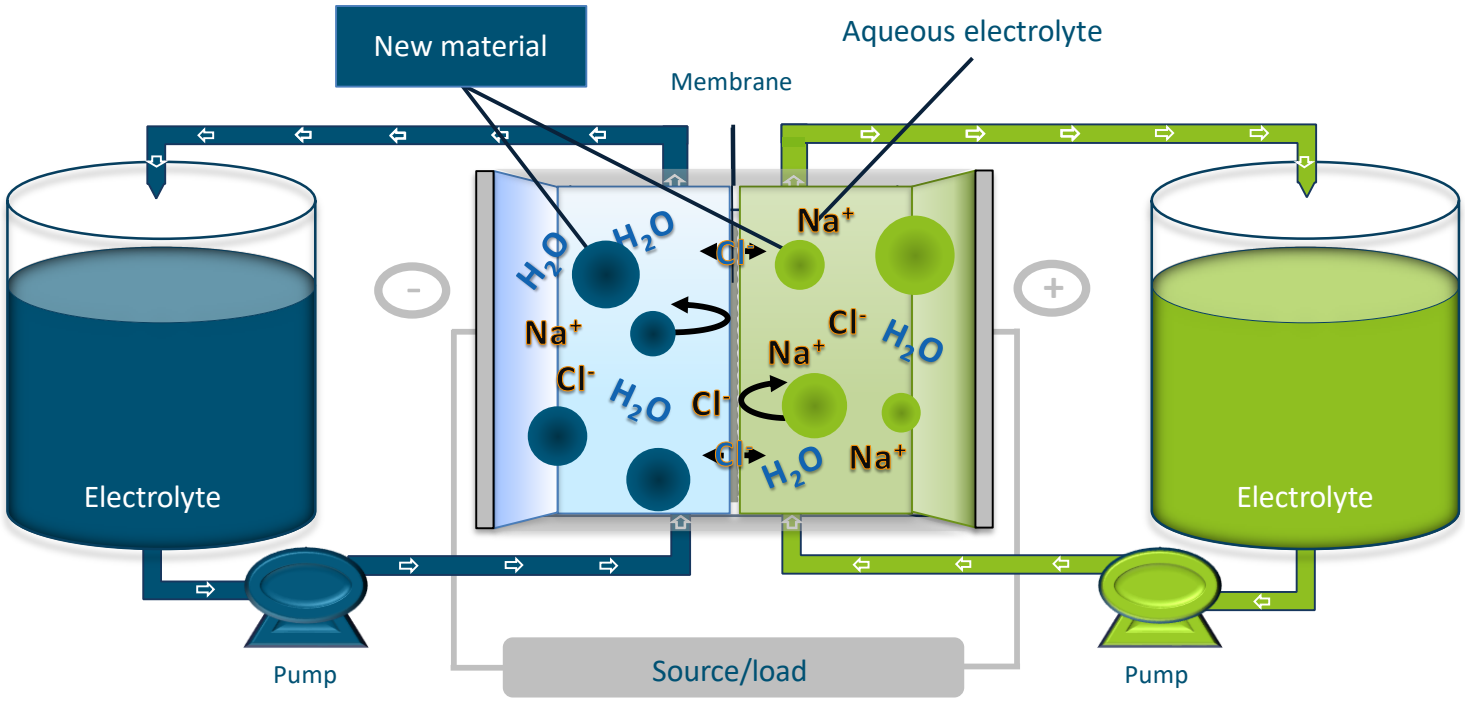
Metal-free redox flow battery

-The answer to the metal scarcity problem-

The EnergyKeeper project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 731239.

Our innovative redox-flow battery



Water based, pH-neutral,
no heavy metals, no critical raw materials

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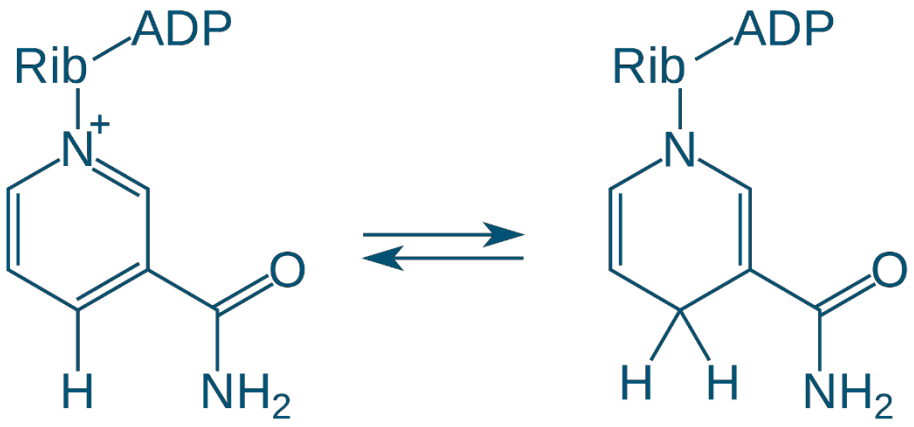
How does an organic material store electricity?

Organic material



Human body

$NAD^+ + H^+ + 2e^- \rightleftharpoons NADH$

Metal

$VO^{2+} \underset{+\,e^-}{\overset{-\,e^-}{\rightleftharpoons}} VO_2^+$ Sulfuric acid

$LiCoO_2 \underset{+\,e^-}{\overset{-\,e^-}{\rightleftharpoons}} Li^+ + CoO_2$ Flammable solvent

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JENA BATTERIES

Metal-free redox flow battery means…

- **Safe & Easy**
  - Free and independent scalability of power and capacity
  - Non-flammable and non-explosive
  - Turnkey energy storage system
- **Clean Energy**
  - No heavy metals or aggressive acids
  - Resource-efficient
  - Near-neutral pH
- **Economical**
  - Inexpensive and readily available raw materials
  - Easy to maintain & long service life > 10,000 cycles
  - Flexible and sustainable investment that adapts to future markets

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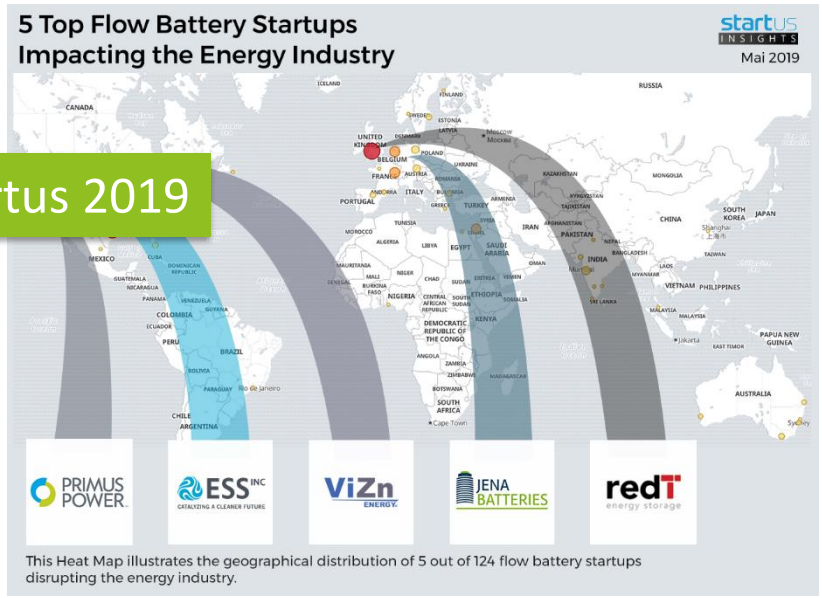
Media response and awards

IQ Innovation Award 2015

IQ Innovationspreis Mitteldeutschland 2015



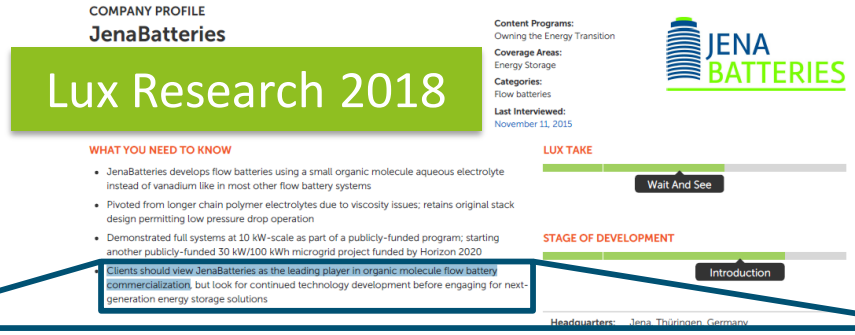
Startus 2019

JenaBatteries:
The battery of the future

We all know that we need to change some things if we want to preserve our planet. Unfortunately, the average stationary battery system is relying heavily on mining and refining in sensitive habitats and is anything but green. JenaBatteries creates revolutionary organic redox-flow-batteries based on metal-free energy

grid applications, micro-grid solutions, island grids, storage of renewable energy, load shifting and peak shaving, emergency and uninterrupted power supply, for e- and many rprise that 'IQ Innovation 2015' in

„Discover Germany“ 2017



Lux Research 2018

Clients should view JenaBatteries as the leading player in organic molecule flow battery commercialization […]

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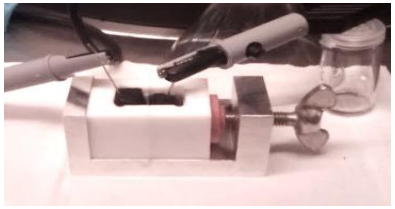
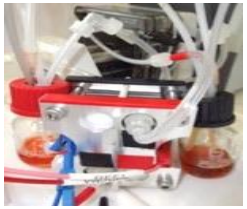
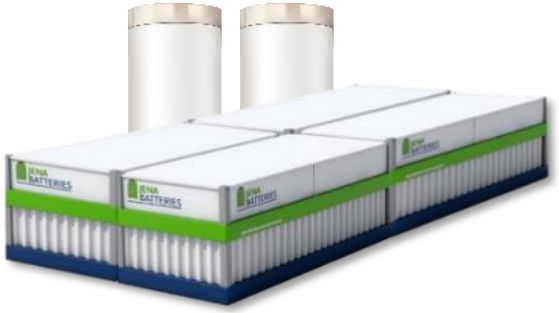
The next step: Market preparation

Technology development (2012 to 2018):


Product development and productioning (2019/2020):

BASIS System → Product Classes → Tailored Solutions

Market entry in 2021

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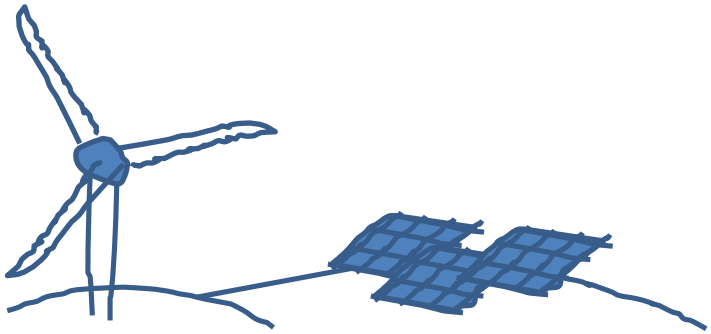
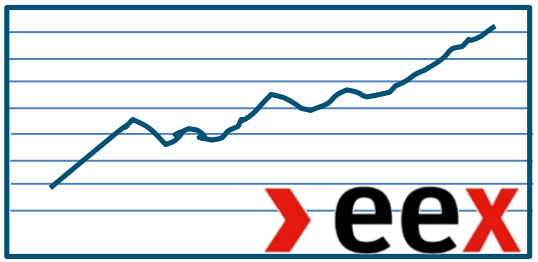
Customers: Project developers & renewable energy market



Electricity Producer



Energy Exchange

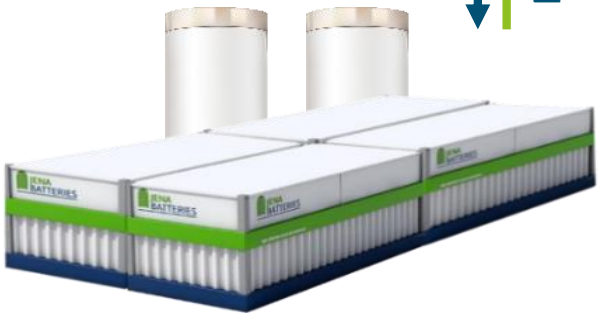
Electricity

Remuneration

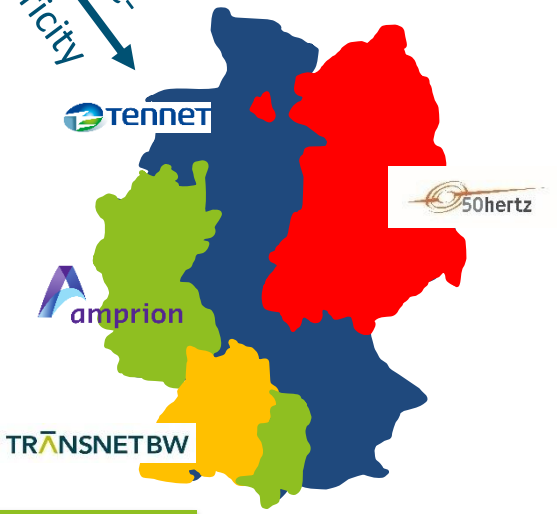
Electricity

Market price

Elec-
tricity



Management Fee



Aggregator/Energy Service Provider

System Operator

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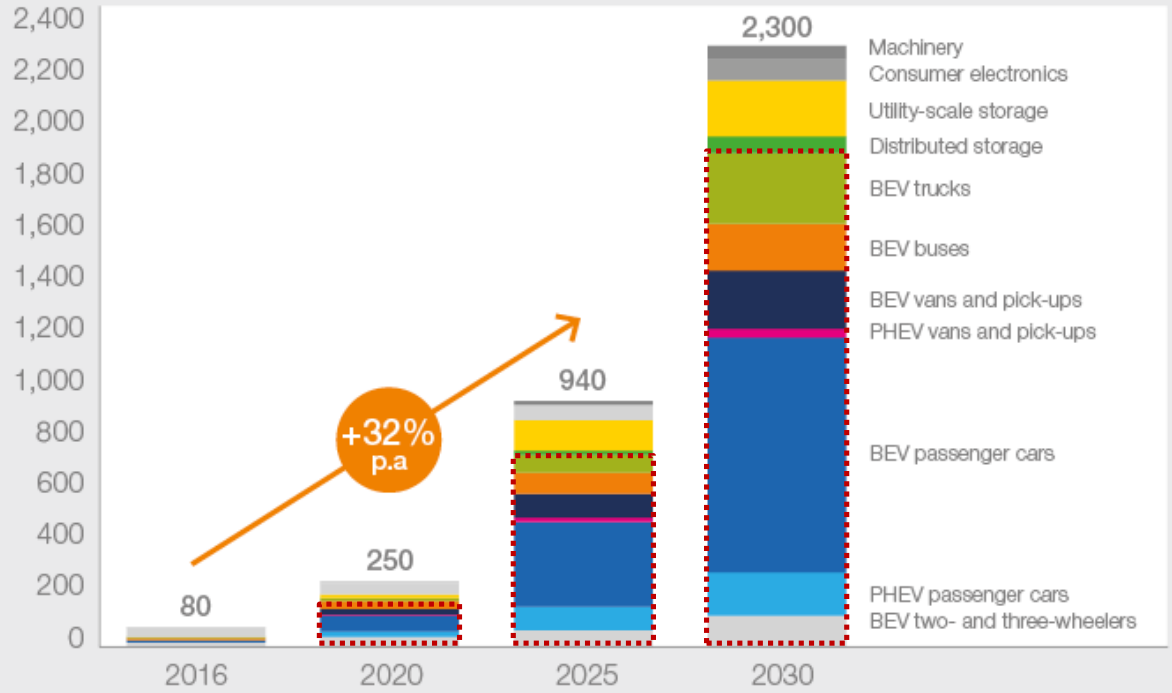
Li-ion batteries – They are needed for cars!

Exhibit 1
Annual battery demand: electric mobility segments, stationary battery storage, consumer electronics, and machinery
GWh/yr



Source: McKinsey Energy Insights' Global Energy Perspective (March 2018), Avicenne

	GWh/year		
	2020	**2025**	**2030**
E-mobility	125	700	1900
- share	50%	70%	82%
Stationary	25	180	300
- share	10%	19%	13%

McKinsey, 2018.

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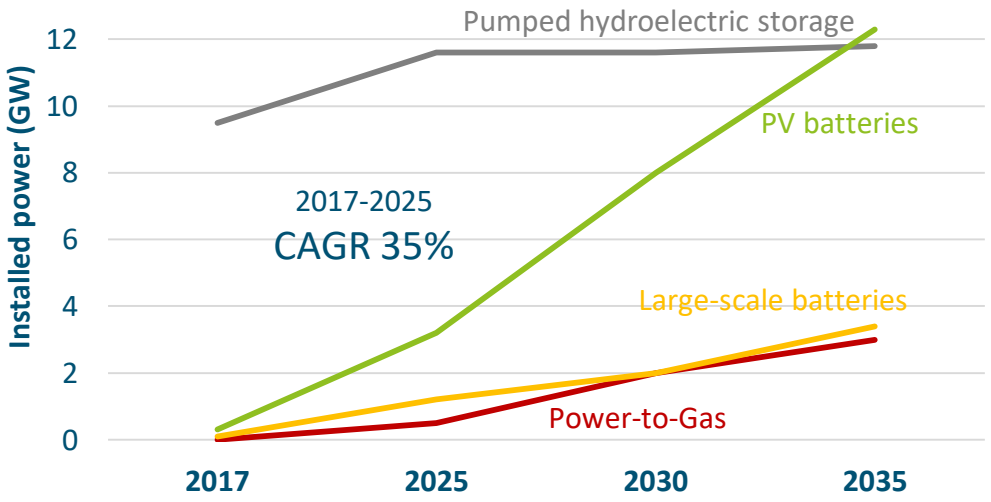
JENA BATTERIES

German TSOs' 2019 draft grid development plan

Batteries are a core technology in the grid expansion



Installed (GW)	2017	2025	2030	2035
Pumped hydro	9.5	11.6	11.6	11.8
Power-to-Gas	–	0.5	2.0	3.0
PV batteries	0.3	3.2	8.0	12.3
Large-scale batteries	0.1	1.2	2.0	3.4
Demand side mgmt.	1.5	3.0	4.0	5.0

Scenario B: Compromise with specifications for maximum CO_2 emissions and a balanced expansion of individual renewable energy technologies and sector coupling.

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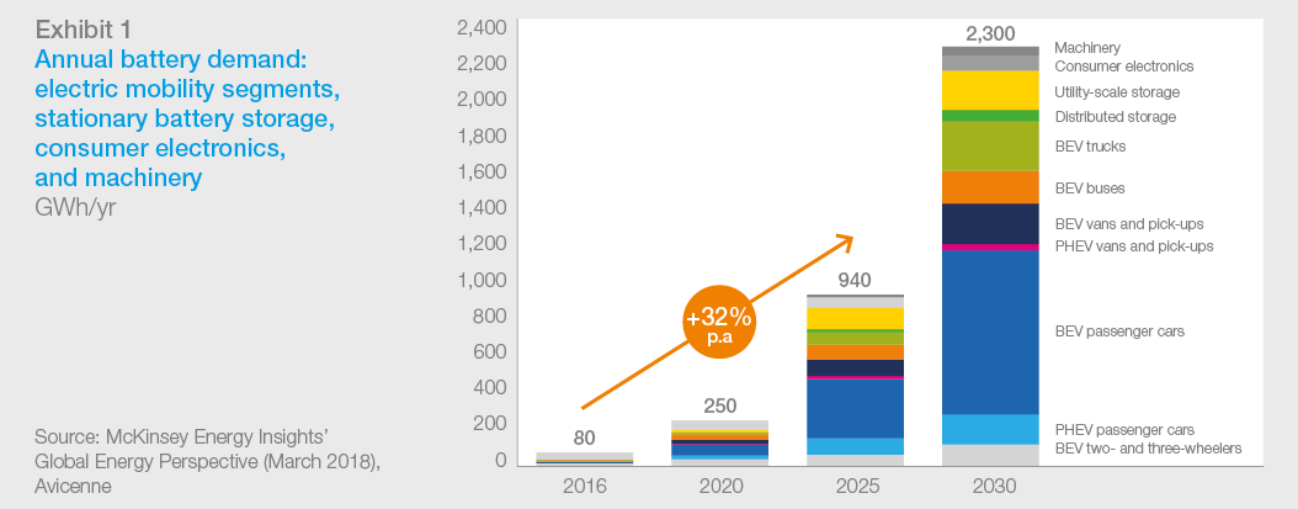
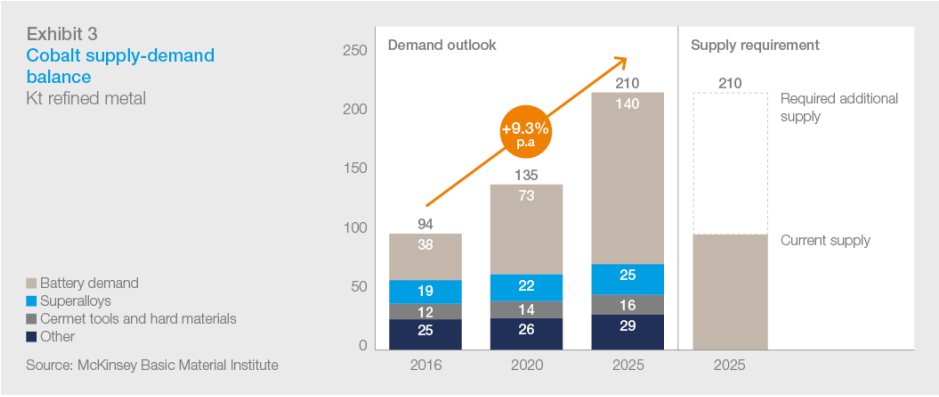
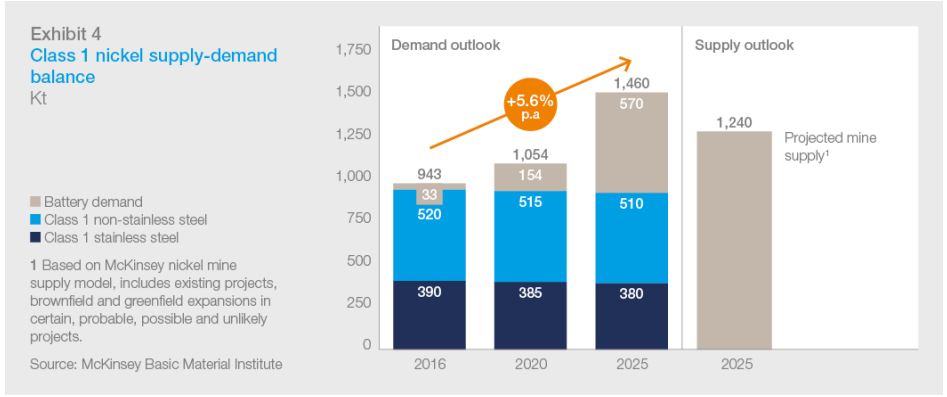
Li-ion batteries – Meeting with raw material obstacles



Cobalt from Congo and substitute **nickel**: A **bottleneck**





McKinsey, 2018.

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The white elephant in the room: Supply chain risks

- **Enormous expansion of production capacity necessary**
  - Sustained increase in production capacity over 15 years with >35% CAGR needed
  - Supply bottlenecks at the expense of non-automotive applications
- **Limited availability of cobalt and nickel**
  - Bottleneck already exists for cobalt and is foreseeable for nickel
  - Transition to LFP for non-automotive applications has started
  - Technology diversification is necessary and most likely
- **Undersupply drives medium-term developments on the metal markets**
  - Long start-up phase for mining development (>7 years from plan to production)
  - Strategic access to raw materials is increasingly under control of China
  - "Anyone looking for suppliers now has already lost the match."

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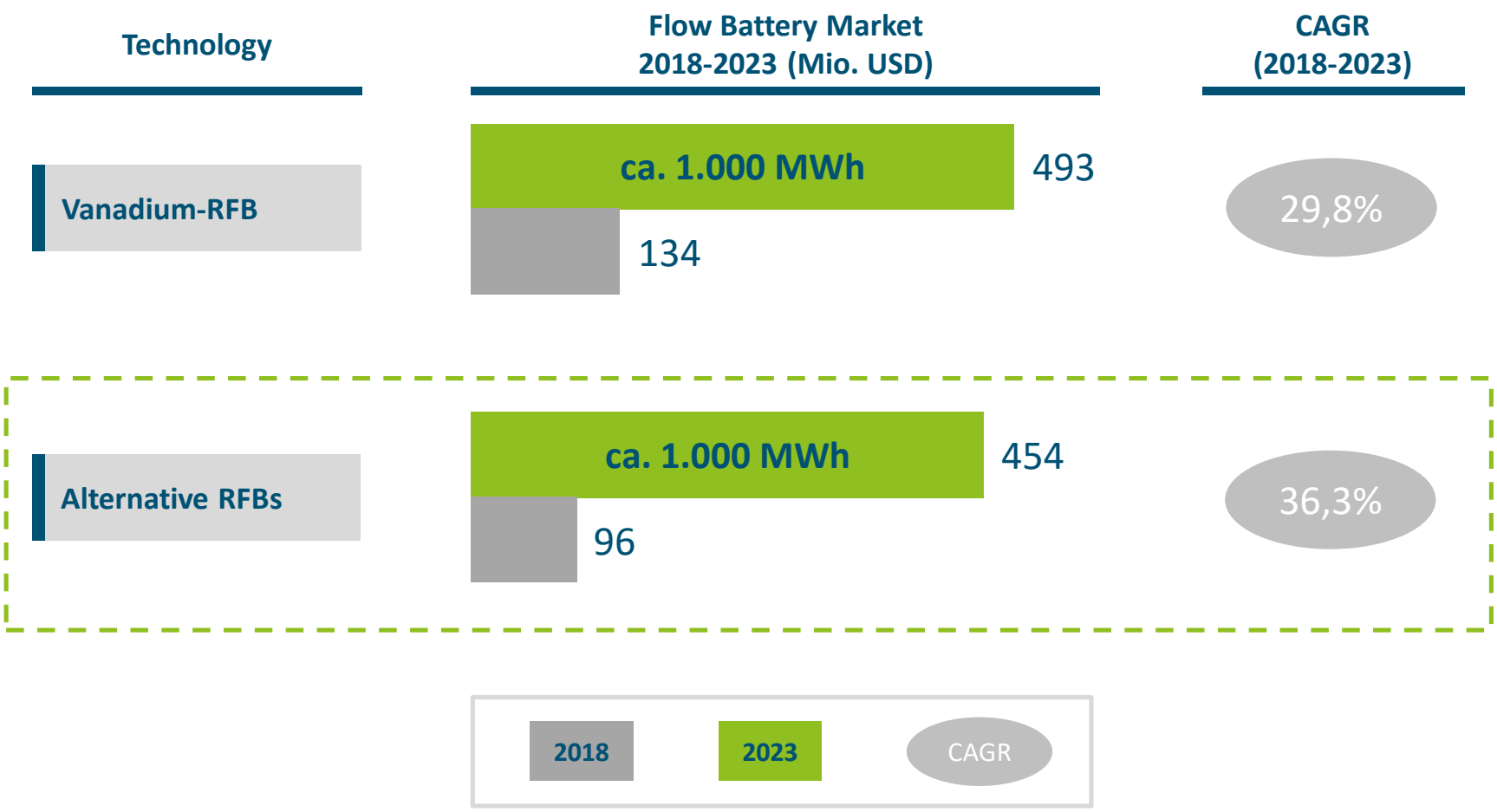
JENA BATTERIES

Market forecast RFB – Technologies



MarketsandMarkets, 2018.

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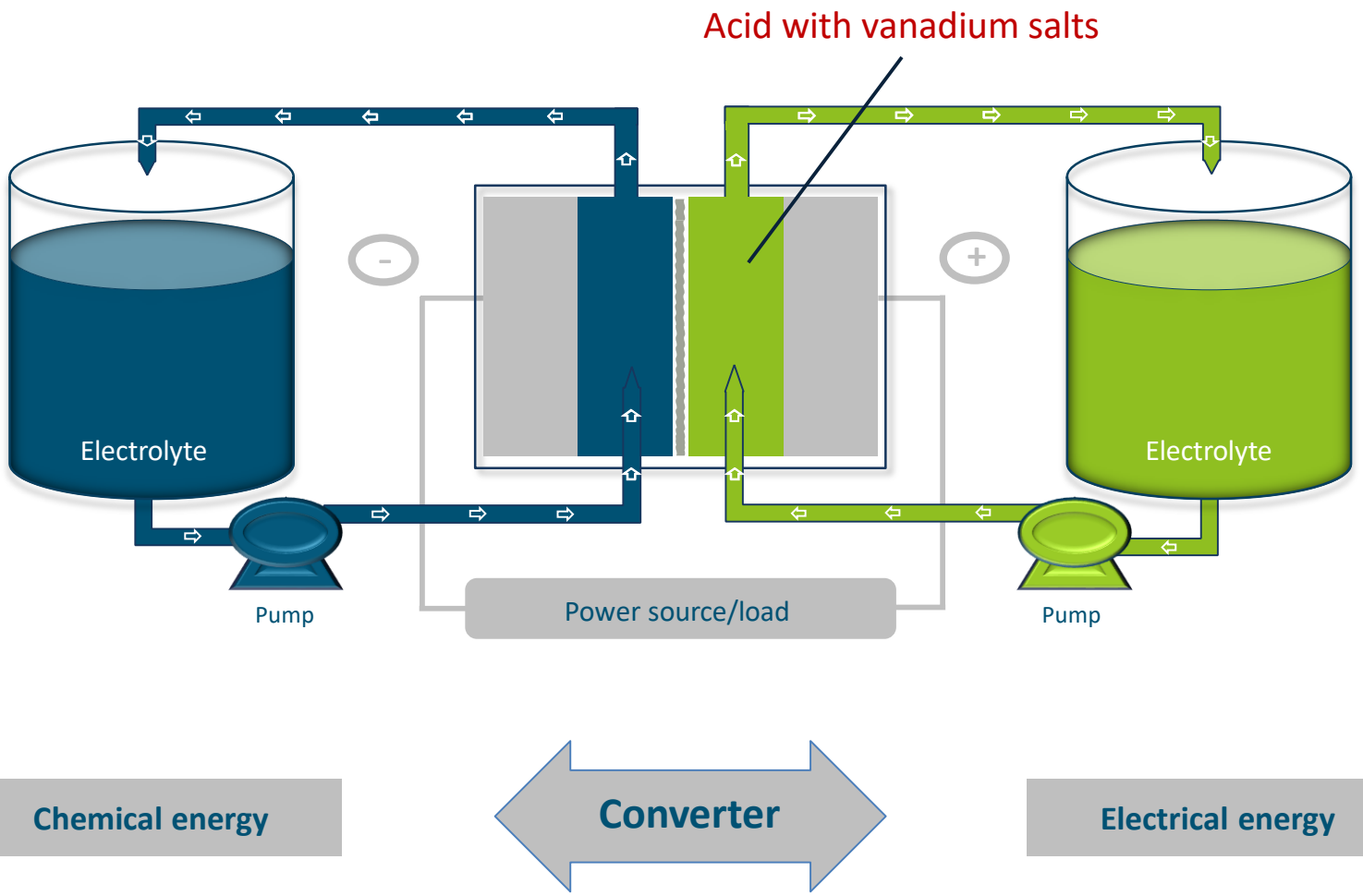
Conventional redox flow batteries



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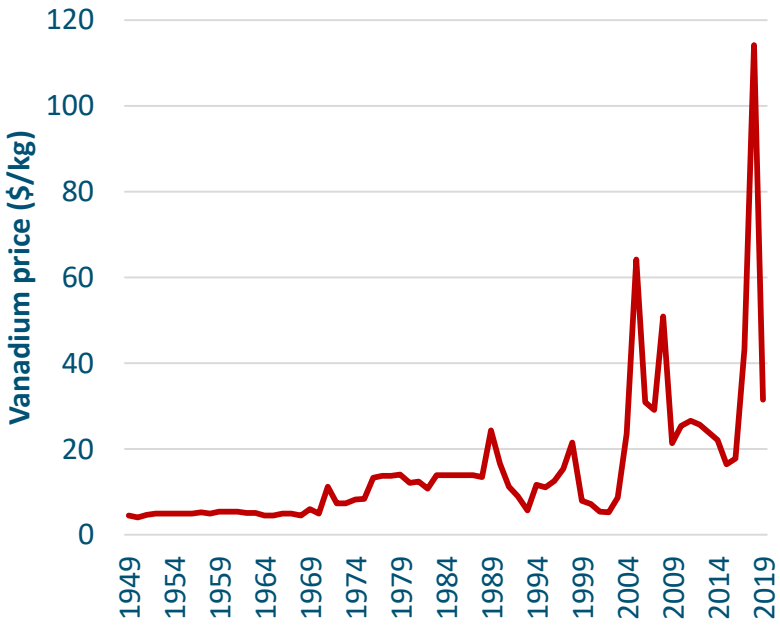
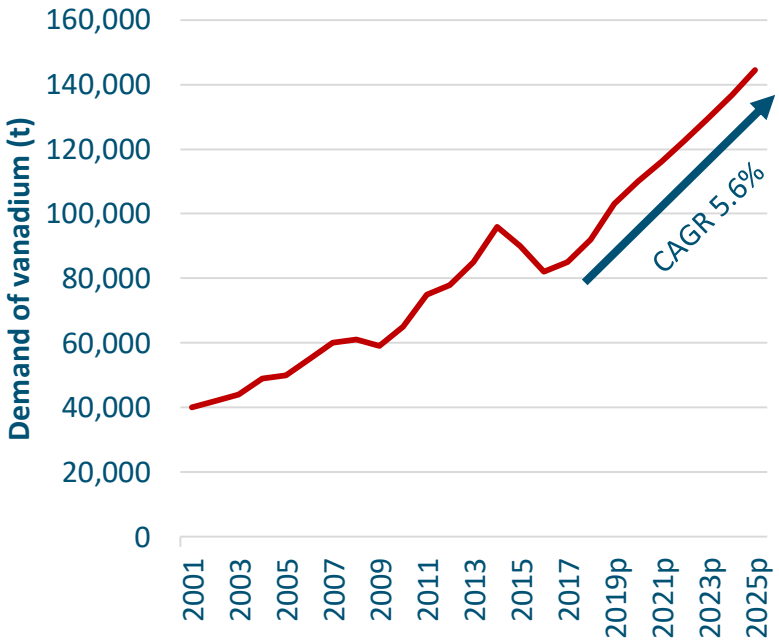
Vanadium-RFB: An unpredictably expensive system





- Demand exceeds supply (80,000 t vs. 75,000 t, 2016)
- China and South Africa are closing down polluting mines
- China introduces stricter standards for structural steel (higher V content)
- High cost of extraction as by-product from coal
- Price drop 2019: high inventory levels and lack of inspections in China

U.S. Geological Survey; www.vanadiumprice.com; IFBF 2018.

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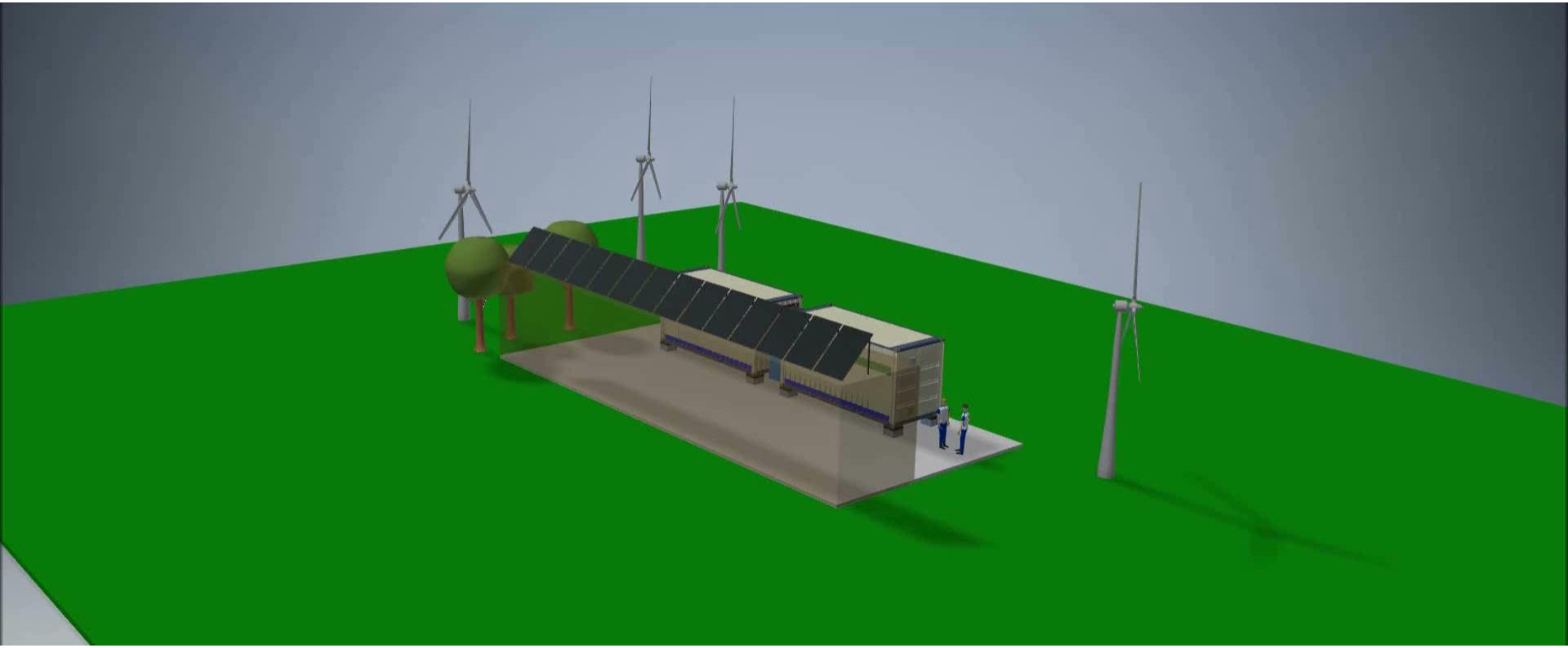
EnergyKeeper battery design



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Battery construction

- Two standardized (intermodal) shipping containers
- Flexible system, space for extensions and future tests
- Module I: Energy storage unit
- Module II: Converter unit

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Battery construction – Energy storage unit

- Storage capacity 100 kWh
- Jacketed reservoirs and jacketed pipes, safety pans
- REACH registration process for novel electrolyte

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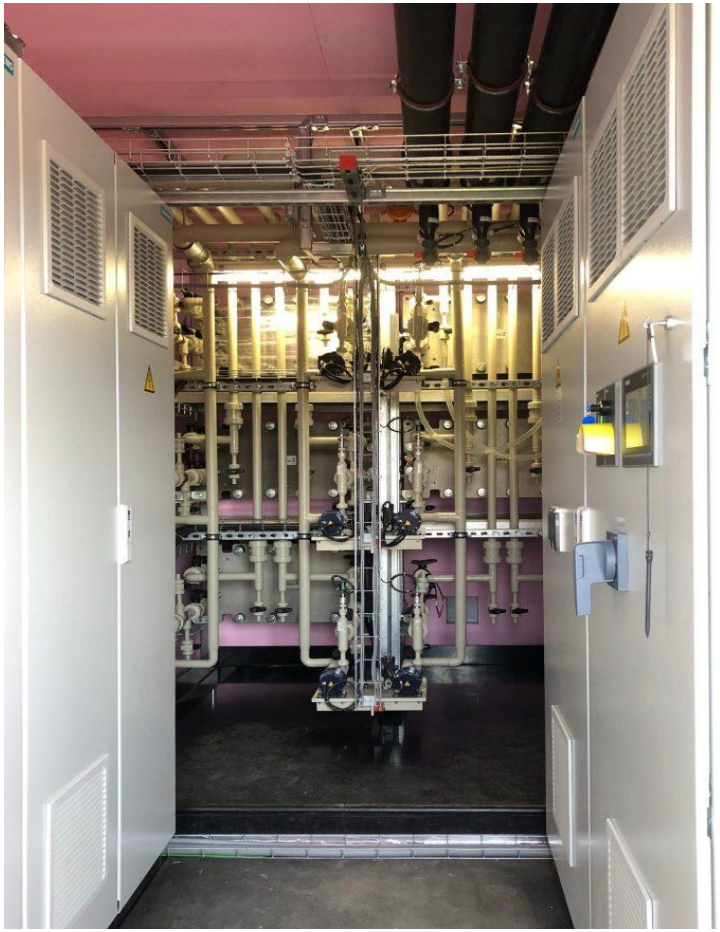
Battery construction – Converter unit



- Max. power output of 30 kW
- Three 400 V AC +PE at 90 A for charging and discharging
- Siemens inverter system
- Five cell stacks mounted to a rack system for easy and safe handling
- Electrical cabinets for BMS

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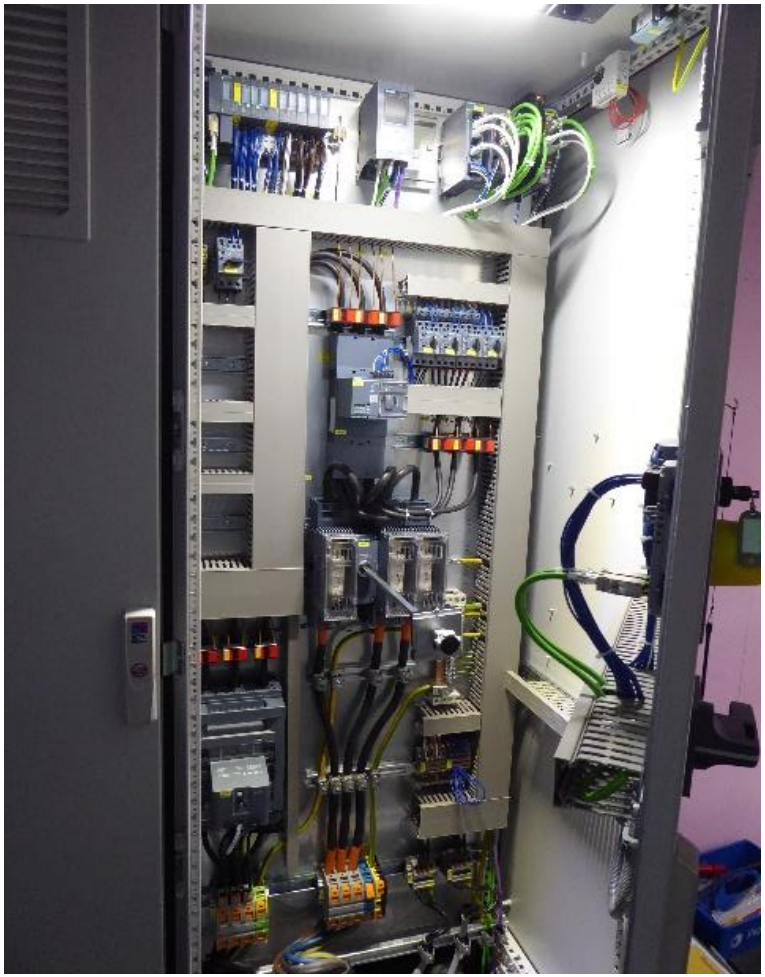
Battery construction – BMS



- Siemens S7 PLC
- Tamper-proof BMS against intentional malfunction and sabotage
- Access control/monitoring scheme (password, keys)
- Network security scheme/data security for communication between the battery control system and the smart grid control
- Grid-to-battery communication via ethernet / Modbus TCP bus protocol
- Remote administration (maintenance etc.) via SINEMA system/internet connection

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Pictures of the installation at ACRRES






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The next step: Market preparation

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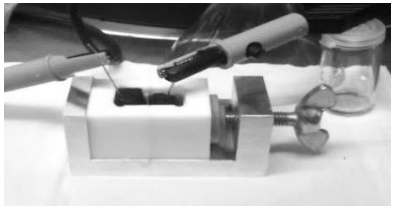
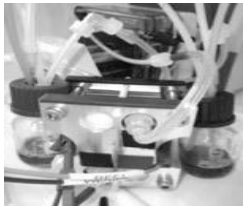
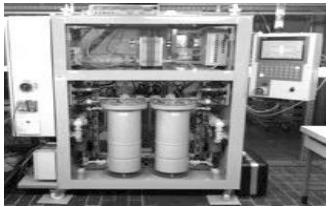

Product development and productioning (2019/2020):

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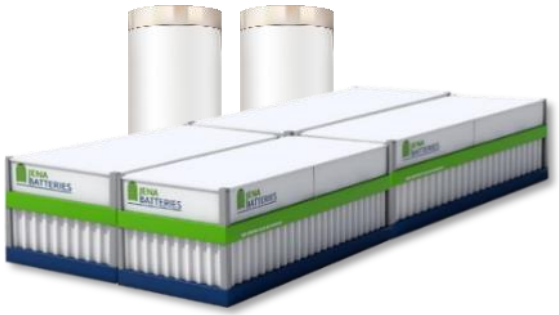

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Product classes – Scalable systems & modular design

BASIS		PLUS
40‘	**Container**	On special request
Yes	**Modular design**	On special request
Yes	**Extensibility**	Yes
100 kW / 400 kWh module	**Size**	On special request
20 years	**Design-Life** (regular maintenance)	20 years
Legal requirements	**Warranty**	Additional package (e.g. 10 years)
No	**Isolated operation**	Possible
-15 to 35 °C	**Ambient temperature**	Extended range
At grade	**Footprint**	Stackable
Terminal strip, interface for operational mode	**Interface**	Integration into higher-level control system
Local Legal requirements	**Certificates**	On special request
Legal requirements	**Safety (IT/physical)**	On special request (e.g. special protocols)
Legal requirements	**Localization** (climate, language, permissions, dust, chemicals, …)	On special request (e.g. language, protection from special environmental conditions)
Yes	**Intrinsic safety**	Yes

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Metal-free RFB: BASIS

„JenaBatteries offers to our clients a metal-free, non-flammable and scalable redox flow battery. The use of a new raw material base ensures minimized price volatility and enables reliable cost planning for the serial realization of modern energy infrastructure projects. Hence, our products allow for innovative business models to increase the security of electricity supply in the face of the energy transition. In addition, they simplify project financing and support insurability. Thanks to the metal-free active materials, maintenance is easy and the battery can be operated reliably. Metal-free redox flow batteries are ideally suited for system sizes starting from 100 kW. They are not competing with applications in other markets, e. g., electric cars or smartphones. Thus, you will always have access to the matching battery for your business model. “ (Olaf Conrad, Managing Director)

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JENA BATTERIES

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