RWE has been passionately producing electricity for over 120 years.
Now RWE is shaping the new energy age.

1898
The future begins over 120 years ago today.

Lignite as the key to cheap electricity.
1914

1928
RWE builds the first supraregional high-voltage power line.

Electricity for the economic miracle.
1950er

1955
Ludwig Erhard opens Weisweiler lignite-fired power plant.

Security of supply with electricity from nuclear power.
1970er

1976
Research, development and testing of renewable energies.

CO2 reduction through lignite-fired power plants with optimised plant technology (BoA).
2002

innogy

2016
Foundation and IPO of innogy SE.

2019
Transaktion with E.ON.

2019 - heute
RWE is one of the world's leading electricity producers from renewable energies.

Potentials of storage technologies

Robert van Treeck – Senior Innovation Manager

June 2023

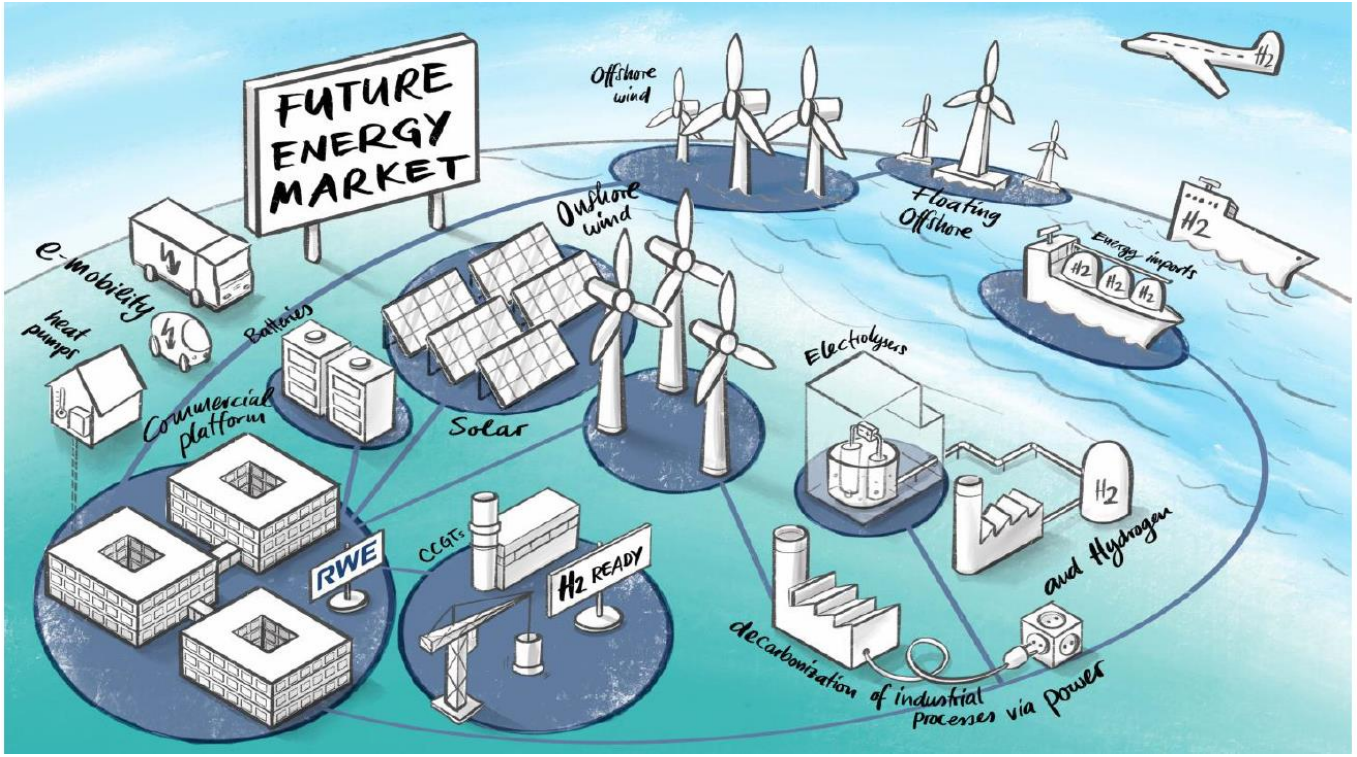
RWE

Global storage engineering in RWE from Dresden

1. RWE Global Storage Engineering
2. Example Storage Project
3. Battery energy storage system (BESS) Hardware
4. Open discussion and Q&A

RWE Global Storage Engineering

The future energy market is powered by green technologies



Worldwide market

With 10 GW installed capacity

Our growth target

2.1 GW per year until 2030

Our Investment

50 billion euros gross through to 2030

Who we are

RWE RES Global Storage Engineering at a glance

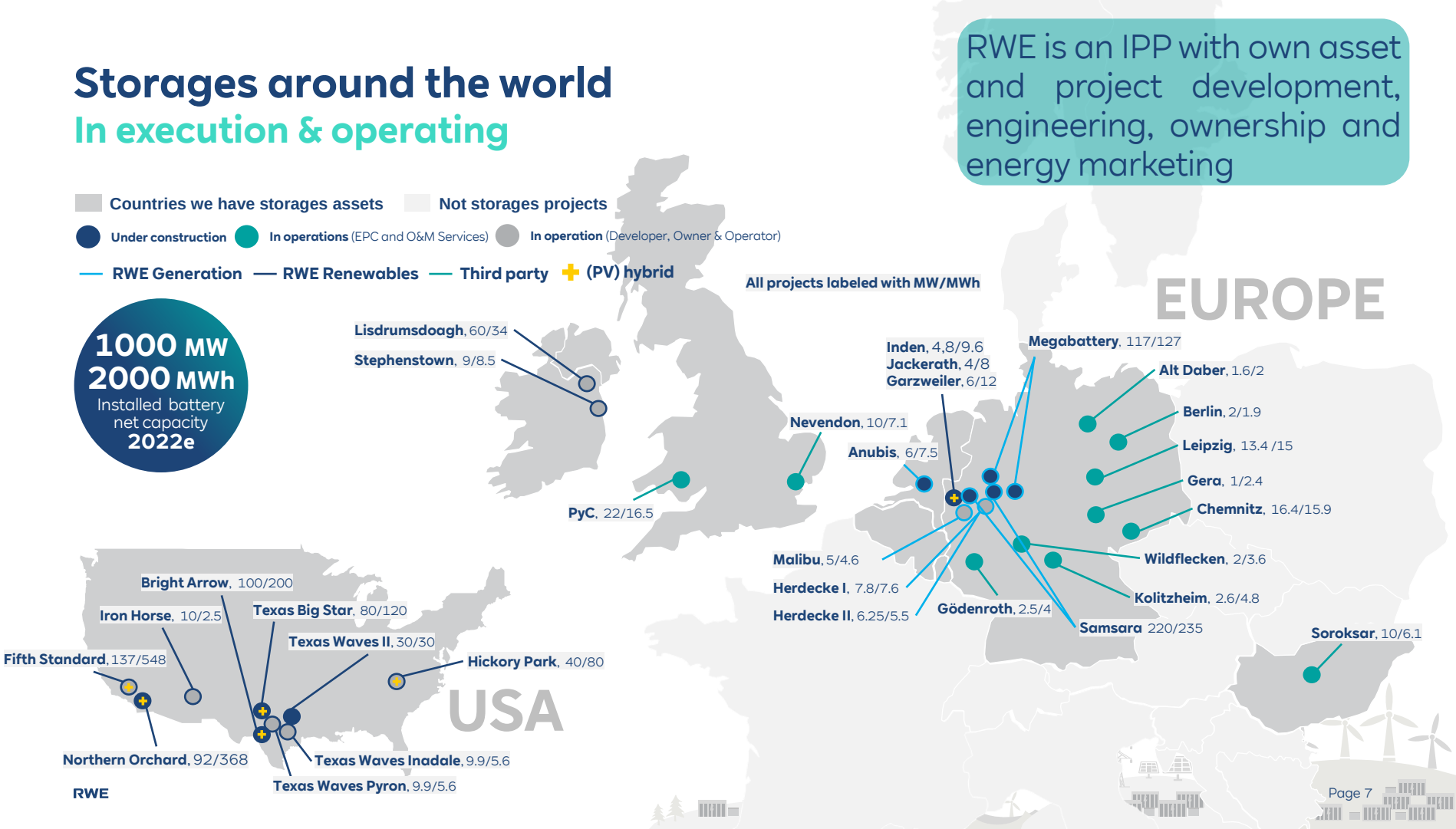
Driving force behind Battery Storage Solutions for RWE – with a powerful position

Team	~60 employees distributed globally (US,EU, APAC)	13 NATIONALITIES diverse and dynamic team	8 YEARS track record of delivering energy storage projects
Project development, construction and technology	1,325 MWH energy storage projects in execution worldwide	660 MWHDC largest project currently in execution	7 stationary and EV batteries integrated
Outlook and ambition	15,000 MWH RWE storage pipeline	15 countries in which we will operate projects	TOP 5 Ambition to be within first 5 storage players

Storages around the world

In execution & operating

RWE is an IPP with own asset and project development, engineering, ownership and energy marketing



What we are working on

competitive and state-of-the-art stationary storage solutions for RWE

Lisdrumsdoagh

Ireland

60MW/34MWh
Standalone Energy Storage

Key Project Characteristics
Provision of a system with a particularly short response time, delivering full power in 150ms.

Herdecke II

Germany

5.5MW/5.5MWh
Standalone Energy Storage

Key Project Characteristics
Project designed and built with the use of 2nd life batteries provided by Audi.

Hickory Park

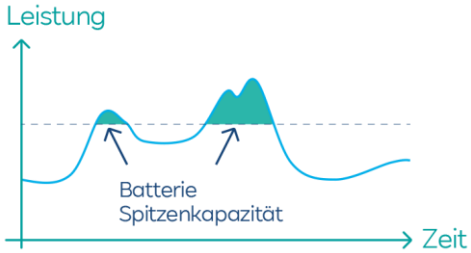
GA, USA

40MW/80MWh
Coupled with Solar PV

Key Project Characteristics
Innovative DC-DC coupling solutions to provide a firm solar profile and recover clipped energy.

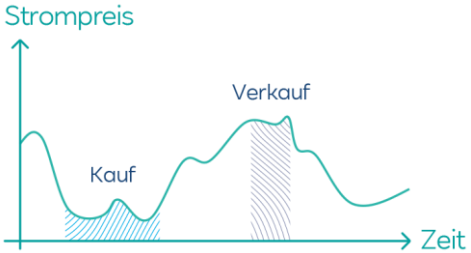
Example storage project

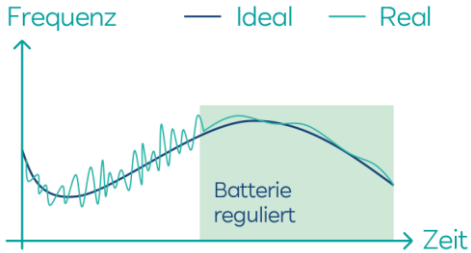
Lithium-Ionen Batterien werden heute bereits für verschiedene Anwendungen genutzt



Energy-shifting & peak-shaving

Arbitrage / Wholesale





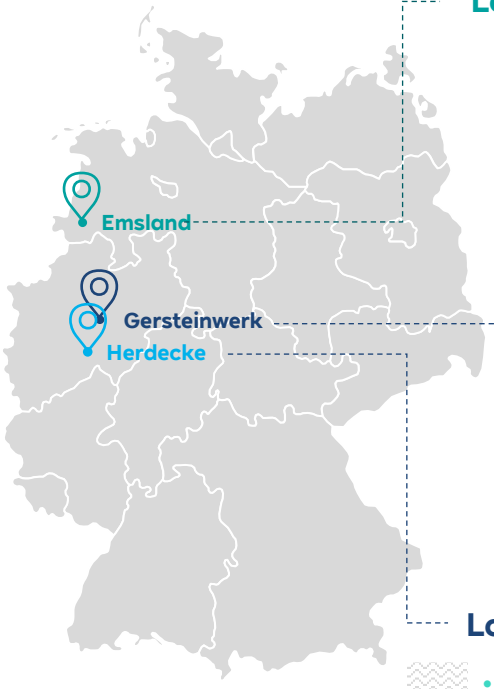
Frequency stabilication

Add-in to other renewables

Project development steps

- Identify and secure potential areas
- Estimate potential business case and cost estimation
- Developing the detailed project plan (engineering and commercial)
  - ✓ Revenues with market model for 20 years
  - ✓ Component selection, civil work planning and contracts, EPCs, …
  - ✓ Battery and Plant sizing, design, SLDs and layouts
  - ✓ Board paper package for final investment decision
- Project execution including last engineering details
- Commercial Operation and Maintenance
- … up to 20 years later: Decommission

One Project, two sites, remotely controlled from Herdecke, supported by local power plant colleagues



Location Emsland

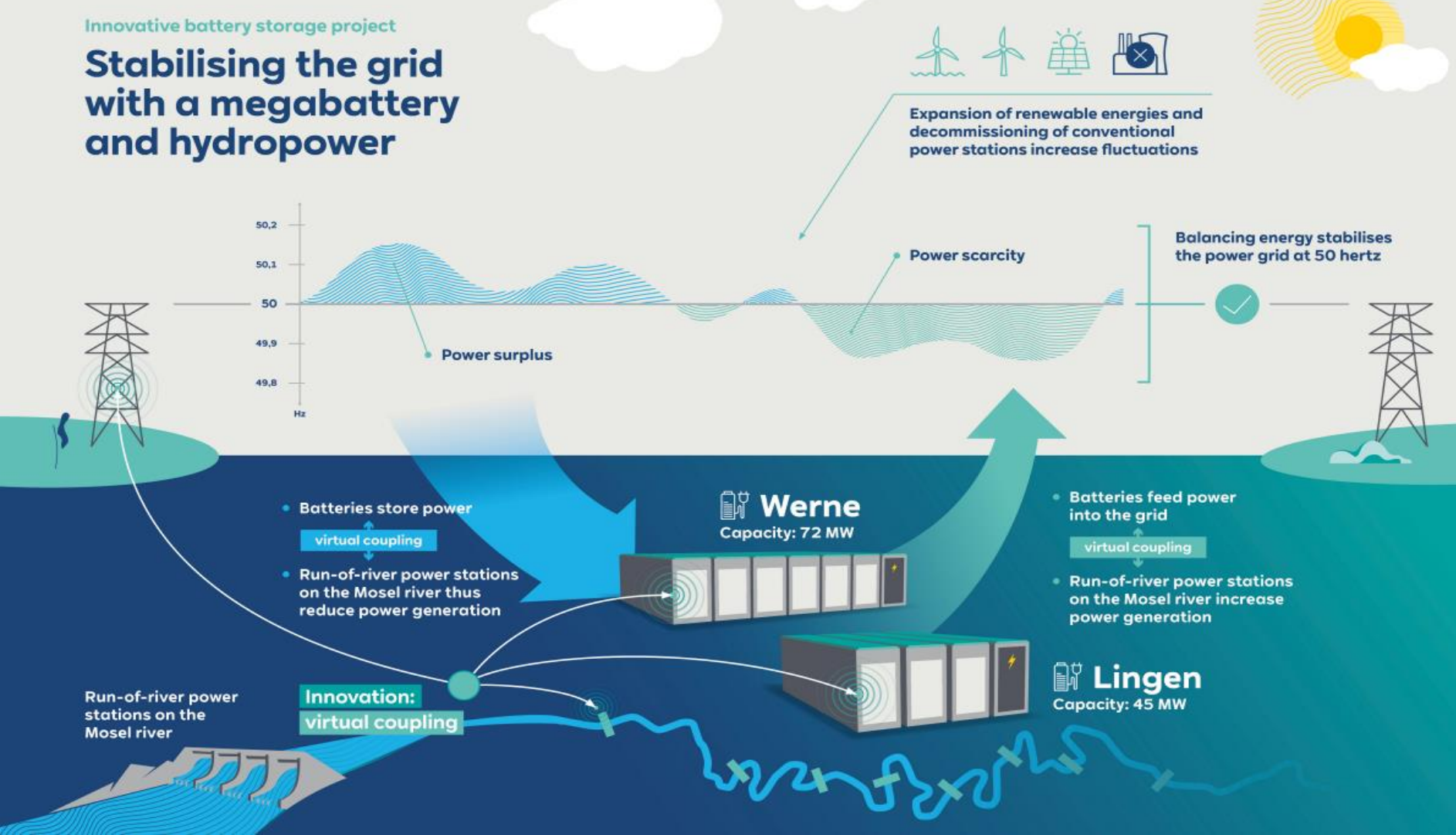
Location Gersteinwerk

Location Herdecke

- 24/7 control room

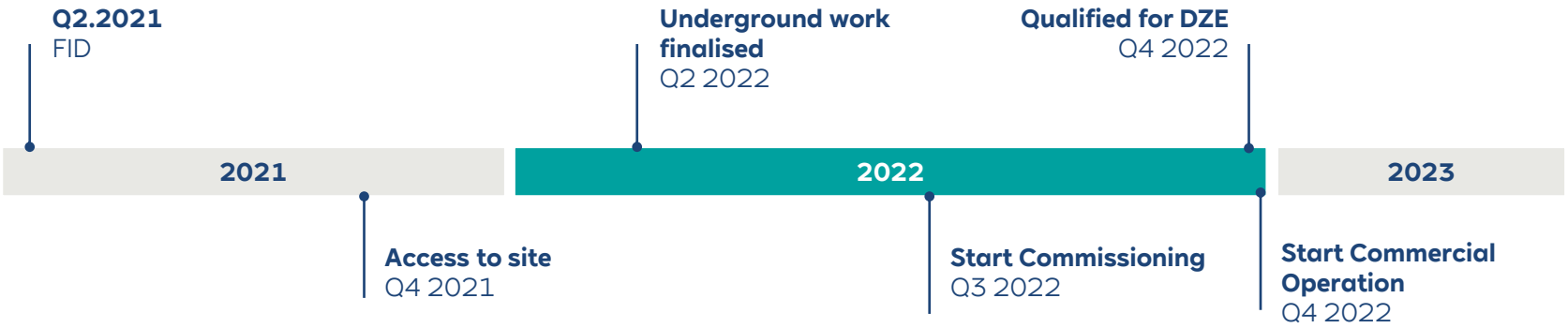
Innovative battery storage project

Stabilising the grid with a megabattery and hydropower



Ambitious Project Timeline and Special Project Hurdles

Key Milestones



Special Hurdles

- International Transportation
- Availability of components
- Civil construction price risk
- Availability of contractors

BESS Hardware

[1] vs full system cost incl. land cost and grid connection

BESS Overview- Battery Container (Approx. 40% of CAPEX)[1]

HVAC System

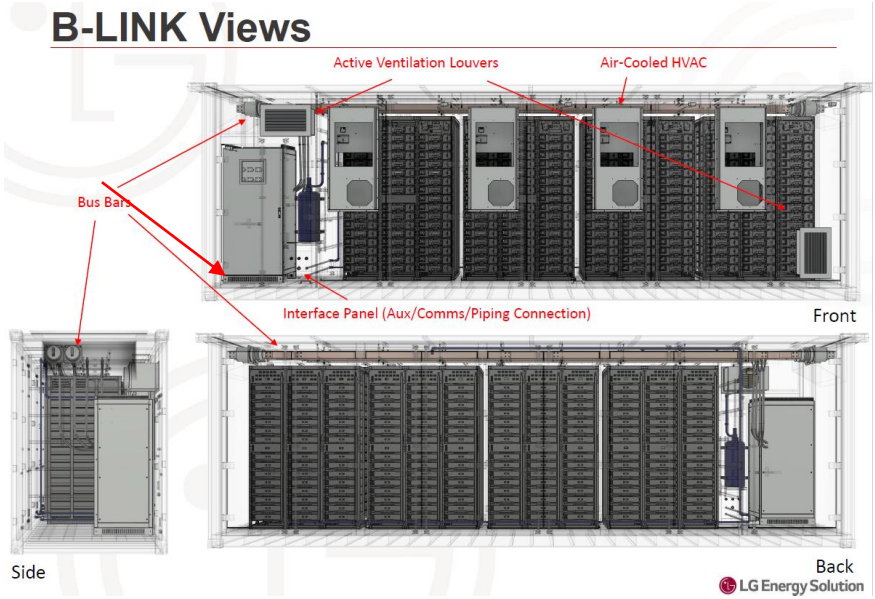
Fire Suppression System

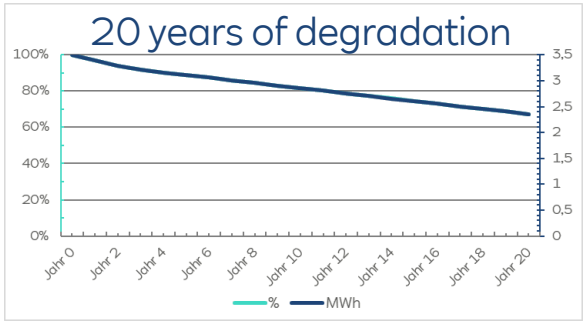
Electrical fire- aerosol based fire system
Battery fire- water based fire system
(UL and NFPA compliance)

Gas Detection System

Explosion Mitigation System

Active Ventilation System





BESS Overview- Inverter skid (Approx. 5% of CAPEX)

Inverter Module:
Sunny Central-UP 2660 to 4600 kVA

Shipping Module
Detachable Beams forming container frame

Connector Module:
Flexible AC Enclosed busbar
4000 A

Base Module:
20' x 8' galvanized steel platform
Oil containment option
Cable Entries

Transformer Module:
Hermetically sealed transformer
12 kV .. 35 kV
Biodegradable liquid (MIDEL or FR3)
Bottom side bushings (LV/MV)
Natural ventilation

Switchgear Module:
SF6 Ring Main Unit

LVac Module:
10/60 kVA Auxiliary transformer
10/20 Miniature Circuit Breakers
Harmonics Filter
Communication Options
Protection Options
Main Earth Connection

3	Inverter Power
0	4000 kVA
1	4200 kVA
2	4400 kVA
3	4600 kVA (with AE Approval)
4	2660 kVA
J	2750 kVA
5	2800 kVA
6	2930 kVA
7	3060 kVA (with AE Approval)

Structure of the Multi-Use-Storage

Intelligent Integration of E-Mobility will be key for CO_2 neutrality

Energy management system (EMS)
Plant-wide monitoring and control

Medium voltage
11 kV

Audi-e-tron-batteries
20 x 95 kWh = 1900 kWh

Cooling system

Substation

226-459V

Transformer 1,25 MV

Converter 4 x 500 kW

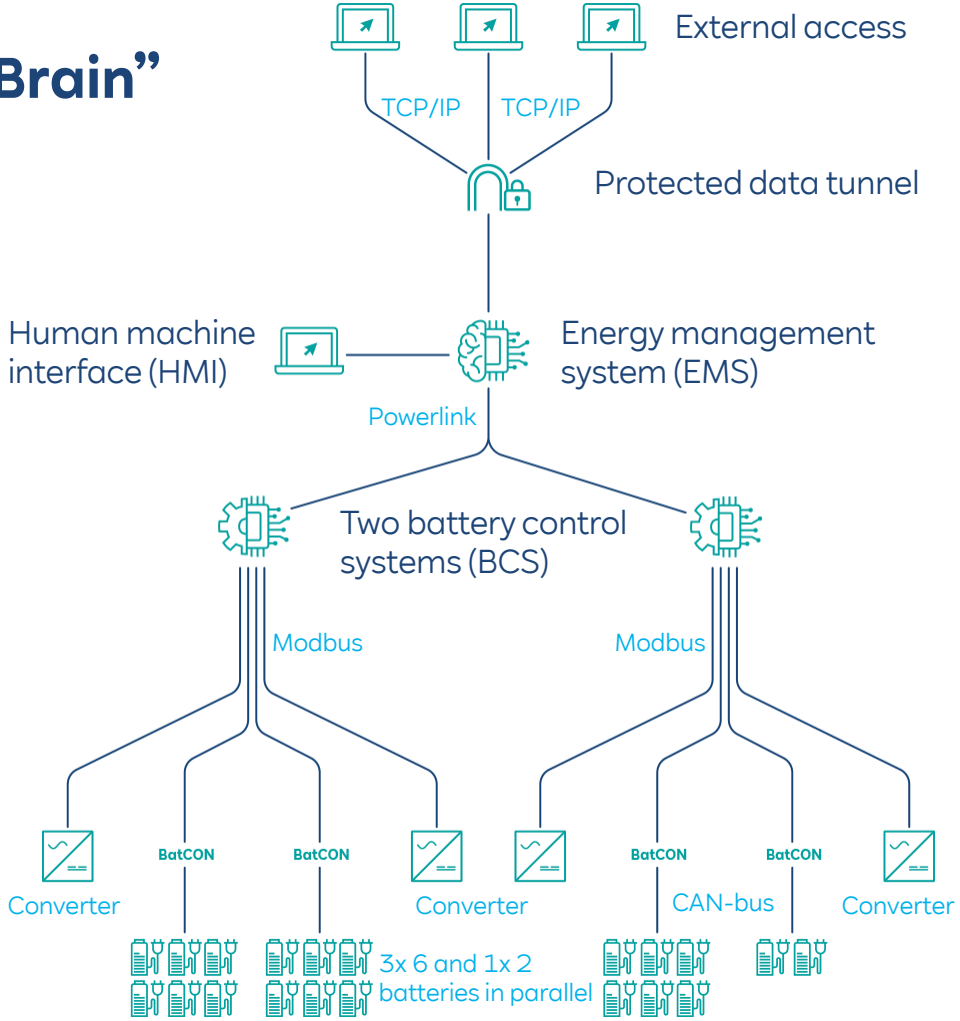
1,9 MWh installed capacity
→ enough to supply the EUREF-Campus for **ca. 2 h**

1,25 MW electrical power
→ equals the max. power rating of **30** houses

Control system – with EMS as “Brain”

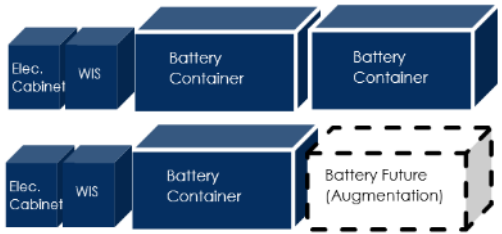
Principle of the communication flow

The control system includes all communication within the plant for data acquisition, monitoring, control and external access. For example, it gets the storage systems tasks from the operator and ensures that the requirements are fulfilled automatically.



2 Hour Standard Example

SMA Inverter Skid
MVPS 4600-S2-US



LG DC-LINK

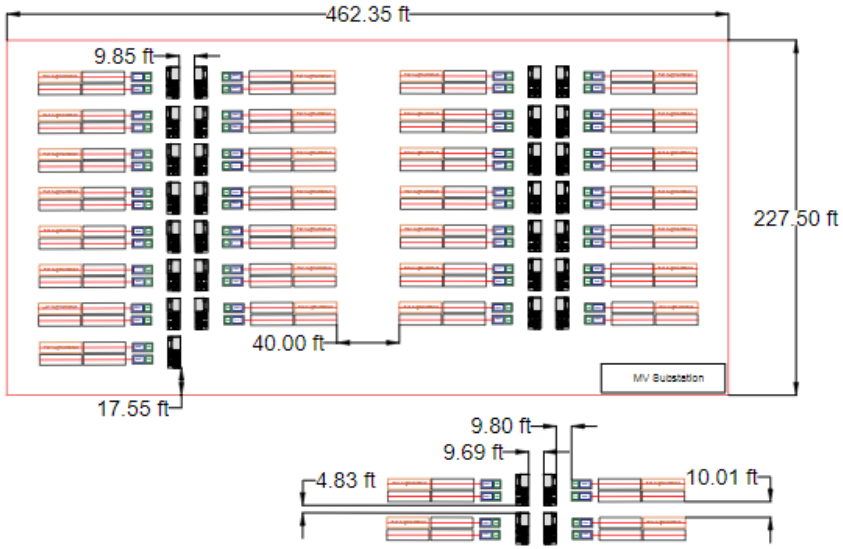
3 Containers X 2.86 MWh = 8.58 MWh

Capacity: 4 x 2.86 MWh = 11.44 MWh
Site area: (85 ft x 25 ft) 198 m^2 or 2125 ft^2

Energy Density: 57.8 kWh/m^2 or 5.36 kWh/ft^2

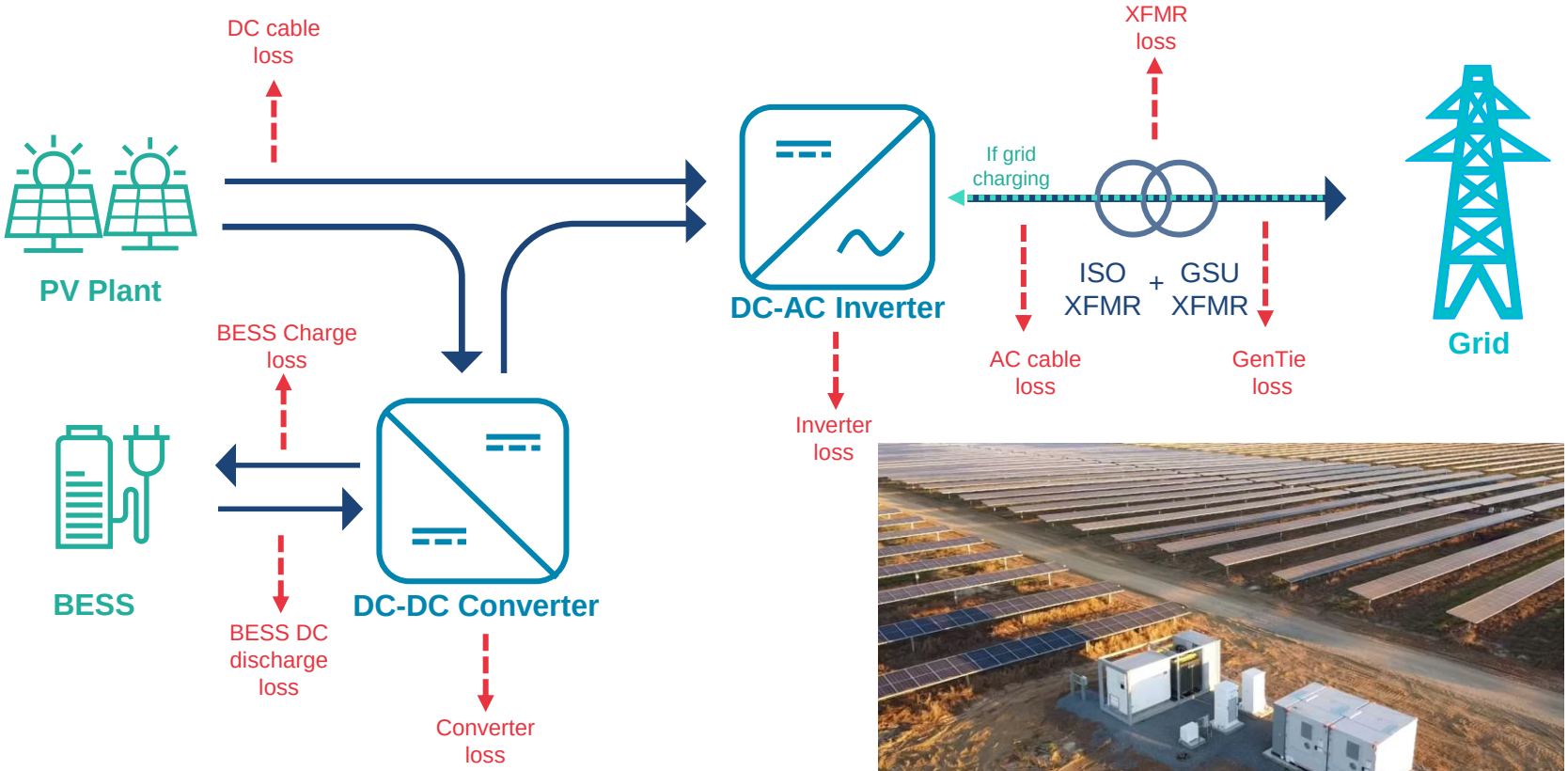
100 MW/ 200 MWh (usable), 248.8 MWh (installed)

- 29 Inverter skids
- 87 Battery Containers

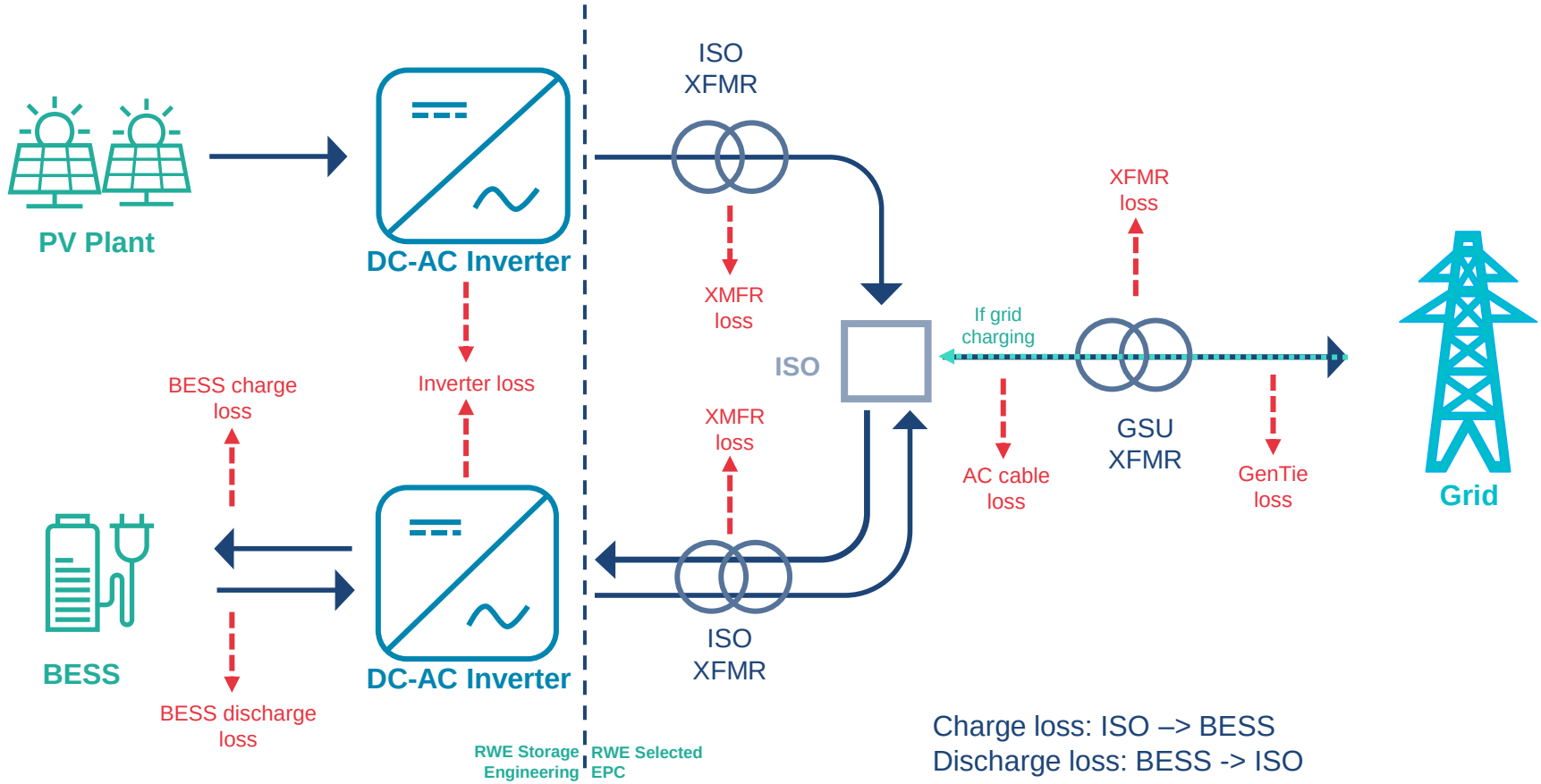


→ So approx. 1000m^2 needed for 100MWh (full system)

Hybrid solar+storage (DC-coupled) ✓

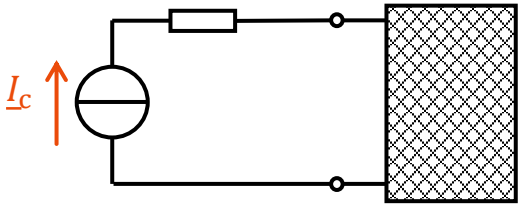


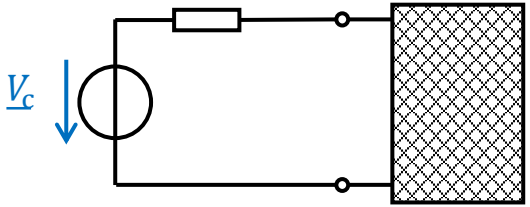
Hybrid solar+storage (AC-coupled) ✓



Charge loss: ISO –> BESS
Discharge loss: BESS -> ISO

Classification of Converters‘ Grid Behaviour





Current Controlled

Grid Following

- Fixed Current Source
- Follows P & Q (ref.)

Grid Supportng

- Controlled Current Source
- Adjusts P & Q (ref.) P(f), Q(V)

Voltage Controlled

Grid Leading

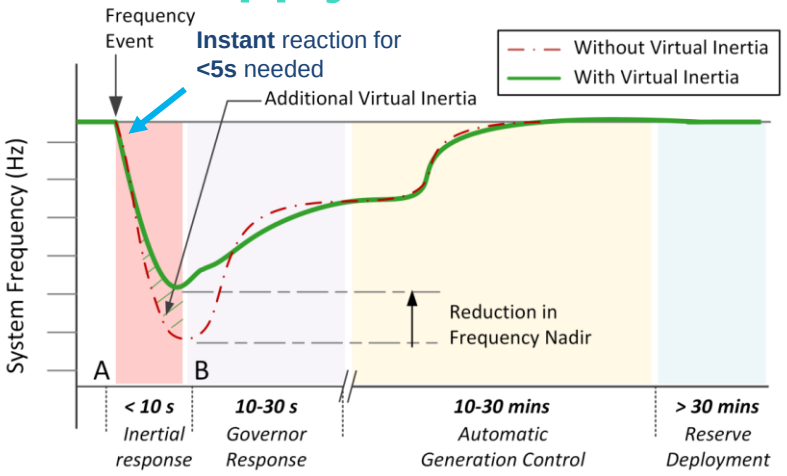
- Fixed Voltage Source
- Provides fixed V & f (ref.)

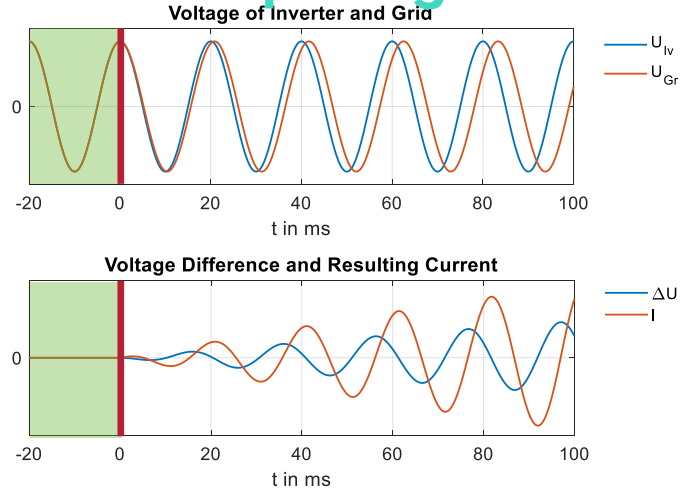
Grid Forming

- Controlled Voltage Source
- Provides V & f (ref.), f(P), V(Q)

Loss of generation power leads to frequency drop

GFCs supply inertia and other service to keep the grid stable





Inertia is the tendency of an object in motion to remain in motion. This kinetic energy in large rotating turbines is released as additional electricity as inherent reaction in case of grid disturbance.

Services provided include:

- **Inertia**, stabilizing the frequency and phase drop for up to 5s
- **Short circuit current**, allows grid protection to react within 100ms
- **Dynamic voltage supply**, stabilizing the grid voltage
- **Harmonic filtering**, reducing unwanted frequencies
- **Black start** capabilities to repower the grid in case of a black out

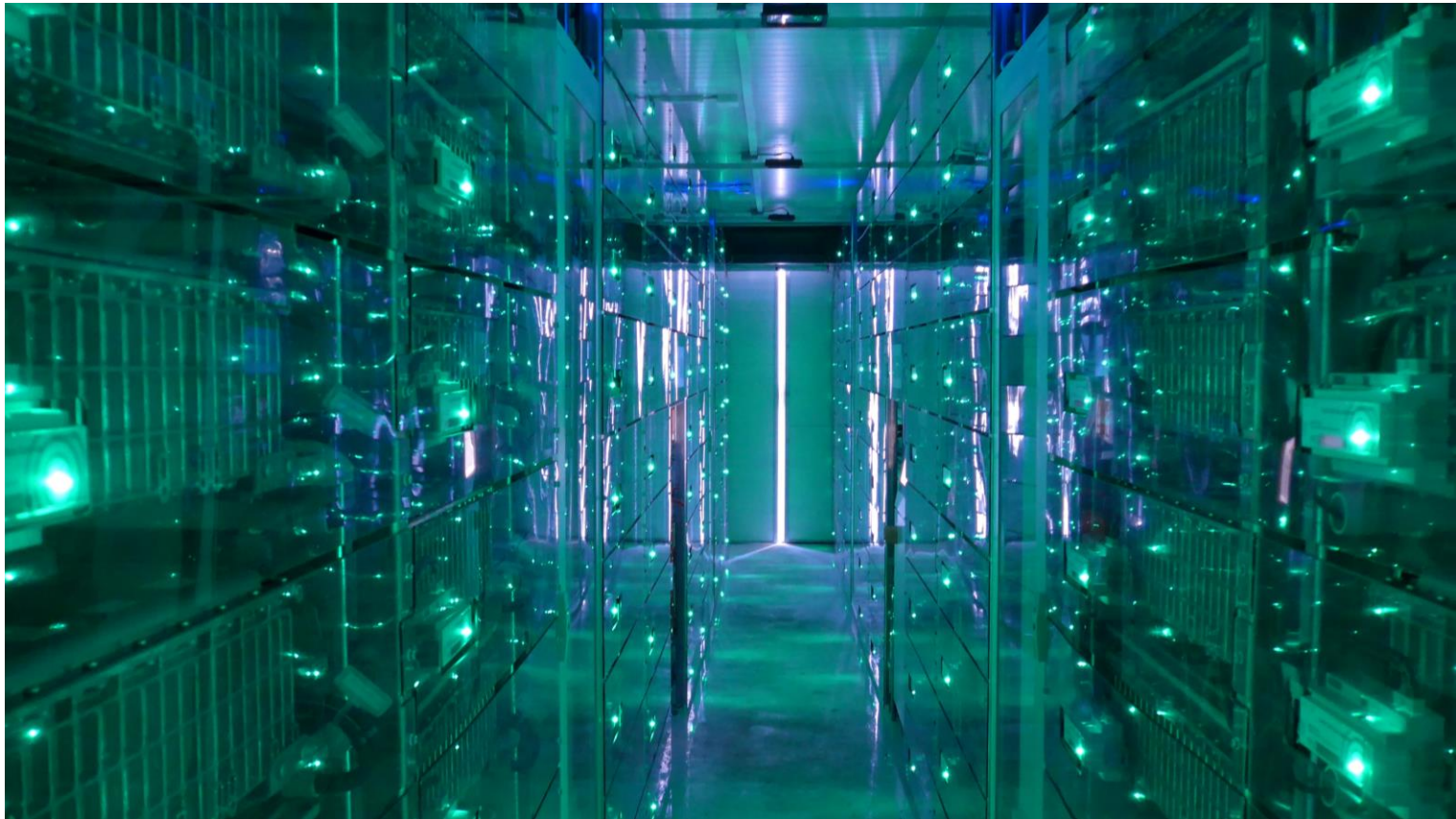
Change in behavior to GFCs

Current controlled inverters measure the grid frequency and react via commands from the plant controller in >100ms, e.g. for “synthetic inertia”.

GFCs are **voltage controlled** and react immediately to grid disturbance, e.g. with **inertia**.

As shown in the picture the **GFC** injects additional current in phase with the grid as **active power** to stabilize the frequency drop.

Open discussion and Q&A



Utility scale BESS
Cloud of topics

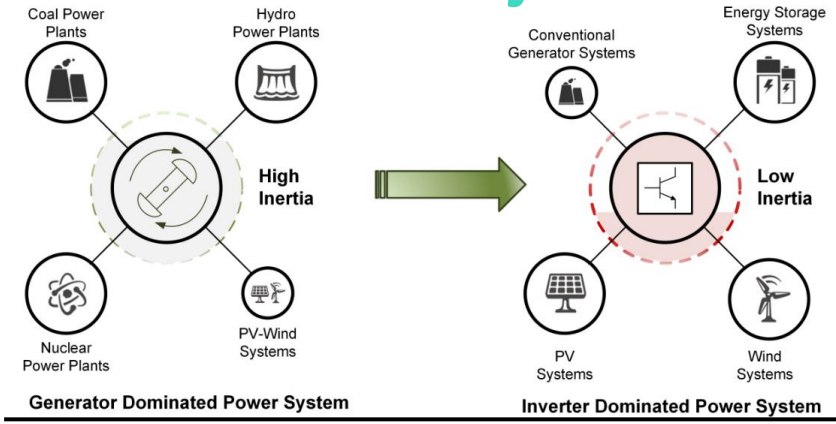
Fire protection
Noise
Augmentation
Electrical
Grid codes
Grid services
EMC
Transport
SLDs
Market
Cabling
In front / back of the meter
Installation
Construction
PV-Hybrid
Net present value
Civil work
Levelized cost of storage
Health, Safety
Recycling
2nd life
Permits
Project development
Battery aging
OCV-Curves U(Q)
Sizing
Enclosure
Plant control
Hardware selection
Cooling
Batteries
SCADA
Converter
Procurement

How a Lithium Ion Battery Actually Works // Photorealistic // 16 Month Project
https://www.youtube.com/watch?v=4-1psMHSpKs


BACKUP

Grid Forming Converter (GFC) Services

Executive Summary



Opportunity

Phase-out of convectional power plants leading to loss of the "non-frequency ancillary services" ("NF-AS") inertia, short circuit current, harmonic damping, voltage stabilization and black start → endangering grid stability.

Renewables, especially battery systems, can replace those via grid forming converters and a smart system design.

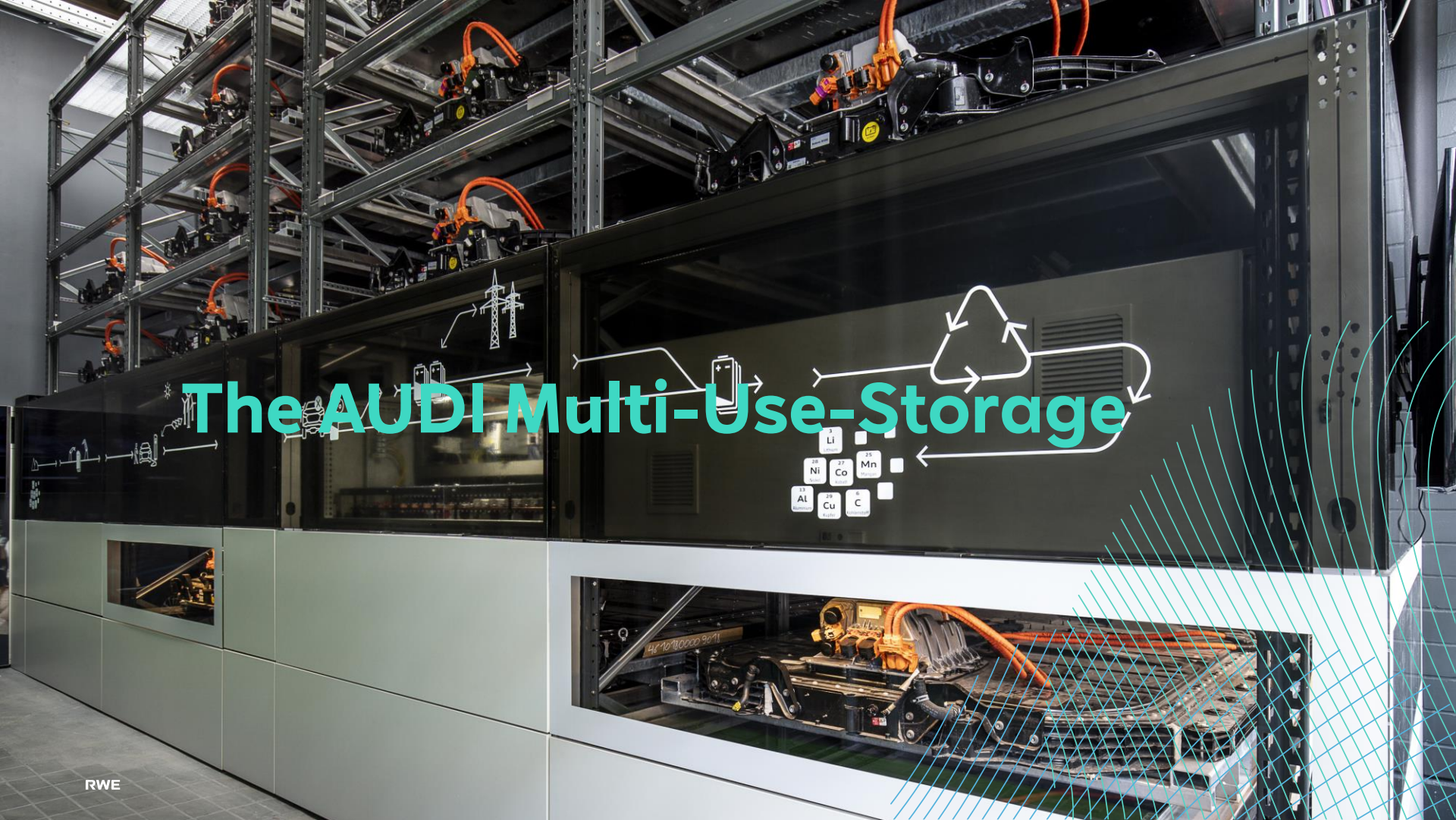
Strategy

Building on past and ongoing innovation activities RWE can define and form the market with partners and get a competitive edge as early mover via innovation tenders and direct discussions with stakeholders.

Technical Approach

The few seconds duration of NF-AS are staked on-top of common market applications like wholesale market or FCR.

The cost is optimized by using standard batteries and inverter enabled to "boost" above nominal limits for a few seconds.



RWE

The storage components

Structure of the Multi-Use-Storage

Intelligent Integration of E-Mobility will be key for CO_2 neutrality

Energy management system (EMS)
Plant-wide monitoring and control

Medium voltage
11 kV

Audi-e-tron-batteries
20 x 95 kWh = 1900 kWh

Cooling system

Substation

226-459V

Transformer 1,25 MV

Converter 4 x 500 kW

1,9 MWh installed capacity
→ enough to supply the EUREF-Campus for **ca. 2 h**

1,25 MW electrical power
→ equals the max. power rating of **30** houses

Battery storage converter – the systems “heart”

The main power electronic, transforming between AC and DC

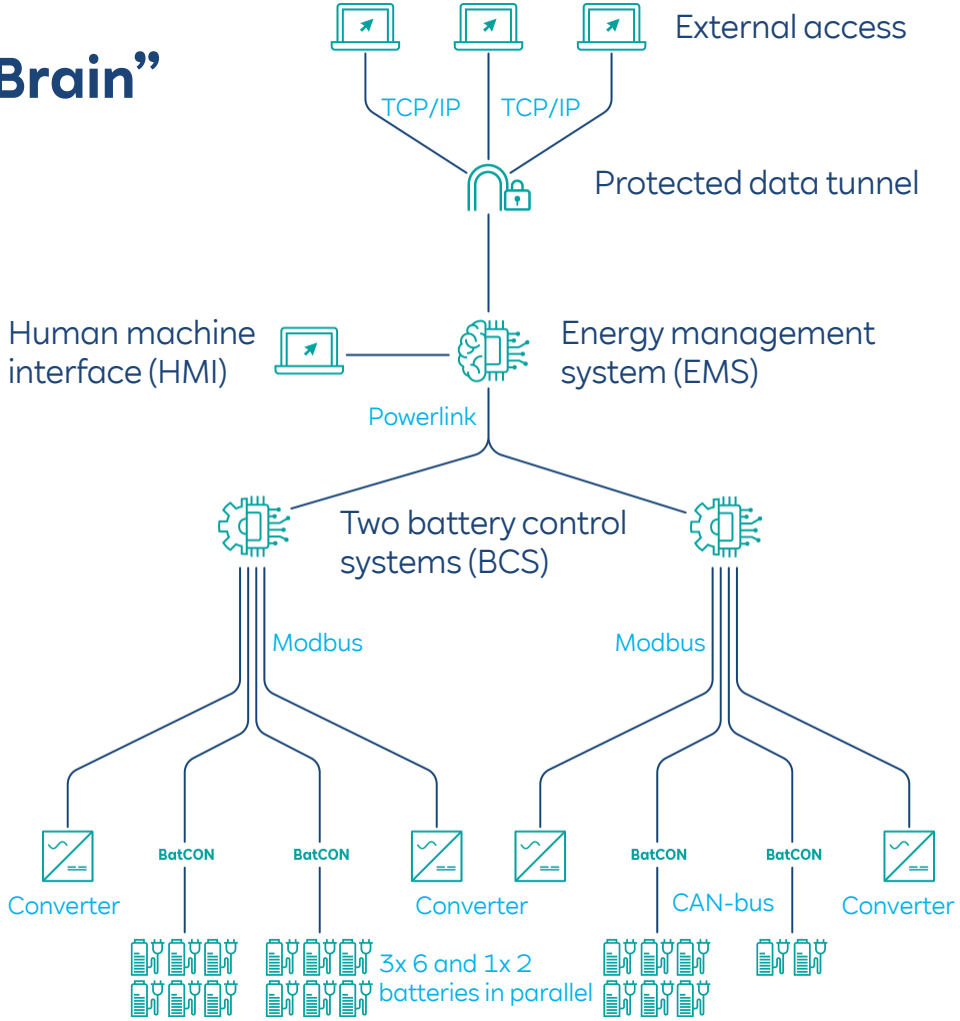
Technical specification of used inverter

- Manufacturer: Gustav-Klein
- Type: AIC 3890
- Nominal power: 500 kVA
- Amounts used: 4
- DC-Voltage: 200-1000V
- AC-Voltage: 620 V
- Size: 1800x600x2200 mm
- Weight: 1600 kg
- Designed for indoor use

Control system – with EMS as “Brain”

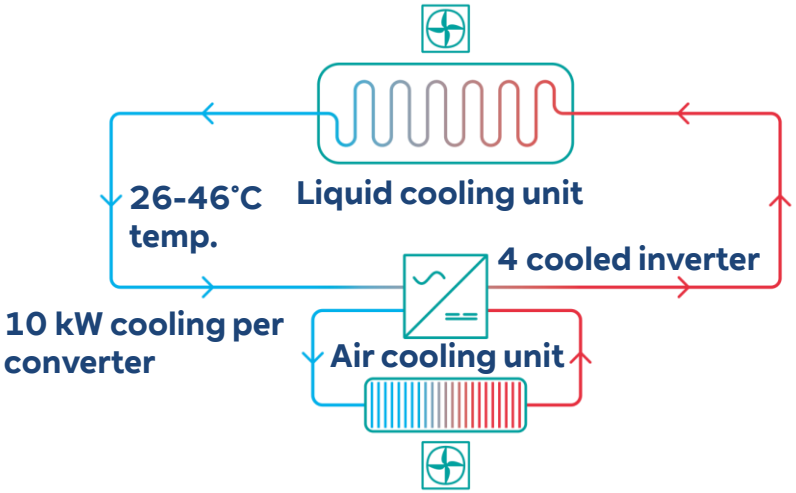
Principle of the communication flow

The control system includes all communication within the plant for data acquisition, monitoring, control and external access. For example, it gets the storage systems tasks from the operator and ensures that the requirements are fulfilled automatically.

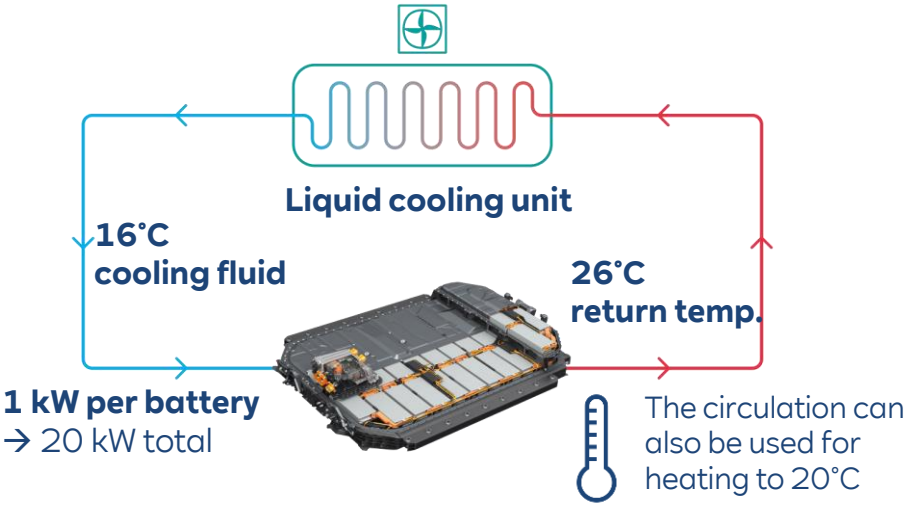


Battery and inverter cooling systems

The temperature is the most important factor for a long battery lifetime



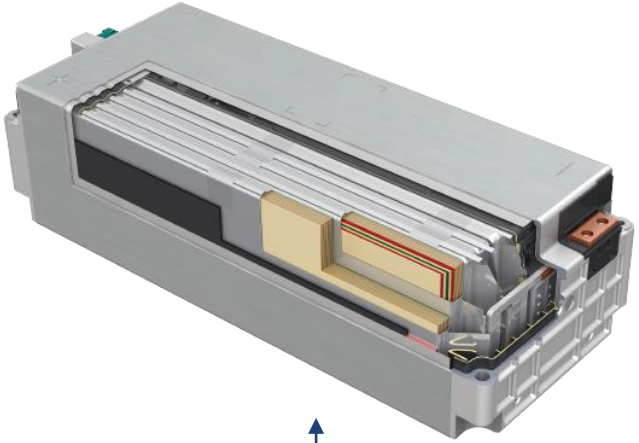
Cooling cycles of the converters (air and water)
The combination of air and water cooling is an uncommon solution for the building integration. Standard is air cooling and the inverter electronics are typically degradation and damage resistance up to 50°C environmental temperature.



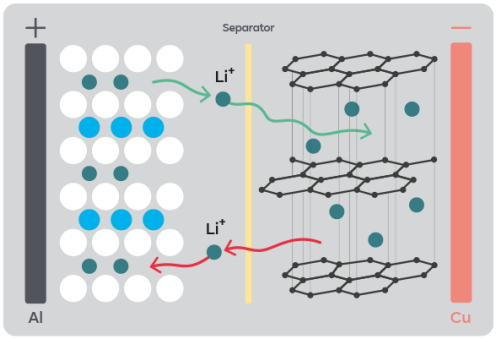
Liquid cooling of the Audi-e-tron-batteries
The batteries are water cooled in the Audi e-tron to ensure fast charging capability and the best car performance. In storage systems the cooling is used to enhance the battery lifetime further by operating them between 20-40°C.

Battery pack – the “muscle”

Module
Serial connection of 3 sets with each 4 cells in parallel, increasing the voltage to 11V and the triple current



Battery pack
36 Modules, 432 cells, 700 kg, 2,2x1,6x0,35m with 95 kWh for 417 km



Li-Ion-Layer
The smallest battery unit battery, consisting of electrolyte for ion transport, Graphite as negative electrode, a positive intercalation metal electrode, lithium, a separator and collectors.

Cell
The cell consists of multiple stacked Li-Ion-Layers that are electrically connected in parallel (increasing the current with constant voltage)