volytica diagnostics

Das Batterie-1-mal-1 auf den Spreewind-Tagen

2023-11-10, volytica diagnostics

volytica diagnostics

A Brief Introduction

volytica diagnostics

We have more than 10 years of practical experience with applied battery diagnostics across industries

2012 **First European E-Busses Monitored**

volytica's predecessor research group at Fraunhofer monitored some of the first e-busses in Europe (link, link)

2017 **Launch of First Battery Monitoring Platform**

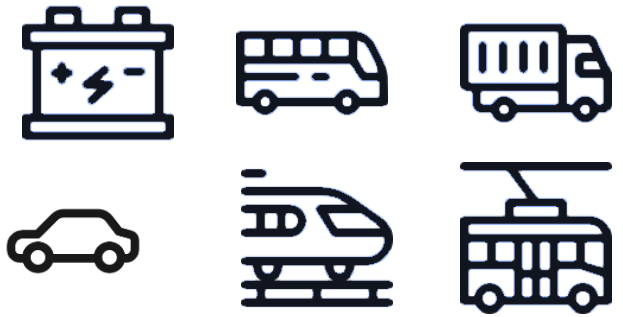
IVImon, the first version of today's *vdx engine,* is launched into pre-commercial operation by Fraunhofer IVI

2019 **Spinoff from the Fraunhofer Gesellschaft**

For further growth and industrialization, volytica is spun out of Fraunhofer Society as a independent company

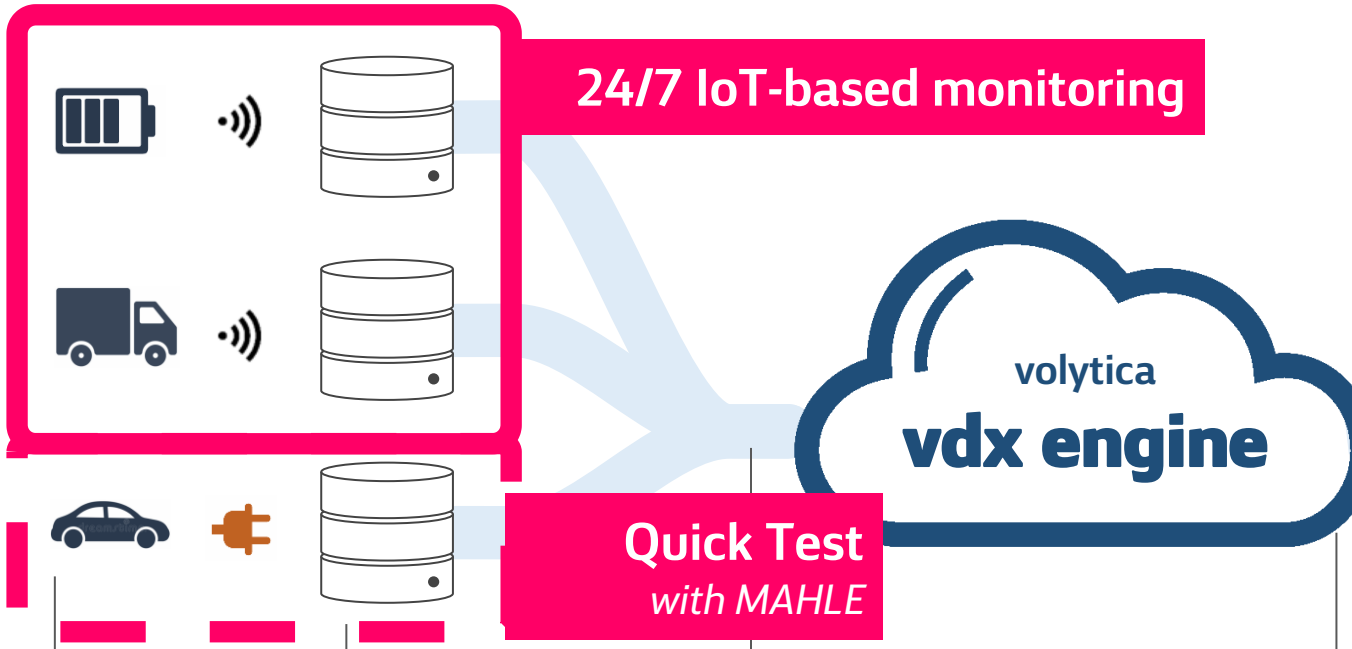
2023 **One of Europe's leading battery diagnostics companies**

With more than 25 experts in Dresden and Berlin, as well as >10 international customers in the commercial & stationary industry



Our Solution

We crack abundant data that others discard, using our proprietary battery algorithms



24/7 IoT-based monitoring

volytica
vdx engine

Quick Test
with MAHLE

No Sensors
We utilize what is always there – abundant, standard data every battery delivers

Industry Agonstic
Every Li-Ion battery is supported

Plug-and-Play
Our algorithms are self-learning. We don't need the typical 6 months lab tests.

Aufo-Config – No Lab
Cloud-based analysis tool for **systematical** battery quality analysis

Fraunhofer *inside*

Utilization & profit optimization

Lifetime extension & replacement planning

Residual value & 2nd life certification

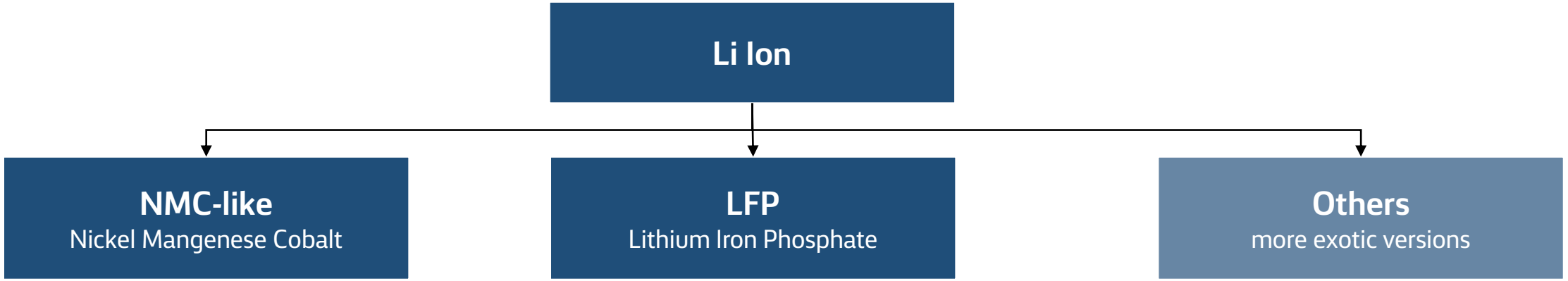
Safety & anomaly detection

Introduction to Battery Technology

Key Facts & Common Misconception

Battery Basics

The “Zoo”



- family of Ni-based cathodes (related to NCA, LMO, ...)
- so far, “the” automotive standard
- higher energy densities (increasing)
- mediocre lifetime, decreasing !!
- higher prices

- also $LiFePO_4$
- “the” standard cell in China, increasing global relevance
- lower energy densities (increasing)
- better lifetime, ‘robust’
- lower prices (increasing) !!

- several other “exotics” chemistries exist or are in pipeline
  - LTO / Titanate
  - Solid State
  - Li-Air, Li-Sulfur, ...
  - (Na Ion ... not Li)

Trend
Lifetime *Decreases*

Trend
“LFP Renaissance”

Trend
Solid State? Wait for it

Battery Basics

Cell to System

Electronics
Actors
Sensors
IoT

Cells

Prismatic

Pouch

Cylindrical

System

<1 kWh

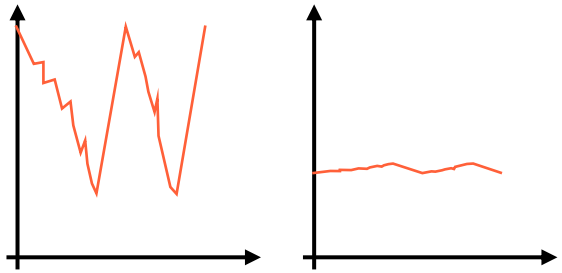
<1 00 kWh

1 000 – 100 000 kWh

Battery Basics

Batteries are Wearing Parts

"Mission Profile"



Operation & Charging
- Temperature
- Power
- SOC window

Standing/ Parking
- Temperature
- parking SOC

Influence

Degradation

Capacity Fade
Energy decreases

Resistance Increase
Efficiency decreases

Safety
Risks increase

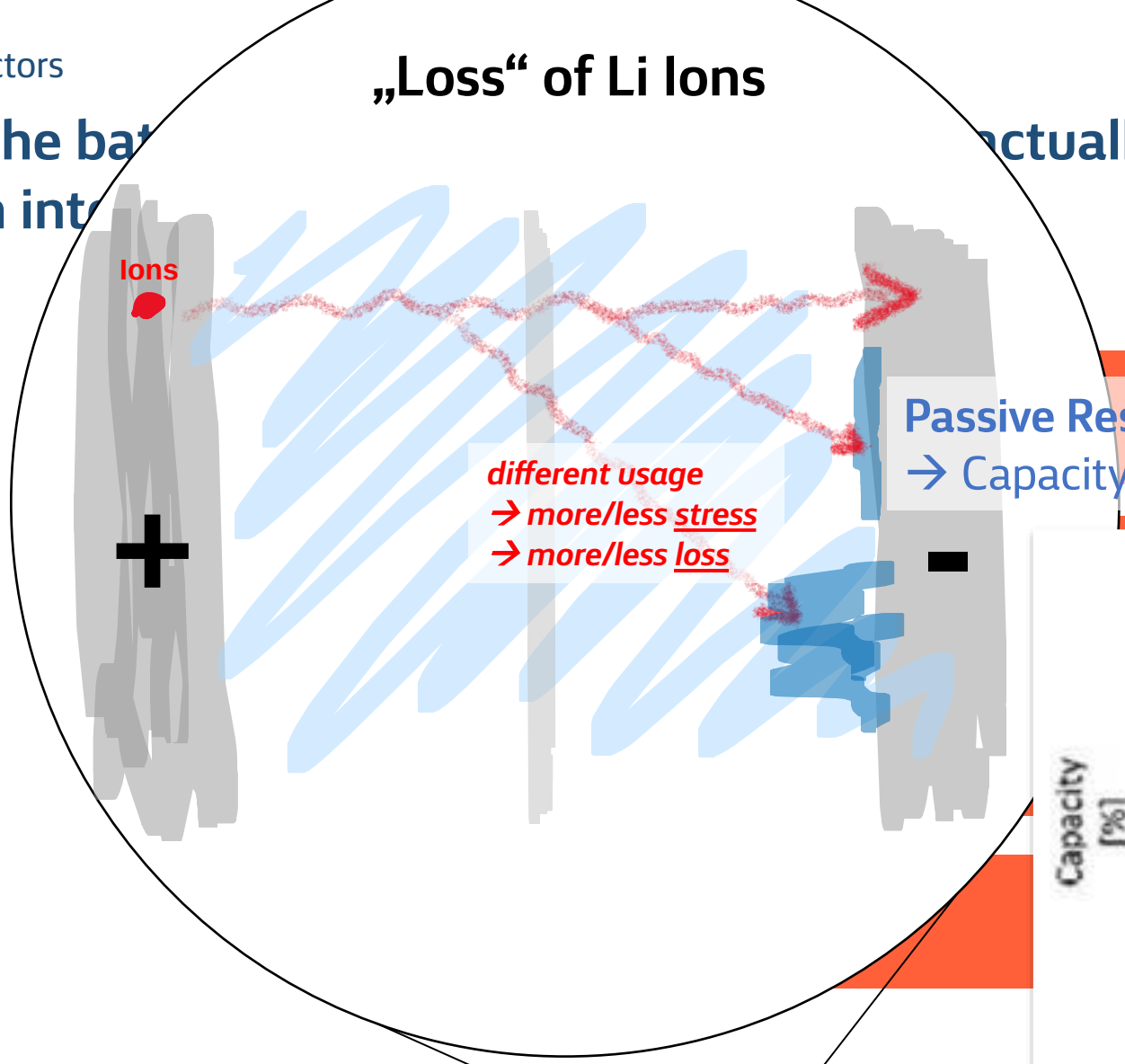
Capacity Fade (“SOH”)

Availability (*BACKUP*)

Safety (*BACKUP*)

Internal Factors

When the bat… …actually happen int…



Multiple internal processes lead to degradation

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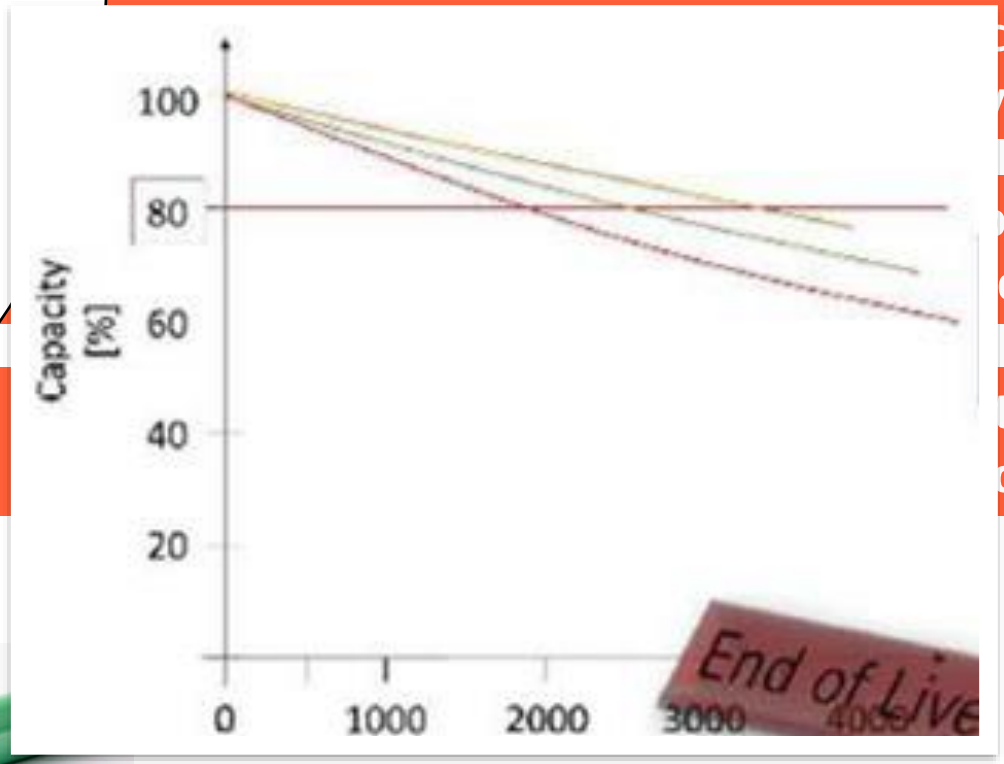
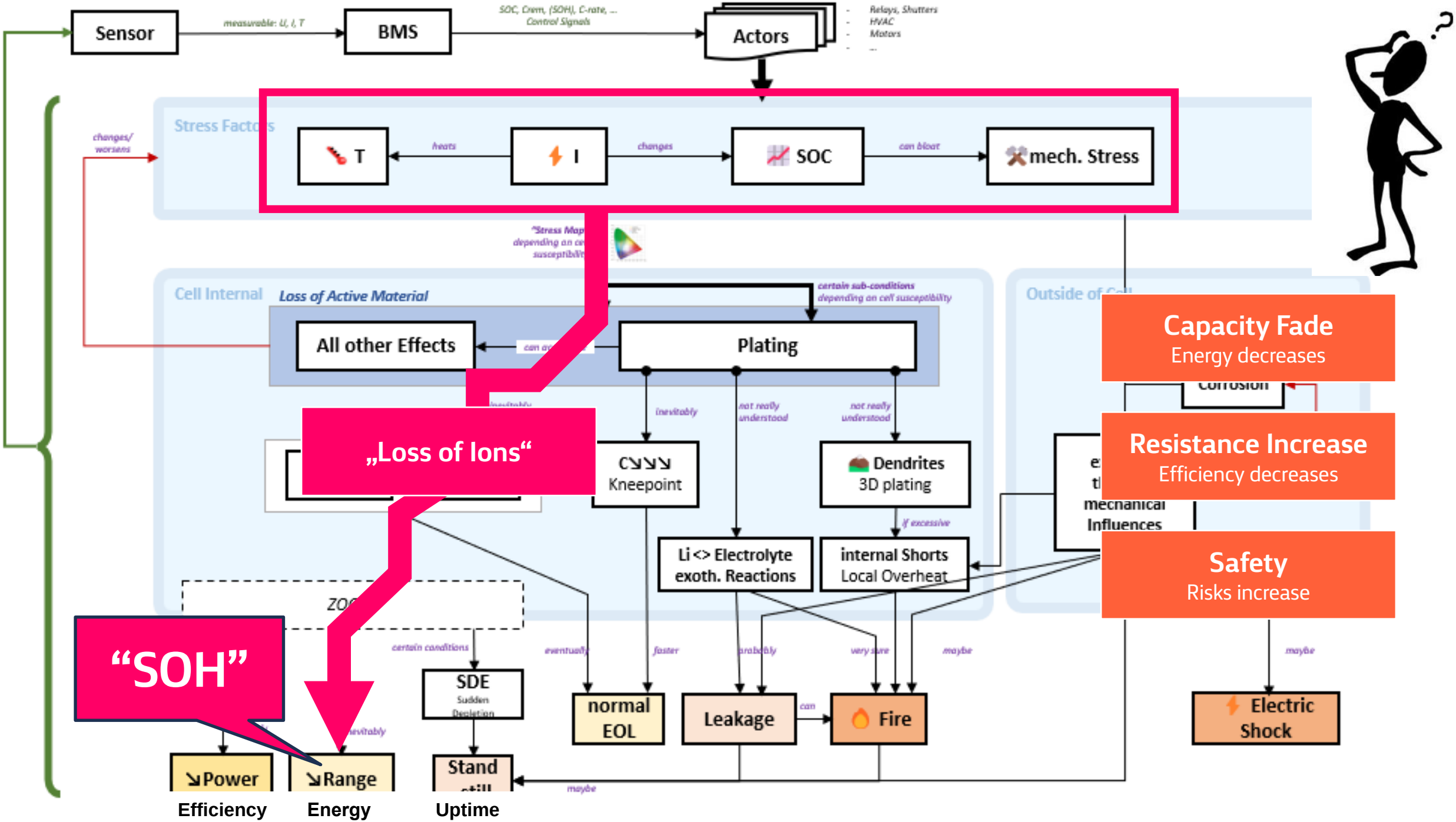
…ons, …ces

…te… …des




Sensor
measurable: U, I, T
BMS
SOC, Cnom, (SOH), C-rate, ...
Control Signals
Actors
Relays, Shutters
HVAC
Motors
Stress Factors
changes/ worsens
T
heats
I
changes
SOC
can bloat
mech. Stress
Cell Internal
Loss of Active Material
certain sub-conditions depending on cell susceptibility
All other Effects
Plating
inevitably
not really understood
not really understood
Kneepoint
Dendrites
3D plating
if excessive
Li <> Electrolyte exoth. Reactions
internal Shorts
Local Overheat
Outside of Cell
Corrosion
mechanical Influences
„Loss of Ions“
“SOH”
certain conditions
eventually
faster
probably
very sure
maybe
maybe
SDE
Sudden Depletion
normal EOL
Leakage
can
Fire
Electric Shock
inevitably
Power
Range
Stand still
maybe
Efficiency
Energy
Uptime
Capacity Fade
Energy decreases
Resistance Increase
Efficiency decreases
Safety
Risks increase

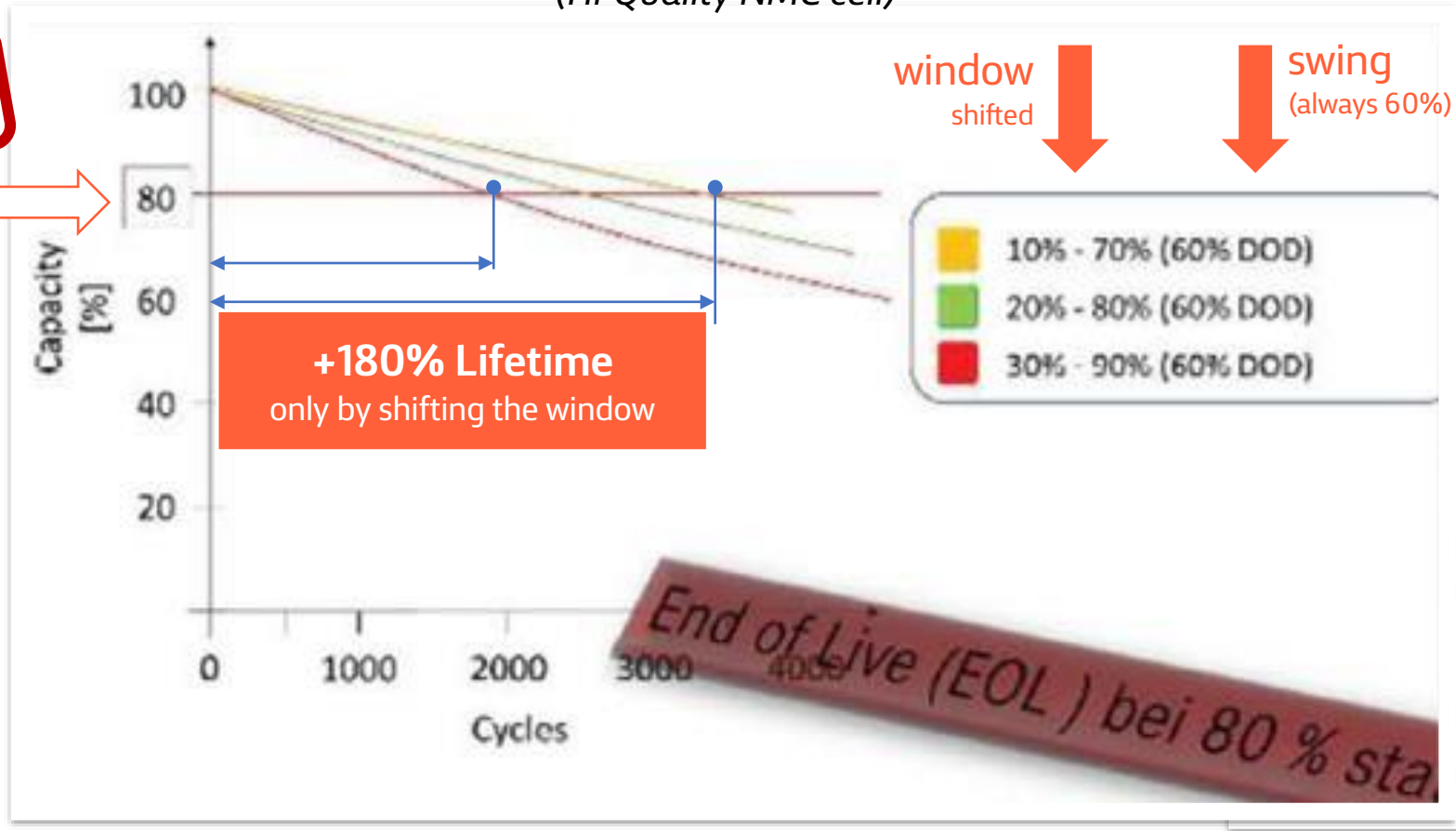
Degradation & Warranty

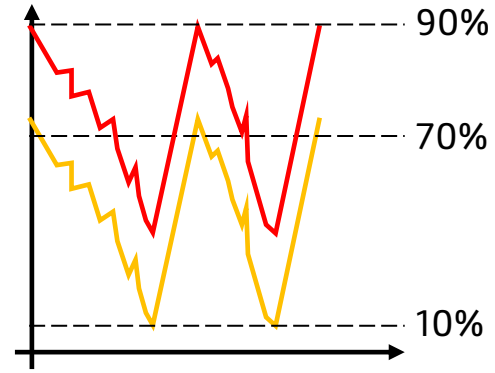
Degradation: Capacity Fade

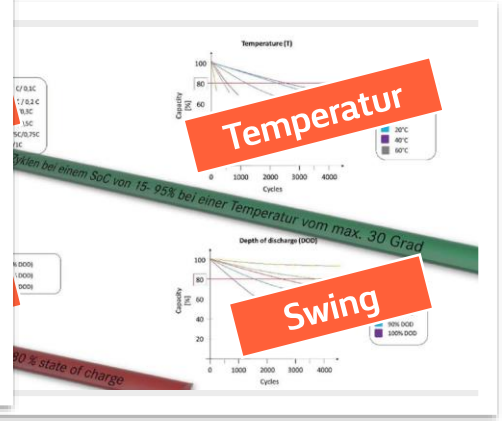
From a Vehicle Data Sheet
(Hi-Quality NMC cell)

End of Life ???/EOL

End of Warranty/ EOW





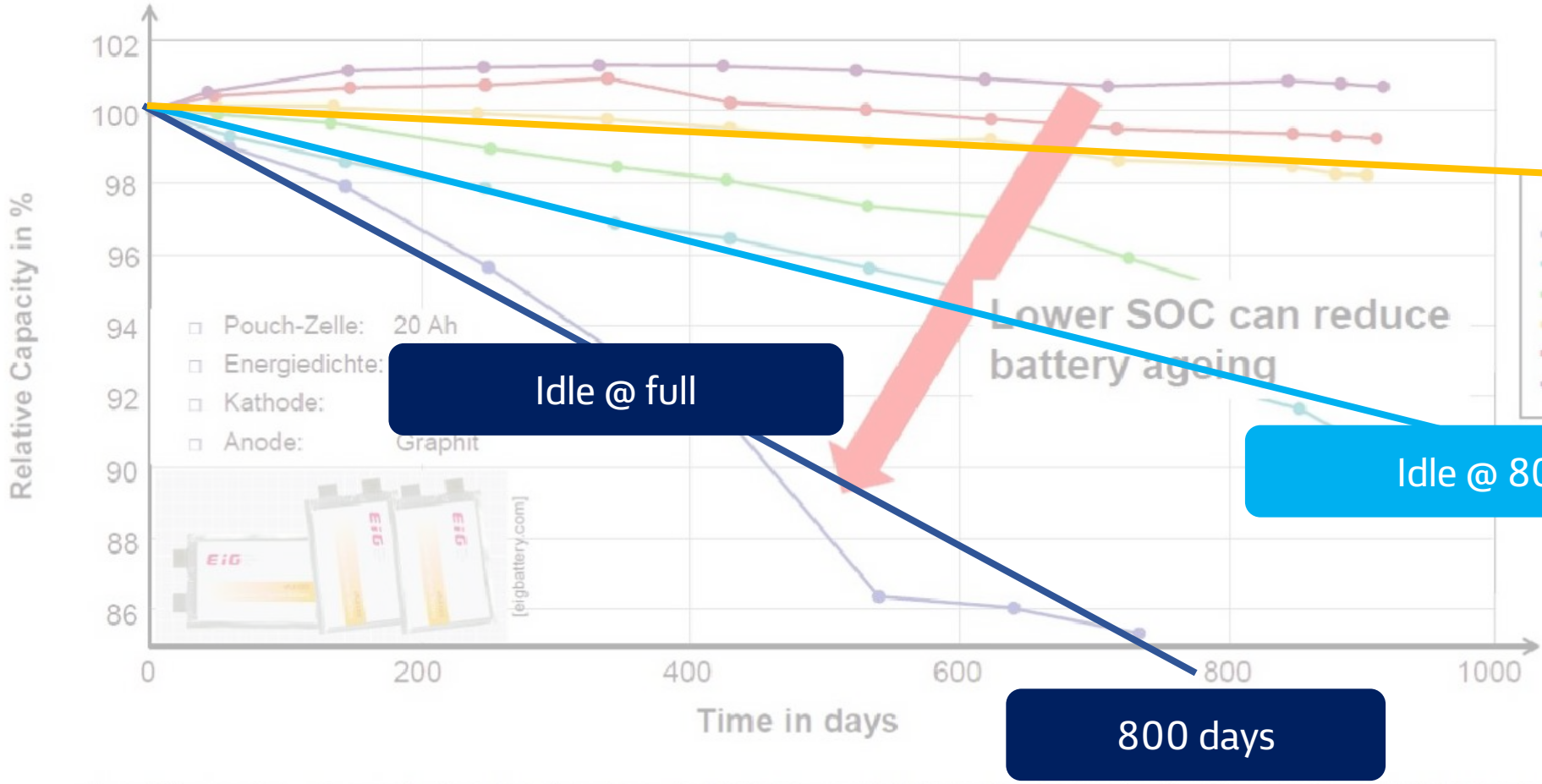


Depending on Chemistry, the Expectable Lifetime is drastically influenced by 4+2 external factors
That often allows for interesting lifetime optimization potentials

Degradation & Warranty

Degradation: Capacity Fade

IDLE SOC



Idle @ 50%

>4000 days

Idle @ full

Idle @ 80%

>1500 days

800 days

A. J. Warnecke, „Degradation Mechanisms in NMC-Based Lithium-Ion Batteries“, Dissertation, RWTH Aachen University, 2017

Tesla Model S/X Mileage vs Remaining Battery Capacity

1000s of Teslas

>100% at 130 000 km

87% at >250 000 km

87% at 40 000 km

84% at 130 000 km

Residual Capacity

100%

95%

90%

85%

0 km

50,000 km

100,000 km

150,000 km

200,000 km

250,000 km

Milage ~ Cycles

One can have the **same** battery quality @ 40 000km and @250 000km

Battery Quality is **not** directly milage or cycle dependent

Battery Quality **must** be assessed individually!

...especially with **decreasing lifetime** expectations!

Degradation Determination & Forecasting

Continuous Analysis of all relevant KPIs

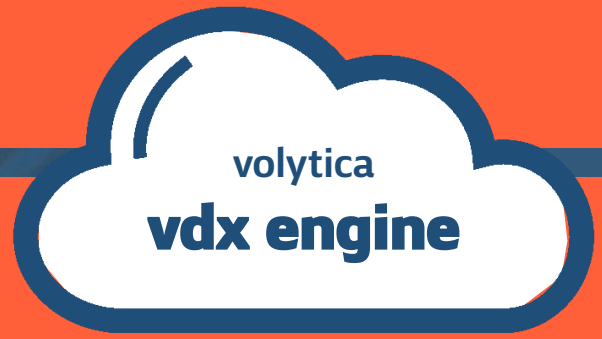
- Stress Level
- Energy Capacity
- Charge Capacity
- Efficiencies

Independent of Manufacturer Electronics

- BMS is often inaccurate
- BMS can not track all KPIs

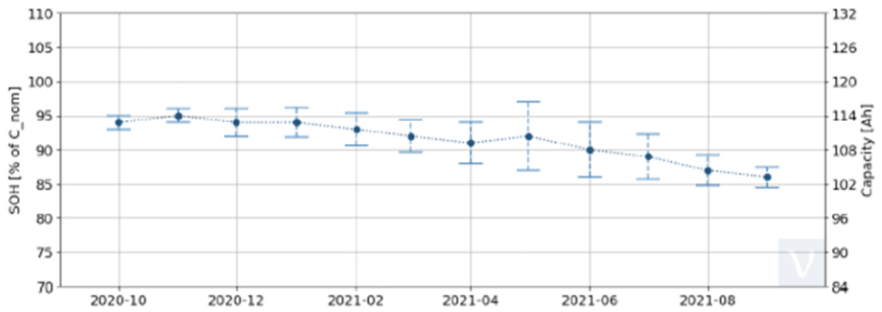
Recommendations

- How to reduce stress
- How to extend lifetime
- How to increase residual value



Degradation Determination & Forecasting

Short-Term Operational Fitness | **Long-Term Operational Fitness**



Capacity				
	First month	Trend Linear fit over data	Last month	
Algo To Data Fit			good ●●●	
Remaining Capacity Estimation of max. extractable remaining capacity under standard conditions, on system level	94.0% ±0.0%	-9.2 %/yr -16.6 %/kFCE	86.0% ±0.0%	
Cell Capacity Fade Estimation of irreversible capacity spread within the system, based on cell-inhomogeneity analysis	not evaluated			spread max-min
	not evaluated			asymmetry

Short-Term Operational Fitness | **Long-Term Operational Fitness**

Influencing Factors and their Impact on Stress Level	
Current avg. Stress Level (SL_{Ref}) = 0.6	
Scenario Description	**Stress Level Reduction**
1. Within Temperature Limits Battery Temperature between 10 °C and 40 °C	-
2. Controlled Battery Temperature Constant Battery Temperature = 25 °C	< 5%
3. Controlled Battery Temperature during Charging Constant Battery Temperature = 25 °C, during charging	< 5%
4. Decreased Idle SOC I max. SOC = 80%, during long idle phases	> 5%
5. Decreased Idle SOC II max. SOC = 50%, during long idle phases	> 10%
6. Downshift SOC Downshift SOC by 10%	not applicable
7. Scenario 2 & 5 Combined Constant Battery Temperature = 25°C & max. SOC = 50%, during long idle phases	> 10%
8. Scenario 1 & 6 Combined Battery Temperature between 10 °C and 40 °C & Downshift SOC by 10%	not applicable

Annotation
- The calculated stress level reduction is based on vdx stressmaps.
- An increase of SL means higher degradation rate. A decrease of SL means lower degradation rate.
- The accuracy of the shown values depends on the quality of the input data and the fit to the stressmap.
- A combination of scenarios does not result in a summed up stresslevel. The correlation is not linear.

Capacity Fade („SOH“)

~~Availability~~ → skipped today

Safety

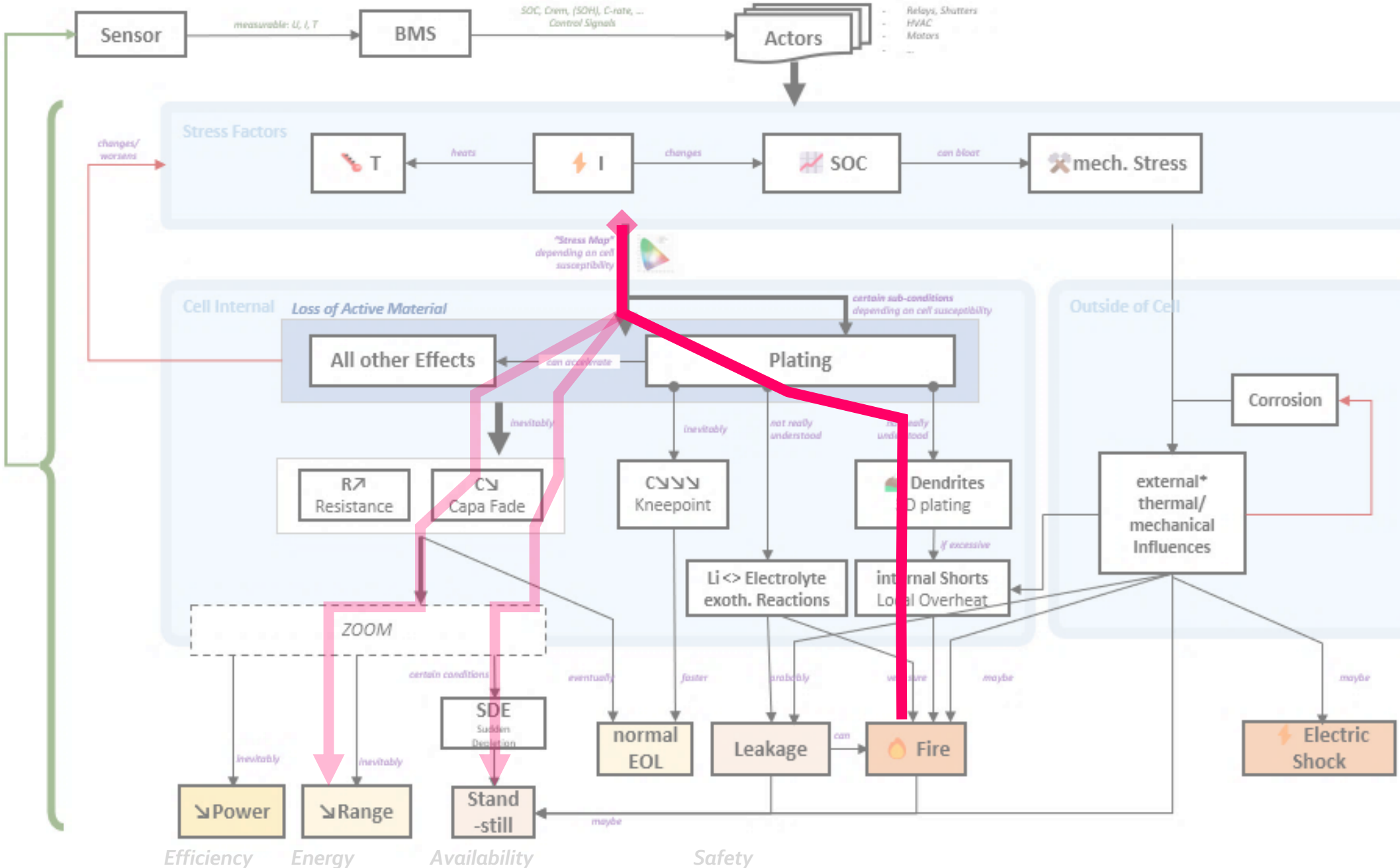
Capacity Fade („SOH“)

Availability

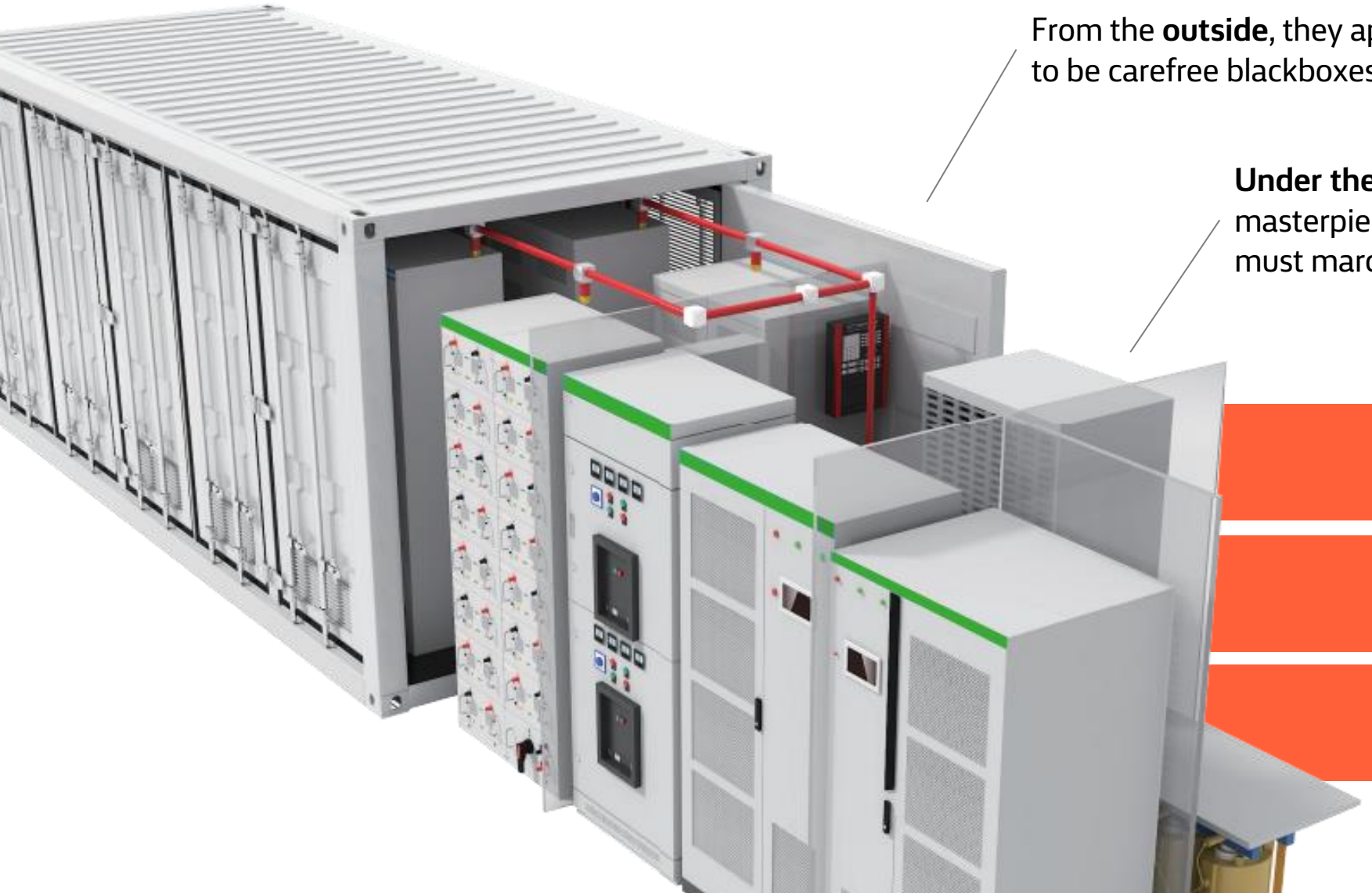
Safety

"How did you go bankrupt?"
Two ways. Gradually, then suddenly."

— Ernest Hemingway, The Sun Also Rises


Sensor
measurable: U, I, T
BMS
SOC, Crem, (SOH), C-rate, ...
Control Signals
Actors
Relays, Shutters
HVAC
Motors
Stress Factors
changes/ worsens
T
heats
I
changes
SOC
can bloat
mech. Stress
"Stress Map" depending on cell susceptibility
Cell Internal
Loss of Active Material
certain sub-conditions depending on cell susceptibility
All other Effects
can accelerate
Plating
Outside of Cell
Corrosion
inevitably
inevitably
not really understood
not really understood
R↗ Resistance
C↘ Capa Fade
C↘↘↘ Kneepoint
Dendrites
O plating
external* thermal/ mechanical Influences
if excessive
Li <> Electrolyte exoth. Reactions
int rnal Shorts
Lo al Overheat
ZOOM
certain conditions
eventually
faster
probably
maybe
maybe
SDE
Sudden Depletion
normal EOL
Leakage
can
Fire
Electric Shock
inevitably
inevitably
↘Power
↘Range
Stand -still
maybe
Efficiency
Energy
Availability
Safety

Batteries are marketed as “maintenance free”. But they are complex masterpieces that deserve proper management.



From the **outside**, they appear to be carefree blackboxes.

Under the surface, they are carefully designed masterpieces: 1000s of cells, sensors and electronics must march in lockstep for up to 20 years!

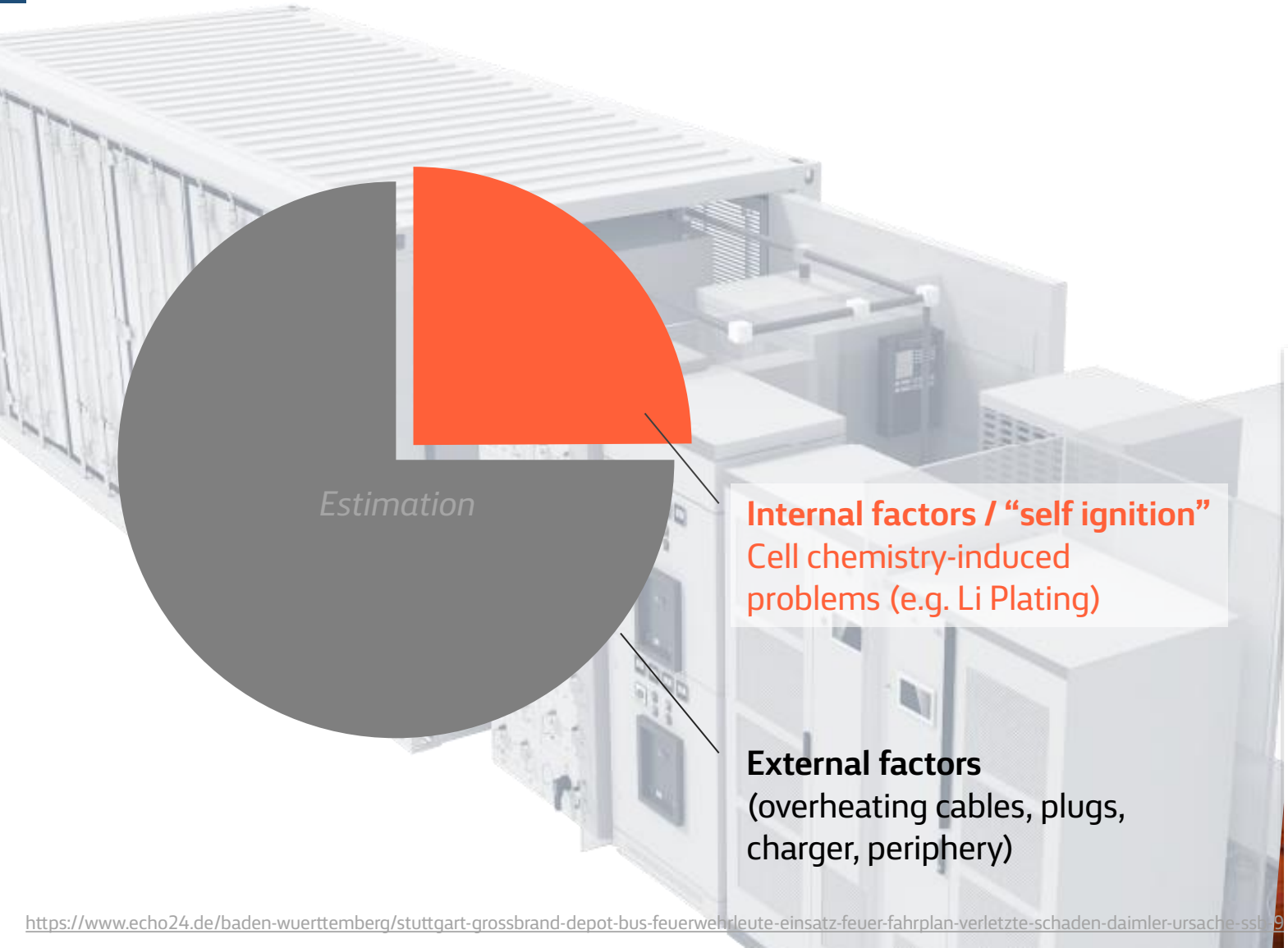
Underutilization
due to overly cautious operation

Safety-critical long-term trends
are not sensed by electronics

End-of-life criteria
are set overly pessimistic by OEMs

Battery Fires

Why do batteries actually burn? Well, we don't really know...



Internal factors / "self ignition"
Cell chemistry-induced problems (e.g. Li Plating)

External factors
(overheating cables, plugs, charger, periphery)

In the EU, at least 100 electric buses, worth >€50m, burnt down in the last 2 years.

This Stuttgart depot burnt down entirely due to a faulty electric bus in 2021: >€100m damage

Sustainable BUS

volytica diagnostics

Sustainable Bus Magazine, Feb 2022

Fire Risk & Safety – An Experts Plea

Claudius Jehle, volytica diagnostics GmbH; Prof. Paul Christensen, Professor of Pure & Applied Electrochemistry at Newcastle University; Paul Markham, PM Risk Consultants Ltd.; Alex Johns, Altelium Insurances Ltd.

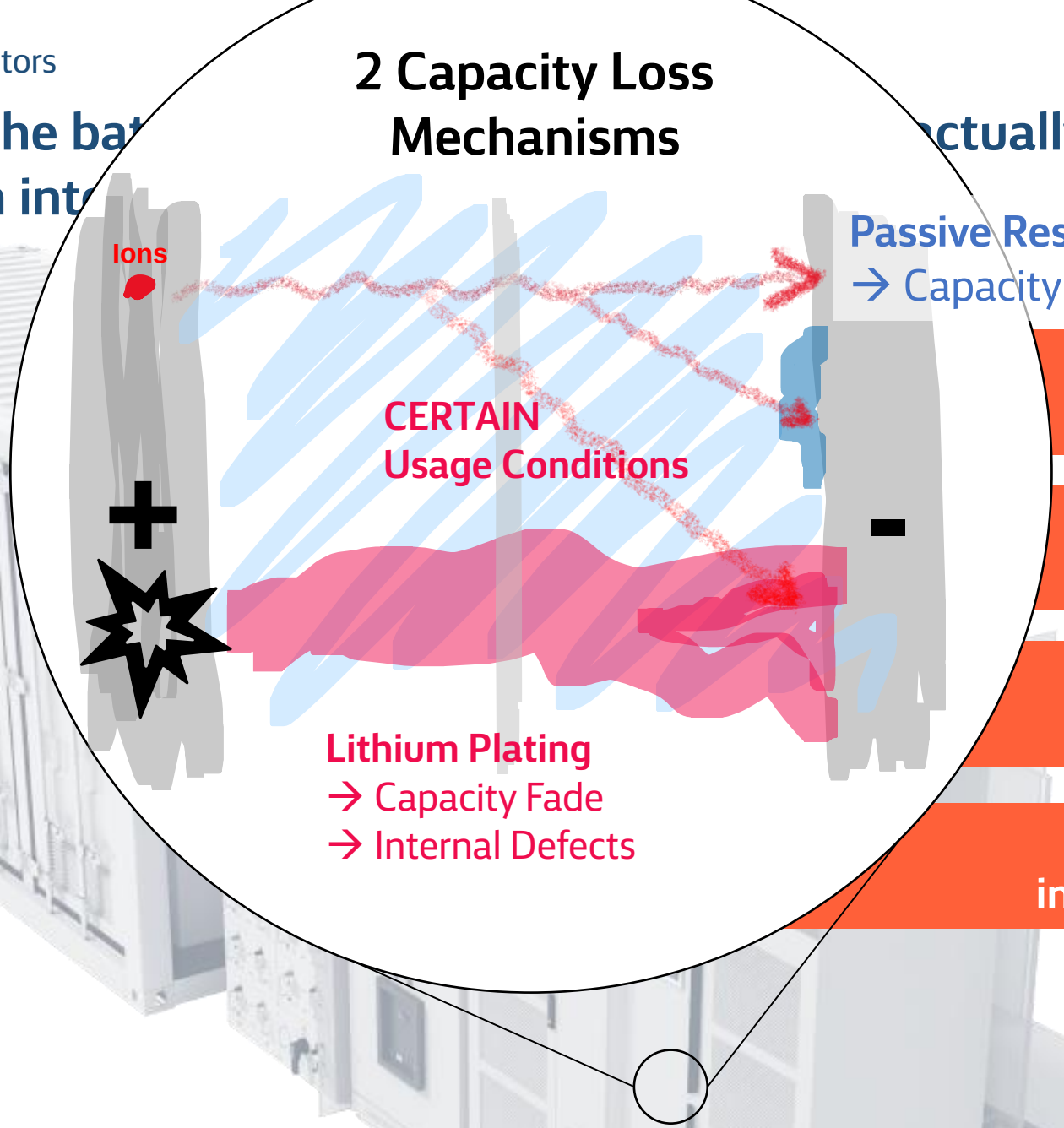
A Historical Example

The 1950s through 1980s saw a drive towards increasing the energy density and size of steam turbines from c. 150MW to 600MW – and incidents judged to have been capable of generating 'missiles' at that time are well recorded[1]. It is apparent from the failure data that there were a number of shortcomings with each of the early designs, particularly with the introduction of the large 500 MW and 660 MW units. But, as in every developing industry, each development is likely to go through, and undergo at times a painful cycle of continuous leaning and improvement.

https://www.echo24.de/baden-wuerttemberg/stuttgart-grossbrand-depot-bus-feuerwehrleute-einsatz-feuer-fahrplan-verletzte-schaden-daimler-ursache-ssb-9

Internal Factors

When the bat… happen int… …ctually



Multiple internal processes lead to degradation

Not all of them are dangerous – but Plating is!

Li Plating is usage-induced. It’s hard to completely avoid!

Certain long-term trends can indicate impending anomalies – if you look!

SOH

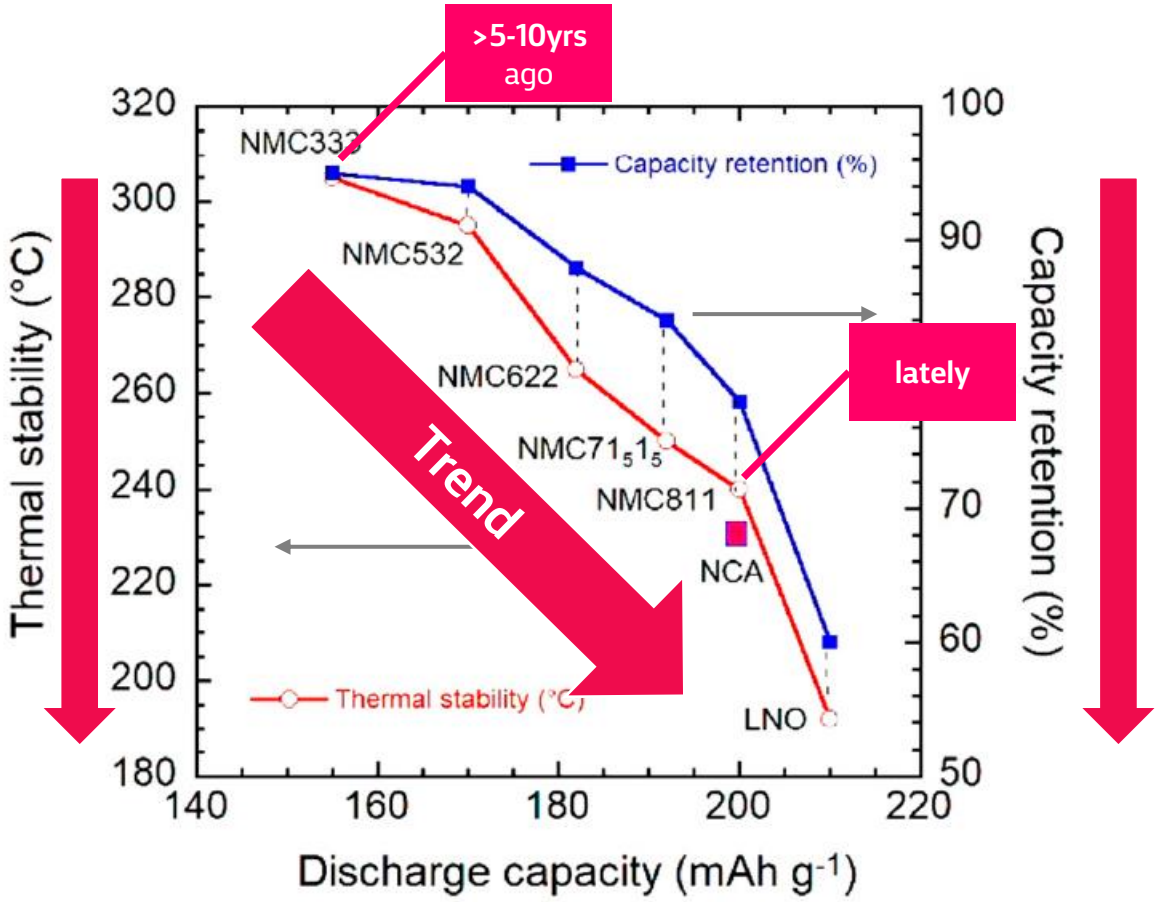
(„state of health“)

IS NOT A MEASURE FOR SAFTY RISK

Safety

Some facts and figures on battery safety and failures from around the world.

2%	approx. 2% of all Korean BESS systems encountered fire issues between 2017-22
€750m	this caused an economical impact of up to €750m total losses
-50%	safety margins of automotive-grade NMC batteries decreased in the last years!
~90%	of all events could be have been detected beforehand, Korean study estimates
LFP	...is *harder* to ignite, but once on fire, can burn more violently than NMC, studies say



NCA, NCM811, and the Route to Ni-Richer Lithium-Ion Batteries
Christian M. Julien * and Alain Mauger
10 October 2020; Accepted: 30 November 2020; Published: 2 December 2020;
Energies 2020, 13, 6363; doi:10.3390/en13236363

Click to learn more!

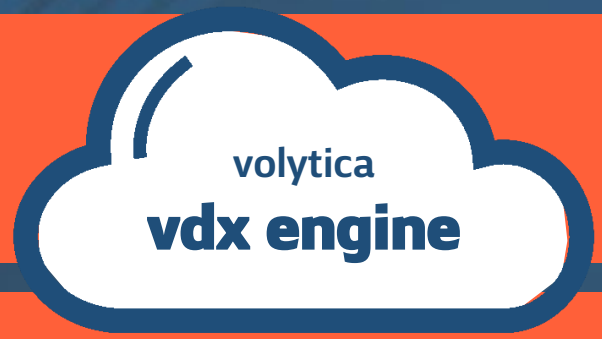
Anomaly & Safety Detection Algorithms

Continuous Analysis of several safety & anomaly-critical KPIs

- Thermal Anomalies
- Balancing / symmetry anomalies
- Cell quality / safety anomalies

Alerting on trends and abnormal behavious

- All KPIs are continuously analysed for trends
- Short- and long-term anomalies are sent via mail
- Mitigation recommendations



Training of personnel

Anomaly & Safety Detection Algorithms

Anomaly Indicators

General / Event Logbook

09.01.2023 22:00:44 to 27.01.2023 11:29:18

Include Subelements: all children | Aspects / Sources: All | Severity: All | Freetext Filter: sym

back to Subsystem Explorer

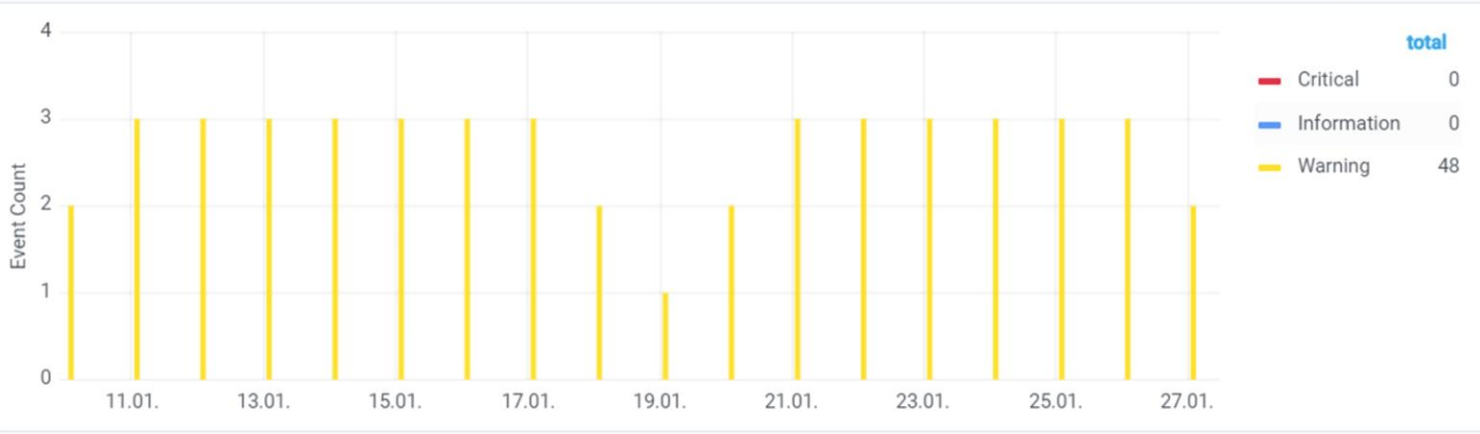
Demo BESS Plant

Hierarchy

└ Demo BESS Plant

Subsystems

- Container 1
- Container 2
- Container 3
- Container 4



Chronologically (Demo BESS Plant incl. all children)

Event Time	Relative Time	Severity	Source	Event Name	Event Description	Link
2023-01-27 01:59:59	vor 6 Monaten	Warning	vdx-peer-group-alerts	[peer_cap-symmetry_daily]	C04 B01 Rack 05: Capacity symmetry differs significantly from peers. Check m...	
2023-01-27 01:59:59	vor 6 Monaten	Warning	vdx-symmetry-alerts	[thermal_symmetry_longterm_anoma...	C04 B01 Rack 03: Slow thermal asymmetry trend. Check manual. (1704a2b2-0...	
2023-01-26 13:59:59	vor 6 Monaten	Warning	vdx-symmetry-alerts	[thermal_symmetry_longterm_anoma...	C04 B01 Rack 03: Slow thermal asymmetry trend. Check manual. (1704a2b2-0...	
2023-01-26 01:59:59	vor 6 Monaten	Warning	vdx-peer-group-alerts	[peer_cap-symmetry_daily]	C04 B01 Rack 05: Capacity symmetry differs significantly from peers. Check m...	
2023-01-26 01:59:59	vor 6 Monaten	Warning	vdx-symmetry-alerts	[thermal_symmetry_longterm_anoma...	C04 B01 Rack 03: Slow thermal asymmetry trend. Check manual. (1704a2b2-0...	

Thank you!

👉 Get in Touch

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