



Berner Fachhochschule  
Haute école spécialisée bernoise  
Bern University of Applied Sciences



# Werden Solarbatterien billiger und besser? Versuch einer Prognose!

BFH Zentrum Energiespeicherung - 2018-04-20 Photovoltaik Tagung

▶ BFH-CSEM Zentrum Energiespeicherung / Prof. Dr. Andrea Vezzini

# BFH Zentrum Energiespeicherung

## Overview

# BFH-CSEM Energy Storage Research Center (ESReC)

- ▶ One of the largest independent energy storage research centers for academic R&D activities available to the Swiss industry



Testing and characterization of large capacity cells and modules and development of hard- and software for complete battery and energy systems



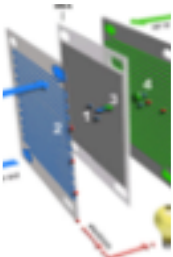
Use and test of energy storage systems for mobility applications to substitute non-renewable fuels and reduce CO2 emission for all mobility carriers (land, air, sea)



Manufacturing technologies for large lithium-ion cells and modules for a cost effective production of the key components of electrical storage systems



Use and test of PV integrated energy storage systems to enable the integration of new renewable energy sources and their impact on power quality and grid stability



Application, test and development of decentralized and mobile fuel cell systems as a basis for long term storage of electrical energy.



Integrated analysis of Innovation-ecosystems enabling the diffusion of battery storage systems as a means to manage the energy turn-around

# Embedded in three national Research Networks

## ▶ FUTURE SWISS ELECTRICAL INFRASTRUCTURE - SCCER-FURIES



## ▶ EFFICIENT TECHNOLOGIES AND SYSTEMS FOR MOBILITY – SCCER MOBILITY























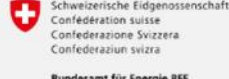


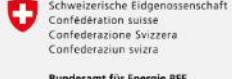


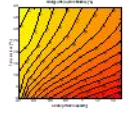

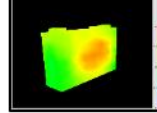
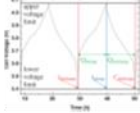

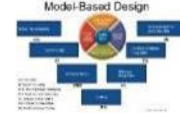









## ▶ HEAT AND ELECTRICAL STORAGE – SCCER STORAGE





# From Research to Products: CA A1 E-Mobility

Industry / Startups		 CH-9245 Oberbüren	 CH-4512 Bellach	 CH-2560 Nidau	 CH-3000 Bern	 CH-3627 Heimberg	 CH-3401 Burgdorf	
Demonstrators P&D Program		 Suncar E-Bagger	 SBB On-Board Battery	 Swiss Trolley+	 Traction DC/DC	 votec evolaris	 110t eDumper	
Communication KTT	 Brochure	 Academia-Industry Dialogue	 Master Thesis Presentation	 Transportation Regulation Report	 Kompetenznetzwerk Li-Batterien	 armasuisse Report	 SCCER Seminar	
Funding / Investments	 Initial invest in equipment	 NTB Interstaatliche Hochschule für Technik Buchs FHO Fachhochschule Ostschweiz	 evolaris	 SBB / Swiss Trolley+	 evolaris	 Invest	 110t eDumper	 EM1 – Electric Mower
Applied Research	 Roadmap	 Performance Tests	 Testing Standardization	 Thermal testing	 Life Cycle testing	 Functional Safe BMS	 FuSi Programming	
Infrastructure	 High Power Testing (EMPA)	 40 Channels (10V/50A)	 +20 Channels (10V/50A)	 Thermal Test Bench (NTB)	 BMS HiL	 +2 Temperature Chambers	 50kVA Smart Building Emulation	
	2014	2015	2016	2017	2018			

- ▶ The International Energy Agency has several working groups. Switzerland has been a member of TCP Energy Conservation and Energy Storage since 2016 and is represented there by the BFH Energy Storage Centre.
- ▶ As part of this cooperation, a database of the energy storage situation in Switzerland is currently being compiled. The website offers a condensed overview for interested parties and researchers
- ▶ At the moment the website is still under construction. We collect information about
  - ▶ pilot projects
  - ▶ Commercially available batteries
  - ▶ research projects
  - ▶ And everything else that has to do with energy storage.

## Swiss Energy Storage Overview

by the BFH-CSEM Energy Storage Research Centre



Pumped Hydro Storage  
Compressed Air Storage  
Commercial Batteries  
Commercial Examples  
Battery Pilot Projects  
Introduction and Summary  
7.5 MWh Battery EKZ  
CKW E-SpeicherWerk Castle Meggenhorn  
EPFL Distributed Electrical Systems Laboratory - Leclanché  
**EWZ BES DORA**  
Energieautarkes Haus Brütten  
Swiss Dual-Circuit Redox Flow Battery  
Swiss Trolley Plus  
The Zurich 1 MW BESS  
Other Energy Storage Pilots  
Energy Storage Research Projects  
Further Links

### EWZ BES DORA

Quartierspeicher bei EWZ

#### Technical Data

Used Technology	Unknown
Charging Power	120 kW
Discharging Power	120 kW
Nominal Energy	720 kWh

#### Links

<https://www.ethz.ch/content/dam/ethz/special-interest/tet/institute-eeh/power-systems-dam/documents/SAMA/2014/Vollenweider-MA-2014.pdf>

# Study: Technology assessment of lithium containing batteries (LIB)



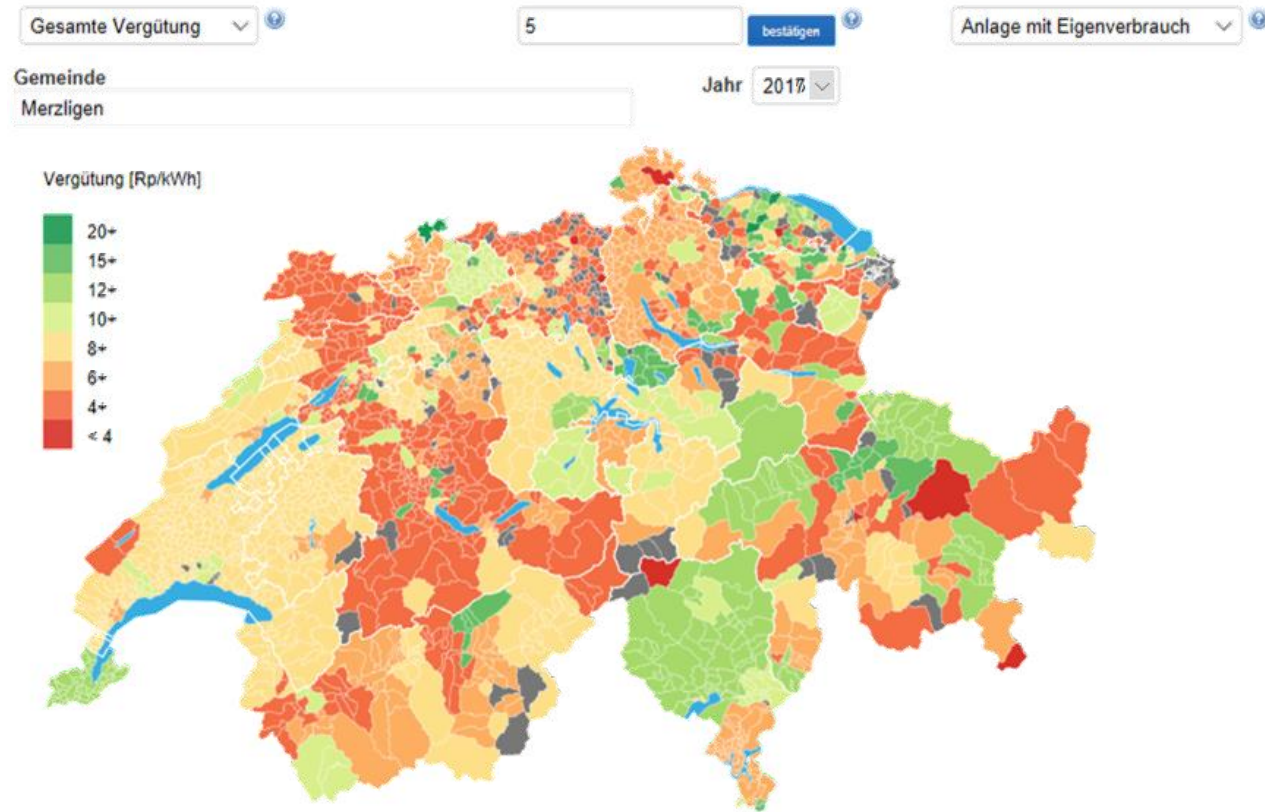
- ▶ Study was carried out on behalf of the armasuisse (2016/17)
- ▶ Attended by a scientific accompanying group
- ▶ Content:
  - Introduction to the basic principles of Li-ion batteries
  - Overview about actual LIB technologies
  - Key chapters about "laws, norms and regulations", "safety aspects" and "experience reports" (e.g. transport regulation ADR 2017)
  - Recommendations about the five life phases of Li-ion batteries we considered: "procurement", "storage", "transport", "application" and "disposal"
  - Out conclusion: With a good choice and a careful handling the safe use of LIB is possible without any reservations - according to the listed recommendations
- ▶ Written in German, 124 pages
- ▶ More than 40 illustrations, 100 references, 55 norm references, ...
- ▶ PDF version can be soon downloaded: [bfh.ch/energy/publikationen](https://bfh.ch/energy/publikationen)

# Trends which will reduce battery prices

Trying to find reasons why battery storage should become cheaper over the next 5 years



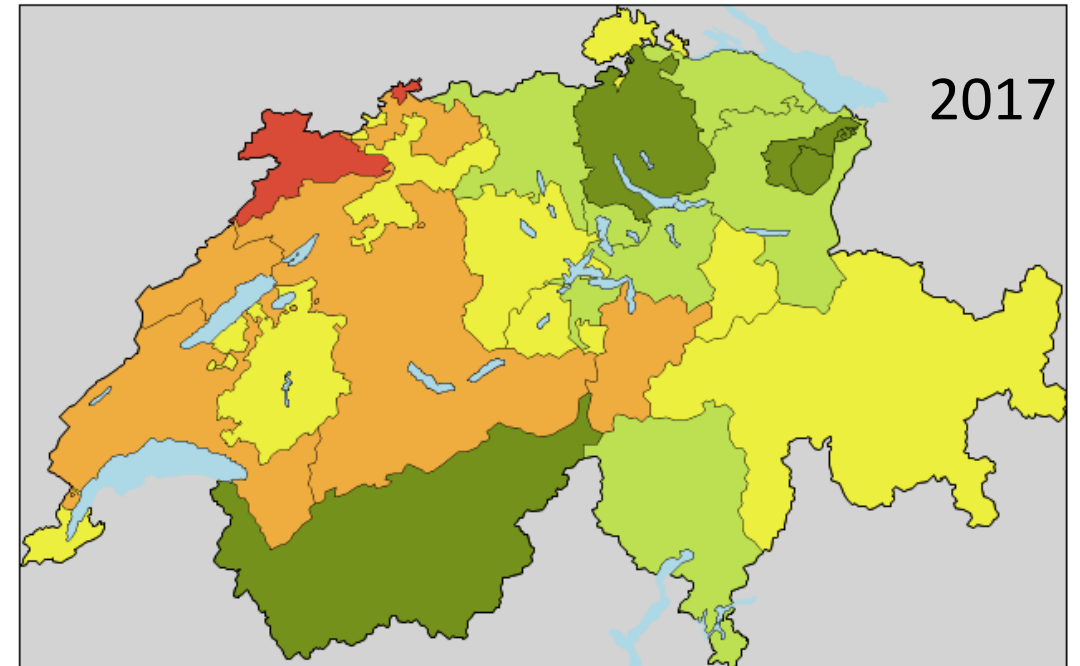
# Energy Prices will make Storage economical viable



## Merzligen (BE) – BKW Energy Green

- 2015: Tarif: 17.22 Rp. (NT) – Einspeisevergütung: 9.72 Rp.
- 2017: Tarif: 22.75 Rp. (NT) – Einspeisevergütung: 4 Rp.

Source: <http://www.vese.ch/pvtarif/>



## Tarifvergleich in Rp./kWh: Kategorie H4, Totalpreis für das Jahr 2017

< 17,08   17,08 - 19,09   19,09 - 21,10   21,10 - 23,11   > 23,11

Source: <https://www.strompreis.elcom.admin.ch/Map/ShowSwissMap.aspx>

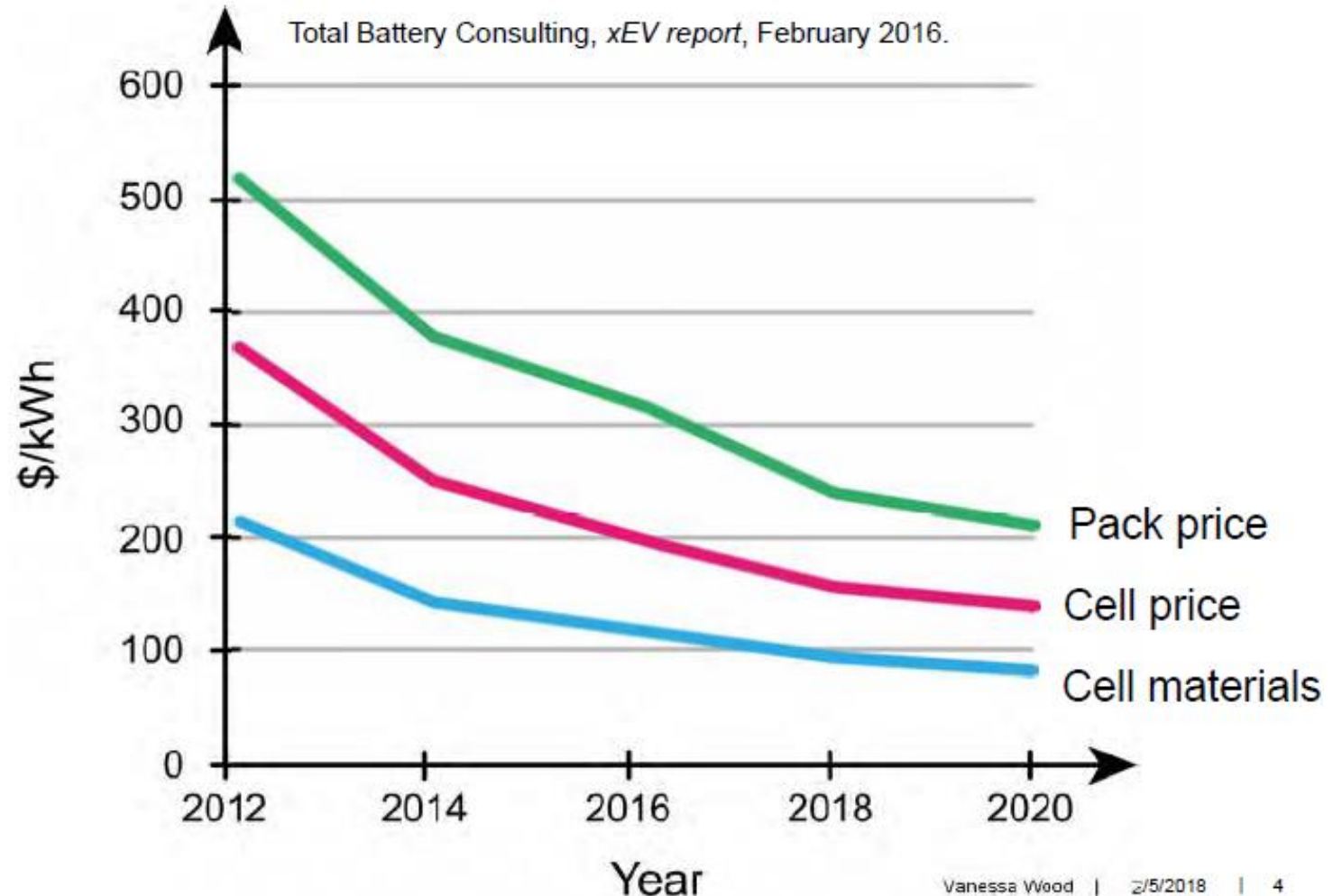
# High volume production decreases costs

Large manufacturers benefit from economies of scale.



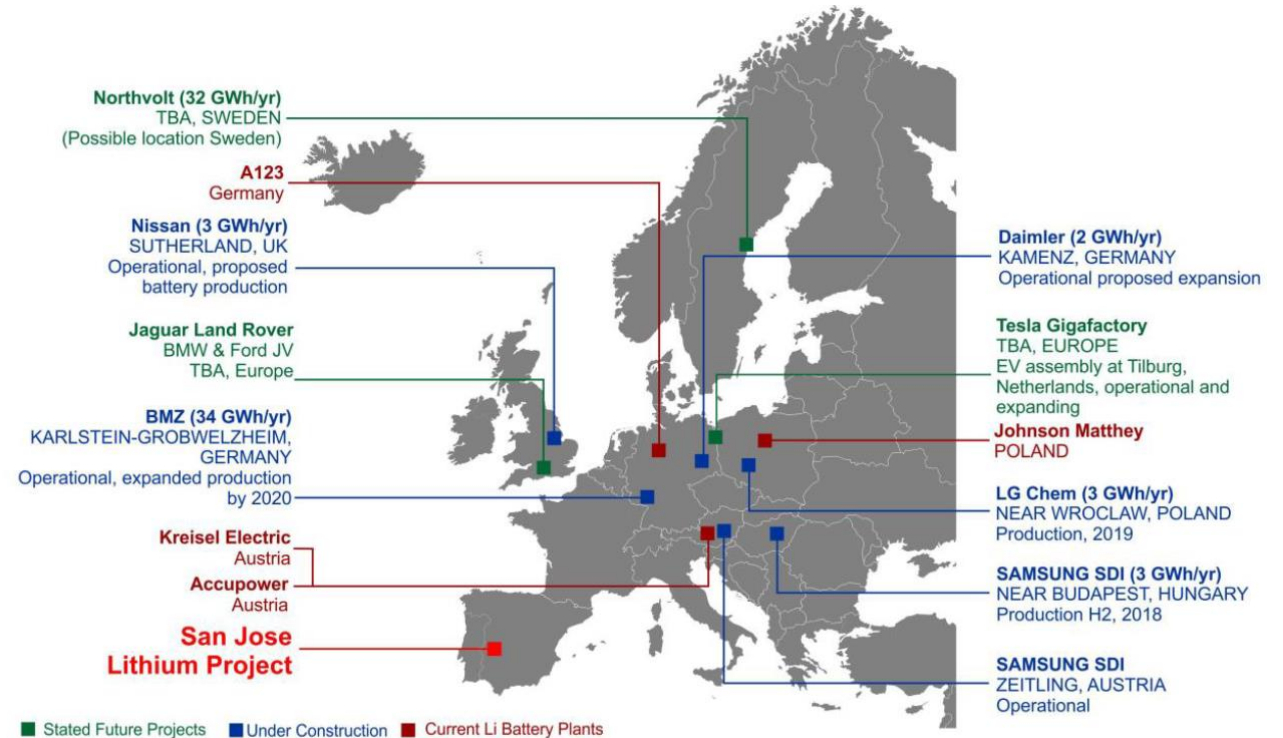
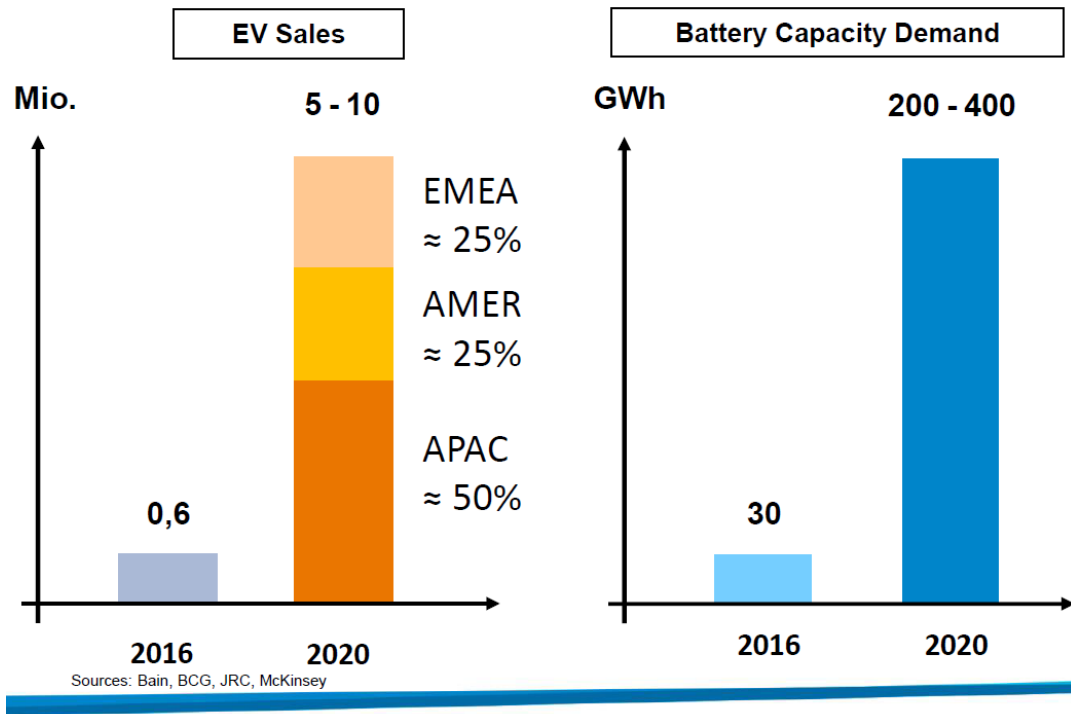
By 2020, materials projected to be > 70% of cell cost.

Price trends for electric vehicle batteries



# E-Mobility Market – new Factories required

Optimistic scenario with sustainable Growth

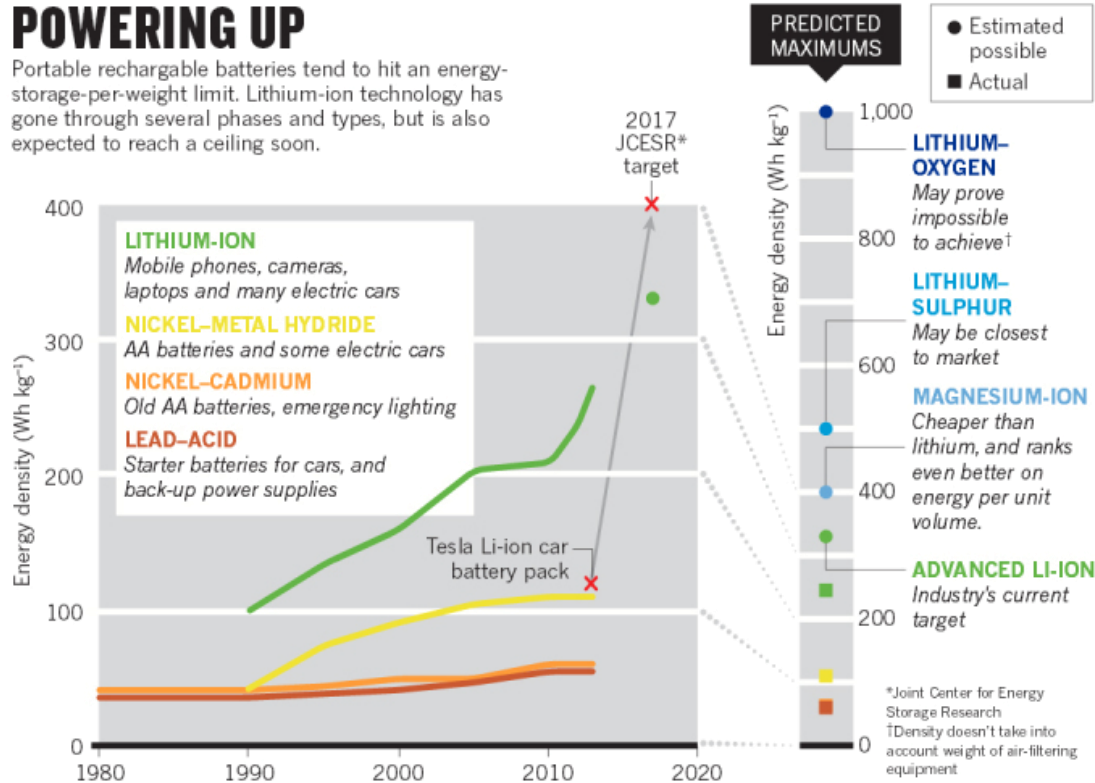


- ▶ Economy of scale can be reached for factories up to 8GWhr/year, after this scale up through paralleling units
- ▶ Between 25-50 such battery factories will be needed if worldwide EV sales are predicted correctly

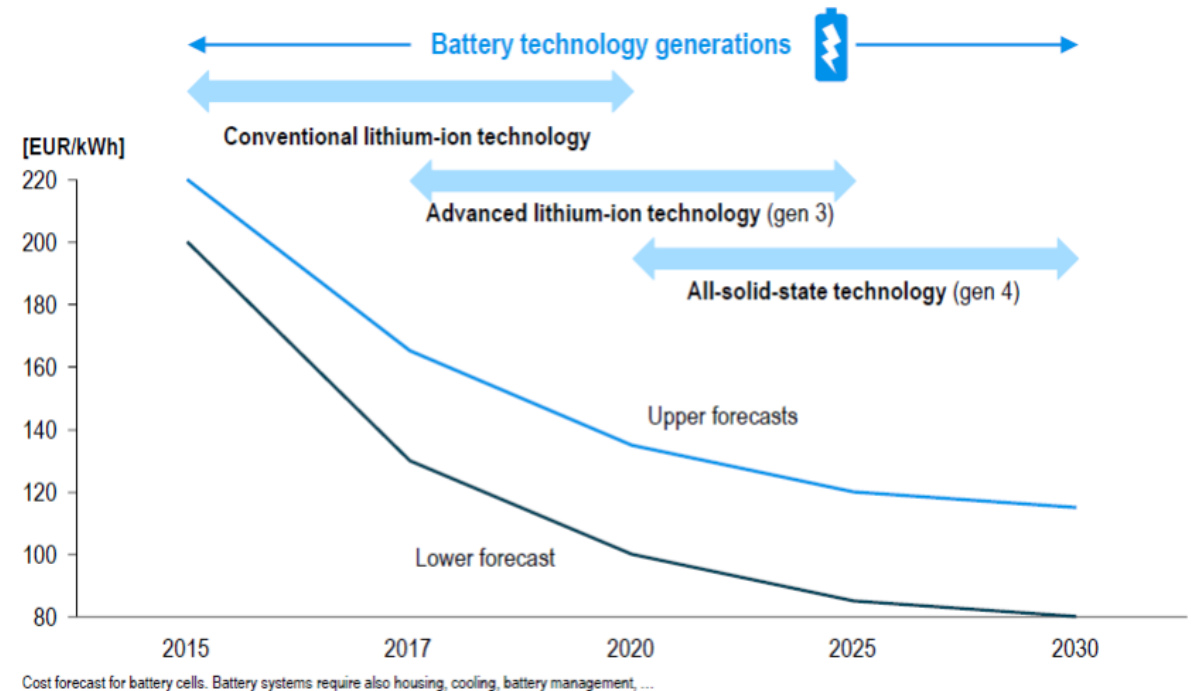
# Technology Development: Advanced and Post Lithium-ion

## POWERING UP

Portable rechargeable batteries tend to hit an energy-storage-per-weight limit. Lithium-ion technology has gone through several phases and types, but is also expected to reach a ceiling soon.



Source: IDTechEX, Advanced and Post Lithium-ion Batteries 2016-2026: Technologies, Markets, Forecasts, 2015



Source: Roland Berger

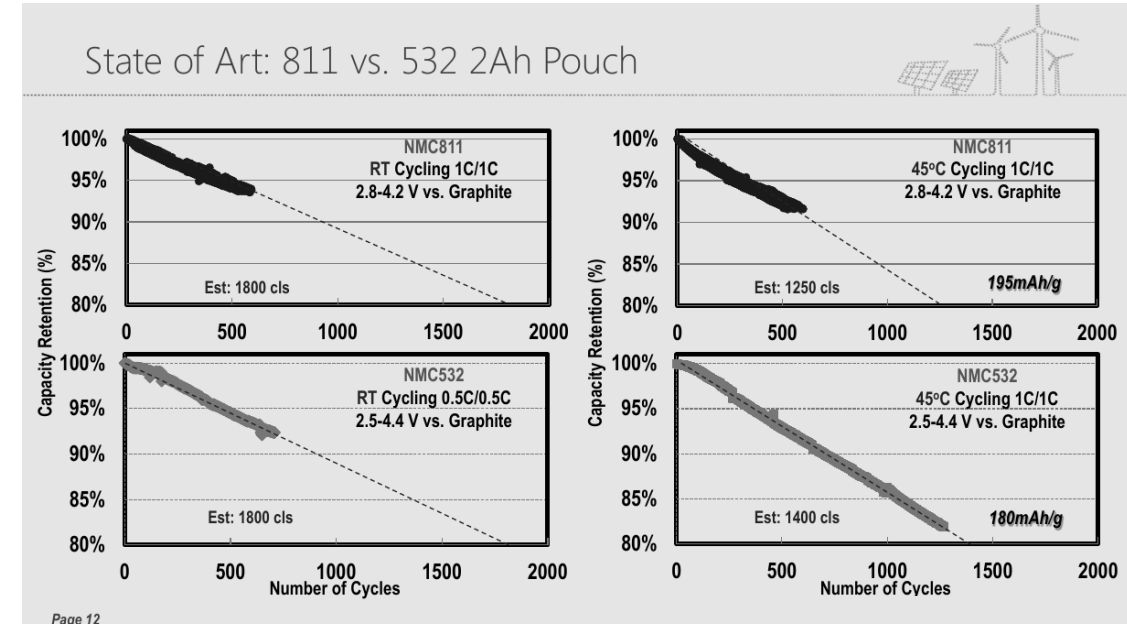
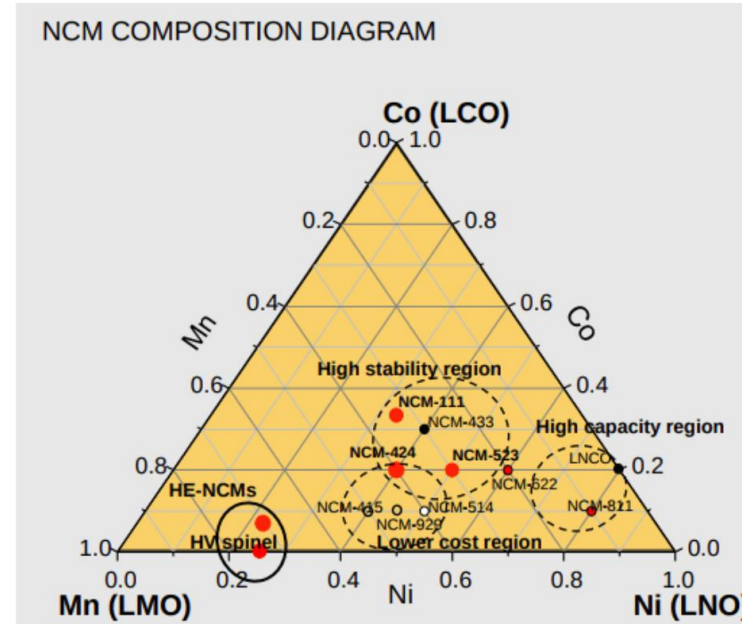
► Higher Energy Density will use less raw material for same capacity and will also have an impact the housing, cooling, battery management



# NMC811 as the next step in battery technology

<https://c1cleantechnicacom-wpengine.netdna-ssl.com/files/2018/02/NCM-Composition.png>

1	State-of-the-art	<b>NCM 111:</b> $\text{Li}_{1+x}(\text{Ni}_{0.33}\text{Co}_{0.33}\text{Mn}_{0.33})_{1-x}\text{O}_2$ Discharge Capacity: 154 Ah/kg @ 0.1C
		<b>NCM 523:</b> $\text{Li}_{1+x}(\text{Ni}_{0.5}\text{Co}_{0.2}\text{Mn}_{0.3})_{1-x}\text{O}_2$ Discharge Capacity: 164 Ah/kg @ 0.1C
		<b>NCM 424:</b> $\text{Li}_{1+x}(\text{Ni}_{0.4}\text{Co}_{0.2}\text{Mn}_{0.4})_{1-x}\text{O}_2$ Discharge Capacity: 155 Ah/kg @ 0.1C
2	Hi Nickel	<b>NCM 622</b> Discharge Capacity: 178 Ah/kg @ 0.1C
		<b>NCM 811 and others</b> Discharge Capacity: >185 Ah/kg @ 0.1C
3	Mn rich	<b>HE-NCM:</b> Discharge Capacity: 260 Ah/kg @ 0.1C
		<b>HV-Spinel:</b> Discharge Capacity: 140 Ah/kg @ 1C



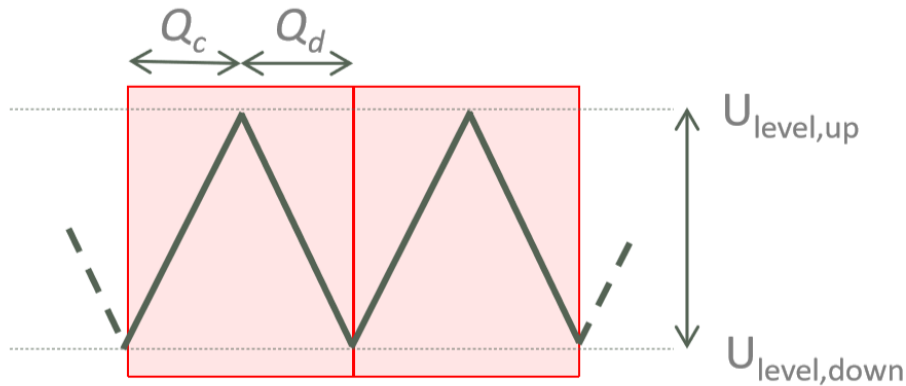
- ▶ High Nickel Content Cells (NMC811) will reduce dependency of cobalt supplies while at the same time increasing energy density of the cells
- ▶ So far life cycle has been an issue for nickel rich batteries, especially at higher temperature, but development is progressing fast



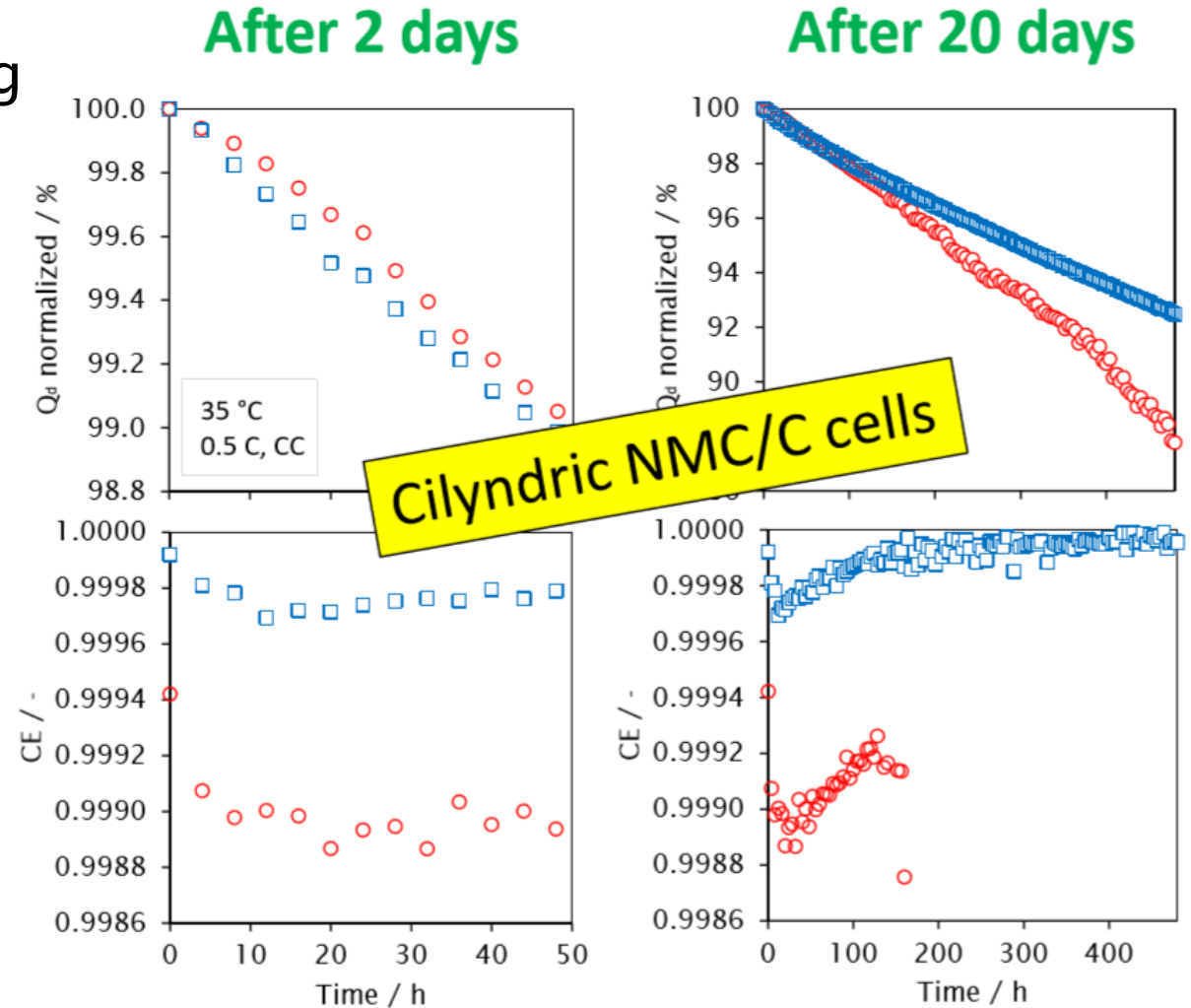
# Time efficient lifespan investigations w. coulombic efficiency

▶ Time efficient lifetime experiments using precise coulombic efficiency measurements

▶  $CE = Q_d/Q_c$  (= 1.0000 -> perfect value)

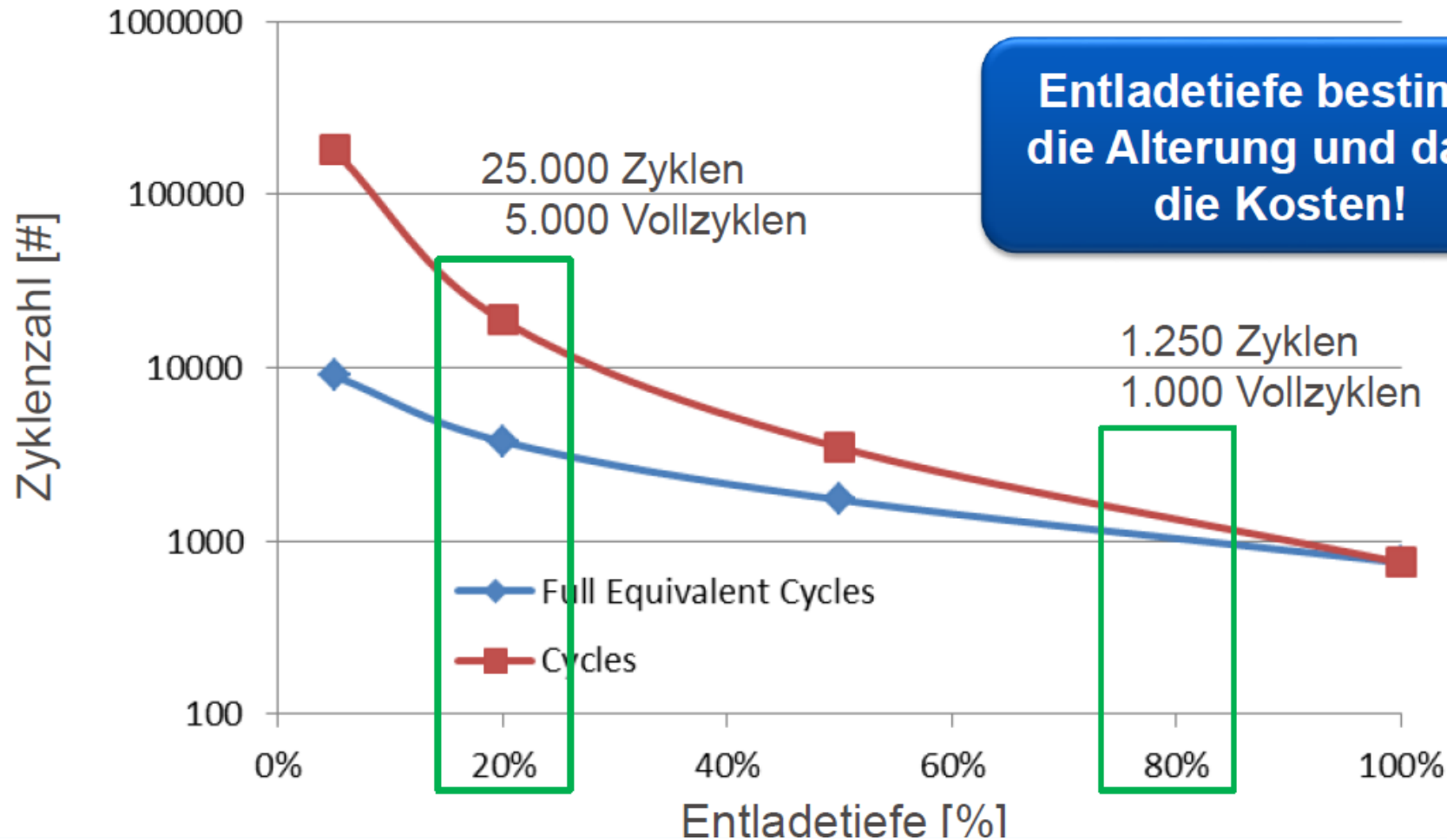


▶ CE values showed which cell would live longer after only a few cycles



# Dual-Use: Cycling and Aging

- Daten von Sanyo Lithium-Ionen Zelle – Typ 18650 (NMC)



▶ Depth of Discharge defines aging and therefore costs

# Dual-Use: Uninterruptable Power Supply

Fall: 1 kWh wird als Netzdienstleistung zur Verfügung gestellt

Investition*:	150 €/kWh	5 x 150 €/kWh	+ 150 €/kWh (USV bezahlt)
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Lebensdauer (zyklisch):	1.000 Zyklen	25.000 Zyklen (20% DOD)	25.000 Zyklen (20% DOD)
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Preis:	→ 15 ct/kWh	→ 3 ct/kWh	→ 0.6 ct/kWh
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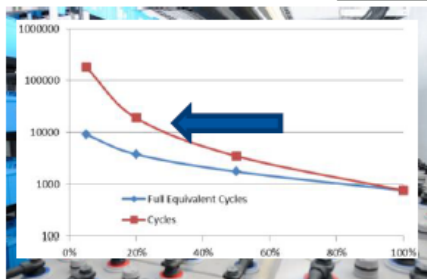
Grid  
services

Grid  
services

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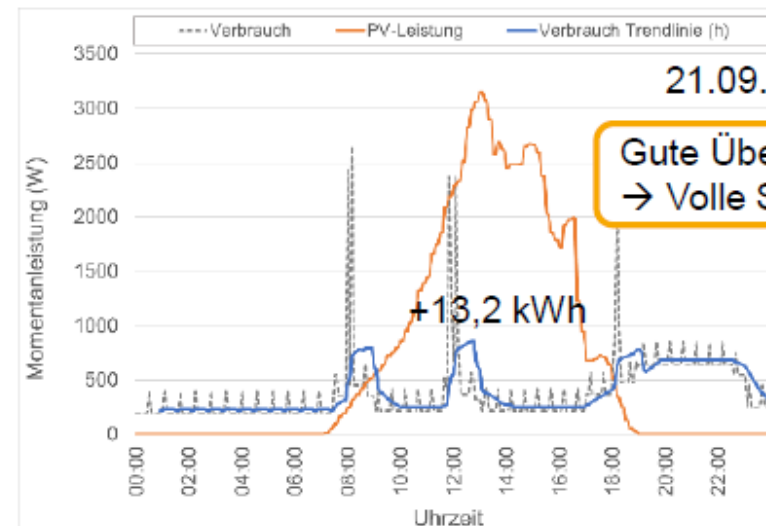
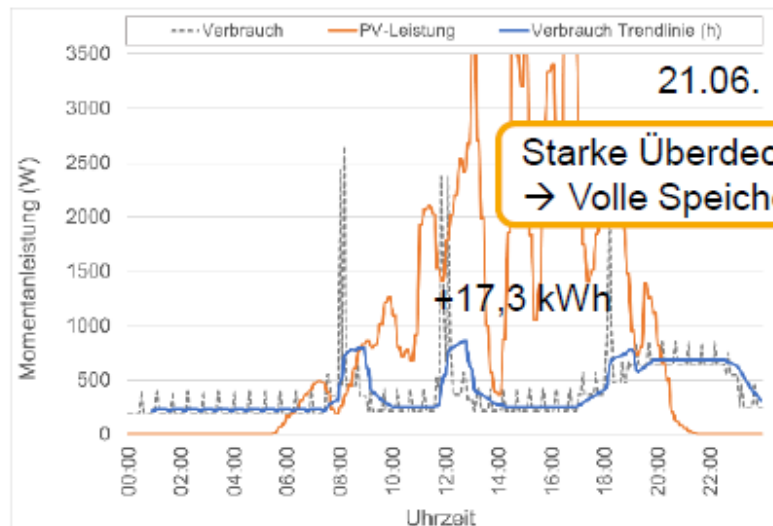
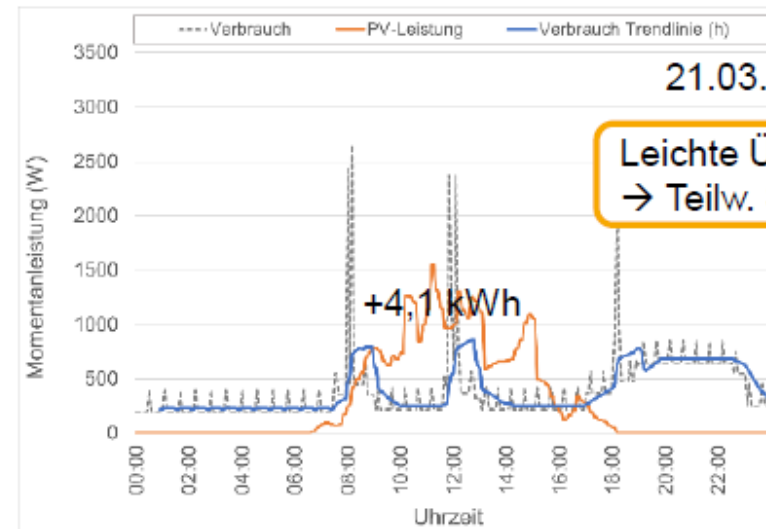
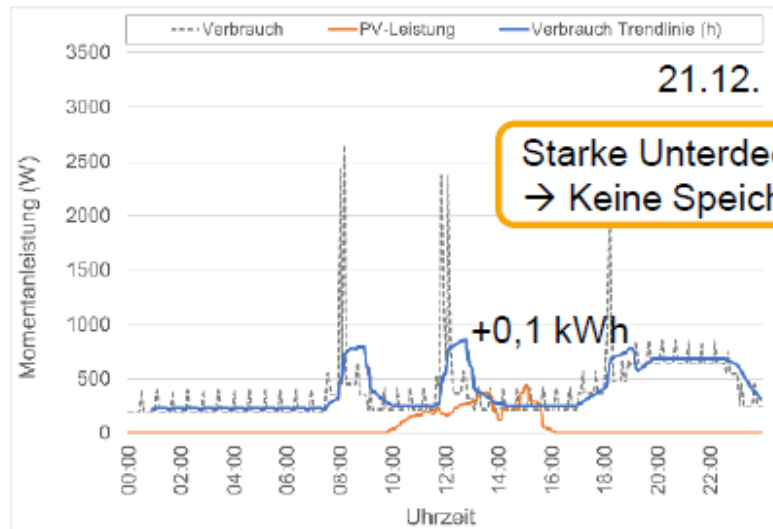
Über-  
kapazität

USV



\* reiner Zellpreisevergleich

# Storage use through one year exhibits variable DoD



© 2018 Energy Depot Swiss GmbH  
Roland Burkhardt, ETG-Fachtagung,  
07.02.2018, EKZ-Dietikon

- ▶ Messungen:
  - ▶ EFH mit Aufdachanlage
  - ▶ Westausrichtung
- ▶ PV-Erzeugung:
  - ▶ 7 kW Generatorleistung
  - ▶ 30-40 m<sup>2</sup> Modulfläche
- ▶ Lastkurve:
  - ▶ Strom: 3500-4000 kWh/a
  - ▶ keine Wärmepumpe

- ▶ Erfahrungswerte:
  - ▶ Durchschnittlich ~220 Zyklen/a
- ▶ Tendenz:
  - ▶ geringe Kapazität = grosse Zyklenzahl
  - ▶ grosse Kapazität = geringe Zyklenzahl

# Optimize SoC - DoD window vs. usable life cycles

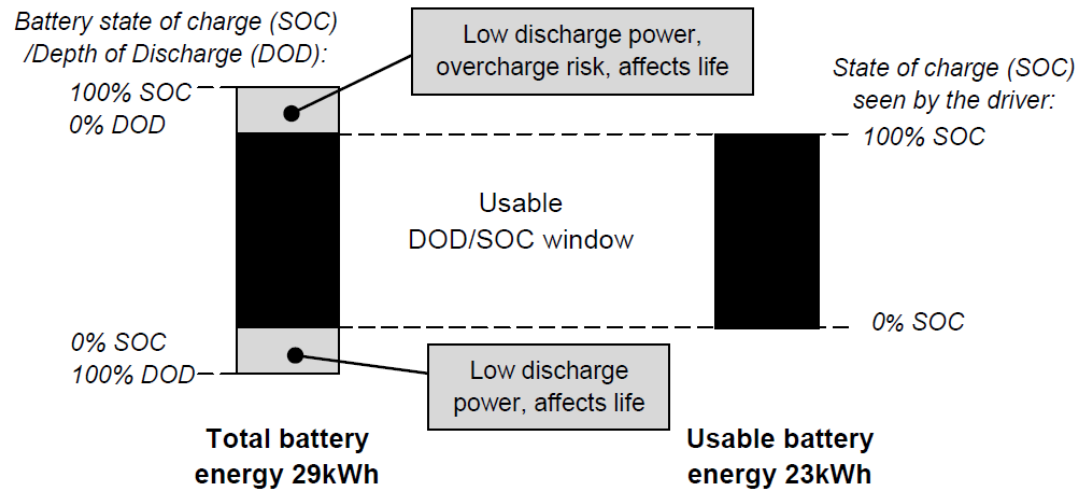
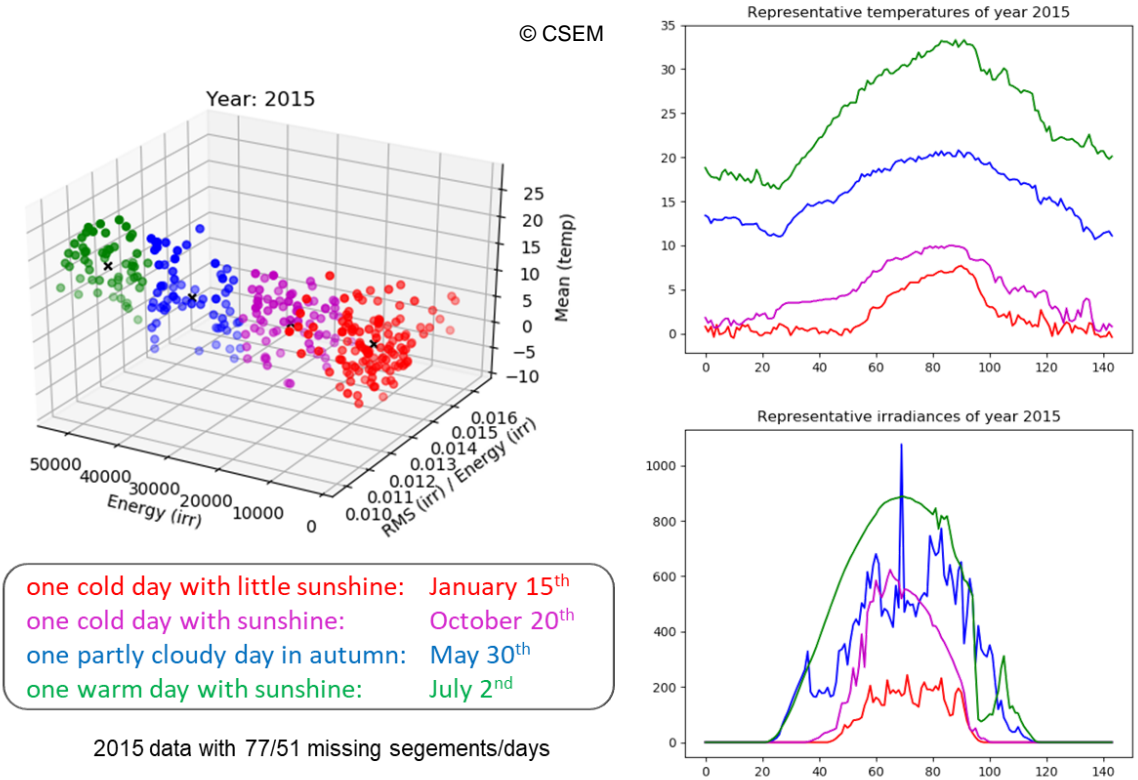


Figure 2-7 Illustration of a battery with 80% DOD/SOC window

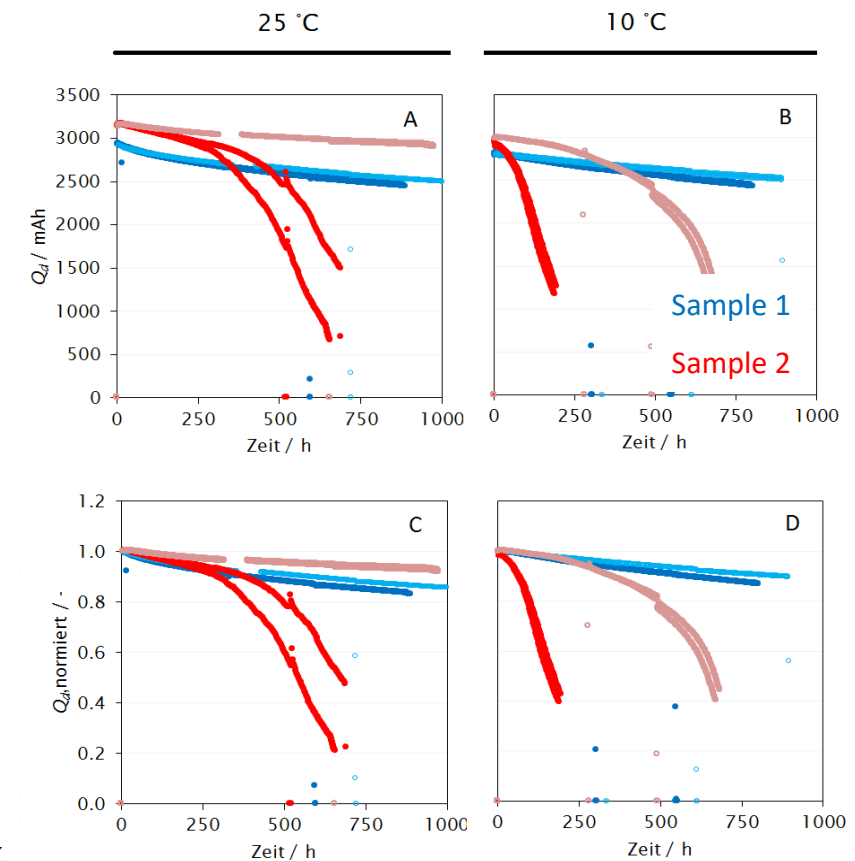
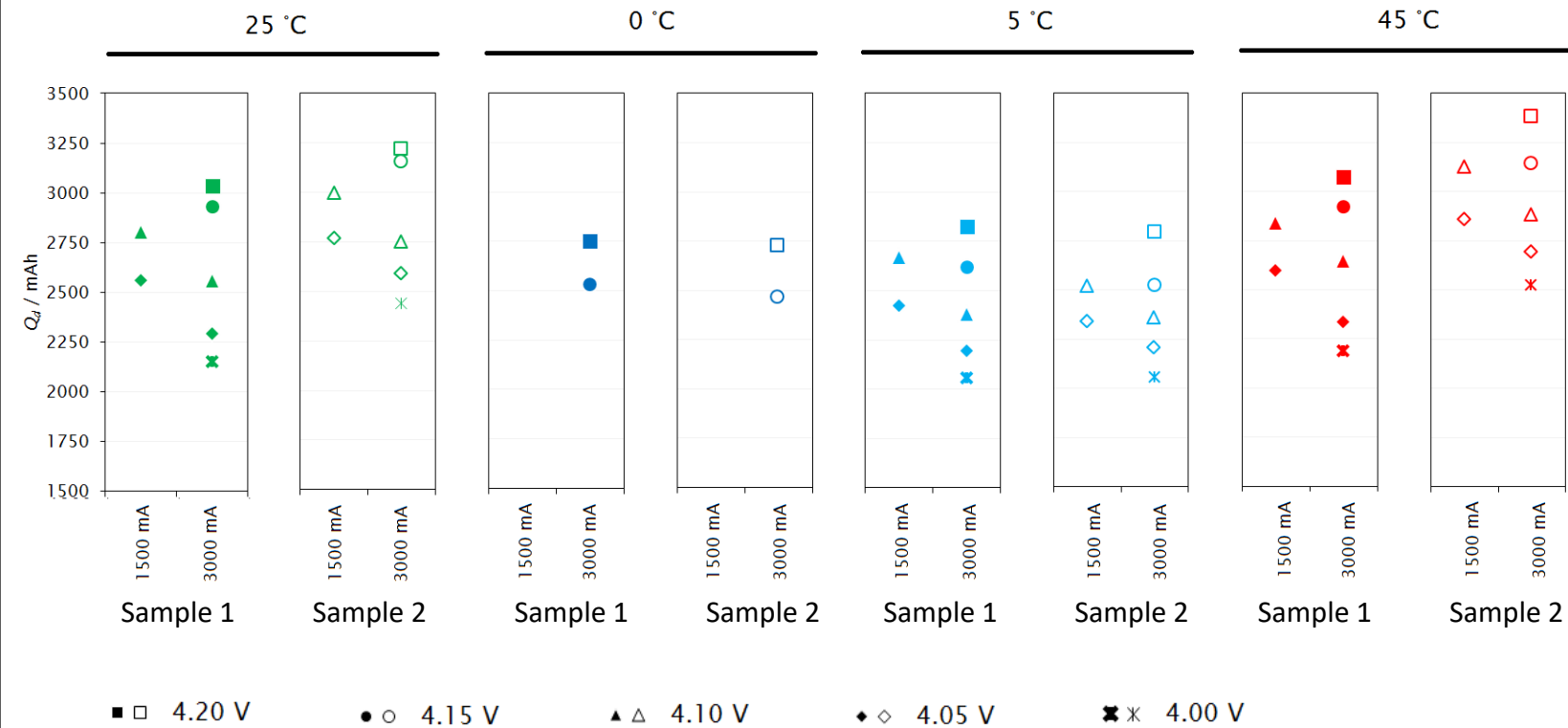
© Cost and performance of EV batteries, The Committee on Climate Change, 2012



- ▶ More advanced Energy Management Systems will trade available capacity vs. lifetime to find maximum economical benefits
- ▶ This will require better understanding of battery aging as well as predictive usage modelling. This is one of the research questions of the BFH ESReC Prosumer-Lab Project



# Performance Tests at BFH Energy Storage Research Center



- ▶ Voltage limits: 2.75 V, CC-CV until and at the corresponding  $U_{\max}$  (4.0 – 4.2V)
- ▶ Variables: Temperature,  $U_{\max}$ , charging rate (2h vs. 1h)
- ▶ Capacity decrease as a function of cycling or exposure time

# BFH – CSEM Prosumer-Lab: Smart Building Emulator



## BYD DESS-B08P09C08C-E

- ▶ 8.5 kWh, 10 kW
- ▶ AC & DC

## VARTA Element 6

- ▶ 6.4 kWh, 2 kW
- ▶ AC

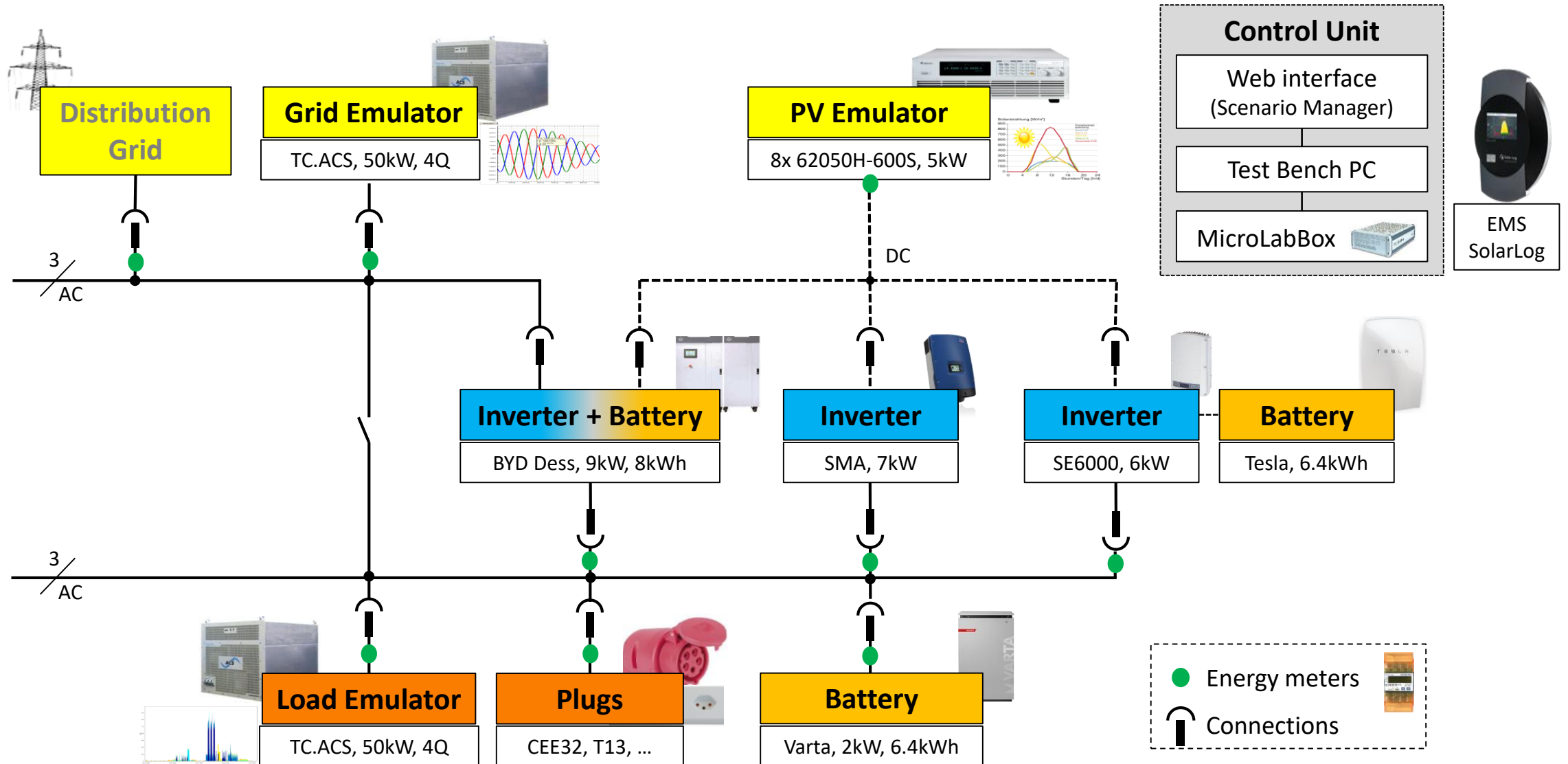
## Energy management systems

- ▶ SolarWatt
- ▶ SmartFox
- ▶ ...

## Prosumer-Lab Racks

- ▶ Grid- & Load-Emulator
- ▶ PV-Emulators
- ▶ ...

# BFH – CSEM Prosumer-Lab: Smart Building Emulator

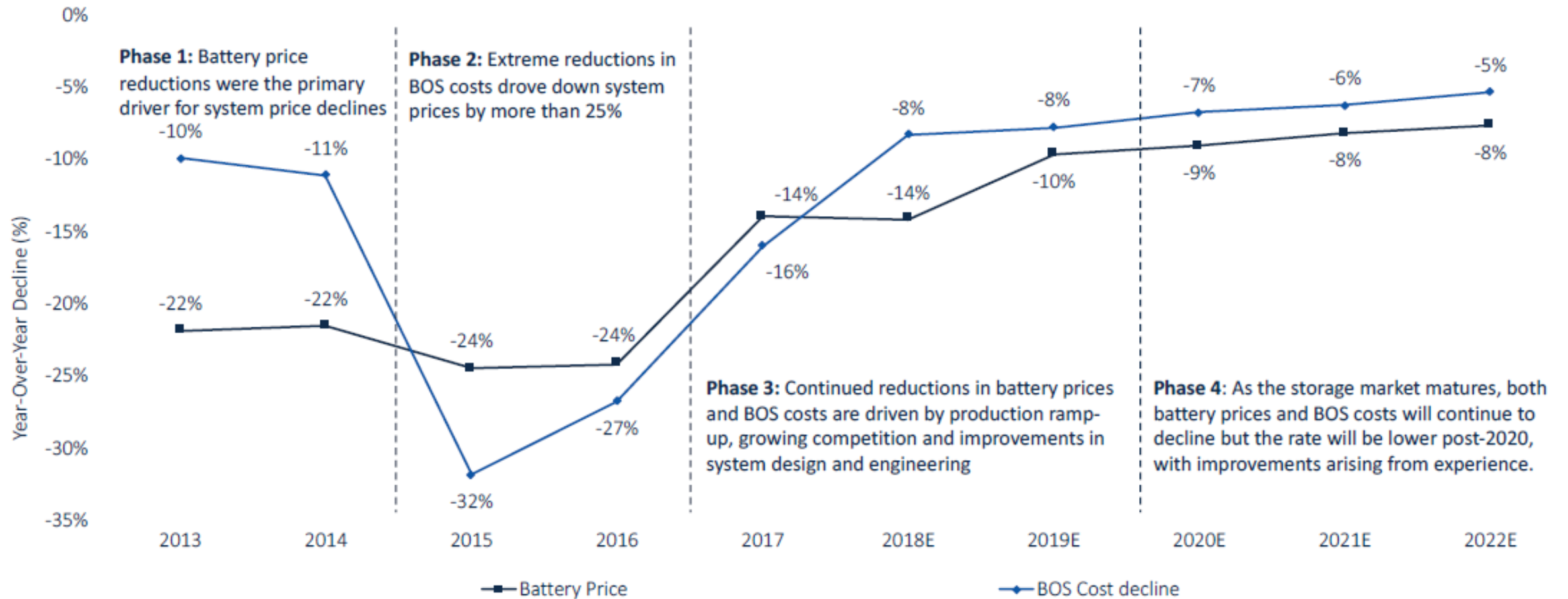


Will there be a significant cost  
reduction for solar home storage?

...and do we really see it in the market?

# Batteries will continue to get cheaper for different reasons

Year-Over-Year Decline in Battery Price and BOS Cost, 2013 – 2022E (%)



Source: GTM Research Report, U.S. Front-of-the-Meter Storage System Prices, 2018-2022



# But today System are far from cheap

	Residential								KMU			Spezial
Nutzbare Kapazität	2 kWh (1.5kW)	4kWh (2.5kW)	6kWh (3 kW)	8kWh (3.3 kW)	10kWh (3.3 kW)	12kWh (3.3 kW)	14kWh (3.3 kW)	16kWh (3.3 kW)	40 kWh (40 kW)	80 kWh (40 kW)	150kWh (60 kW)	2 MWh (1 MW)
Hardware (CHF)	4'500	6'900	9'400	11'300	13'800	15'400	17'300	19'000	58'000	99'000	189'000	2'320'000
VRG (CHF)	80	160	240	320	400	480	560	640	1'344	2'688	5'600	31'850
Transport (CHF)	170	170	170	170	170	170	170	170	450	800	2'000	18'000
Installation (CHF)*	1'600	1'800	1'800	1'800	1'800	1'800	1'800	1'800	5'900	9'100	13'500	38'000
<b>Schlüsselfertig installiert (CHF)</b>	<b>6'400</b>	<b>9'000</b>	<b>11'600</b>	<b>13'600</b>	<b>16'200</b>	<b>17'900</b>	<b>19'800</b>	<b>21'600</b>	<b>65'700</b>	<b>111'600</b>	<b>210'100</b>	<b>2'407'900</b>

Alle Preise exkl. MwSt.

\* Bei gleichzeitiger PV-Installation



Electrosuisse Tagung 07.02.2018 – Roger Burkhart

# Summary

- ▶ Battery Storage will become economically viable due to increased gap between feed in tariffs and electricity cost.
- ▶ High volume production drives the price down along the learning curve. Volume growth will come from increased Electric Vehicle sales.
- ▶ New battery technology developments will potentially be lower priced due to lower and cheaper raw material usage. This will also influence BOS.
- ▶ New strategies for the use of storage system (dual use, intelligent Energy Management Systems) will increase profitability
- ▶ Storage price will decrease with an annual rate between 8% to 15% during the next 5 years
- ▶ For smaller systems installation, transport and taxes account for up to 30% of the turn-key system price. This will be one of the challenges for the next year.



# Herzlichen Dank für Ihre Aufmerksamkeit

Prof. Dr. Andrea Vezzini

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