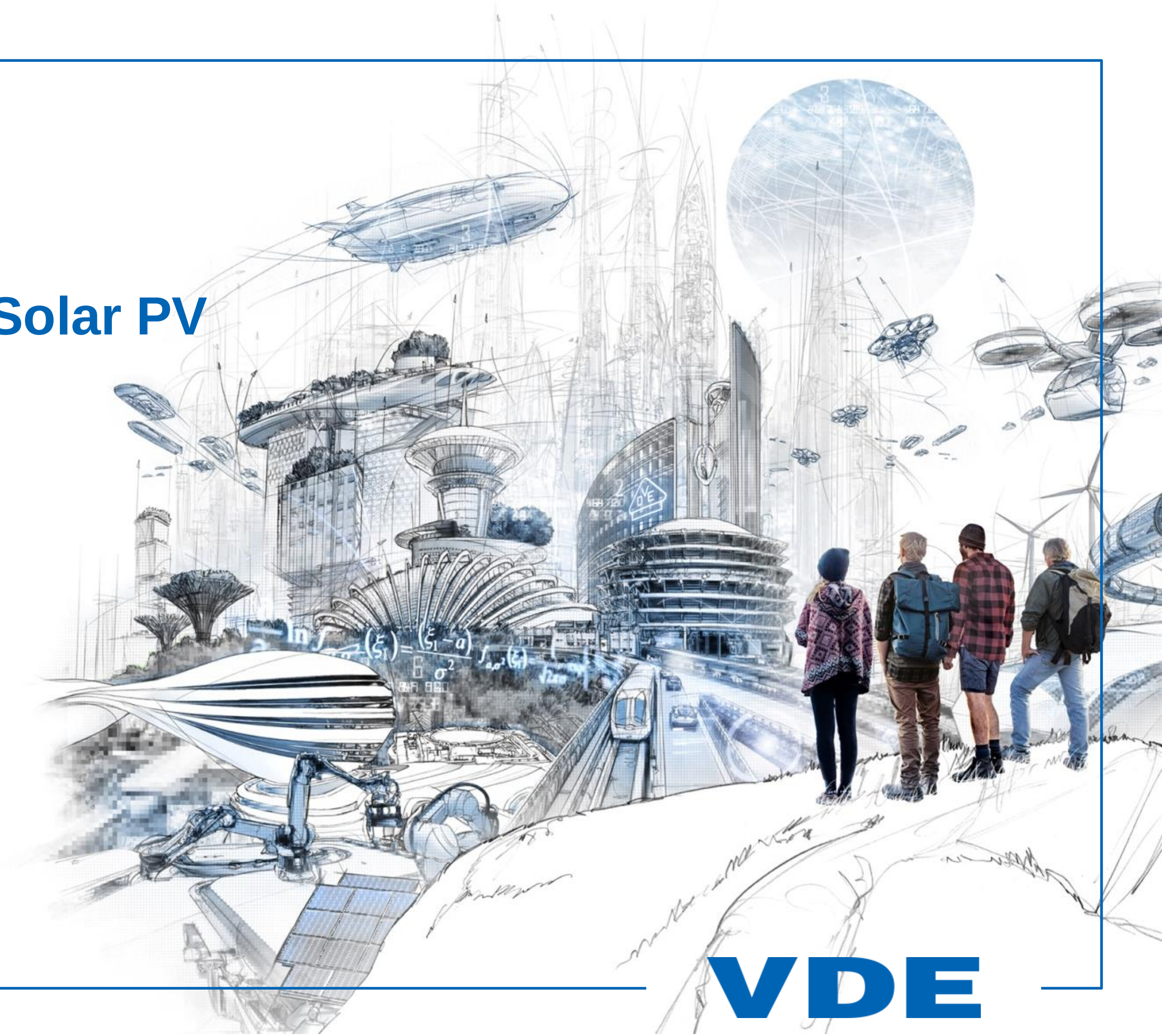
Battery Energy Storage for Wind Energy: Lessons Learned from Solar PV



Global Offshore Wind Summit

Taiwan

October 2020

VDE

Agenda

- What have we learned about technical and financial risks from PV?
- What is the role of battery-based Energy Storage Systems (ESS) in renewables?
- Which risks need to be considered for implementation of ESS?
- Examples of accidents
- Quality assurance: Compliance to standards and best practices
- VDE’s approach and track record

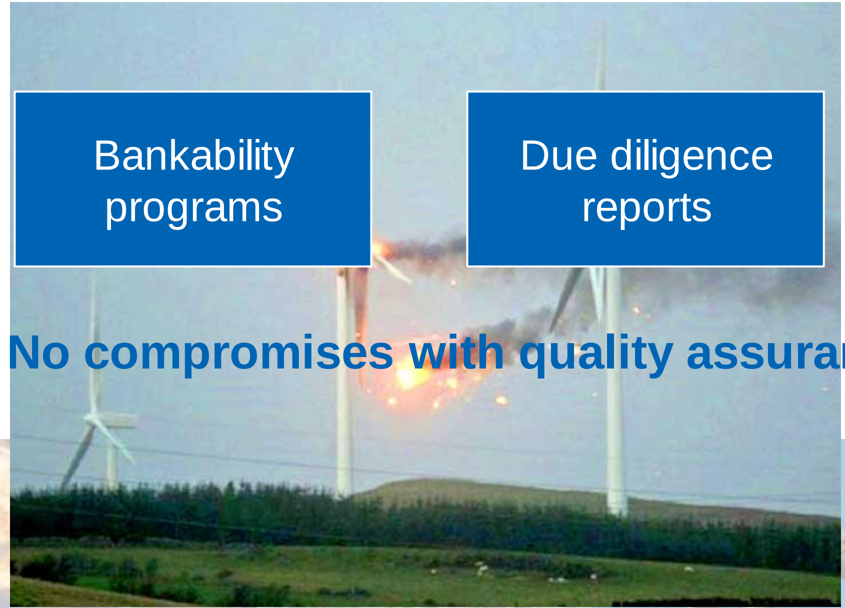
Reducing technical and financial risks

Certification

Bankability programs

Due diligence reports

Independent engineering



➔ No compromises with quality assurance!

Where do risks arise from?
25 years of experience and lessons learned

Components	Systems	Grid interconnection	Installation quality	Off-take, rating
Improper execution of test processes Fire and explosion risk	Project development	Grid codes lacking standards	Insufficiently trained installers	Reliability of subsidies and incentives
Current state of technology surpasses international standards	Installation, design	Missing grid interconnection	Design failures	Political risk
Incomplete or inaccurate performance and reliability tests	Operation	Incomplete, incorrect off-take agreements	Fragmented execution, too many interfaces	Country/project rating

UK 18MV PV plant: USD 7-digit losses after 4 years of operation

Background: VDE assessed PV plant in the UK after system performance started declining after only 4 years of operation.

Issue: DC cables were buried directly into the ground, but cables were not rated for this type of application and started to fail. Additional issues were non-operational strings and gaps in the O&M procedures.

As remediation, 5km of trenches needed to be dug up and 66km of new and proper cables needed to be put in place. Other issues were fixed as well.

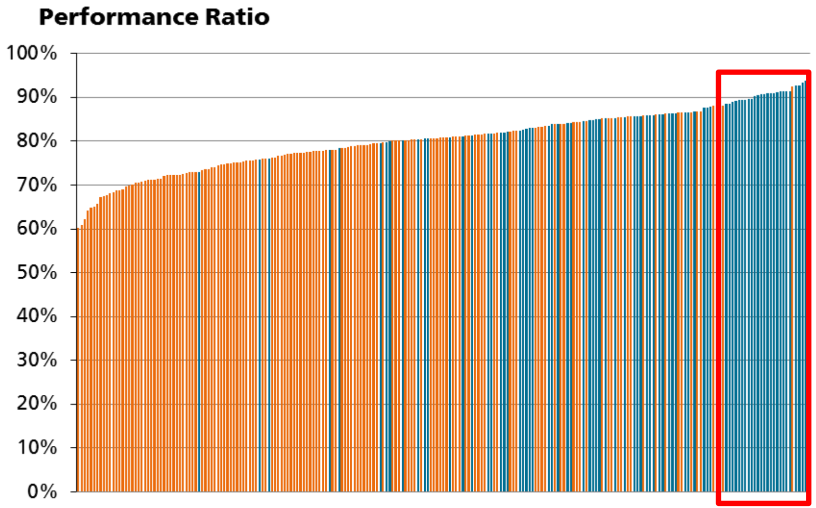
Key lessons learned by owners and operations team were that a similar quality assurance assessment (which includes cable-related checks) done earlier in the project could have avoided the high remediation costs.

Financial business case: The costs for cable replacement was about EUR 1 million and other remediation costs about EUR 500k. A proper quality assurance assessment costs only about 4% of those remediation costs.

Where is the business case?
System level quality is key for performance

Measured performance ratios for 300 PV plants

Blue bars represent new plants with quality assurance and continuous O&M.

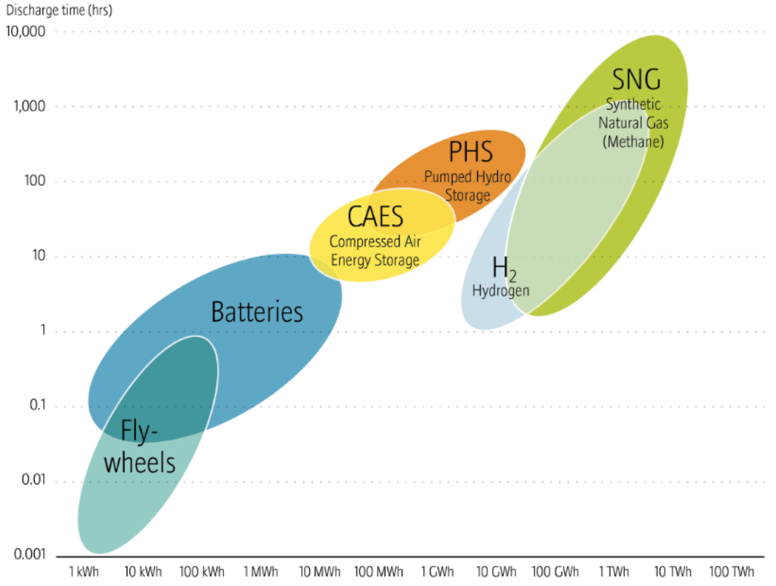


Fraunhofer ISE, Annual assessment PV power plants

➡ **High Quality PV plants in central Europe achieve PRs of up to 90%**

What is the Role of Batteries in Energy Storage?

Overview storage capacity of different energy storage systems

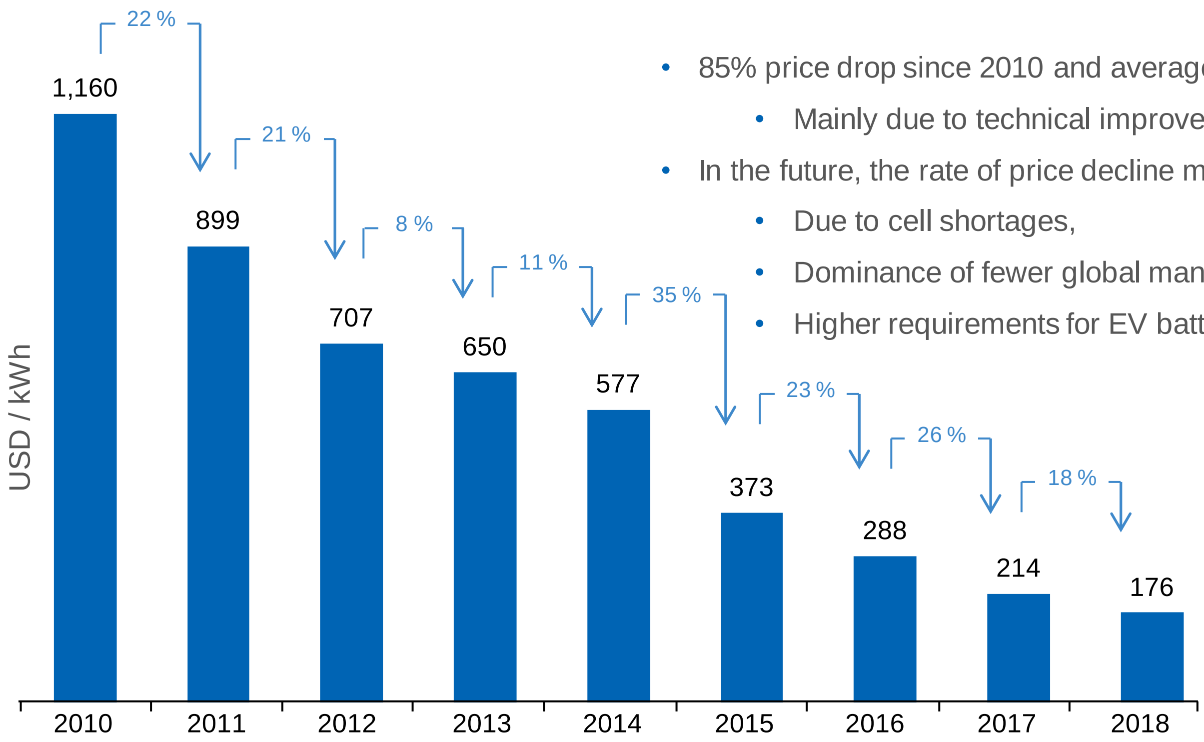


Renewables Global Futures Report Great debates towards 100 % renewable energy

Source: Fraunhofer Institute, Germany, 2014

- Increasing share of renewables in power generation
  - EU: 17.5% in 2017, 67% increase since 2007
  - 100 GW new PV commissioned in 2019
- Intermittency of renewables requires storage
- Projections for Germany by 2050:
  - 110 – 190 GWh total storage
    - including 40 – 120 GWh of battery storage
  - 193 – 536 GW total renewables
    - including 122 – 290 GW of PV systems

Price Development of Lithium-ion Batteries



- 85% price drop since 2010 and average drop of 20% anually;
  - Mainly due to technical improvements, e.g. higher energy density cathode
- In the future, the rate of price decline may slow down;
  - Due to cell shortages,
  - Dominance of fewer global manufacturers,
  - Higher requirements for EV batteries, e.g. fast charging and cooling systems

Source: Bloomberg NEF, Jan 2019

Note: The data in this chart has been adjusted to be in real 2018 dollars. Volume average of 2018 does not take into account the contracts signed this year by major OEMs for future purchase agreements.

Risks Associated with Battery Energy Storage

incineration

electric shock

chemical danger

fire (out of the device)

high temperature

overcurrent

misuse

unbalancing

mechanical danger

explosion

leaking liquids

fault current

gas release

Risks of Battery Storage Systems

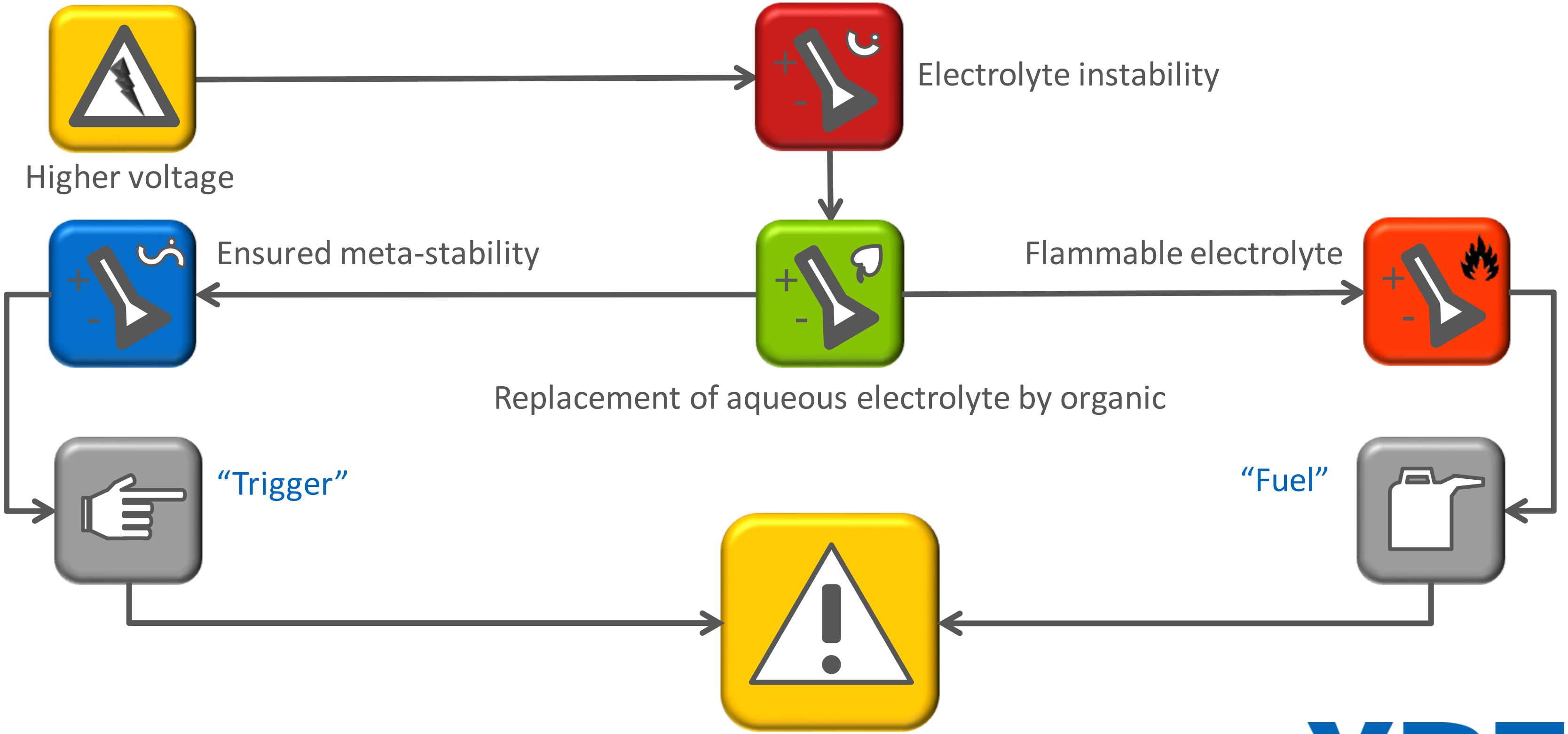
Technology risks

- What makes Li-ion batteries inherently risky?
- What can go wrong with batteries and how?
- Where do the risks arise from?
- What properties are affected and how are they connected?
- What happens to battery during its lifetime?

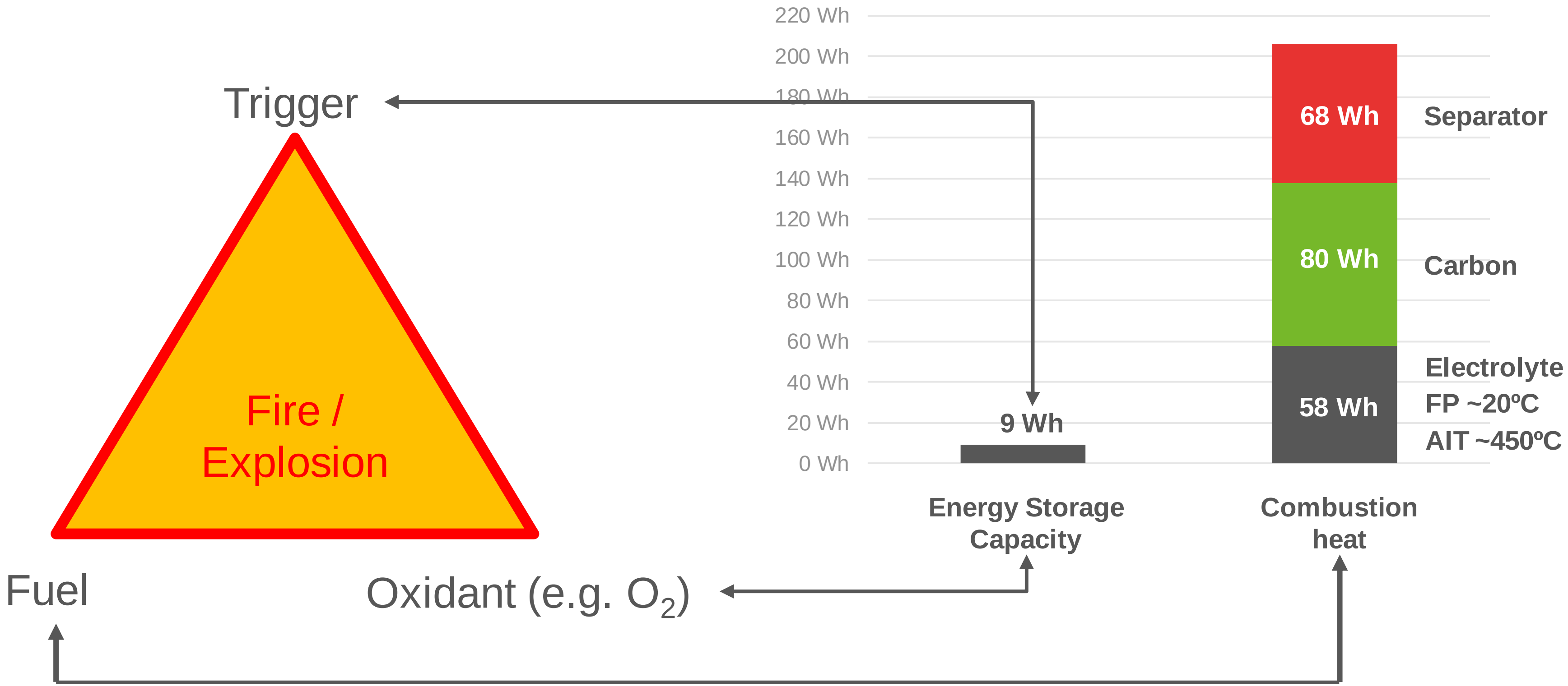
Application risks

- Overview of BESS risks:
  - Component and subsystems risk
  - System design risks
  - Installation and site related risks
  - Risks related to operation, management, and maintenance
- Examples of accidents and their causes

What makes Li-ion batteries burn / explode?

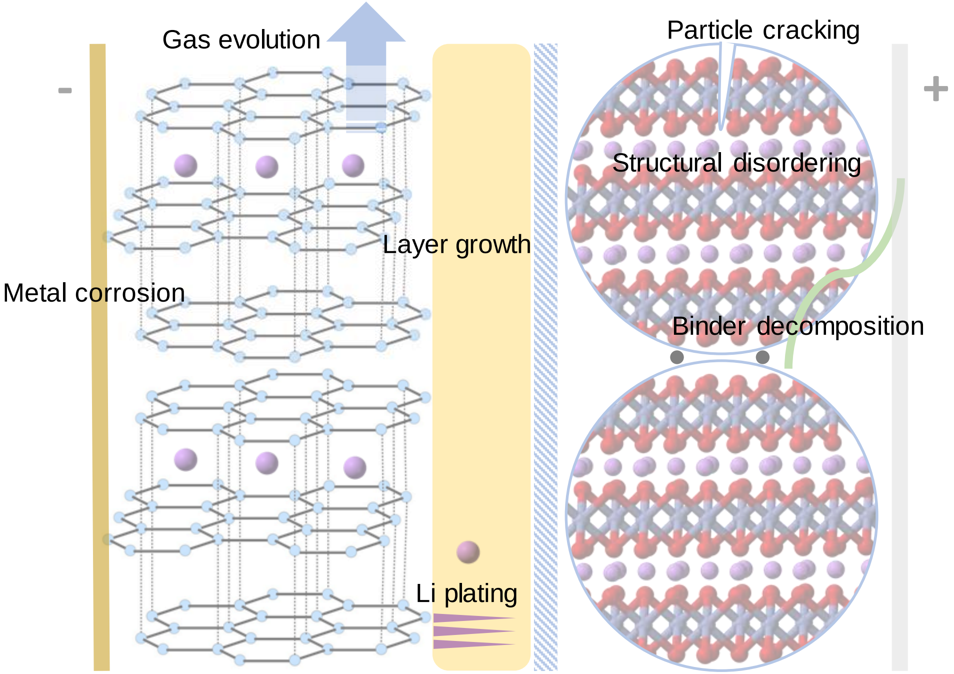


What makes batteries burn / explode?



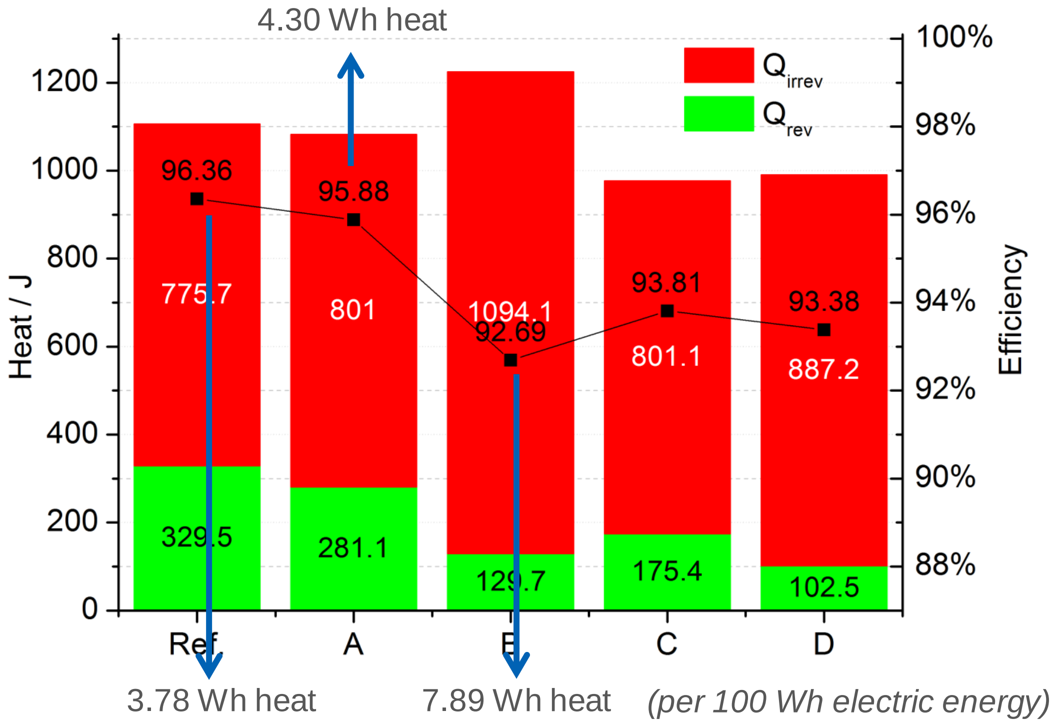
What happens over the ESS lifetime?

Irreversible ageing of Li-ion cells



- Decrease of capacity
- Increase of internal resistance
- Drop of cyclic efficiency
  - Excessive heat generation
  - Safety risks due to higher temperature
  - Vicious circle of accelerated ageing

Aged cells – potential safety challenge



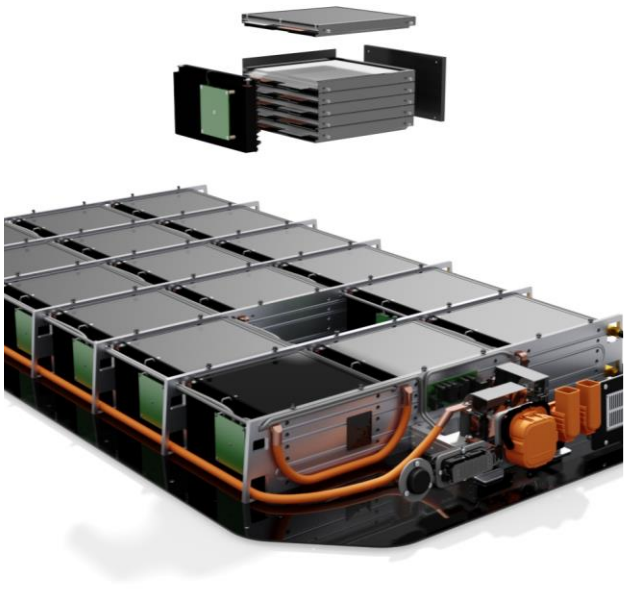
(per 100 Wh electric energy)

$$\eta_{dis} = \frac{utilized\ electric\ energy}{total\ energy\ released} = \frac{E_{dis}}{E_{dis} + Q}$$

Significant loss of energy efficiency

More heat release per unit of energy stored

Risks: Components and subsystems: Batteries



- Safety: Thermal runaway
  - Propagation of thermal runaway to adjacent cells
  - BMS failures
  - Faulty insulation
- Performance/Efficiency
  - Faulty cell / string balancing
  - Inadequate dimensioning
  - Faulty thermal management
- Lifetime
  - Degradation of internal components

Risks: Components and subsystems: BMS, EMS, PCS

- Communication failures
  - Especially in failure case
- Improper integration of systems
  - Dimensioning issues
  - Hierarchy
- Non-conformance with grid requirements
  - Lack of interoperability
  - Frequent shutdowns

Risks: Components and subsystems: Auxiliary components

- Cabling
  - Insulation failures
  - Grounding failures
- Protective systems
  - Inadequate fire extinguishing systems
  - Failure of shut-down: automatic and manual
- Environment systems
  - Temperature management / humidity
  - Shutdown in case of failure
- Inadequate housing of components

Risks: System design

- Dimensioning
  - Under- or over-dimensioned ESS: performance loss
  - Ratings of auxiliary system
- Renovations and upgrading
  - Lack of risk analysis
- Safety features
  - Inadequate safety distances
  - Lightning protection system
  - Fire extinguishing system: quantity and type
  - Control and surveillance system

Risks: Installation site

- Environmental impacts
  - Climate / weather: temperature and humidity
  - Geography: floods, high tide, landslides
- Human impact
  - Accessibility (unintended damage and vandalism)
  - Traffic
- Risk of system to surroundings
- Adjacent facilities
  - Sources of fire / chemical risk
  - Sources of electromagnetic interference

Risks: Operations, Management, and Maintenance

- Personnel involved
  - Lack of competence
  - Not trained for ESS; e.g. first responders
- Operation procedures
  - Risk management and risk assessment
  - Lack of quality control
  - Inadequate emergency procedures
- Tracking of system
  - Inadequate document control
- Cybersecurity

Accident example: Korea ESS fires of 2018

- 23 large fires in 2018 and early 2019
- MWh-range ESS were affected
  - PV peak-shaving ESS
  - Industrial load shifting ESS
- 765 out of 1490 ESS were suspended
  - (at peak in Q1/2019)
- Millions of $ in damage

Accident example: Root causes

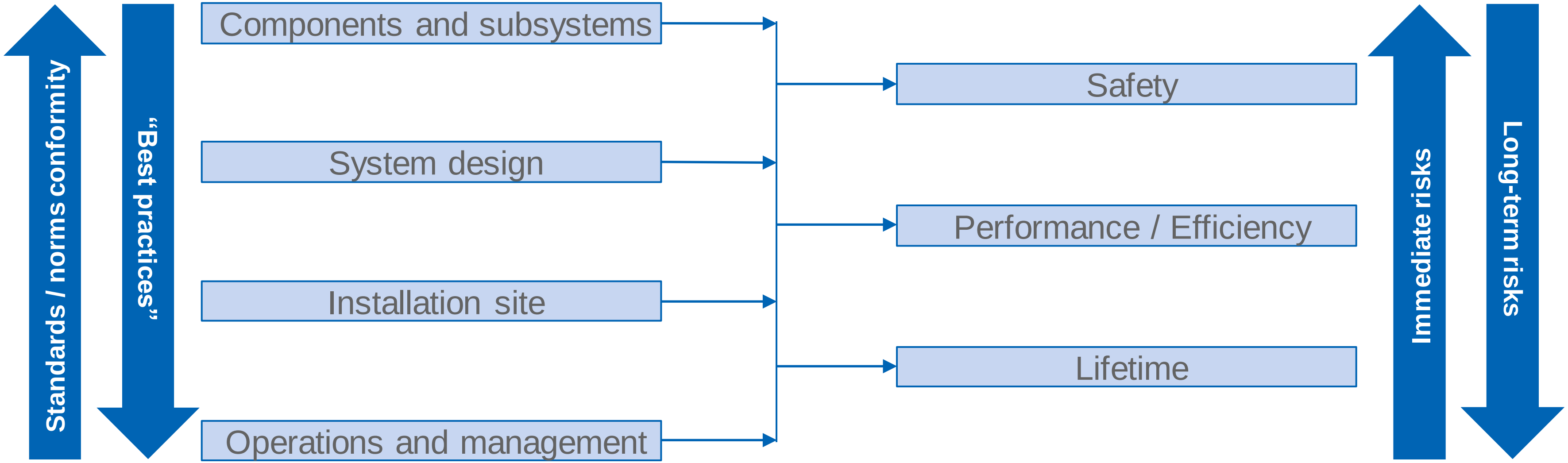
An energy storage system was destroyed at the Asia Cement plant in Jecheon, North Chungcheong Province, on Dec. 17. Courtesy of North Chungcheong Province Fire Service Headquarters

- "Insufficient protections against electric shocks"
  - Ground faults / short circuits
  - Fuse interruption failure → cascade over busbar
- "Inadequate management of operating environment"
  - Harsh conditions: large swings in temperature
  - Degradation of insulations
- "Faulty installations"
  - Wiring / mechanical failure during installation
- "ESS system integration"
  - Inadequate information sharing between EMS/PCS
  - Failed abnormality checks

Multiple Risk Sources Affect ESS

RISK SOURCES

AFFECTED PROPERTIES

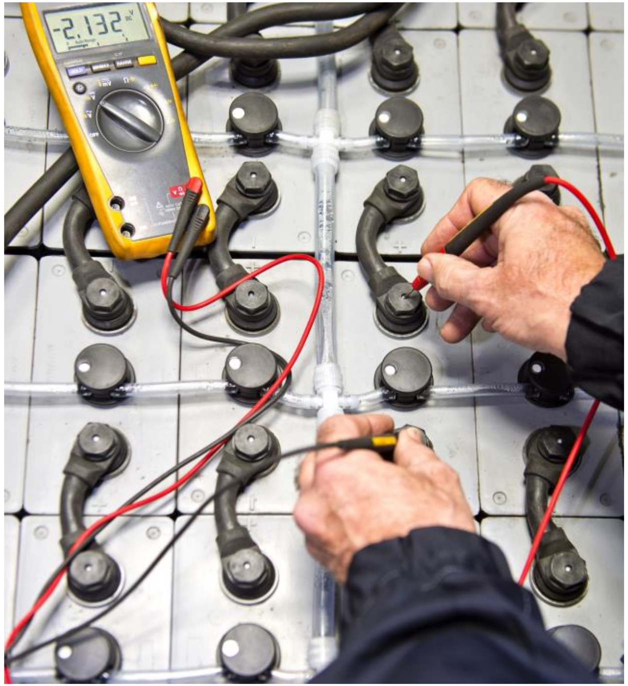


Quality Assurance: Cornerstone of Risk Management

- Evaluation of energy storage technology
- Review of components / OEMs
  - Component design / performance / safety
  - Manufacturing processes (Factory inspection, PSI)
- System-level testing and certification

- Project review and evaluation
- Construction, operation and management review
- Risk management plan review evaluation

Conformity of Components: Basis for System Quality



- Components in a system can be broken down to smaller components
- Basic level:
  - Cells
  - Electronics
  - Cables and auxiliary components
- Basic components need to be tested to conform to quality standards;
- With increasing level of components' complexity, design reviews become more critical (in contrast to testing)

Devising a holistic risk management system

Application Guideline

- Consists of requirements and best practices
- Covers designing, installing, and managing ESS

Criteria Catalogue

- Lists relevant criteria tailored to application
- Checklist that enables evaluation of systems vs. the guideline

Inspections / Audits

- Procedure of regular inspections
- Audit of compliance documents
- Done internally and by independent engineers

VDE quality pyramid: The three layers of quality assurance

Pro-active approach:

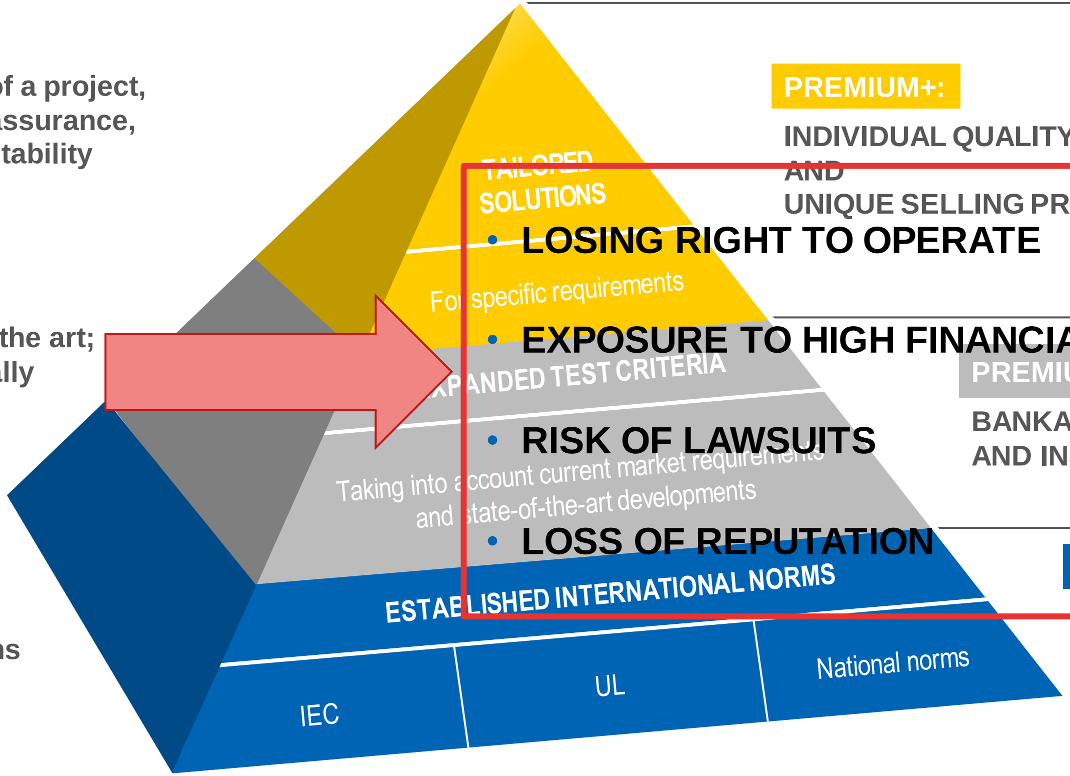
Consider unique specifics of a project, engage in superior quality assurance, minimize risks – boost profitability

Responsive approach:

Keep pace with the state of the art; create high-quality, financially sound projects

Reactive approach:

Only follow basic regulations



PREMIUM+:

INDIVIDUAL QUALITY CRITERIA
AND
UNIQUE SELLING PROPOSITIONS

PREMIUM:

BANKABILITY
AND INSURABILITY

BASIS:

STANDARD
MARKET CRITERIA

- **LOSING RIGHT TO OPERATE**
- **EXPOSURE TO HIGH FINANCIAL LIABILITIES**
- **RISK OF LAWSUITS**
- **LOSS OF REPUTATION**

VDE

VDE track record

On the pulse of the market with trustworthy customer relationships

More than 6,000 projects since 2010	Actively driving the **creation of new international standards** for renewables and **ESS**	Knowledge platforms with over 2,000 banks, investors, insurers, industry players and public authorities
Premium certification for banks and insurers that go beyond established international standards	**Over 3 GW of solar projects evaluated and certified**	Accreditation of global partner labs and VDE **Prime Labs in the energy storage sector**
High technical competence and “quality without compromise”	Strategic partner of the Utility Week Initiative and Green Energy Innovation Center	Ongoing further development of quality criteria for banks, investors and insurers

Support of the entire energy supply spectrum

– from generation to distribution, through to storage and e-mobility –

Generation	Distribution	Storage	Mobility
Photovoltaics	Smart Grids	Electrical energy storage	Electric vehicles
Wind	Interconnection requirements	Hydrogen storage	E-bikes
Biomass	Data management	Power-to-X	E-trucks E-buses
Hydro	IT-Cybersecurity		Maritime applications

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Thank you for your attention!

We shape the e-dial future.
Experience it with us.

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