Project financing made easy!

The calculable battery for your energy park

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ZIM Zentrales Innovationsprogramm Mittelstand

EUROPÄISCHE UNION

Thüringer Aufbaubank

RANFT IMMOBILIEN GRUPPE

WIRTHWEIN AG

JenaBatteries GmbH

Google Maps, 2018.

Dr. Olaf Conrad
Managing Director
since 2016

Carsten Oder
System & Electronics
since 2014

Dr. Tobias Janoschka
Corporate Development
Co-Founder/Inventor

Dr. Norbert Martin
Electrolyte & Materials
since 2014

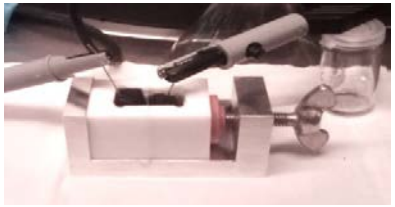
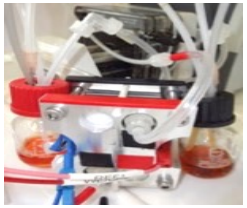
Wirthwein AG

Ranft Gruppe

SUPRAMAT Technologies AG

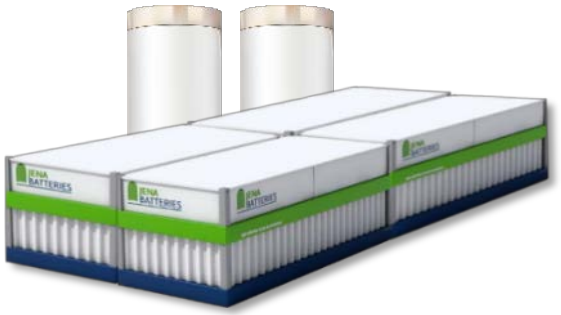
The next step: Market preparation

Technology development (2012 to 2018):

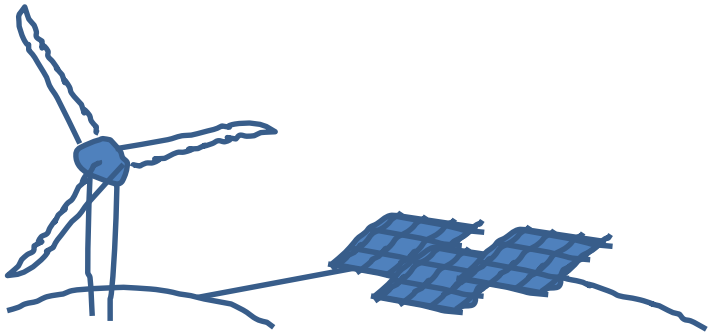

Product development and productioning (2019/2020):

BASIS System → Product Classes → Tailored Solutions

Market entry in 2021

Customers: Project developers in the renewable energy market



Electricity Producer

Energy Exchange

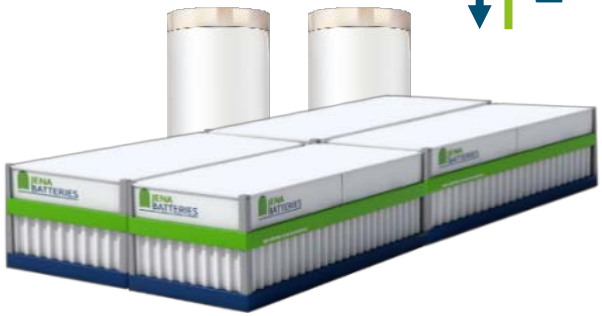
Electricity

Remuneration

Electricity

Market price

Elec-
tricity

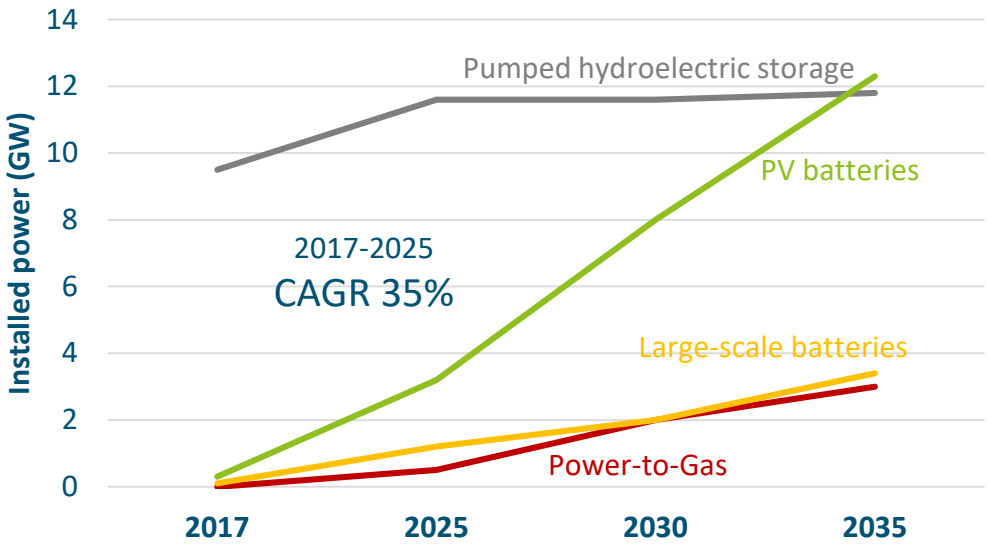


Management Fee

Aggregator/Energy Service Provider

System Operator

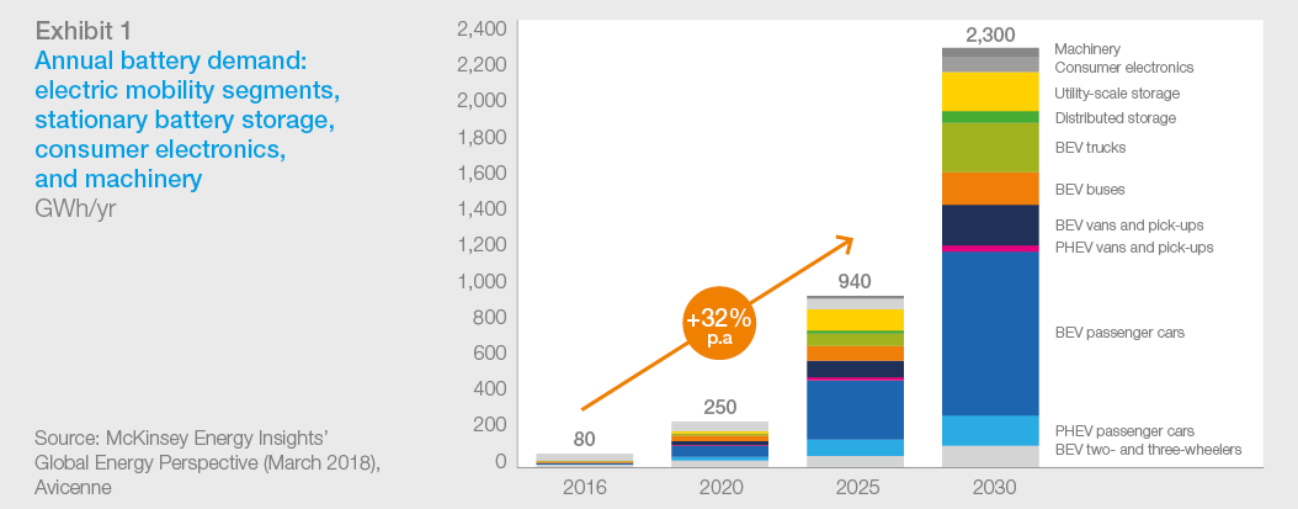
German TSOs' 2019 draft grid development plan



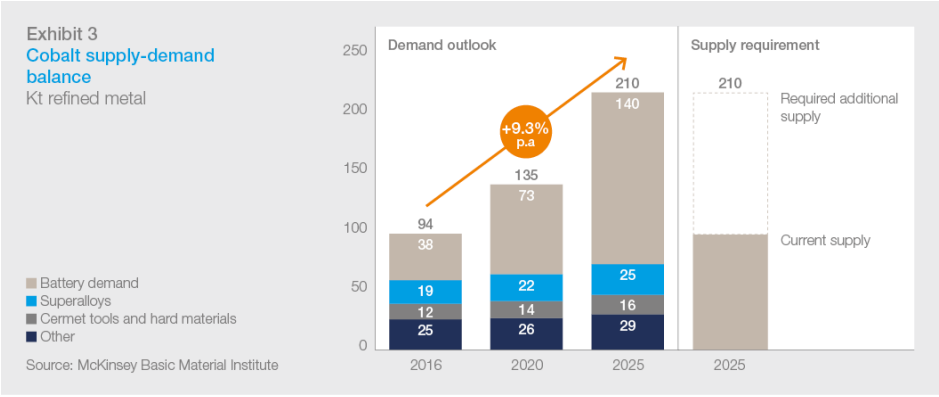
Installed (GW)	2017	2025	2030	2035
Pumped hydro	9.5	11.6	11.6	11.8
Power-to-Gas	–	0.5	2.0	3.0
PV batteries	0.3	3.2	8.0	12.3
Large-scale batteries	0.1	1.2	2.0	3.4
Demand side mgmt.	1.5	3.0	4.0	5.0

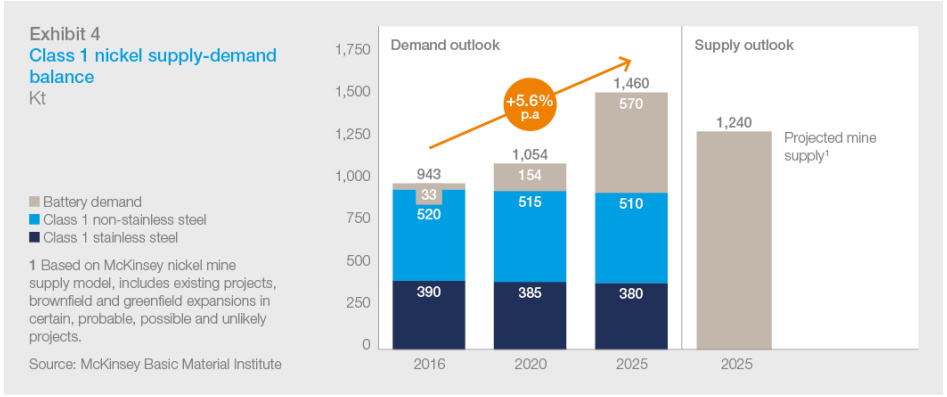
Scenario B: Compromise with specifications for maximum CO_2 emissions and a balanced expansion of individual renewable energy technologies and sector coupling.

Li-ion batteries – Meeting with raw material obstacles



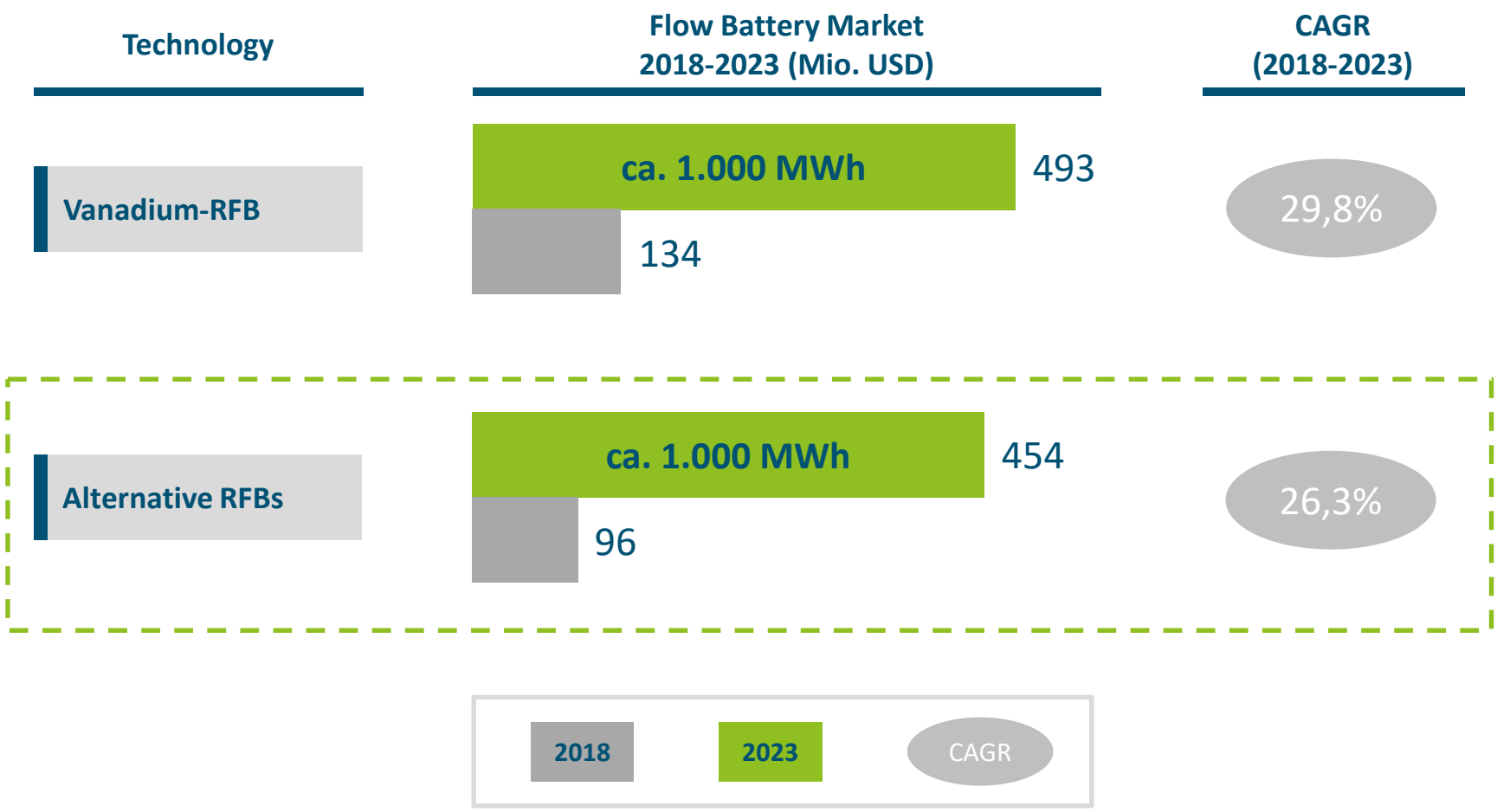
Cobalt from Congo and substitute **nickel**: A **bottleneck**





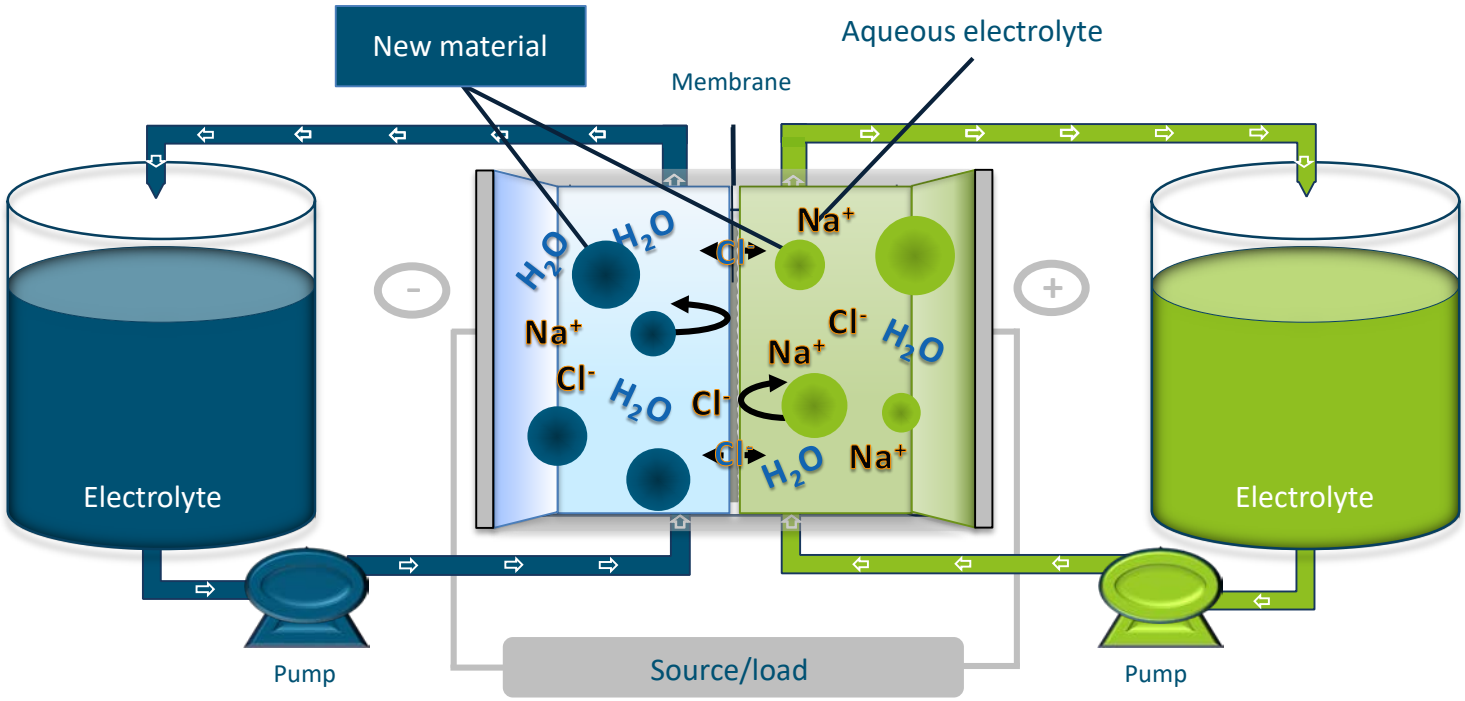
McKinsey, 2018.

Market forecast RFB – Technologies



MarketsandMarkets, 2018.

Our innovative redox-flow battery



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

The calculable battery for your energy park

Li (cobalt) battery

+ Advantages

- High energy density
- High efficiency

- Disadvantages

- Intensive battery management for durability and safety
- Limited resources (lithium, cobalt, nickel) with increased price sensitivity
- State of charge from 20-80%
- Fire hazard

Metal-free RFB

+ Advantages

- Independent scalability of power and capacity
- Avoids heavy metals or aggressive acids
- Non-flammable and non-explosive
- Long cycle life
- Wide SOC window

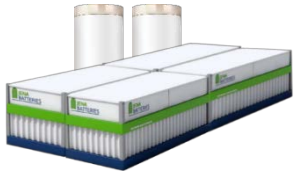
- Disadvantages

- Medium energy density
- Average efficiency

Li-ion battery for E-mobility and home storage

Metal-free RFB for stationary, large-scale storage

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

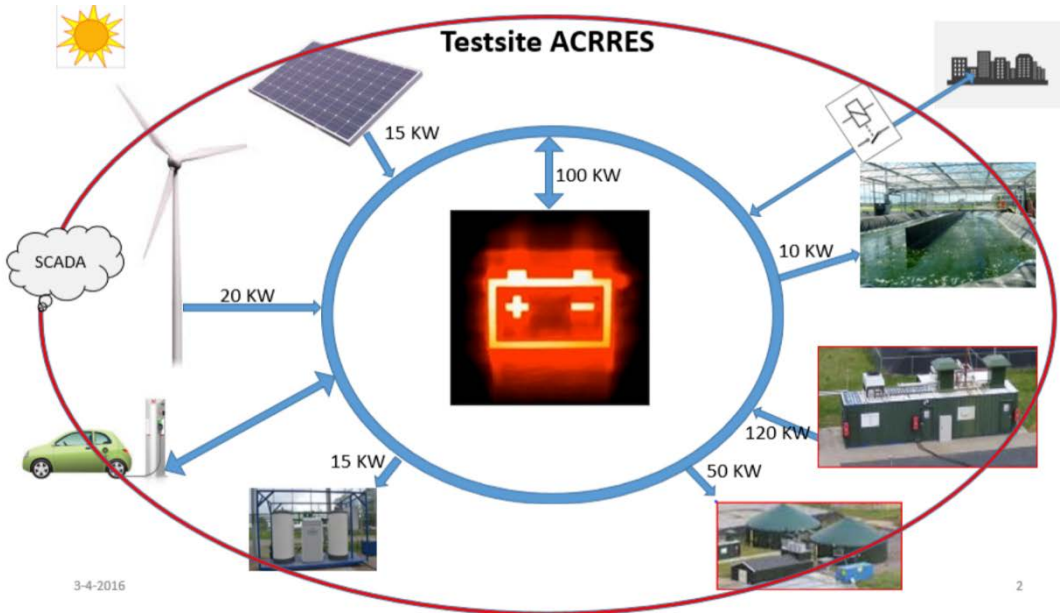
Key activities in EnergyKeeper

TESTING BATTERY AND BATTERY MANAGEMENT SYSTEM

Intergration with real RES (Renewable Energy Sources), Electric Vehicle chargers and variable power consumption at the ACRRES test site

SMART GRID CONTROL AND COMMUNICATION LAYERS

Communications architecture, grid control and demand side management systems will be designed and implemented

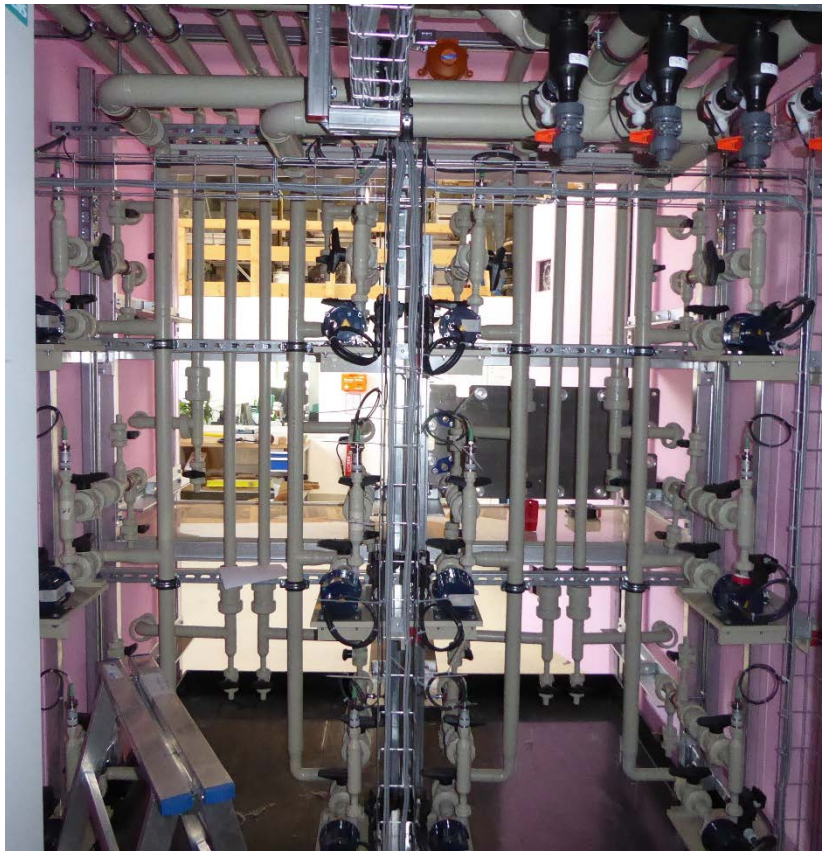


DEVELOPMENT OF SEVERAL PROSUMER BUSINESS MODELS

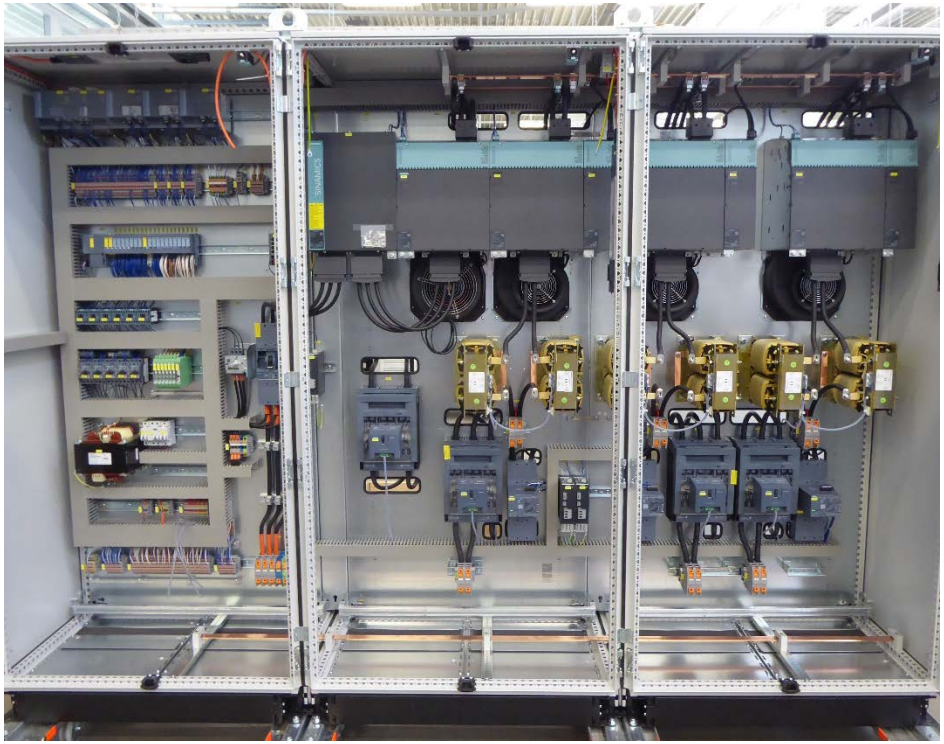
Prosumer business models oriented to different types of communities

Successful installation at ACRRES test site

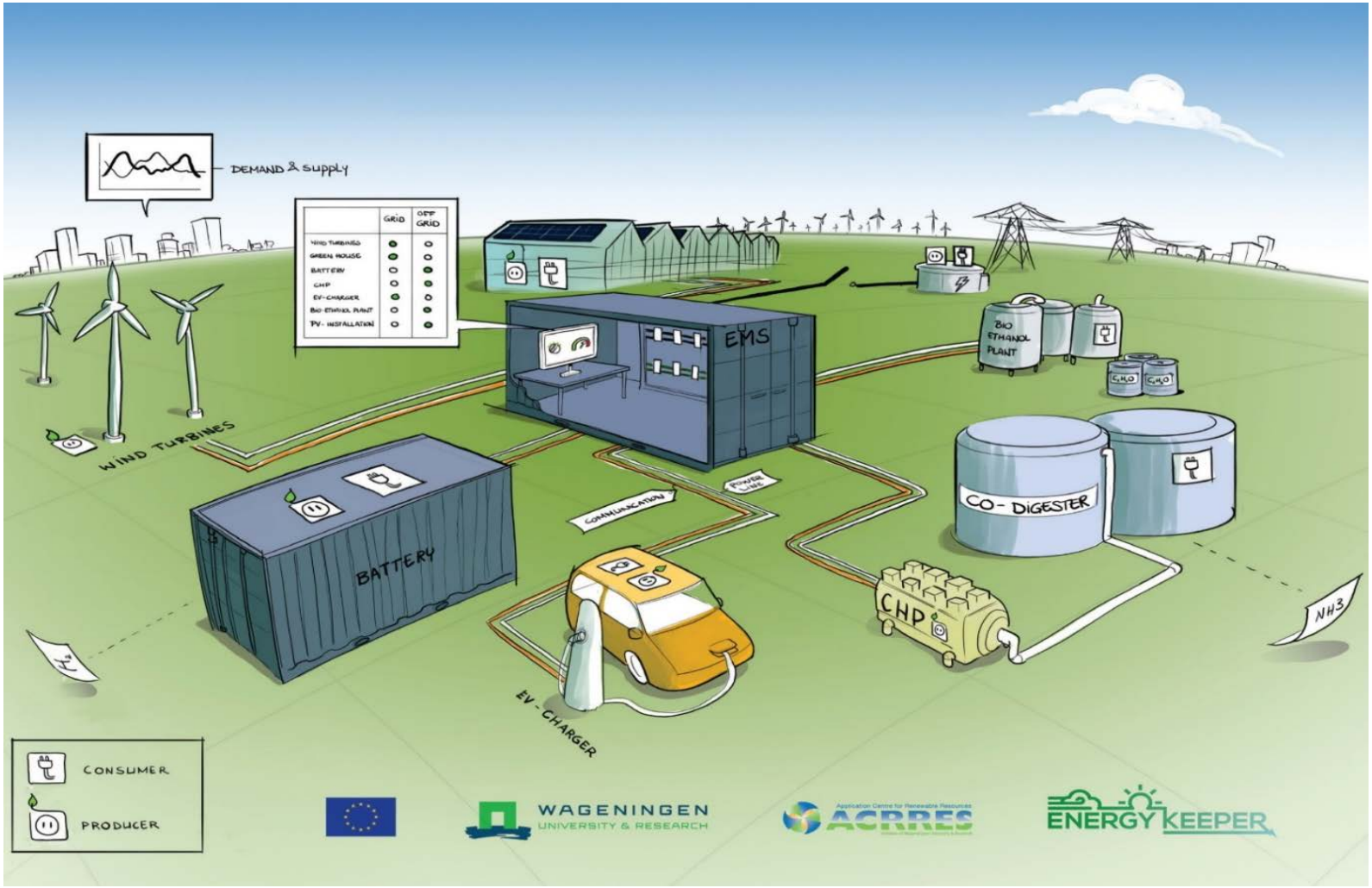
Hydraulic and electric installations easily accessible



Design for longevity and servicability



ACRRES test site



Developing a new technology

Some important lessons learned

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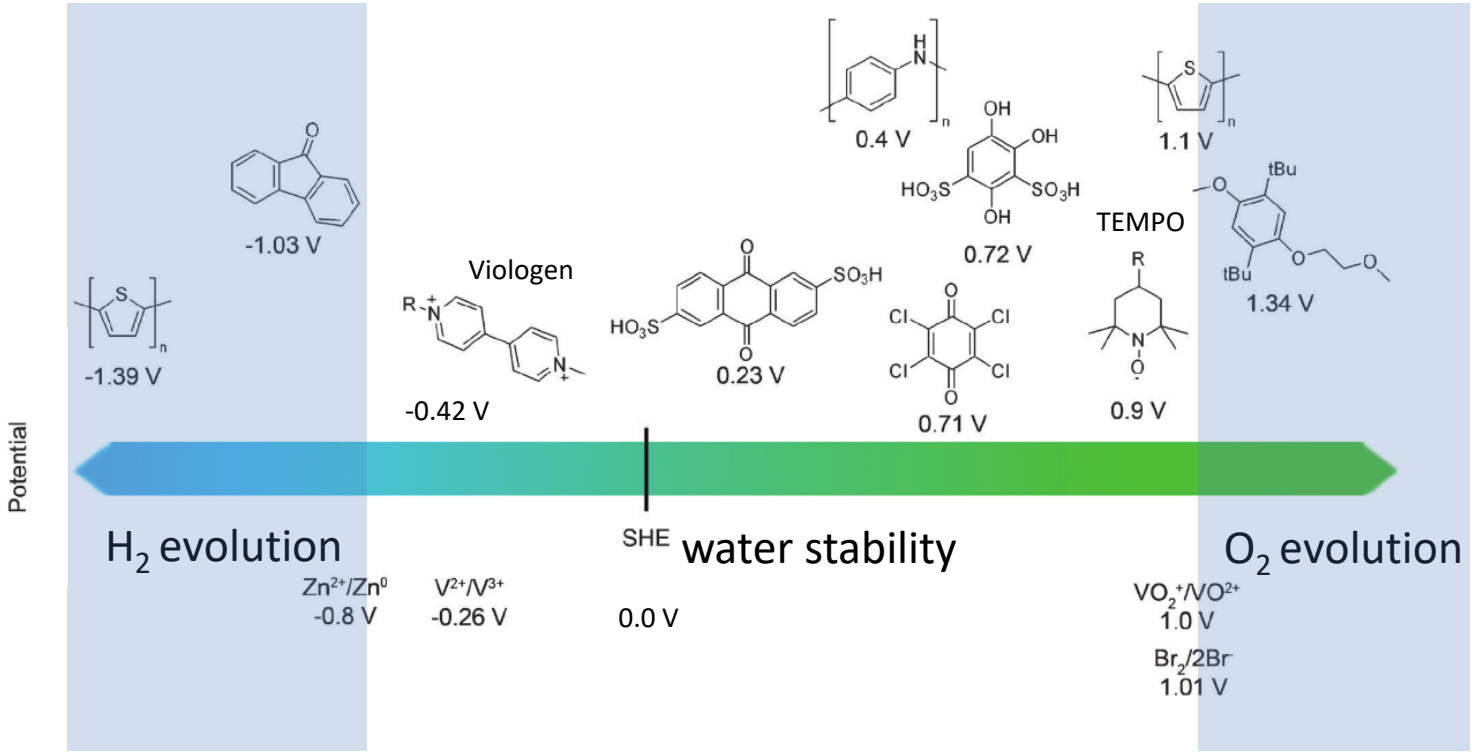
WIRTHWEIN AG

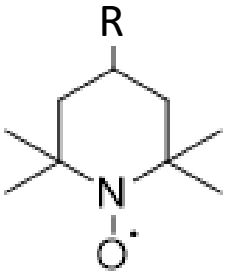
Organic active materials – what matters?



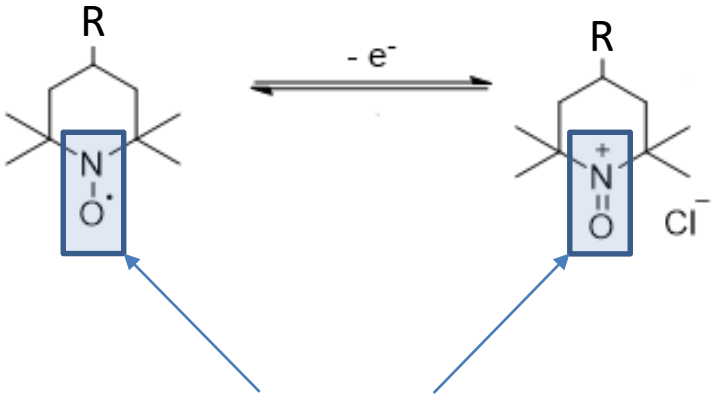
- Aqueous solutions are favored due to cost, safety and conductivity
- TEMPO/viologen-system uses a great part of water stability window

J. Winsberg *et al.*, Angew. Chem. Int. Ed. **2017**, *56*, 686-711.

Organic active materials – what matters?



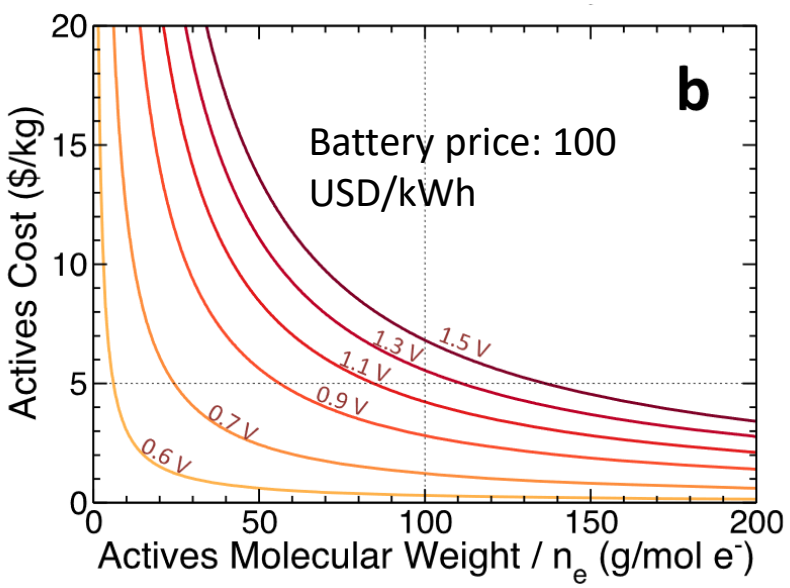
- 2,2,6,6-Tetramethylpiperidinyloxyl (TEMPO)-Derivative
- Stable organic radical
- Cheap and readily available precursors (acetone und ammonia)
- Easy synthesis procedure depending on R



Active component

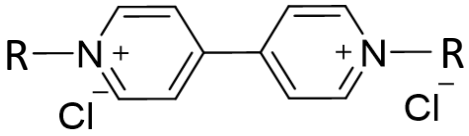
Molecular weight N-O: 30 g/mol

Molecular weight TEMPO: 156 g/mol

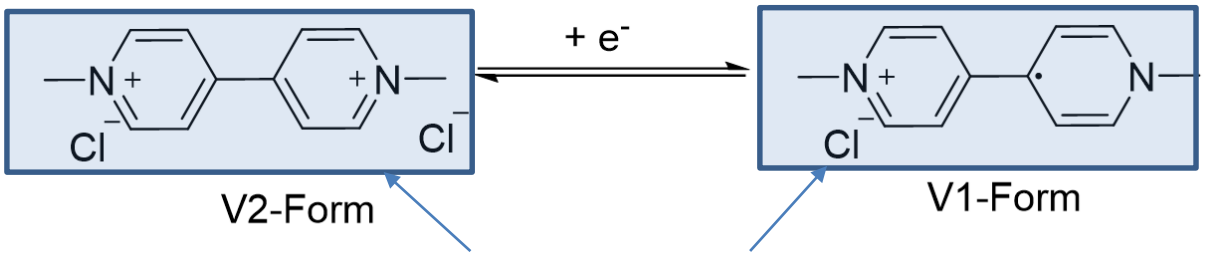


R. Dmello et al., Journal of Power Sources **2016**, DOI: 10.1016/j.jpowsour.2016.08.129.

Organic active materials – what matters?

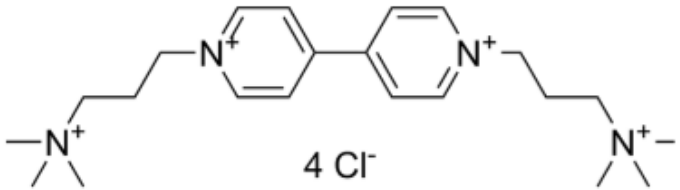


- 4,4‘-Bipyridinium-Derivative (Viologen)
- Fast redox kinetics
- Upscaled production capabilites for some derivatives available



Active component

Molecular weight = 257 g/mol

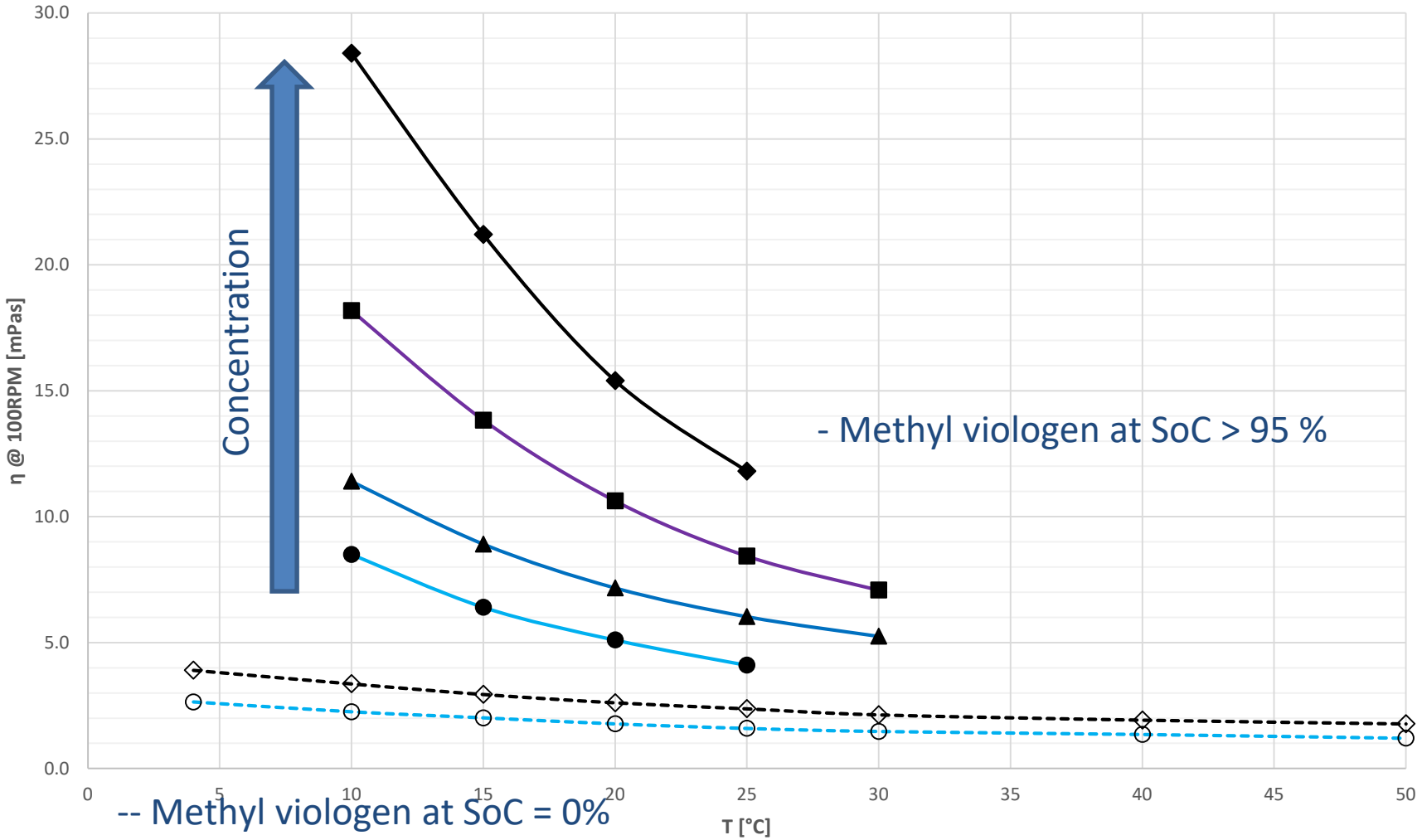


BTMAP-Vi

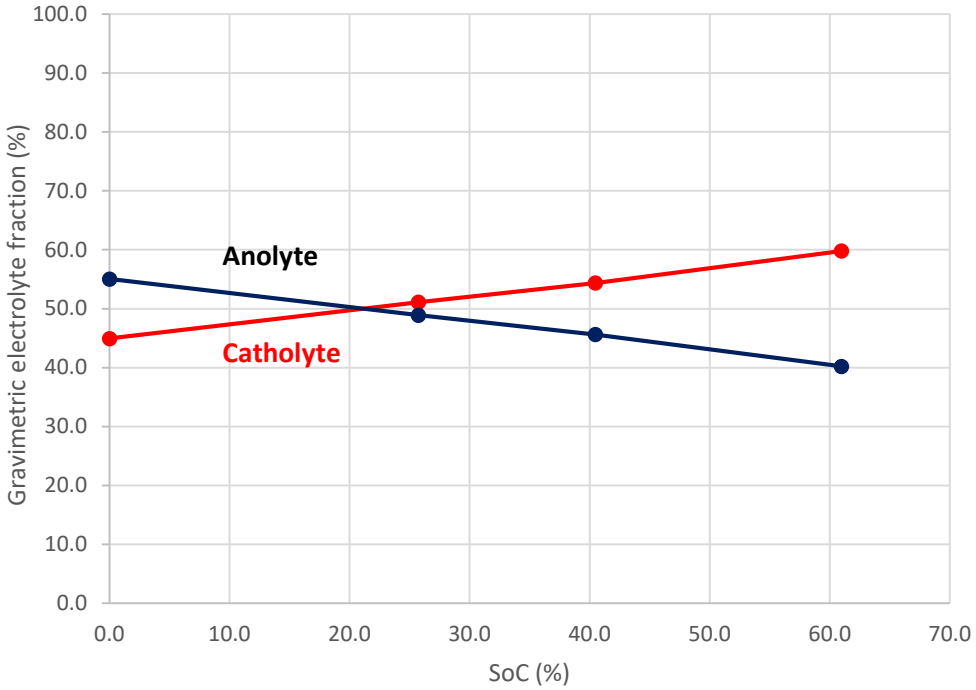
E.S. Beh *et al.*, *ACS Energy Lett*. **2017**, 2, 639-644, DOI:10.1021/acsenergylett.7b00019.

Molecular weight = 500 g/mol

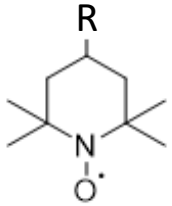
Viscosity of electrolyte

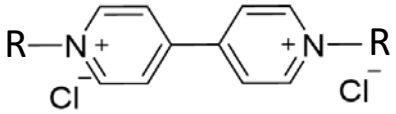


Influence of SoC on effective volume of the electrolytes



- Battery was charged to a defined SoC
- Electrolyte solutions were pumped at constant SoC until gravimetric fractions remain constant
- Electrolyte system:
  - TEMPO
  - Viologen





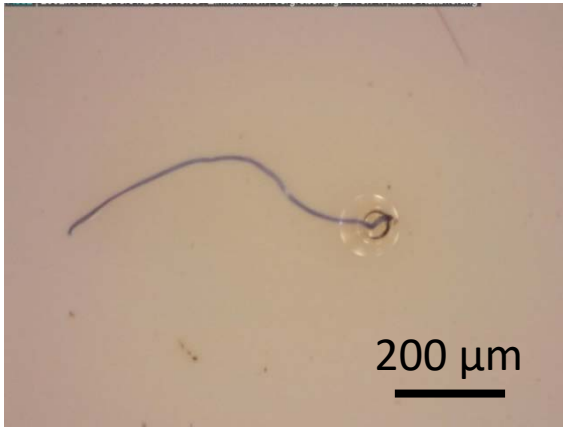
- Volume change of the electrolytes depending on SoC has to be considered when designing the tanks
- Initial concentration of each electrolyte, the active species itself and additives also influences the equilibrium concentration at a given state of charge

Important technical requirements for a membrane

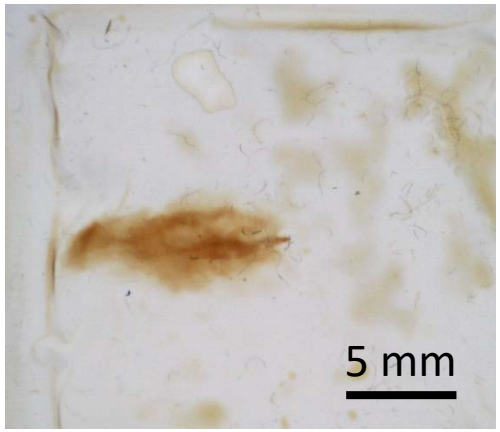
- Mechanical properties
  - Strength
  - Thickness
  - Available size
  - Pin holes

- (Electro) Chemical properties
  - No functional degradation during battery use
  - No catalyst for electrolyte decomposition
  - High permeability for charge compensating ions
  - Low permeability for electro active species

Examples of membrane related topics

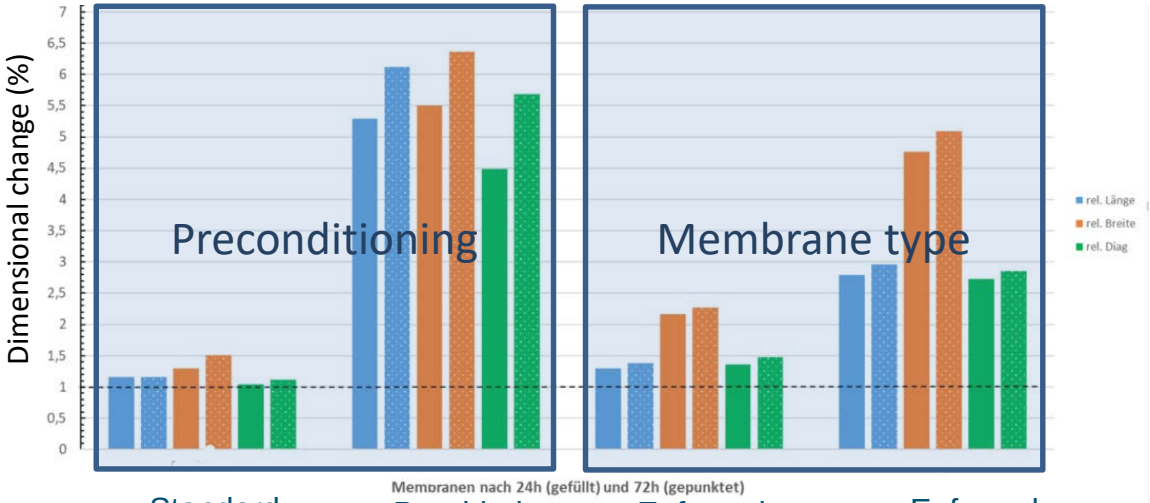


Pinhole before test



Pinhole and resulting discoloration after cell test

- Pin holes may lead to material crossover and local alteration of the membrane
- Thorough QA neccessary

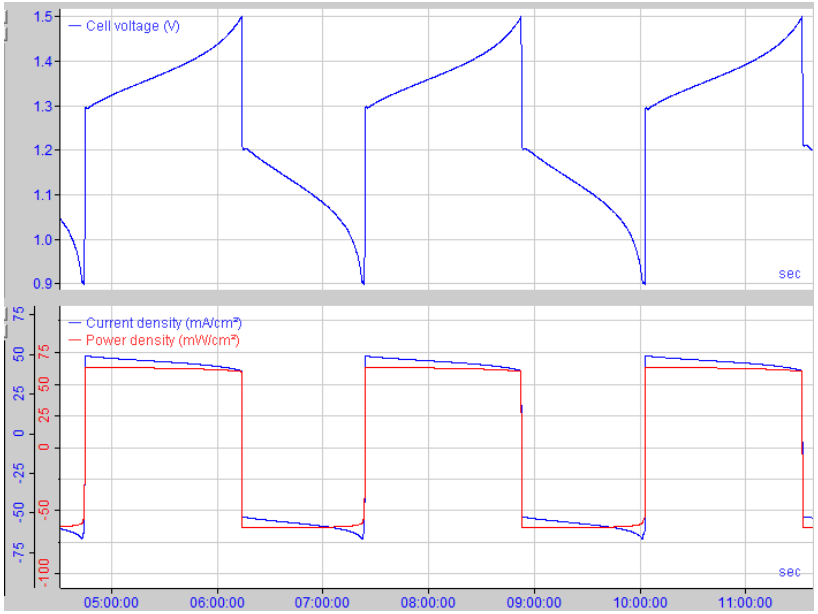


- Swelling of the membrane after they are immersed into electrolyte strongly depends on membrane type and preconditioning

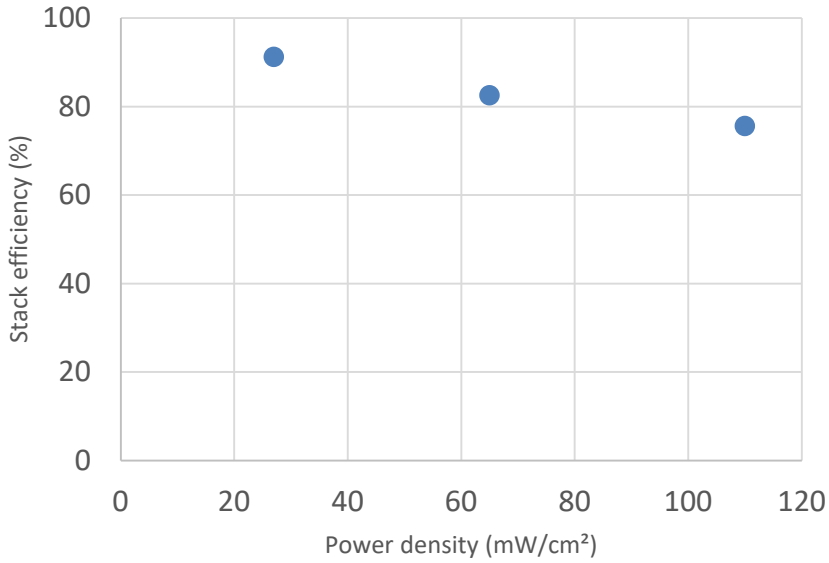
Long term testing at pilot scale

- Max Power: 3.5 kW
- 40 L electrolyte volume
- Additional sensors: pH, redox potential, conductivity, flow rate, pressure
- Can be adapted to multiple stack sizes and designs

Long term testing at pilot scale



Example of constant power cycling



Stack efficiency depending on Power density

- Stack efficiency = Coulomb and Voltage efficiency at stack level
- Lab test results, further optimization ongoing

Summary

- Molecular weight per electron very important parameter for organic active materials
- Electrolyte properties like osmosis and viscosity under various conditions tested and included in battery design
- Membrane is a very crucial component – especially for assymetric electrolytes
- Testing over more than three months at pilot scale leads to a high projected lifetime of the battery