AVL DITEST

E-MOBILITY AFTERSALES

Battery lifetime cycle & aging models, diagnostics

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AVL DiTest GmbH

ABOUT US

AVL GROUP


AVL List
Affiliates
World wide
Engineering – Sales - Service
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MEMBER OF THE AVL GROUP
PIEZOCRYST
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AVL DiTEST Graz
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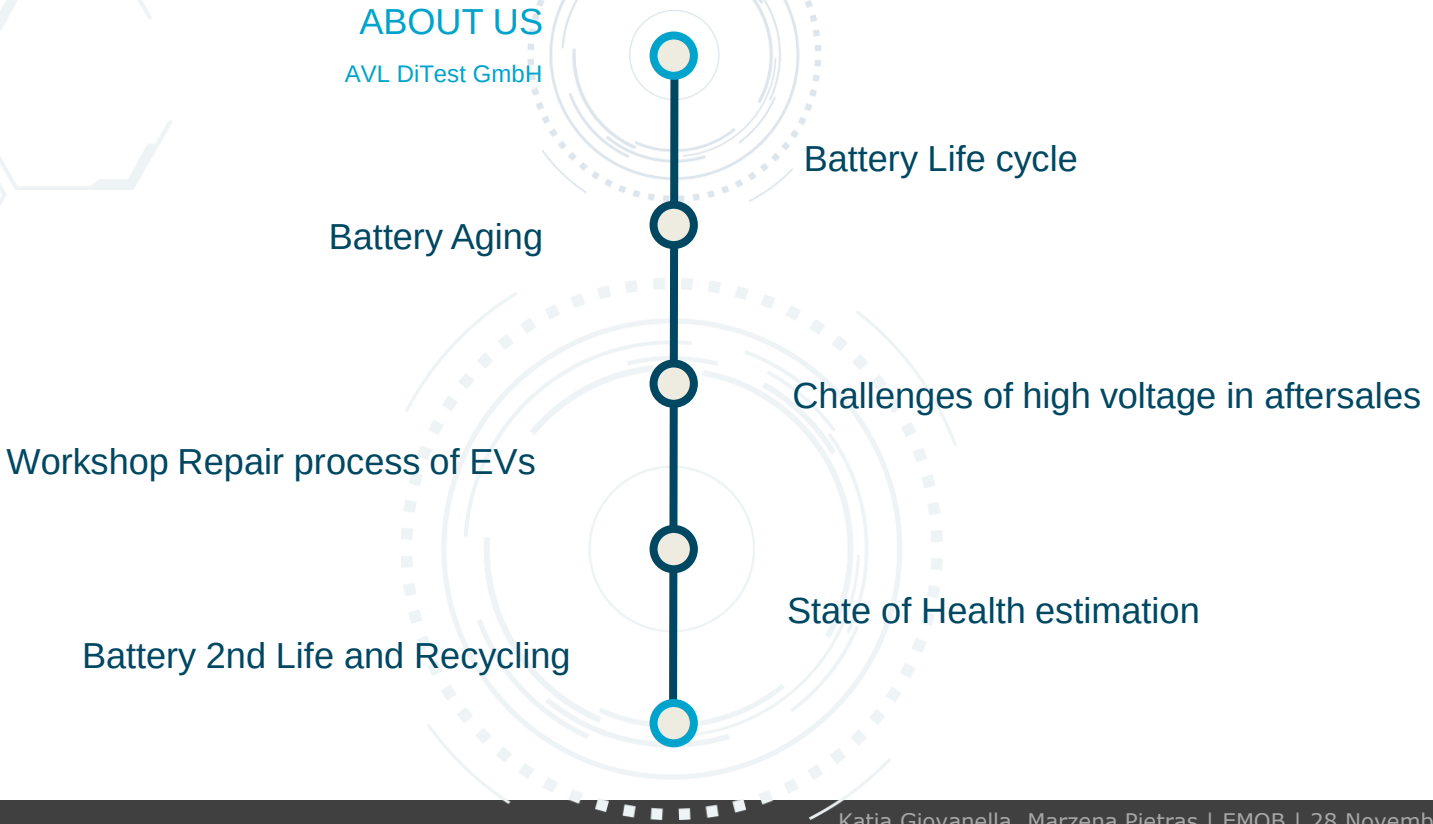
Germany
JV
China
independent
partners in more
then 50 countries

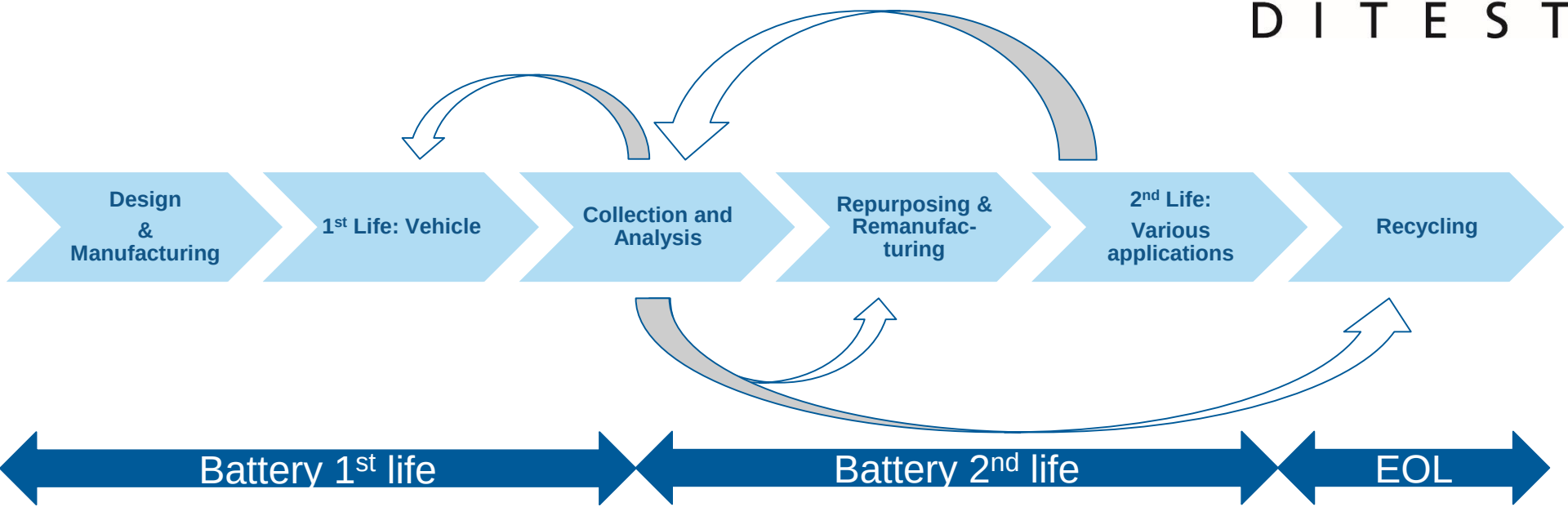
TODAY'S AGENDA



Battery Lifecycle

From raw to raw material

BATTERY LIFECYCLE



Battery Aging

Main influencers for the battery aging and how it impacts the user

BATTERY AGING DRIVERS

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QUESTION:

WHAT ARE THE AGING DRIVERS FOR THE TRACTION BATTERY IN THE ELECTRIC VEHICLE?

AGING DRIVERS – WHAT INFLUENCES BATTERY LIFETIME?

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- **Vehicle operation mode**

  Driving, parking, charging

- **Environment**

  Road profile, climatic condition

- **Battery pack design**

  Cooling system, electrical connection, mechanical load

- **Cell design and chemistry**

  Material degradation, chemical reactions

Source: AVL

BATTERY LIFETIME IN AUTOMOTIVE APPLICATIONS

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QUESTION:

WHAT % OF REMAINING CAPACITY IS CONSIDERED AS ENF OF BATTERY LIFETIME FOR AUTOMOTIVE APPLICATIONS?

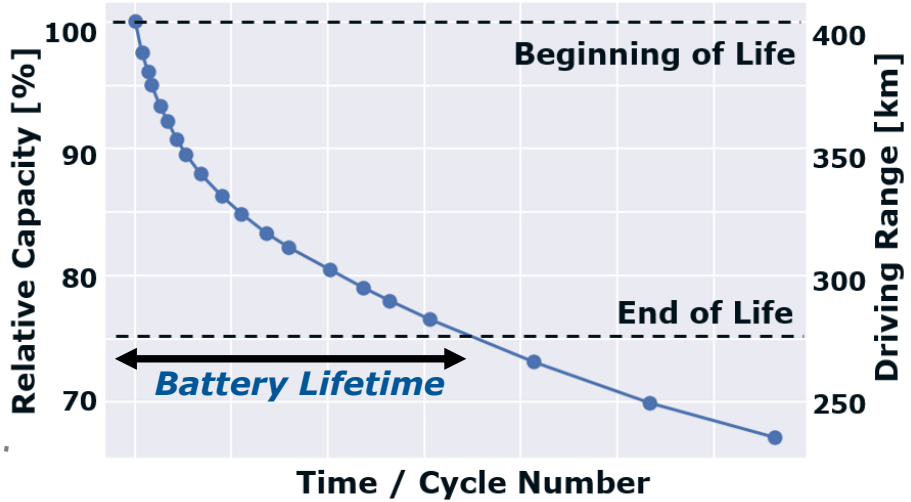
a) 50%
b) 80%
c) 90%

HOW IS THE BATTERY LIFETIME DEFINED?

Source: AVL

Automotive **battery cells** age over time

- Capacity loss → Driving range reduction
- Internal resistance increase → Power reduction
- Safety issues



AGEING MECHANISMS IMPACTS

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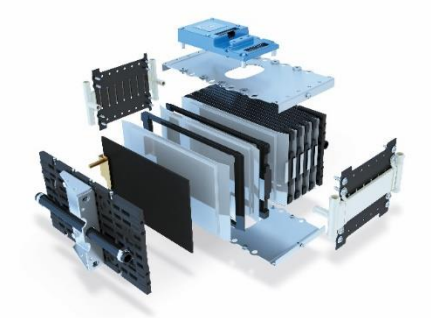
For the battery pack

- Capacity fade
- Power fade
- Self discharge
- Increase of internal resistance
- Heat generation increase over time
- Safety issues

For the vehicle user

- Reduction of driving range
- Poor performance (acceleration, top speed, hill climbing)
- Increase of energy consumption



HOW CAN BATTERY AGING BE MODELED?

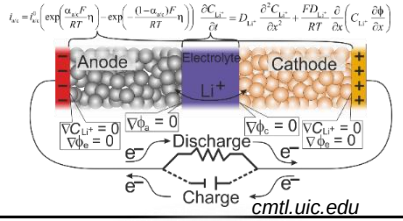
AVL is working on different modeling approaches:

Test Data Amount

Physical Chemical Details

Physics - Based Model

- Physical, chemical, biological laws
- No aging experiments
- Electro-chemical modeling

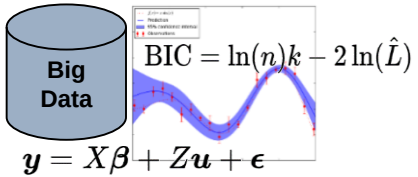


Half - Empirical Model

- Half-empirical data driven model
- Based on aging experiments
- Statistical methods

Data - Driven Model

- Purely data driven
- Based on many aging experiments
- Machine Learning, Neural Networks



Accuracy

Complexity

Source: AVL

BATTERY LIFE CYCLE ALONG THE VALUE CHAIN

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Development | Design & Engineering | Testing & Validation | Production | Aftersales | In-Use | Second Life

Universities
Cell Test Labs
Manufacturing Plants
Financial Institute
Consumer
Infrastructure Provider
Cell Manufacturer
Engineering Centers
Battery OEM
OEM Aftersales Unit
Fleet Operators
Workshops
Building Owners / Operators

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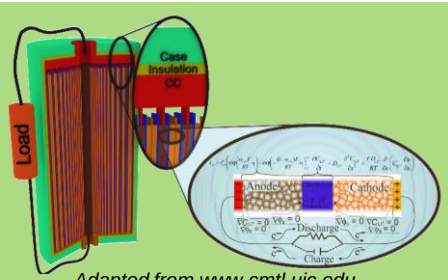
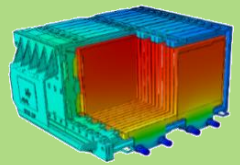
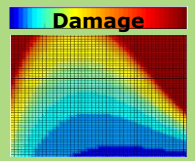


Adapted from www.cmtl.uic.edu





Depending on the use case, **different modeling approaches** are used.

Source: AVL

High voltage

Challenges of high voltage technology in aftersales

QUESTION:

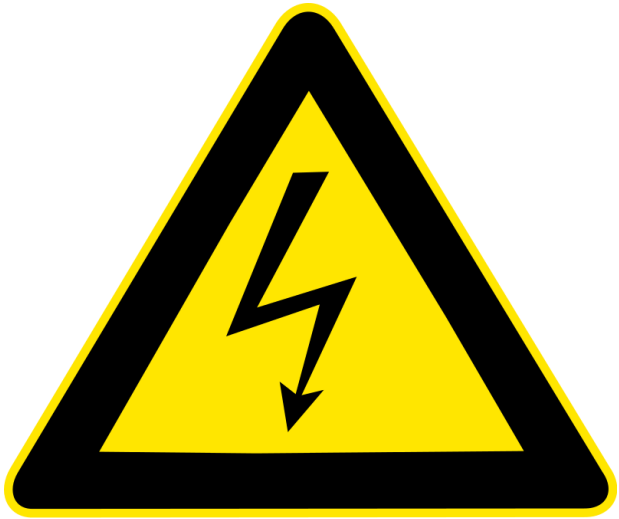
THE INTERNATIONAL ELECTROTECHNICAL COMMISSION DEFINE HIGH VOLTAGE AS

a) **30VAC / 60VDC**
b) **50VAC / 120 VDC**
c) **1000VAC / 1500VDC**

HIGH VOLTAGE ACCORDING TO IEC

IEC voltage range	AC RMS voltage (V)	DC voltage (V)	Defining risk
High voltage	> 1 000	> 1 500	Electrical arcing
Low voltage	50 to 1 000	120 to 1 500	Electrical shock
Extra-low voltage	< 50	< 120	Low risk

In automotive engineering, high voltage is defined as voltage in range 30 to 1000 VAC or 60 to 1500 VDC



CHALLENGES DUE TO THE HV TECHNOLOGY

- Special High Voltage training required

Purpose	General repair (Maintenance and repair excluding high voltage electrical systems)	Working on high voltage electrical systems (de-energised)	Working on high voltage electrical systems (life working)
Example	• Test driver • Bodywork • Oil, wheel change	• Disconnect HV power • Secure against restoration of HV power • Verify zero potential on all HV components • Exchange of HV Components (de-energized)	• Troubleshooting • Exchange HV System under voltage (or near any component under voltage)
Training	• Level 1	• Level 2	• Level 3

DGUV Information 200-005 - Qualifizierung für Arbeiten an Fahrzeugen mit Hochvoltsystemen (bisher: BGI/GUV-I 8686)

WHY VETTEL IS JUMPING?

a) He is happy to win the Russian circuit

b) He is unhappy due to the incident

c) His car is electrical unsafe

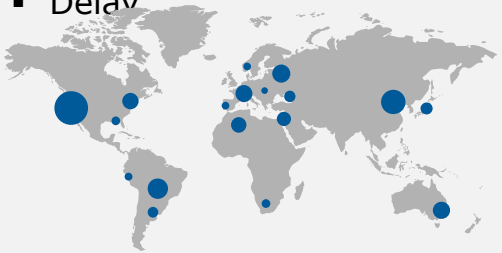
Workshop Repair process of EVs

From exchange to repair of the traction battery

LOCATION OF REPAIR WORKSHOPS

Centralized

- Few repair centers
- Highly sophisticated process
- Delay



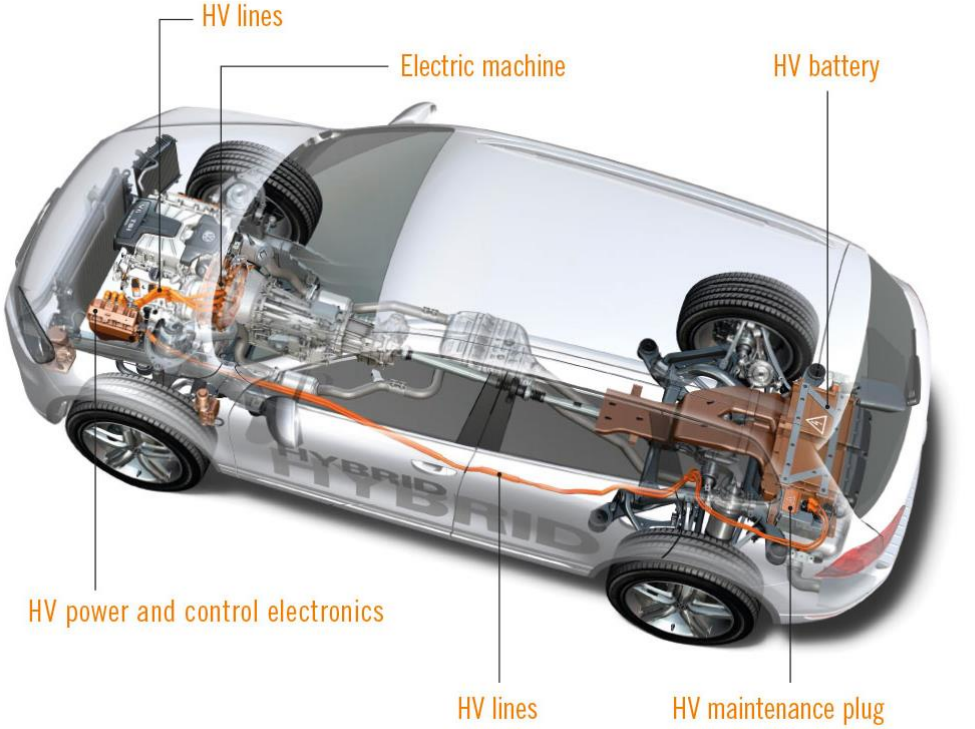
Decentralized

- Each authorized repair shop
- Simple process
- Fast

Free market

- Independent workshops
- Uncontrolled by OEM
- Training required

FAILURES IN A HIGH VOLTAGE POWERTRAIN



Source Volkswagen AG

- E-Motor
- Inverter
- Charger
- Cable
- Auxiliaries
- Battery

DIAGNOSTIC IS NOT ALWAYS ENOUGH MEASUREMENTS ARE ALSO NEEDED

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We get from diagnostic	**We do NOT get from diagnostic**
Suspect cell or module	Exact failure mode
Sensor	Sensor or electronic
Electronic	Electronic or supply
Connector	Connector or cable
Isolation failure	Exact position of isolation failure
Battery End-of-Life	Battery fit for 2nd life

REPAIR OF THE TRACTION BATTERY
WHAT CAN BE DEFECTIVE IN A BATTERY

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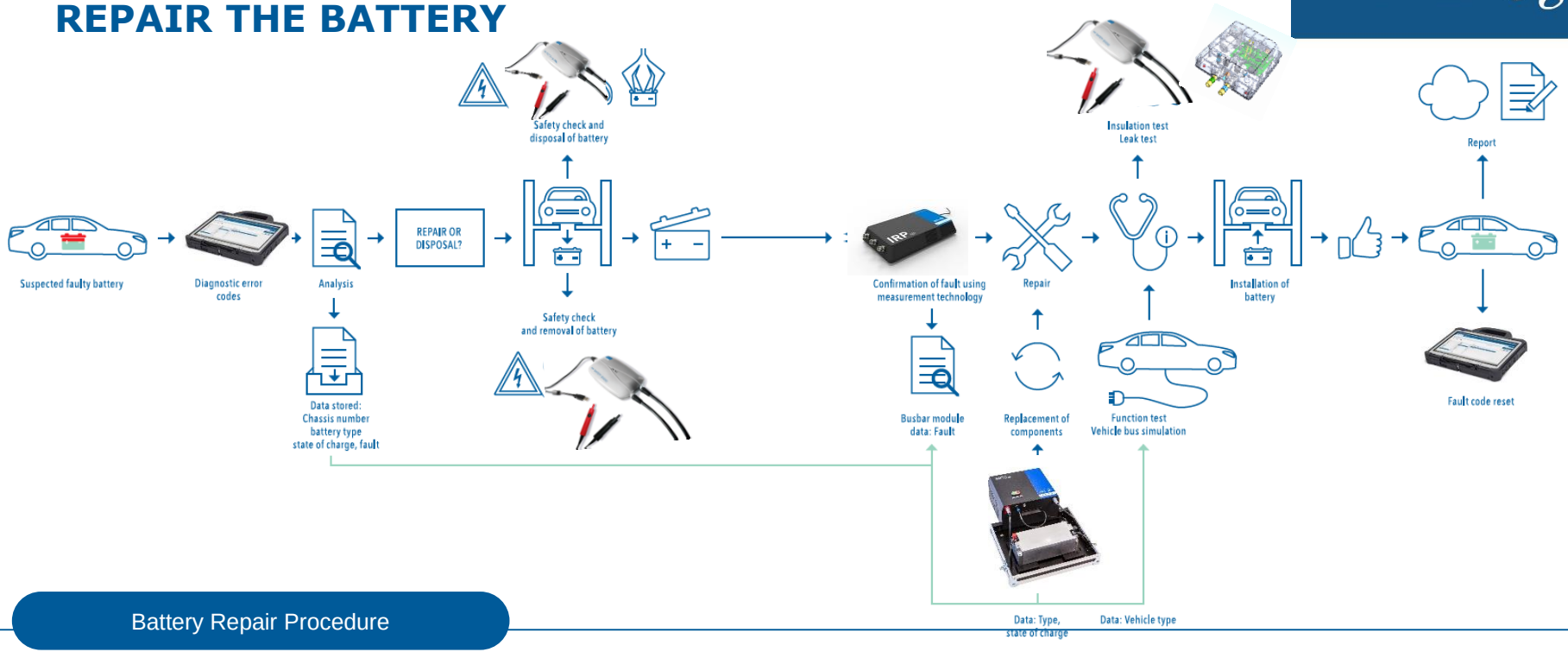
Which parts are likely to get a defect in real life (empirical)

- Cells / Modules
- Cooling system
- Isolation
- Cables
- Connectors
- Electronics
- Sensors
- Contactors
- Fuse
- Housing
- Sealing
- Membranes

FAILURES IN A HIGH VOLTAGE POWERTRAIN
REPAIR THE BATTERY



Battery Repair Procedure

- Read the diagnostic and follow guided steps
- Prove it is safe to work
- Diagnose battery problem
- Dismount the battery pack
- Open the battery pack
- Find or confirm failure
- Condition new module
- Exchange defective module
- Check equipotential bonding
- Check isolation resistance
- Check the diagnostic and print job protocol

FAILURES IN THE HIGH VOLTAGE POWERTRAIN
EXCHANGE OF A MALFUNCTIONING COMPONENT

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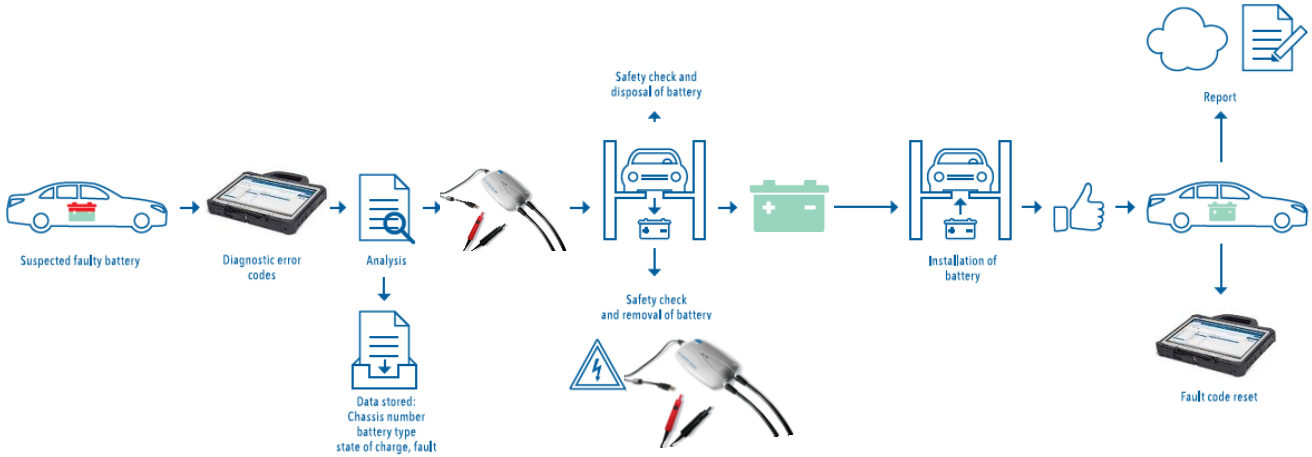
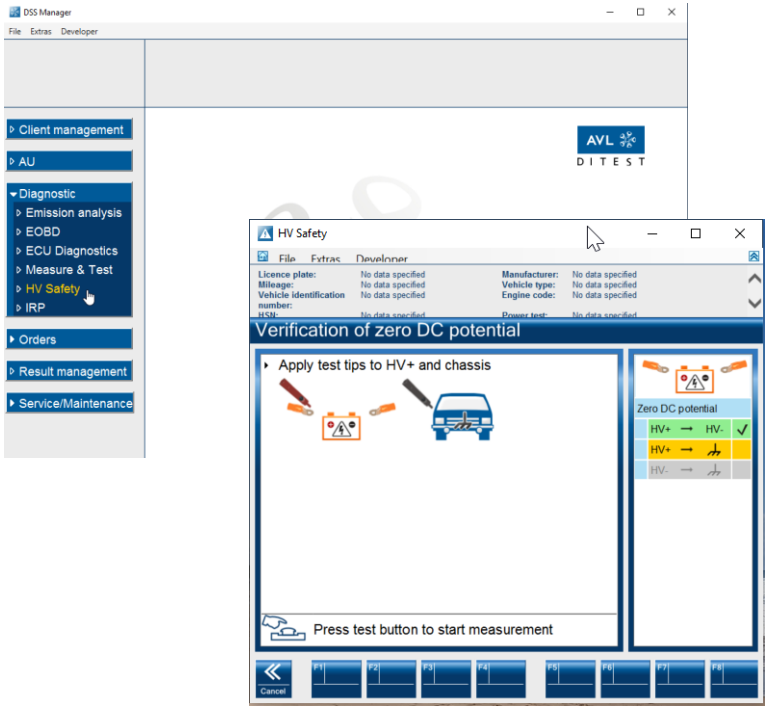


Exchange Procedure

- Read the diagnostic and follow guided steps
- Prove it is safe to work
- Localize the failure component
- Exchange the component
- Check equipotential bonding check and isolation resistance
- Check the diagnostic and print job protocol

GUIDED AND DOCUMENTED

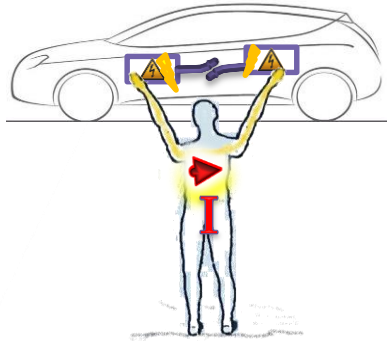


For all repair steps

- Easy to use
- Guided fault diagnosis
- Self-explanatory GUI
- Process protocol
- Authorization levels

WHAT ABOUT HV SAFETY OF THE PROCESS?

Action	Deinstallation of a HV component of the HV battery	Reinstallation of HV battery
Details	• Proof that system is deenergized is needed	• Before reenergizing HV system an isolation resistance check is mandatory (ECE100, SAE J1766) • Equipotential bonding check is needed to prove HV Safety (ECE R100)



SOH Estimation

State of Health estimation in the module level

STATE OF HEALTH

- SOH measurement method has no standard.
- SOH refers to the current state of the battery in comparison to the condition in the beginning of its life.
- Mainly characterized by the loss in capacity and the increase in resistance.

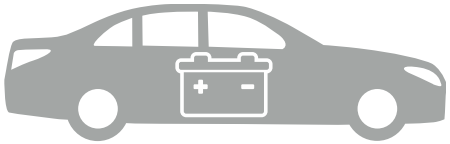
$$SOH = \frac{Current\ actual\ capacity}{Nominal\ capacity}$$

End-of-Life (EOL) conditions could be:
70%-80% of initial capacity
250% of initial resistance

STAKEHOLDERS IN AFTERSALES

STATE OF HEALTH
(remaining life, remaining value, energy throughtput)

- Technical expert (insurance, ÖAMTC ...)
- Vehicle dealer (exchange used vehicles)
- Leasing company (residual value)
- Vehicle manufacturer (warranty costs)
- Workshops (exchange of batteries and repair)
- Disposer (evaluation if 2nd Life is possible in stationary use)



Battery Quality

ANALYZE BATTERY QUALITY METHODS

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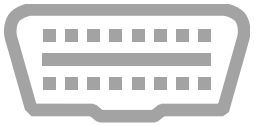
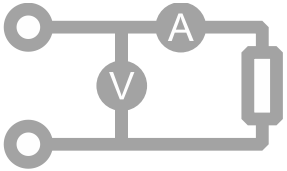
Diagnostic Data
OBD



Driving
GPS, OBD

Battery Quality

Measuring
Testing



Statistic
Big Data

HOW CAN THE SOH OF THE MODULE BE MODELED?

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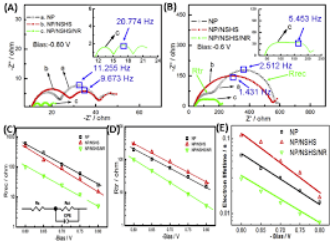
Test Data Amount

Complexity

Direct measurement

- Comparing the begin of life value and the current one
- Example: Internal Resistance and Impedance Measurement Method

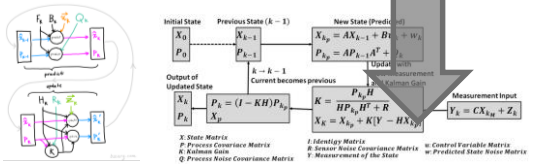


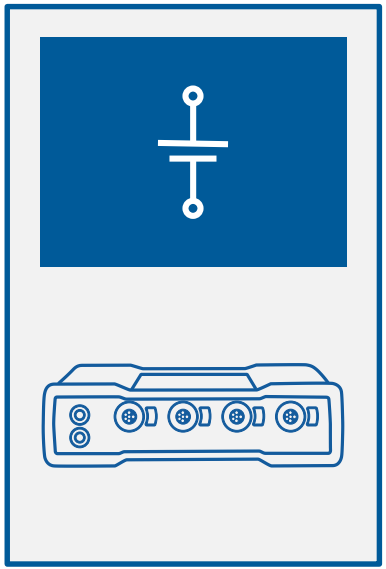
Models based on measurements

- Measure of parameter
- Look at table to define the model
- Example: Gaussian Process Regression, Coulomb Counting Method

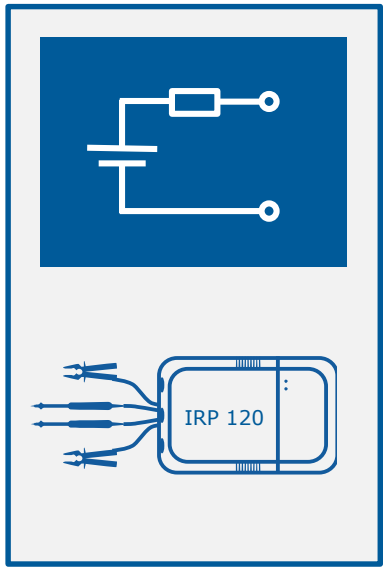
Adaptative methods

- Purely data driven
- Module model required
- Examples: Kalman Filter, Least squares

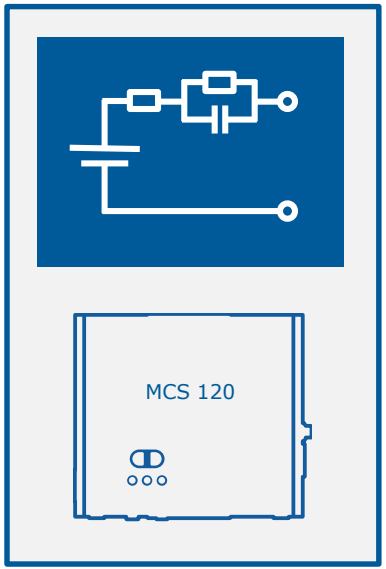




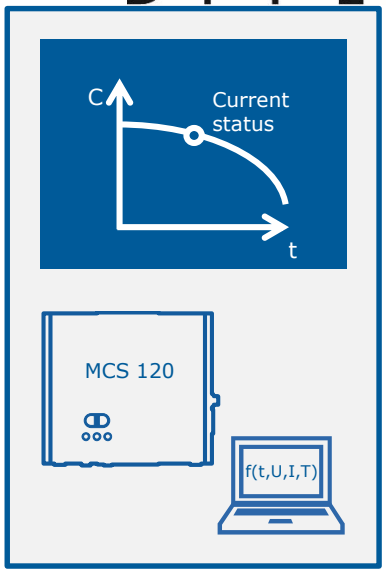
Voltage measurement



Internal resistance measurement



Capacity measurement



Algorithm to evaluate the current status in the life cycle

Battery 2nd Life and Recycling

What is the business behind?

BATTERY 2ND LIVE
PROJECT EXAMPLES AS ENERGY STORAGE

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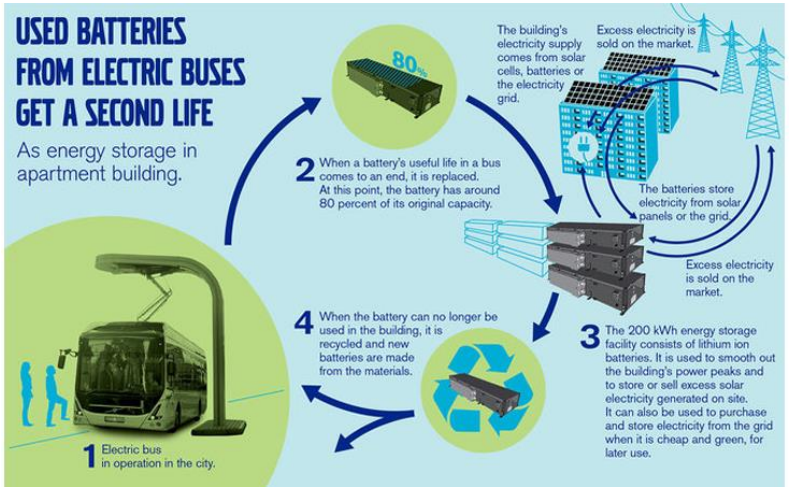
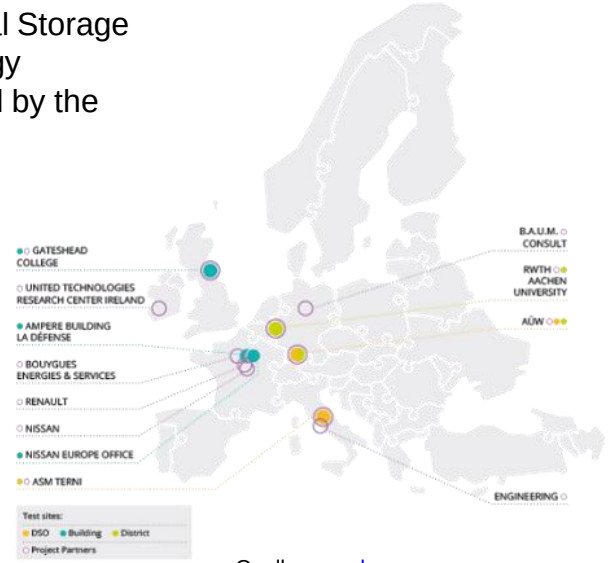


Volvo bus batteries find 2nd life as solar energy storage (Dec. 2018)

Quelle: www.volvobuses.com

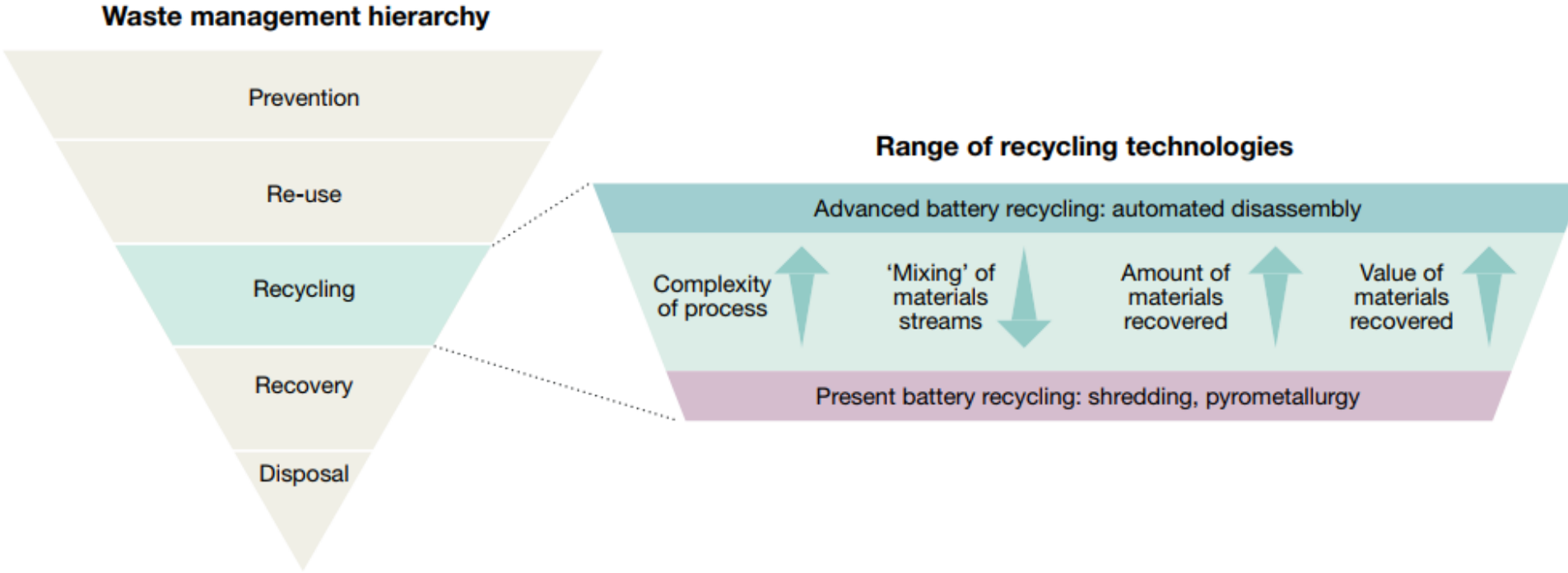
ELSA: STORING LOCAL ENERGY THANKS TO SECOND LIFE BATTERIES
(Nov. 2018)

ELSA (or Energy Local Storage Advanced) is an energy storage project funded by the European Union (EU)



Quelle: www.bouygues-es.com

BATTERY LIFETIME MANAGMENT



Source: Recycling lithium-ion batteries from electric, Nature, Vol 575

vehicles

E-Mobility Aftersales Outlook

E-MOBILITY AFTERSALES OUTLOOK & TRENDS

- Design for 2nd Life and Recycle needed to optimize the battery usage through the total lifecycle
- Decentralized repair strategies on module level reduces TCO
- SOH estimation within short time is required for second hand marked
- Alternative solutions for SOH estimation are still under consideration
- Trend is to track the entire life cycle information of the battery (on pack and module level)

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