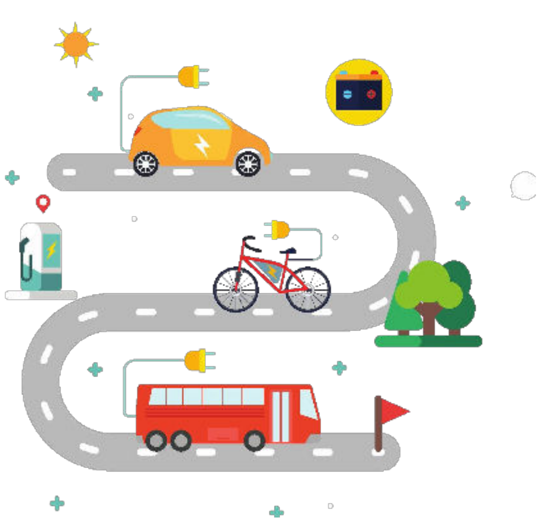

ELECTRIC MOBILITY FORUM

ENGAGE
Connecting Big Ideas To Action

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Battery Monitoring – Importance and Solutions for Public Transport Companies

July 31 , 2020
4:00 PM - 5:00 PM (IST)
WRI India

Speaker:
Lutz Morawietz, Dipl.-Ing
Head of Battery Diagnostics,
Volytica diagnostics GmbH

Moderator:
Shravani Sharma
WRI India

Supported by:
Rohan Shailesh Modi
German Chancellor Fellow,
Die Alexander-von-Humboldt-Stiftung

WRI INDIA — ROSS CENTER

SHAKTI SUSTAINABLE ENERGY FOUNDATION

volytica diagnostics GmbH

Who we are? - Key facts

Claudius Jehle, CEO
5yrs Group Manager
Battery Diagnosis

Sebastian Stoll, CTO
11yrs Cloud Engineering
Experience (Industry)

Spinoff 10/2019
@TRL6-7

Now

2 Experienced Founders
with relevant Market & Technology Background

4 High Profile Employees
experts from Battery, AI and Software Engineering

Strong Technology & Network
Close Research (Fraunhofer and TU Dresden) and Industry Network, Pilot Projects from Q2/2020

Ambitious Strategy
Ambitious, yet long-term, sustainable growth with strong focus on indepences and trustworthiness

2025

2 Core Target Markets
Diagnosis Software for Non-Car OEM/Tiers

Service Provider for Car Battery Assessments

volytica diagnostics GmbH

What do we do? - Our solution

Field Data — U, I, T → vdx engine — $f(x)$ → Degradation KPIs — SOH

Source-agnostic
Use existing telematics solution or choose from our third-party portfolio

No Sensors
We use the signals every battery provides: only U, I, T are needed

Minimal Data Volume
We've got SDKs for 10:1 onboard compression

Cloud-Based
Automated, scalable software deployed in trustable and safe clouds

Plug and Play
Minimum apriori parameterization due to self-learning algorithms

Top-Notch Quality
Built on >10 years of Li Ion diagnostics, characterization and machine learning experience

Full Transparency
Get rate, state, predictions and *realistic* ageing information over the lifecycle

Save Costs...
Less testing, optimize system size, reduce service costs, warranty risks...

... and Earn Money
Boost after-sales, sell warranty top-ups, lease & pay-per-use, full service and many more...

Battery Monitoring – Importance and Solutions for P. T. C.

Agenda

1. Setting the Frame: Why is Degradation important?
2. Battery Basics and Degradation in a Nutshell
3. Battery Monitoring - Why and How?
4. Outlook: Tendering

Battery Monitoring – Importance and Solutions for P. T. C.

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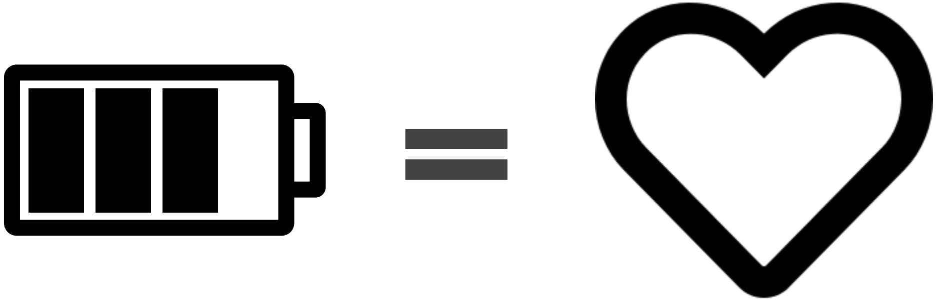
Setting the Frame: Why is Degradation important?

Problem to solve - The Battery is …



30%

of vehicle value

?

… single most expensive component

… subject to usage-dependent wear

...extremely complex to diagnose & predict

Setting the Frame: Why is Degradation important?

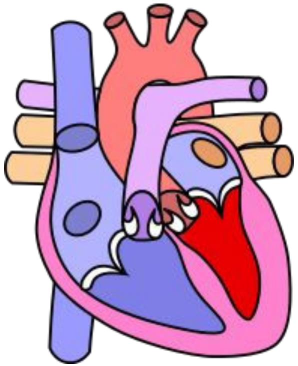
Battery - The Heart of an EV

The **essential component**

Degrades inevitably

Health assessment needs a ‘deep view’

“A vehicle battery is like a human heart”



Source: https://commons.wikimedia.org/wiki/File:Heart_normal.svg

Determines overall performance

Degradation is usage dependent

Take good care!

Battery Monitoring – Importance and Solutions for P. T. C.

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1. Setting the Frame: Why is Degradation important?

2. **Battery Basics and Degradation in a Nutshell**

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Battery Basics and Degradation in a Nutshell

Chemistry

Li-Ion
Li Iron Phosphate

- short: $LiFePO_4$, LFP, …
- “Chinese Automotive Standard”
- modest energy (lower risk?)
- modest prices
- difficult SOC determination
  - tendency for prone to balancing problems

Li-Ion
Nickel Manganese Cobalt

- short: NMC, NCA, …
- “European, Korean Automotive Standard”
- higher energy (higher risk?)
- higher prices
- better SOC determination

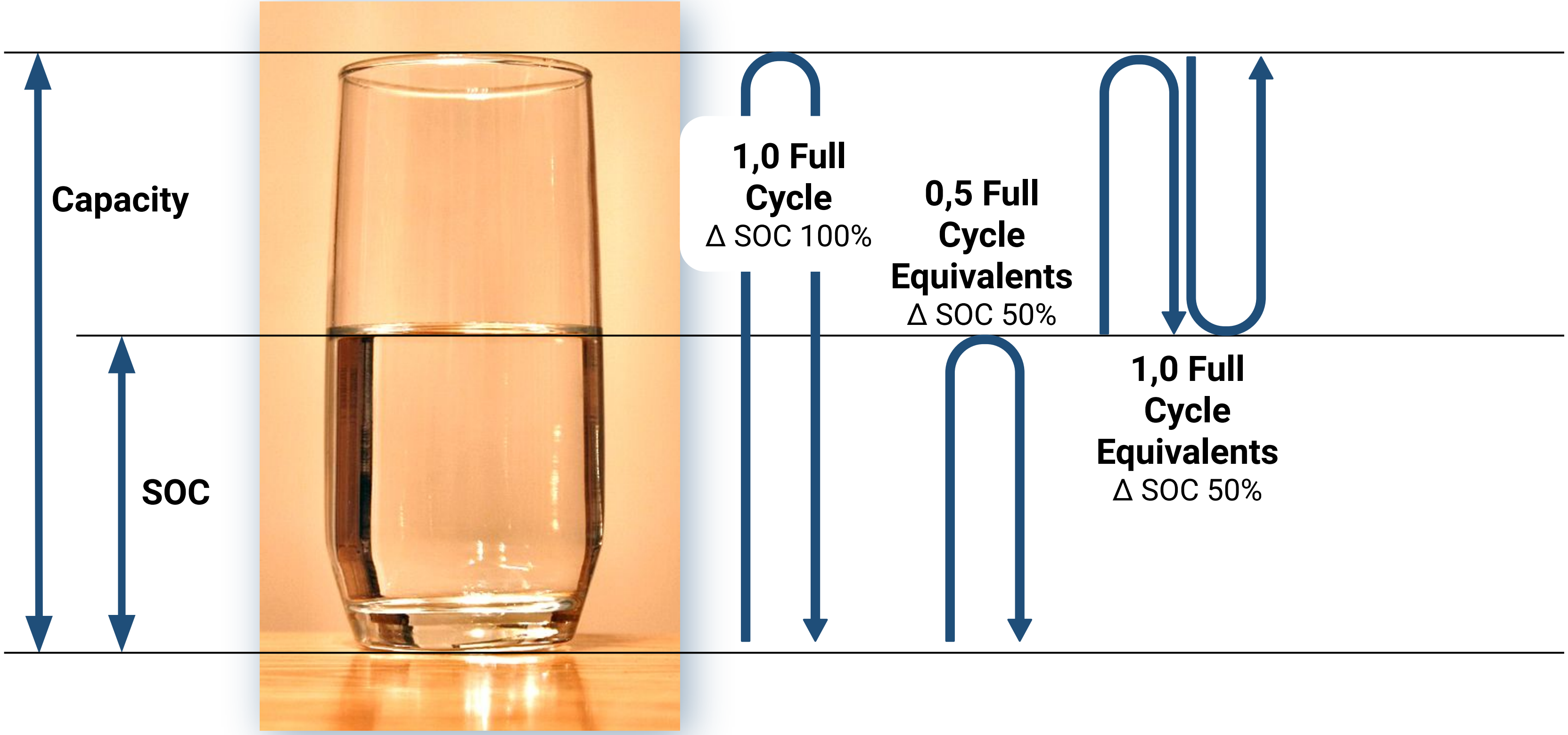
Li-Ion
Rest

- several other “exotic“ chemistries in the pipeline
  - LTO / Titanate
  - Solid State
  - Li-Air, Li-Sulfur, …

(i) Good to know: Li-Poly is just a reference to the internal liquid!

Battery Basics and Degradation in a Nutshell

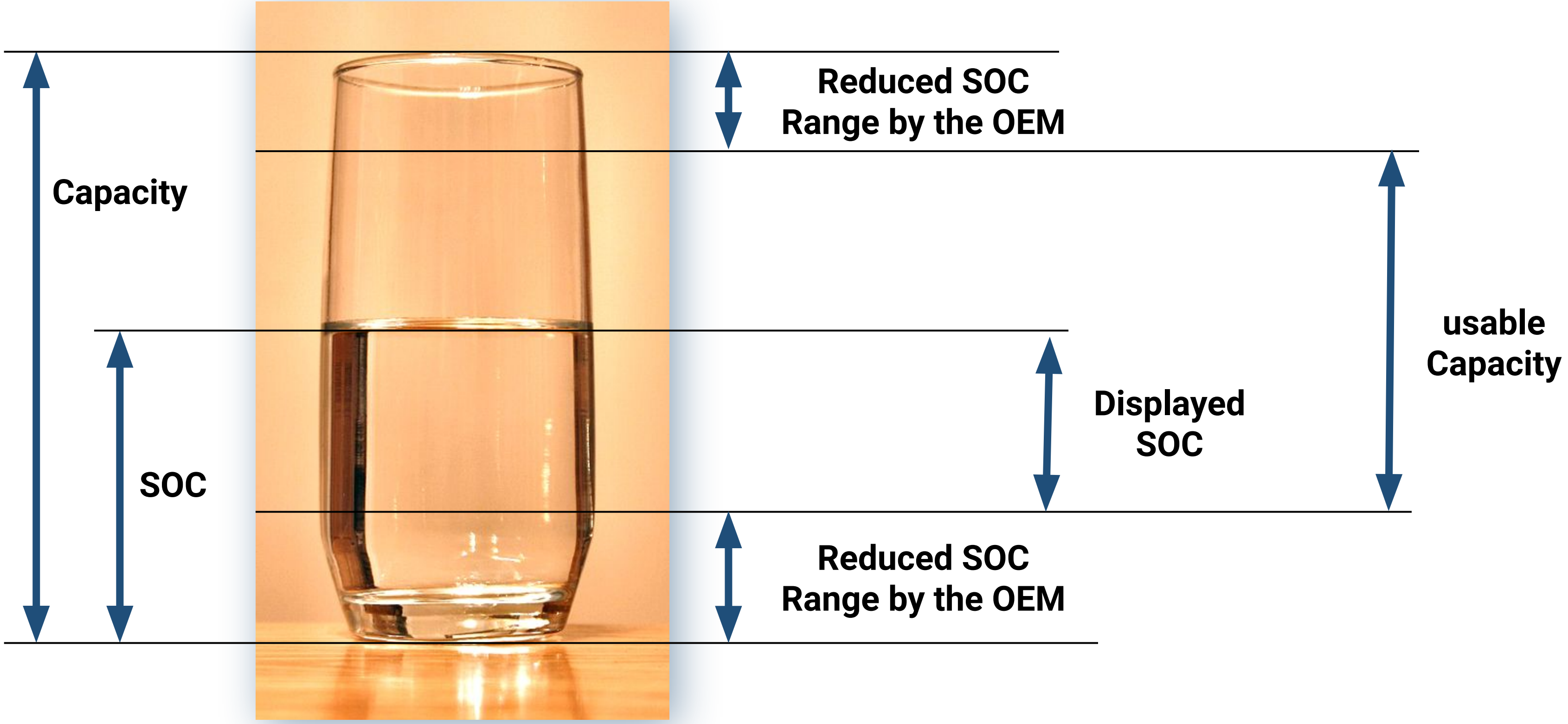
Capacity and SOC



Source: https://en.wikipedia.org/wiki/File:Glass-of-water.jpg under public domain

Battery Basics and Degradation in a Nutshell

Usable Capacity and Displayed SOC



Source: https://en.wikipedia.org/wiki/File:Glass-of-water.jpg under public domain

Battery Basics and Degradation in a Nutshell

Some further Terms and Wordings

Nominal Capacity C_N:
Is the minimum amount of charge that can be discharged at **nominal current I_N** and at **nominal temperature T_N** from a new fully charged battery

$$C_N = I_N * t$$

Actual Capacity:
The capacity actually available to the system depends, among other things, on:

- Discharge current rate
- Temperature
- Time pattern of the discharge
- <u>Ageing of the battery</u>

C-Rate:
To compare cells and batteries of different capacities, charge and discharge current is specified in relation to the capacity.

As an example for battery with C_N = 3.5 Ah:

- 1C ≙ 3.5 A
- 0.2C or C/5 ≙ 0.7 A
- 10C ≙ 35 A

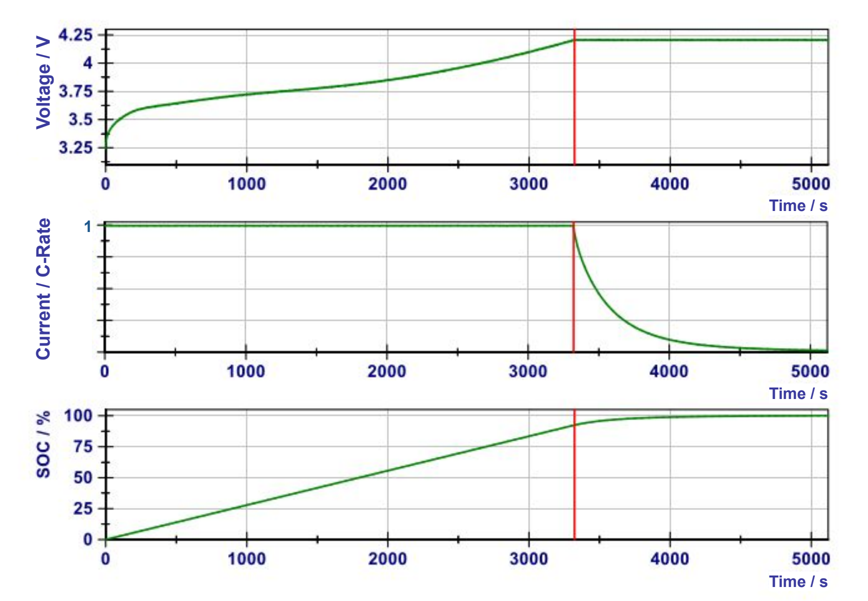
Battery Basics and Degradation in a Nutshell

Charging Method

CC-CV-Method:

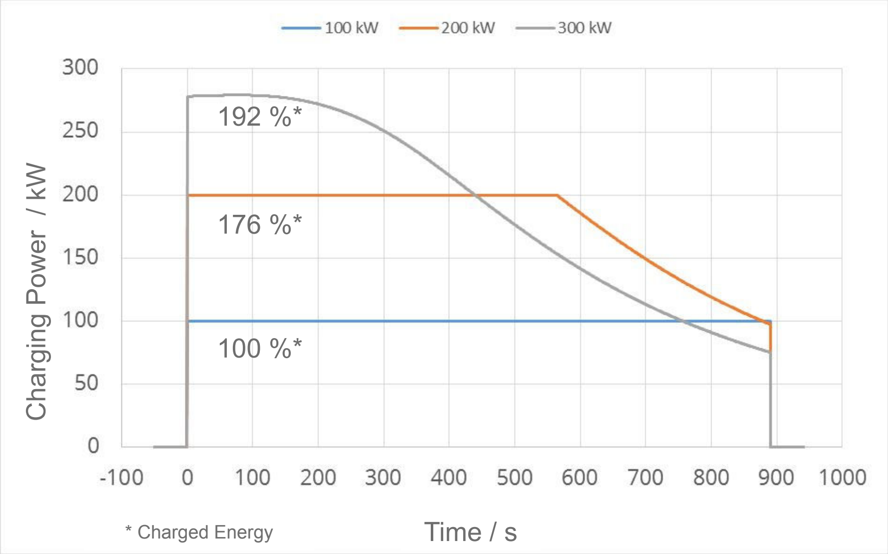
- Common method for LI-Ion-batteries in laboratory to reach a fully charged battery
- In the “real world” often slightly adapted

1. <u>Phase CC:</u>
   - CC = Constant Current
   - Charging with a constant current until the charing cut-off voltage is reached
   - Typical current with 0.3 to 1 C
2. <u>Phase CV:</u>
   - CV = Constant Voltage
   - Charging with a constant voltage until the current felt below a limit
   - Typical current limit C20



Battery Basics and Degradation in a Nutshell

Sense and nonsense of high charging power



Boundary Conditions:

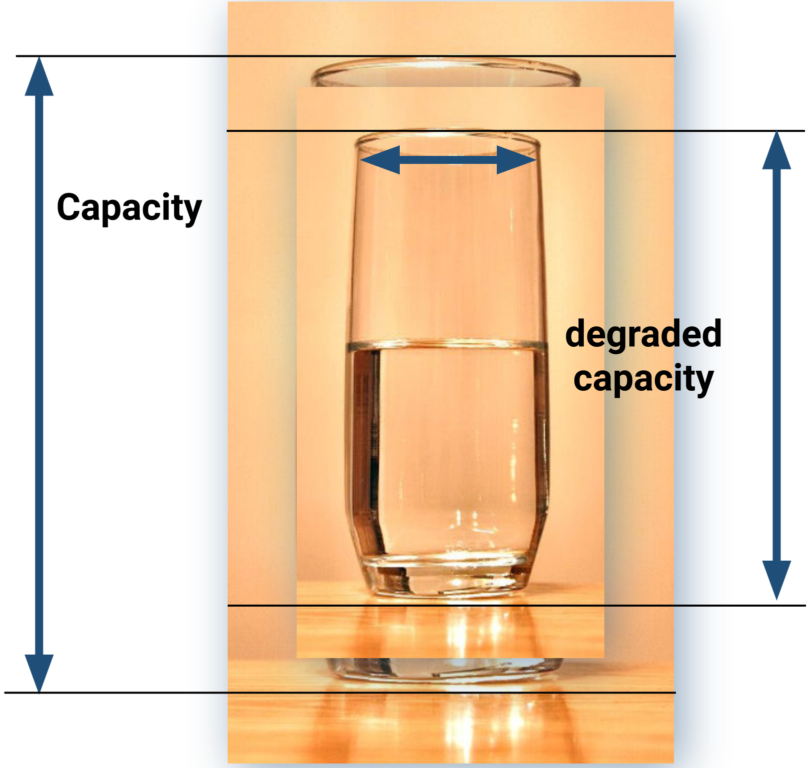
- Simulation results of an existing tracktion battery of an electric bus
- Cell chemistry LFP
- Start-SOC 50%
- Surrounding temperature 30°C

- **Increase in charging power → Shorten the charging time**
- BUT: Increased power = reduced service life

Source: Bunzel, A.; Morawietz, L.; Ufert, M.: Technologische und ökonomische Bewertung der Elektrifizierung von ÖPNV- Busflotten im Werkstatt- und Betriebshofbereich. Vortrag bei der Fachtagung „Werkstatt- und Betriebshofkonzepte für Elektrobusse“, Dresden, 11.-12.10.2018.

Battery Basics and Degradation in a Nutshell

Degradation Effects



Reduced Capacity

inevitable *(Ageing)*		evitable* *to be excluded by design*	
R ↗	C ↘	Inhomo-geneity	catastr. failure

range & power decrease (R, C, Inhomogeneity)

early failure (Inhomogeneity, catastr. failure)

** in a "nominal case", i.e. disregarding extreme situations*

Source: https://en.wikipedia.org/wiki/File:Glass-of-water.jpg under public domain

Battery Basics and Degradation in a Nutshell

Ageing - Everything is easy?

How long will a battery live?

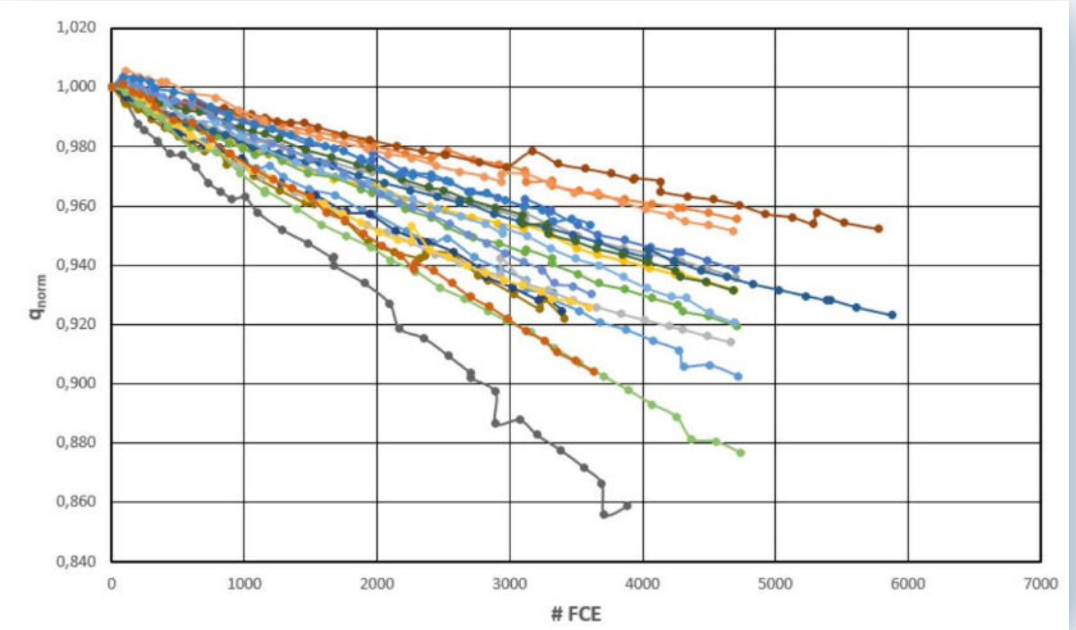
There exist definitions, which determine the end of life of a battery:

- Usable capacity decreased to 80% of its initial value in mobile applications (for stationary batteries it´s 70%)
- Internal resistance increased to 200% of its initial value

Calendrical Ageing	Cyclical Ageing
Reduction of capacity (80%) reduced range	
Increase of internal resistance (200%) reduced performance with impact on acceleration ability, charging time, maximum speed	
Function of time	**Function of charge throughput**
Key factors: temperatur; mean SOC	**Key factors:** temperature; SOC-Swing; current rate; mean SOC

Battery Basics and Degradation in a Nutshell

Broadness of Degradation Evolution



Different degradation gradients for a single cell type because of different operation conditions (laboratory measurement at 25°C)

Speed of Degradation strongly depends on the operating condition and can not be estimated without detailed knowledge of them

Battery Basics and Degradation in a Nutshell

Ageing - Conclusion and Take Away

Influencing Factor	Temperature	Δ-SOC	mean SOC	C-Rate resp. Power
Optimal Values*	15°C - 30°C	the lower the better	~50% better than ~80%	the lower the better
Mitigation Strategy	• (Difficult to influence during operation) • Avoid parking in the sun	• (Most difficult to influence) • Strongly depends on the needed usage time • Modest charging more often	• (Difficult to influence) • Avoid parking @ 100% • If available, use “smart charging”	• Far-sighted driving • Full usage of recuperative braking • Raising driver awareness

*** the concrete value is highly dependent on the used cell**

Battery Monitoring – Importance and Solutions for P. T. C.

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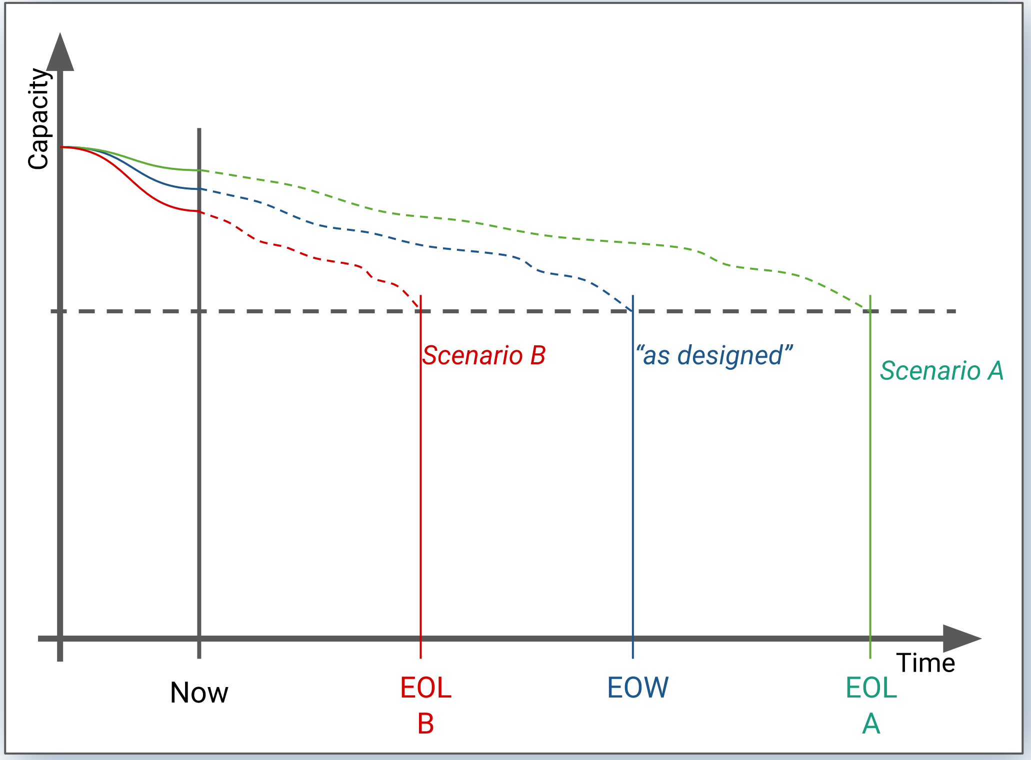
Battery Monitoring - Why and How?

Knowing the Health of a Battery



EOL: End of Life EOW: End of Warranty

Scenario A:

- Conservative design
- Easier usage profile than assumed

Scenario B:

- Harder usage profile than assumed
- Warranty condition breach

Take away:

- Relevant for both the OEM and the PTC
- To predict the future, detailed knowledge on the battery and the usage profile is crucial

⇨ **Only possible to recognize via detailed battery monitoring**

Battery Monitoring - Why and How?

Things to be considered

Collecting Data (U, I, T) → **Storing Data** ($f(x)$) → **Evaluating Data** (SOH)

What is the data source?
Additional sensors? CAN-interface? Where to get the CAN-Matrix? Available Data (U, I, T)?

Telemetry hardware?
Space to mount? Power supply? Who provides it?

How to transmit the data?
Mobile network provider? Needed data rate and amount? Network Stability? Security?

Where to store the data?
Cloud Service Provider? Own server in the basement? Security? Fail-safe operation?

Scalability?
How many vehicles? When will they go online? How long to store the data? Data reduction/compression?

What speed is needed?
Latency of the data? Evaluation period (daily, weekly,...)? Real time view needed?

What to evaluate?
Statistics? Mission profile? Merging of data sources? Degradation reports? Lifetime prediction?

Algorithms?
Who is developing the needed algorithms? Do they work online (dashboard) or offline (paper report)?

Knowledge?
Battery parameters? Stress-Maps? Battery knowledge?

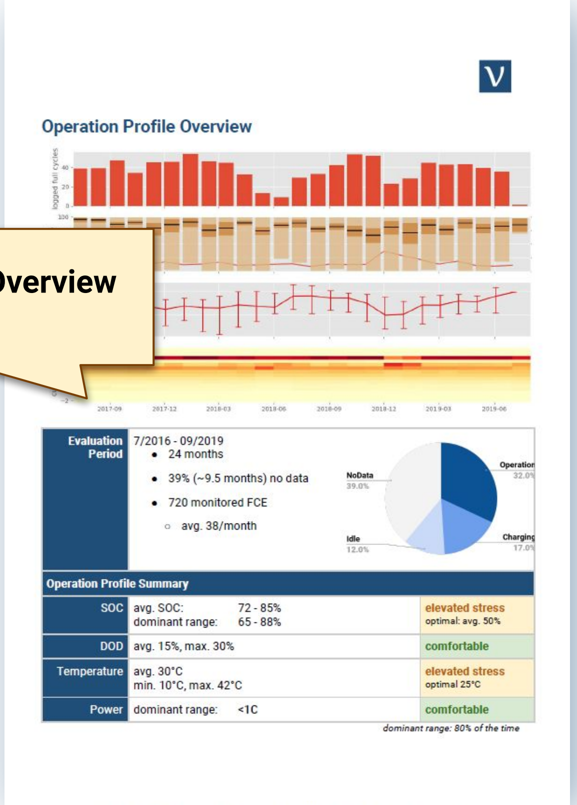
Battery Monitoring - Why and How?

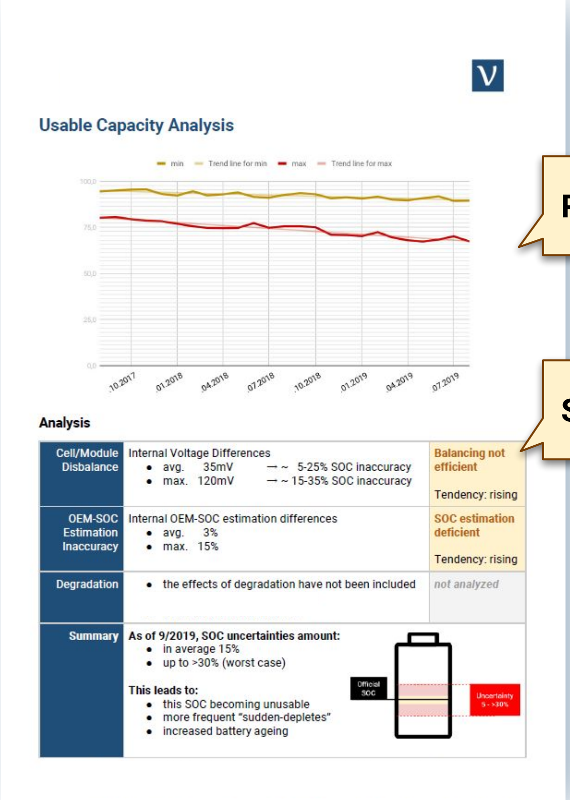
Web Dashboard - “Asset Cockpit”

Battery Monitoring - Why and How?

Volytica Report

Operation Profile Overview
(Operation Conditions)





Residual Capacity

SOC-Consistency

Battery Monitoring – Importance and Solutions for P. T. C.

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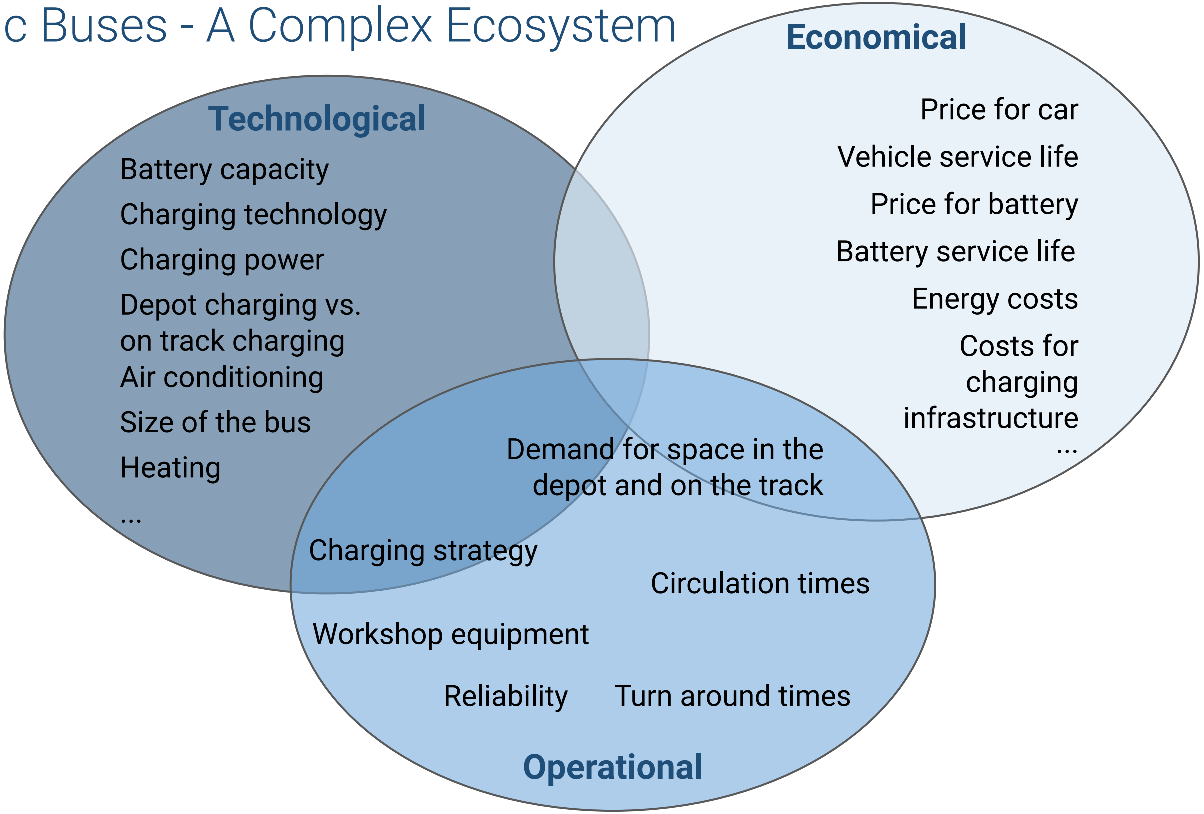
Outlook: Tending

Full Electric Buses - A Complex Ecosystem



Nearly every point is linked at least to on other point in another domain and all have to be considered together

⇨ Strong need for experts and consultants

Outlook: Tending

Takeaways

- Be aware of the complex ecosystem “full electric bus”. It’s not only buying an electric bus and replace a diesel bus, at least if you want to do it right.
- Every single decision has an impact on other points you have to decide. ➪ Take the helping hand of experts and consultants.
- Look out for an intelligent charge control system to:
    - Enhance battery life
    - Reduce energy costs
    - Reduce infrastructure costs
- The evaluation of battery ageing is a challenging thing to do, from knowing the actual State of Health up to predicting the End of Life.
- It can only be done by detailed monitoring during the whole life of a battery.
- A minimum data set should be provided by the OEM:
    - Battery voltage
    - *Lowest and highest cell voltage*
    - Current with a high sampling rate or with a lower sampling rate an additionally the Charge throughput
    - Mean temperature of the battery
    - *Lowest and highest cell temperature*
    - Average State of Charge
- The detailed monitoring could also be a gain for the OEM ➪ Win-Win-Situation for both

volytica diagnostics
battery diagnosis as a service

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