TÜV SÜD E-Mobility

Battery Safety
& 2nd Life of Battery Systems

2019 June 20, TAI Automotive Summit, BITEC

Volker Blandow
Global Head of e-Mobility, TÜV SÜD China Holding

Mehr Wert.
Mehr Vertrauen.

Add value.
Inspire trust.

Testing Services for Electrical Energy Storage Systems

TÜV SÜD Mission statement

Since 150 years TÜV SÜD stays true to its founding principles of protecting people, environment and property against the adverse effects of technology.

24.000+ Employees

2,4 Billion Revenue

57 Countries

1000+ Locations

TÜV SÜD e-Mobility Services

Testing/Certification
Charging Equipment

Battery Safety; Battery Testing

Type Approval for
Hydrogen Filling Stations,
Fuel Cell Testing

Pedelec/ e-bike Testing and Certification

Type Approval, Vehicle Safety,
Functional Safety, EMC-testing

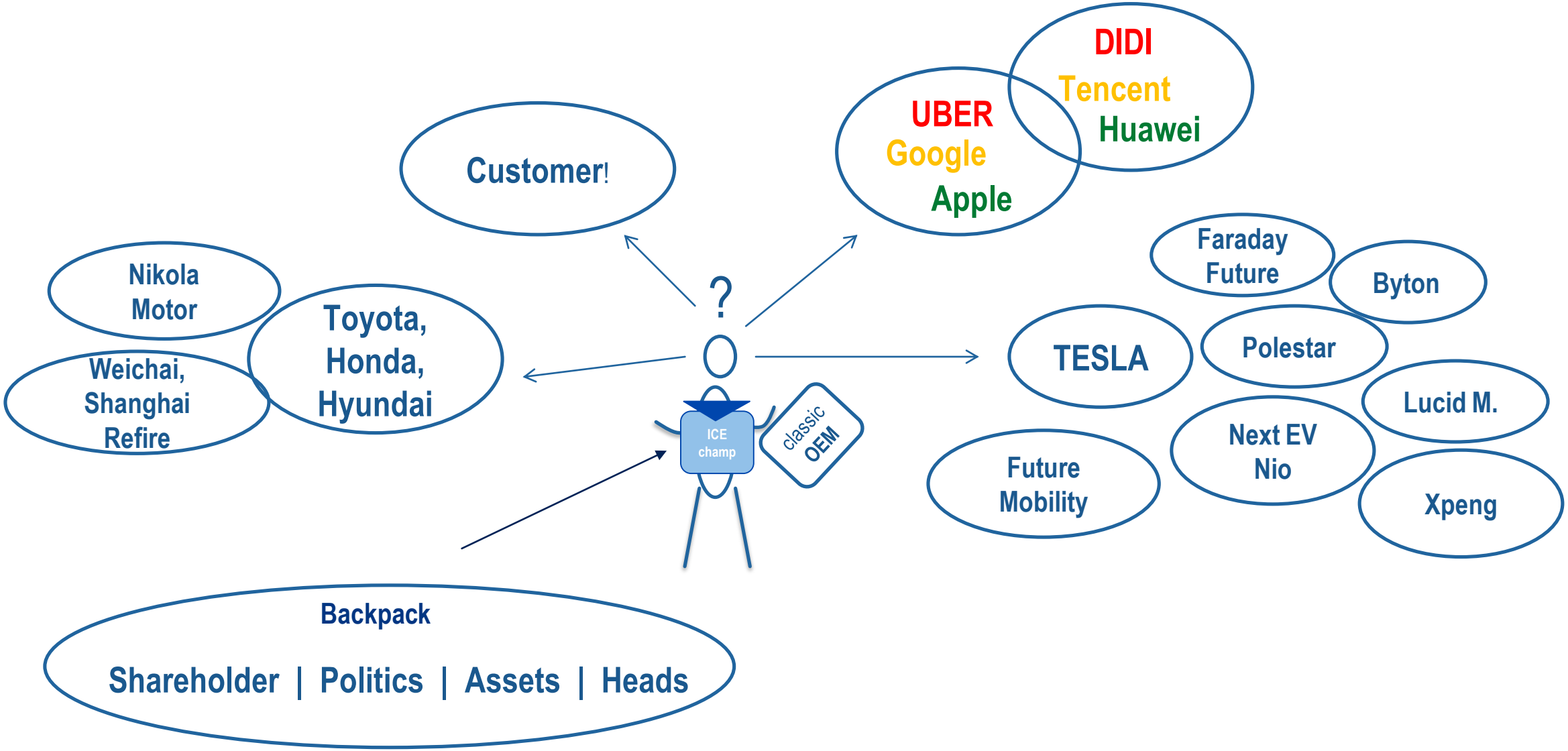
Fleet Management,
Carbon-Footprint, Periodic Inspection

High Voltage/ Battery Saftety Trainings

New to come – the largest and most complete battery testlab in the ASEAN region

Thai Automotive Institute and TÜV SÜD

Global automotive challenge – new players, new technologies, new services – the perfect storm!



The global automotive challenge:

1.3 Billion vehicles are on the road globally

89 Million will be produced in 2018

this leads to additional

100 Million **vehicles every 3 years**

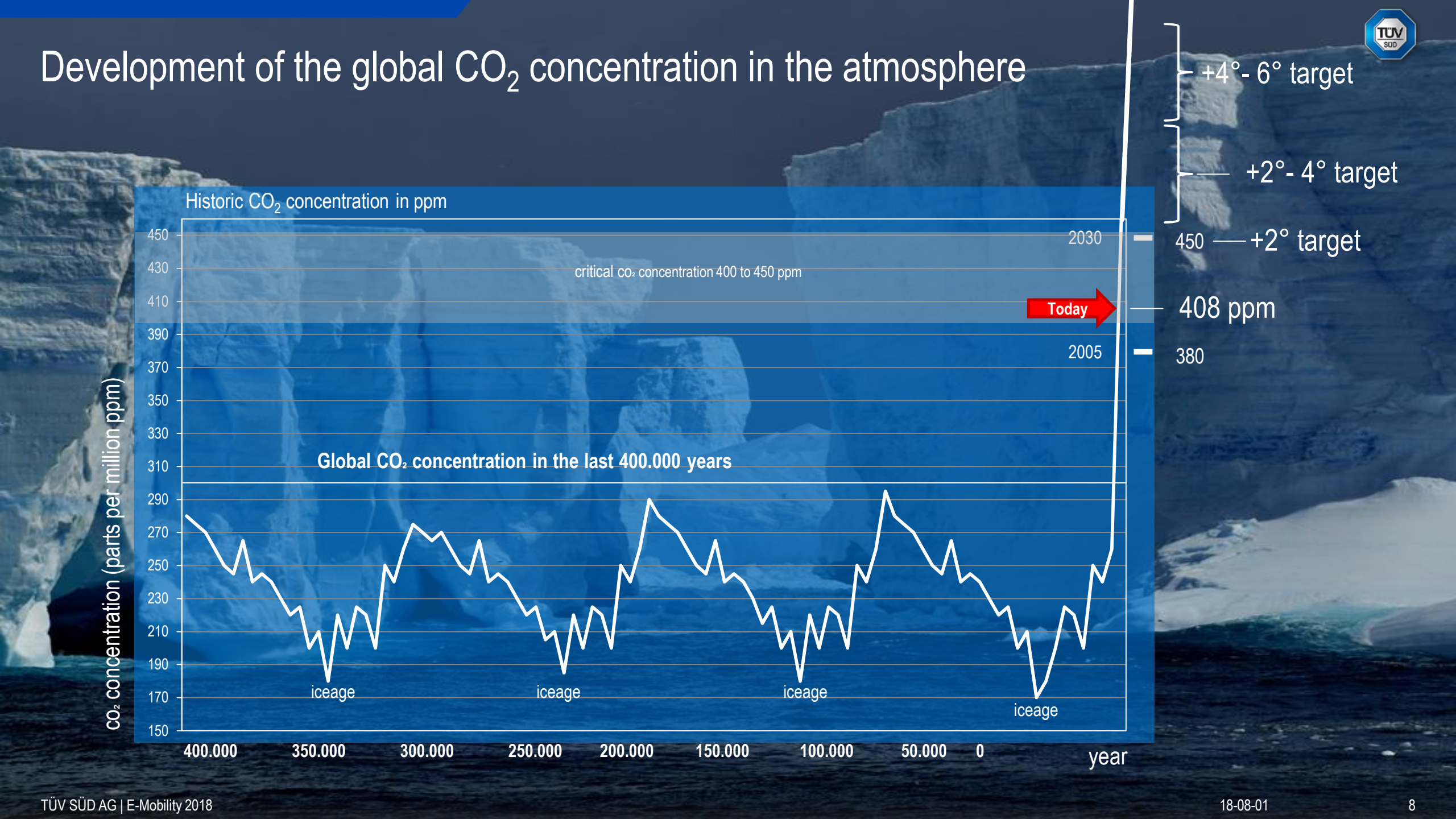
The global automotive challenge:

@ current growth rate we end up @ **2,4-2,9 Billion** vehicles in 2050 !

(@ 10 Billion people in 2050 on our planet)

current transport emission reduction schemes are **only** looking
@ fleet emissions, **not** reflecting the total fleet growth!

Development of the global CO_2 concentration in the atmosphere



Why Thailand should seriously move towards e-Mobility!

- **Reduce foreign energy dependency** / money drain out of Thailand
- **Benefit the people** (economically, polution, noise)
- **Stimulate Thai industries** – get more independent, head for state of the art
- **Create more local content in the vehicle market!**
- **Even established players in the US, EU and Japan not yet have mature products** – but they head (again!) towards leadership!
- **Create energy jobs in Thailand!** REN Energy potential is huge!
- **Contribute to global greenhouse gas reduction**

New dynamic encounters

The German postal service became a vehicle manufacturer!

Why e-Mobility also makes sense for „ordinary“ people in Thailand?

+

@ PV 1.5 kWp (12-14 sqm)

Invest: 2500 US$

= 10,000 km/a

@ **no** fuel cost for 25 years!

Why e-Mobility also makes sense for „ordinary“ people in Thailand?

+

@ PV 1.0 kWp (7-8 sqm)

One time invest: 1400 US$

= 2 x 20,000 km/a

@ **no** fuel cost for 25 years!

Let‘s take a look @ Thailand on a macro economic level

Today Thailand has to spend about **26 Billion US$** for oil imports

The total „economic value“ of Thai oil production + oil imports are **58 Billion US$** (total annual consumption)

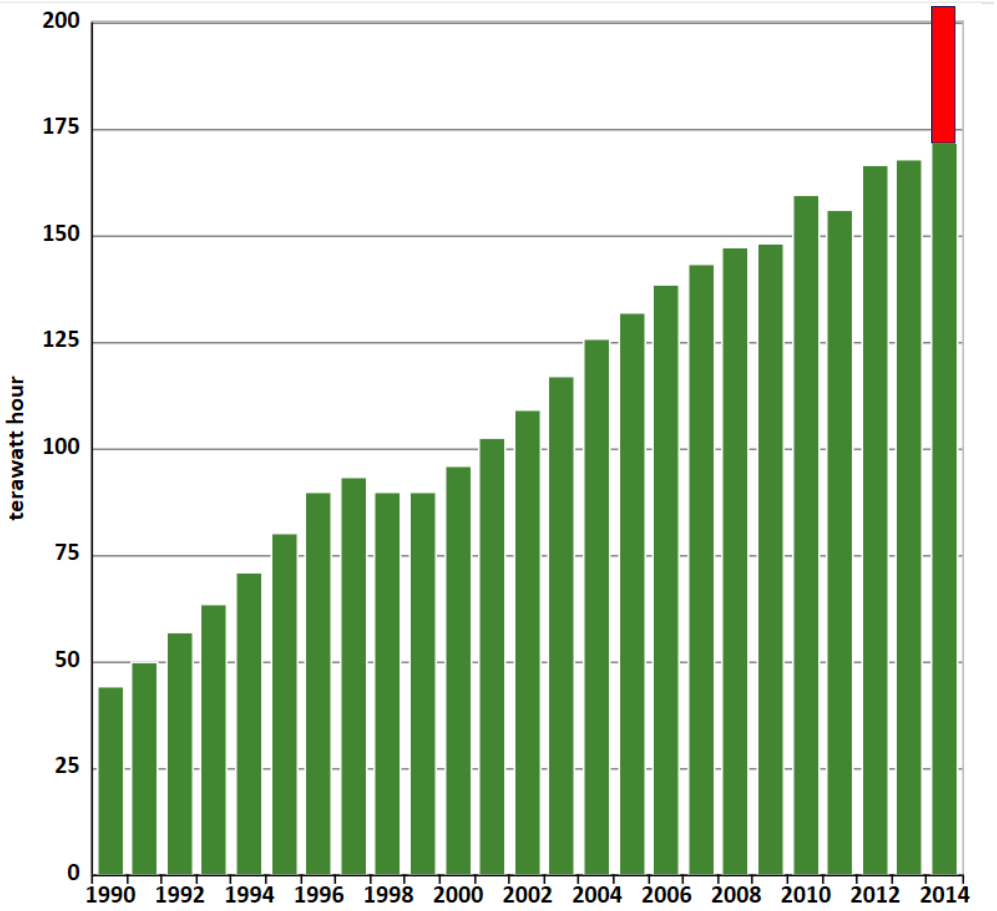
How much investment is needed to cover 100% of Thailands transport by Solar-Electricity? **48 Billion US$!**

This 48 Billion US$ Investment suppliesThailand for at least **25 years** with **cost free GASOLINE!**

PLUS: Thailand can sell the remaining 1 MBD on the oil market and can create an annual income of **32 Billion US$**

That creates financial „space“ to provide subsidies for the purchese of EV and Electric Scooter!

Electric energy needed for a 100% electrified Thailand:



No. of **cars/trucks** by end 2018:

Roughly **16 Mio**

Travel km/a **14,000**

Require **31,5 TWh**

of additional power!

What motivates governments to push for EV markets?

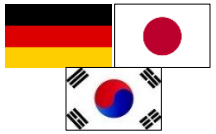
Climate change, local pollution / air quality in cities

Local pollution / air quality in cities

Global technology domination in electric vehicles (NEV)

(PV & REES & EV Batteries & EV & Charging Equipment)

(In) dependence on oil) imports, India spends 80+ Billion US$ on oil imports anually - own production is in decline – demand is still growing!



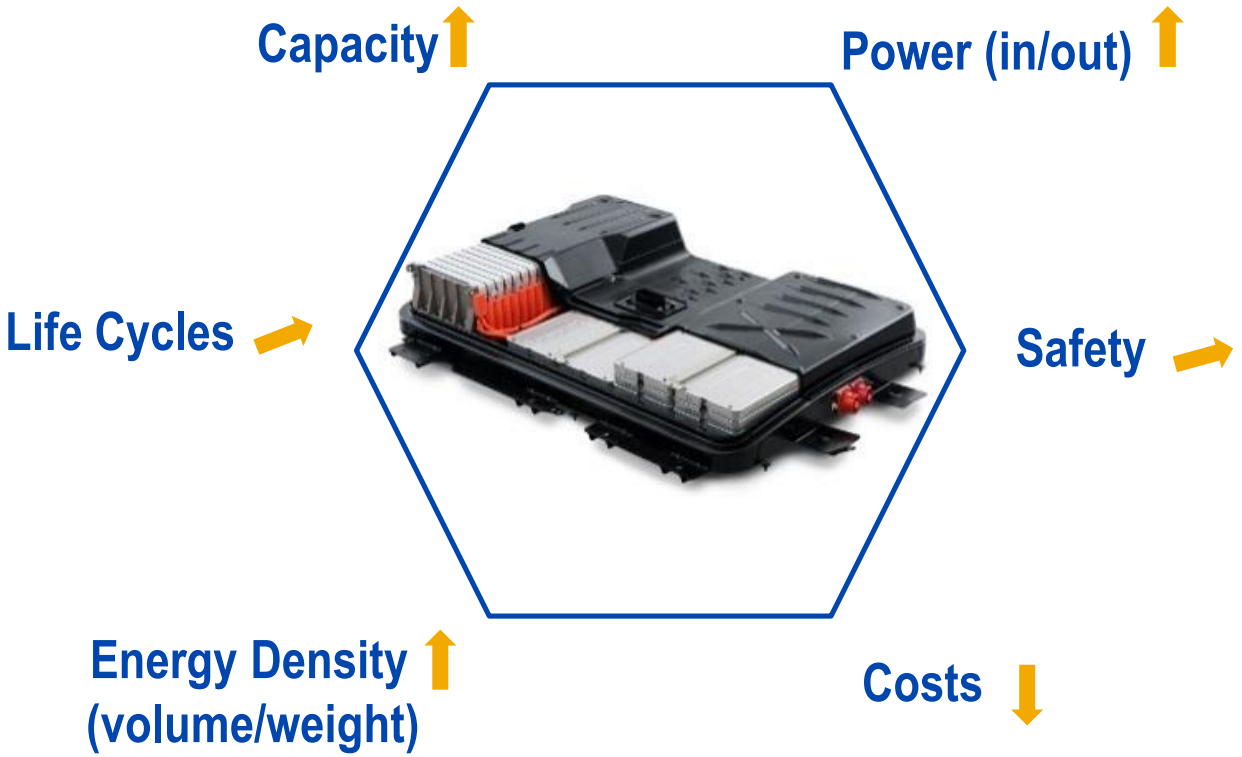
New radical players challenge the establishment - defend global market share! **Survive!**

Impact of E-Mobility on the labour market!

E-Motor: Maintenance free, oil free, no moving parts, minimum 10 Years, 95% efficiency!

Source: E-Force One AG

The battery challenge: Six characteristics equilibrium



Typical range expectation: 300-500 km … leads to battery capacities of 45–100 kWh!

Know your risks

- **Identify** the safety level of your cells, modules and battery packs
- **Optimize** safety level and performance of your battery system
- **TÜV SÜD** supports from the early development phase towards certification and product evolution

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

source: mydailynews.com

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

Crash in an accident
How much can the battery be deformed?

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

Crash in an accident
How much can the battery be deformed?

Mechanical shock
Does anything get lose?

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

Crash in an accident
How much can the battery be deformed?

Mechanical shock
Does anything get lose?

Vibration
Does driving influence the battery safety?

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

Crash in an accident
How much can the battery be deformed?

Mechanical shock
Does anything get lose?

Vibration
Does driving influence the battery safety?

source: NTSB

Propagation
If a cell reacts, does it spread to other cells?

Uncover the blind spot

Environmental influences
How does the battery react to temperature & humidity?

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

Environmental influences
How does the battery react to temperature & humidity?

High temperature
How does a defect cooling affect the battery?

Immersion/Leakage
What does water in the battery generate?

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

Environmental influences
How does the battery react to temperature & humidity?

High temperature
How does a defect cooling affect the battery?

Immersion/Leakage
What does water in the battery generate?

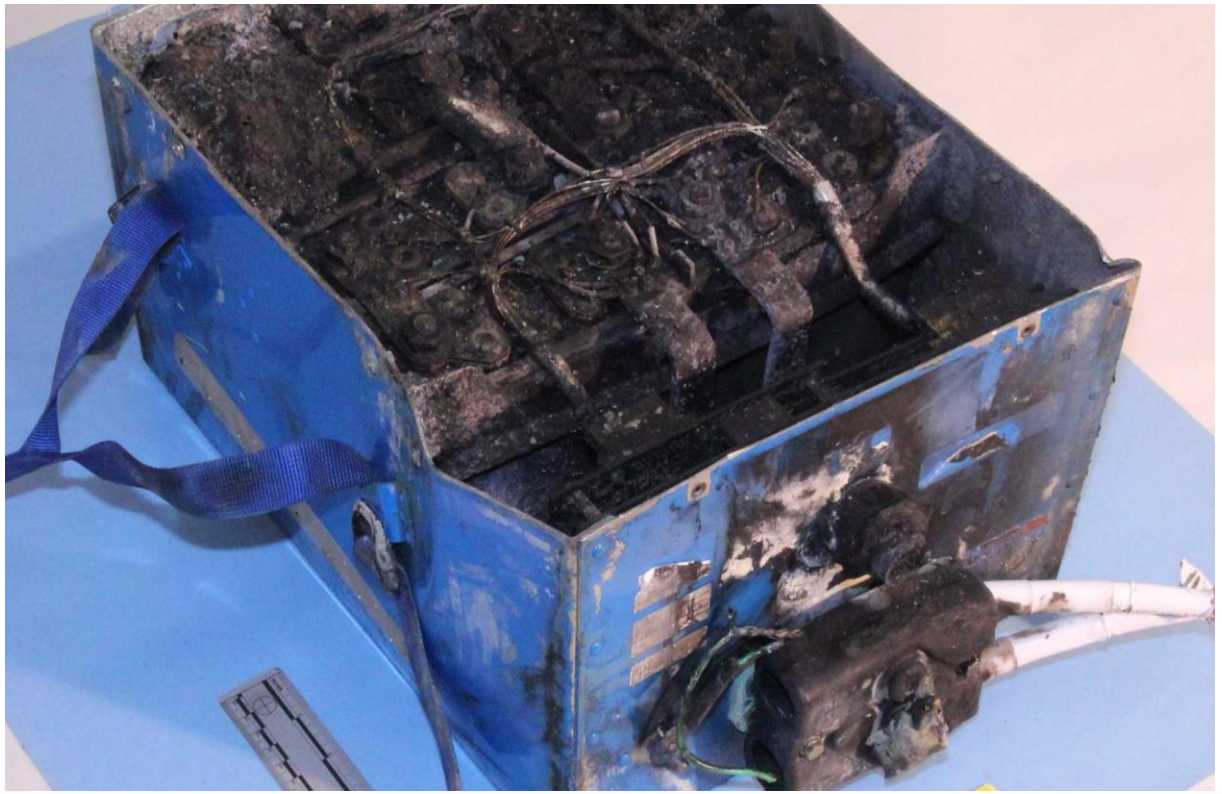
Management failure
Has a defect of the controller a negative effect?

Uncover the blind spot

Penetration of the battery
What happens if a metal intrudes the battery?

Environmental influences
How does the battery react to temperature & humidity?

High temperature
How does a defect cooling affect the battery?

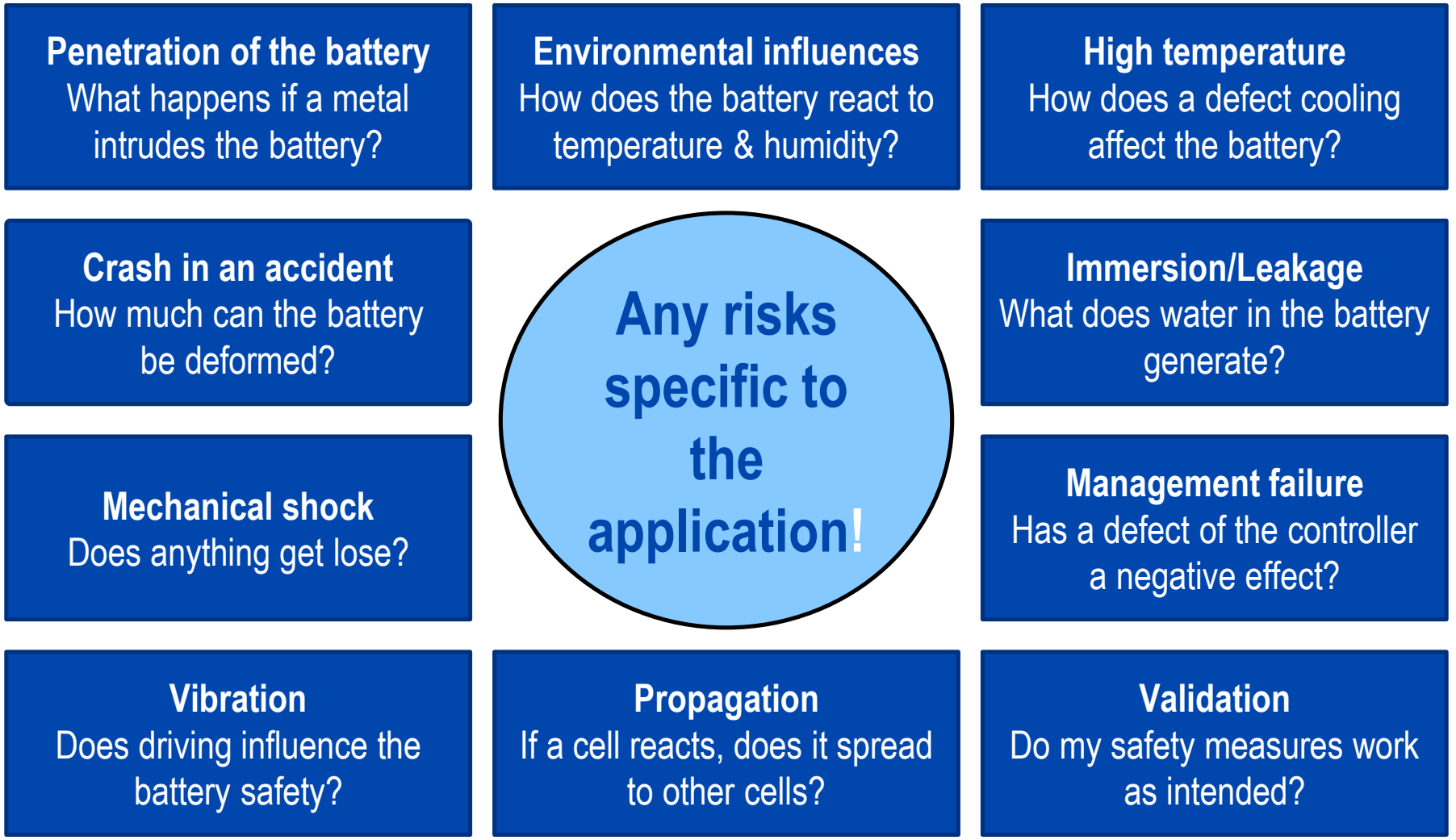


Immersion/Leakage
What does water in the battery generate?

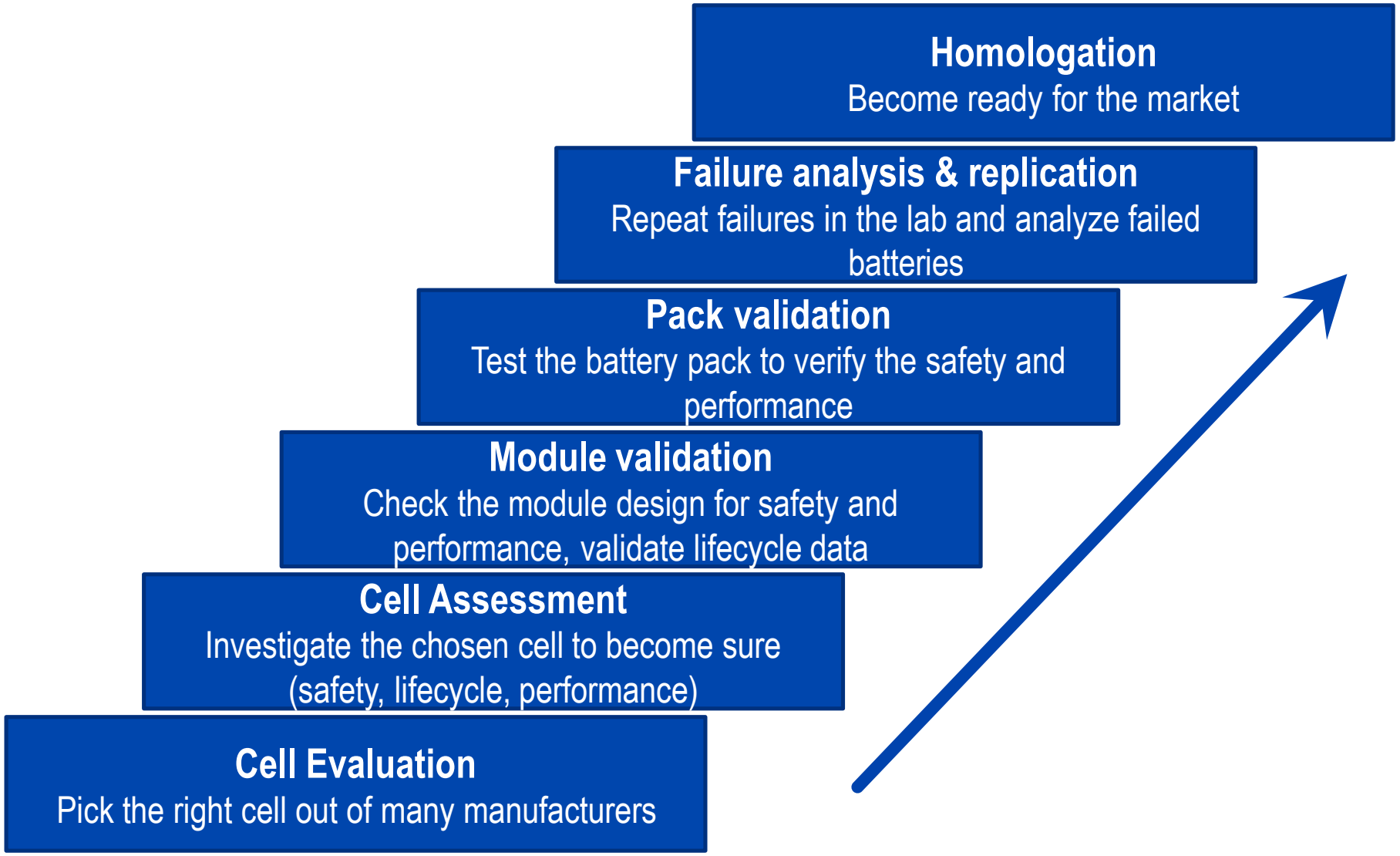
Management failure
Has a defect of the controller a negative effect?

Validation
Do my safety measures work as intended?

Uncover the blind spot



Different steps that lead to high performing and safe EV batteries!



Battery homologation / certification and how to create a safe battery!

Regulations
(e.g. R100 type approval)

Industry standards
(e.g. national automotive standards like VDA)

Vehicle manufacturer standards
&
Product Liability
&
Quality Management

Image: Porsche AG

Custom tailored testing requirements
e.g. based on Thai/ ASEAN road conditions!

Cell Evaluation

Tests to be performed

- Initial safety assessment
- Initial performance assessment
- Comparison between several suppliers or cell types
- Looking for potential weak points

Motivation for tests

- Selection of suitable cell
- Selection of right supplier
- Minimize the initial risk

Cell Assessment

Tests to be performed

- In depth safety assessment
- Performance assessment
- Lifetime assessment
- Data collection for simulation and BMS parametrization
- Thermal behavior of cell

Motivation for tests

- Knowledge about lifetime and safety
- Gaining trust in next development steps
- Speed up development with measurement data

Module Validation

Tests to be performed

- Safety assessment of module
- Performance assessment
- Lifetime validation
- Examination of mechanical and thermal aspects

Motivation for tests

- First insight into behavior of pack/ system
- Validation of safety, lifetime and performance expectations
- Thermal design of pack/system

Pack Validation

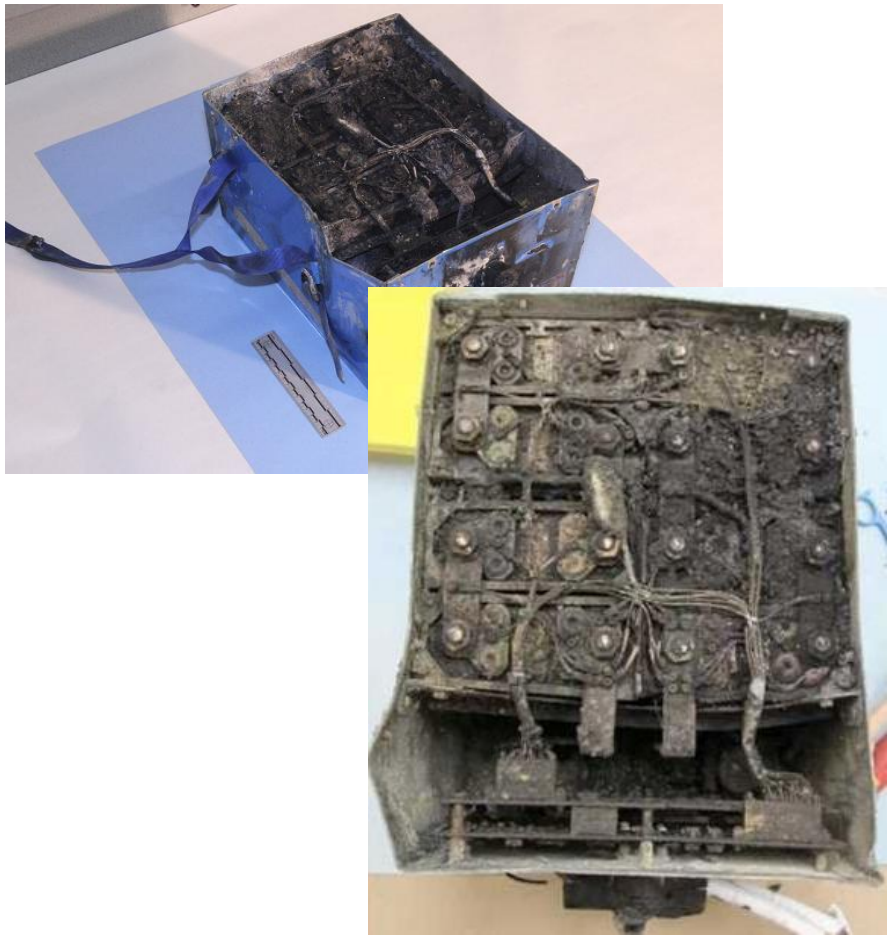
Tests to be performed

- Safety assessment
- Performance assessment
- Examination of mechanical and thermal aspects
- Environmental assessment

Motivation for tests

- Validation of protection toward environment
- Validation of safety and performance
- Thermal validation

Failure Analysis



Tests to be performed

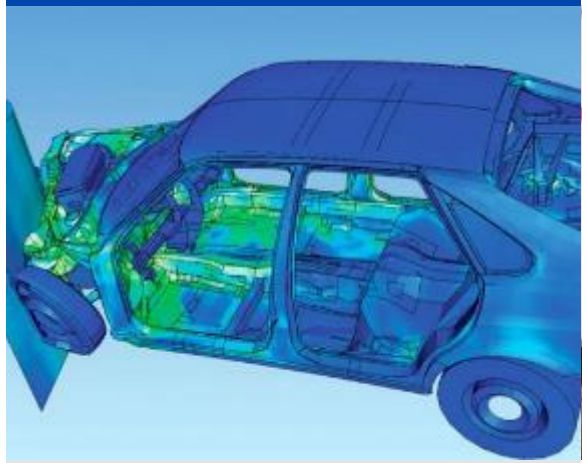
- Potential failure modes
- Expected mishandling of battery
- Root cause examination (slow speed test repetition)

Motivation for tests

- Validation of safety concept
- Finetuning of design
- Learning for the future

Examples of failure replication tests

Data collection for simulation



- Evaluation of mechanical strength and deformation for crash simulation
- Resonance investigation during vibration
- Thermal property assessment

Validation of safety measures

- Validation of trigger levels of BMS or fuses
- Check of shutdown mechanisms
- Evaluation of containment of thermal events

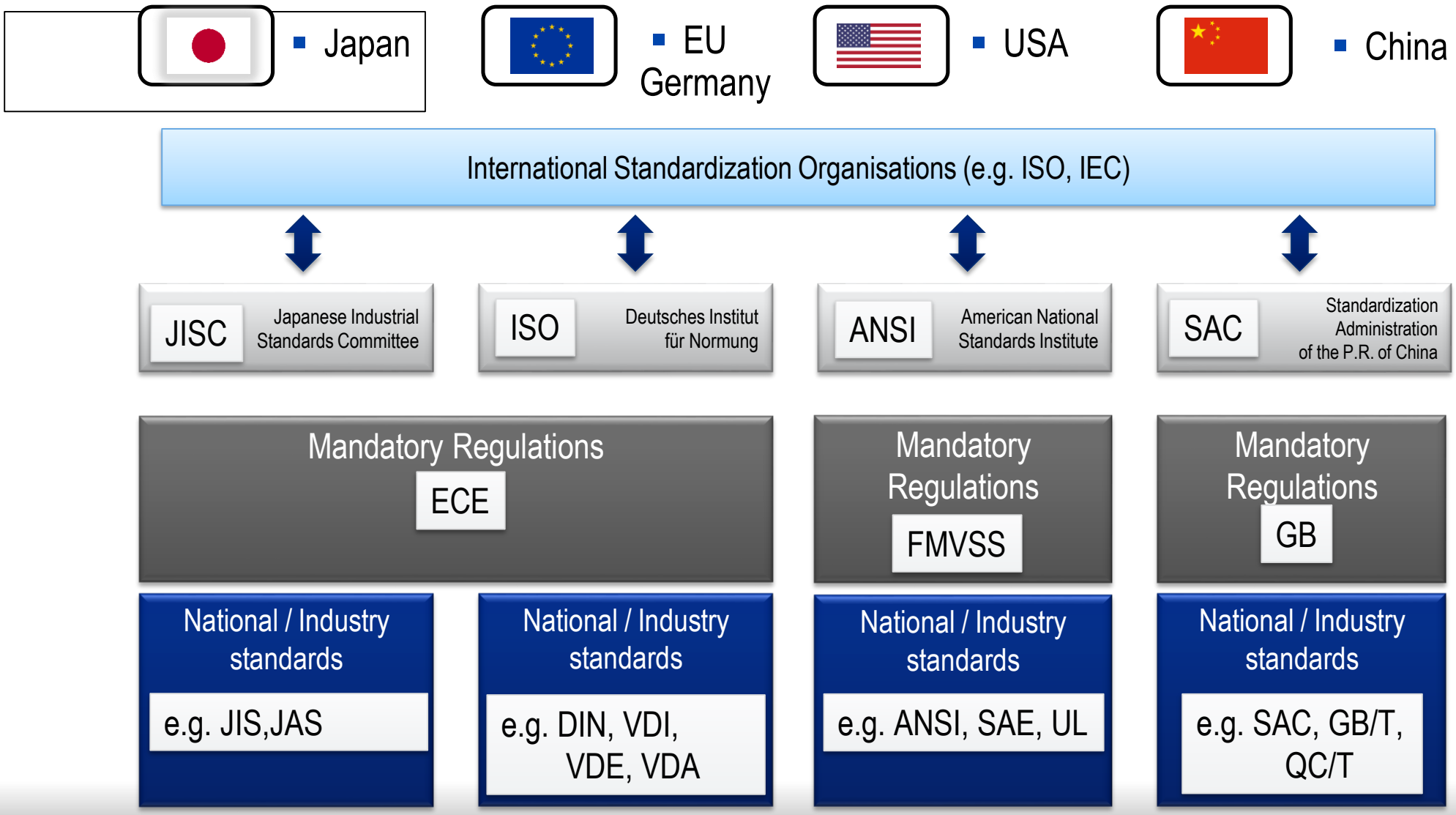
Reproduction of failures

- Bring the failures from the outside in the controlled atmosphere of the lab and examine step by step

Analysis of failures

- See the worst possible result
- Freeze reactions during the test and investigate the initiation reasons

Sources for validation standards & regulations for xEVs



China: Overview of new GB standard scheme

Electric vehicle standards system

Electric vehicle

Component

Charging system interface

Electric motor

Battery/Battery system

Electric control system

Ancillary apparatus

Battery cell & module
GB/T 31484
GB/T 31485
GB/T 31486

Battery/Battery system
GB/T 31467.1
GB/T31467.2
GB/T31467.3

Mandatory!

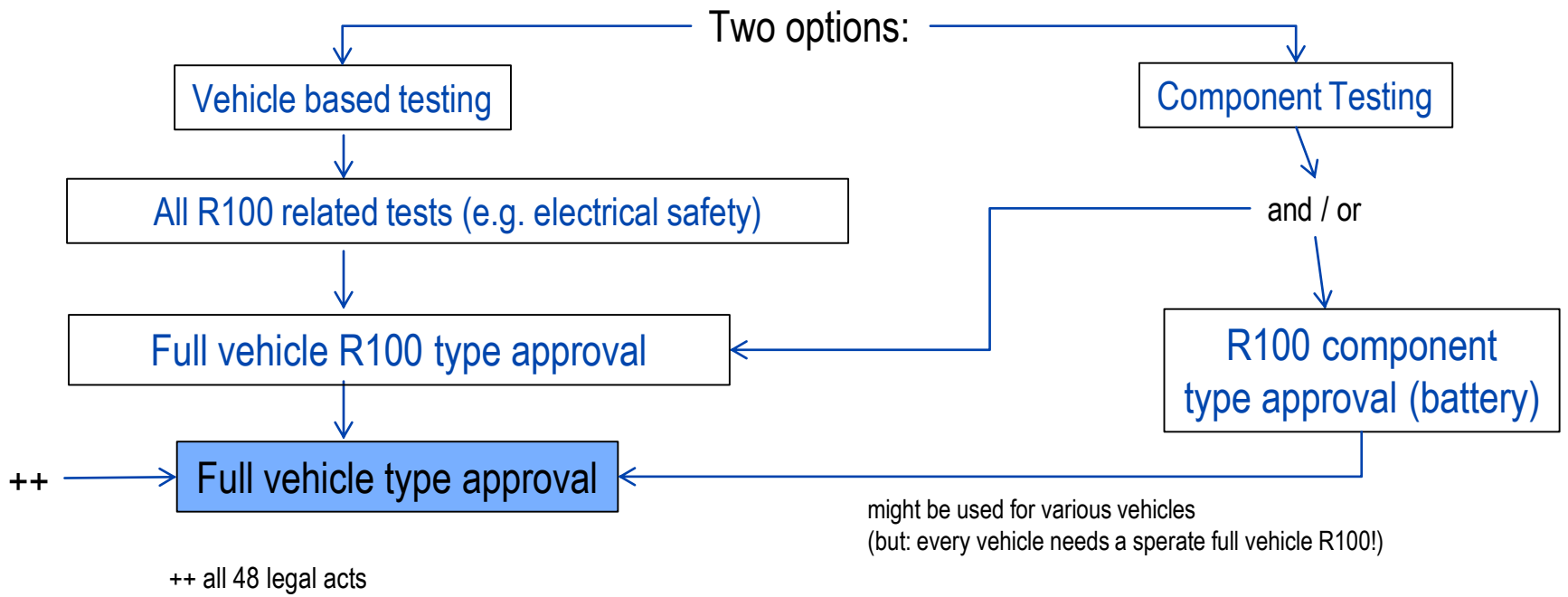
Voluntary!

But exceptions!

UN ECE Homologation R100

New EV, PHEV or FCEV

Need:	Full vehicle type approval
Focus:	UN ECE R100 / Rev. 2 (mandatory July 2016)



Homologation

UNECE R100	
Mechanical shock	**Very high risk for <u>expensive</u> test equipment! (Crash facility / large Shaker)**
Vibration test	
Thermal shock cycling	**Fire protected chamber necessary!**
External short circuit	**Test should be performed in dedicated safety area**
Overcharge protection	
Over-discharge protection	
Over-temperature protection	
Mechanical integrity (crush test)	
Fire resistance (fuel fire test)	**High temperatures & Hazardous gases**

- Necessary to pass the tests and get an homologation by a registered technical service (e.g. TÜV SÜD) for access to UNECE area with >50 countries
- For access to countries like US / Canada and China TÜV SÜD can assist as well

TÜV SÜD is a experienced partner in EV testing and certification

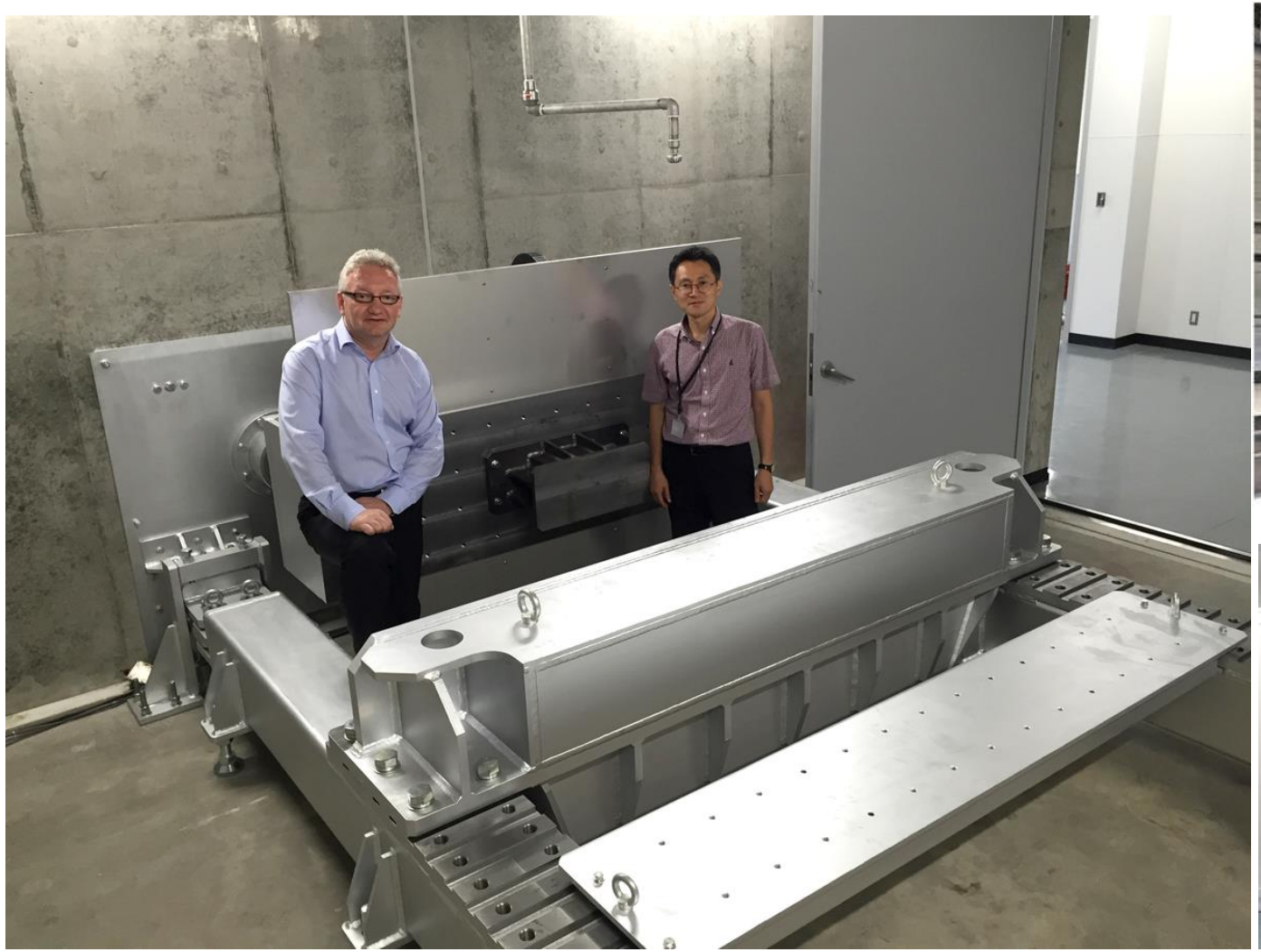
- TÜV SÜD soon operates **9 EV battery labs globbaly**, 6 opearable, 3 labs are under construction, 2 more in planning stage
- TÜV SÜD started EV battery system testing 12 years ago (>6000 EV batteries tested so far)
- More than 50 UN ECE R100 rev2 certifications
- TÜV SÜD has a global network of experts (> 100 staff in battery testing)
- TÜV SÜD has a global customer base (EU, USA, Japan, Korea, China)

Expertise sharing is a key success factor for our labs!

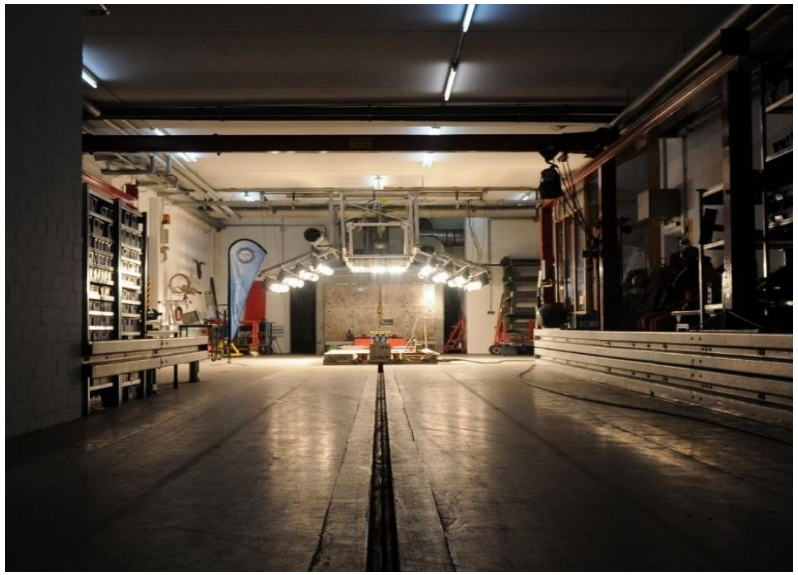
Toronto, Canada Auburn Hills, USA	Garching, Germany	Shenzhen, China	Singapore	Suwon, Korea	Utsunomiya, Japan
Complete service portfolio for cell, module and system testing	Complete service portfolio for cell, module and system testing	Performance, environmental and abuse testing on cell and module level – system level in 2018	Performance and environmental testing on cell, module and small system level	Performance testing on cell, module and system level, Abuse test on cell level	Abuse and environmental test on cell, module and system level

TÜV SÜD EV Battery Testing

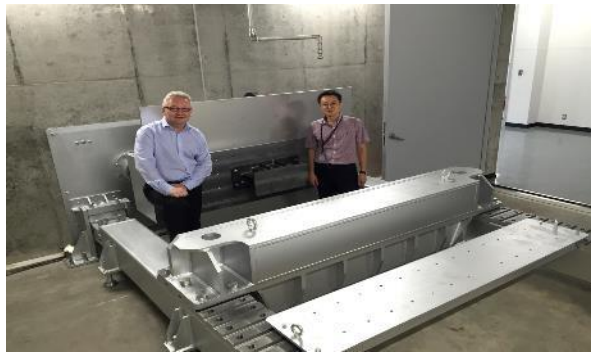
TÜV SÜD EV Battery Testing



TÜV SÜD EV Battery Testing – Mechanical Shock Test Facility



Global Network of TÜV SÜD EV Battery Service Labs



Utsunomiya, Japan / Shenzhen, China

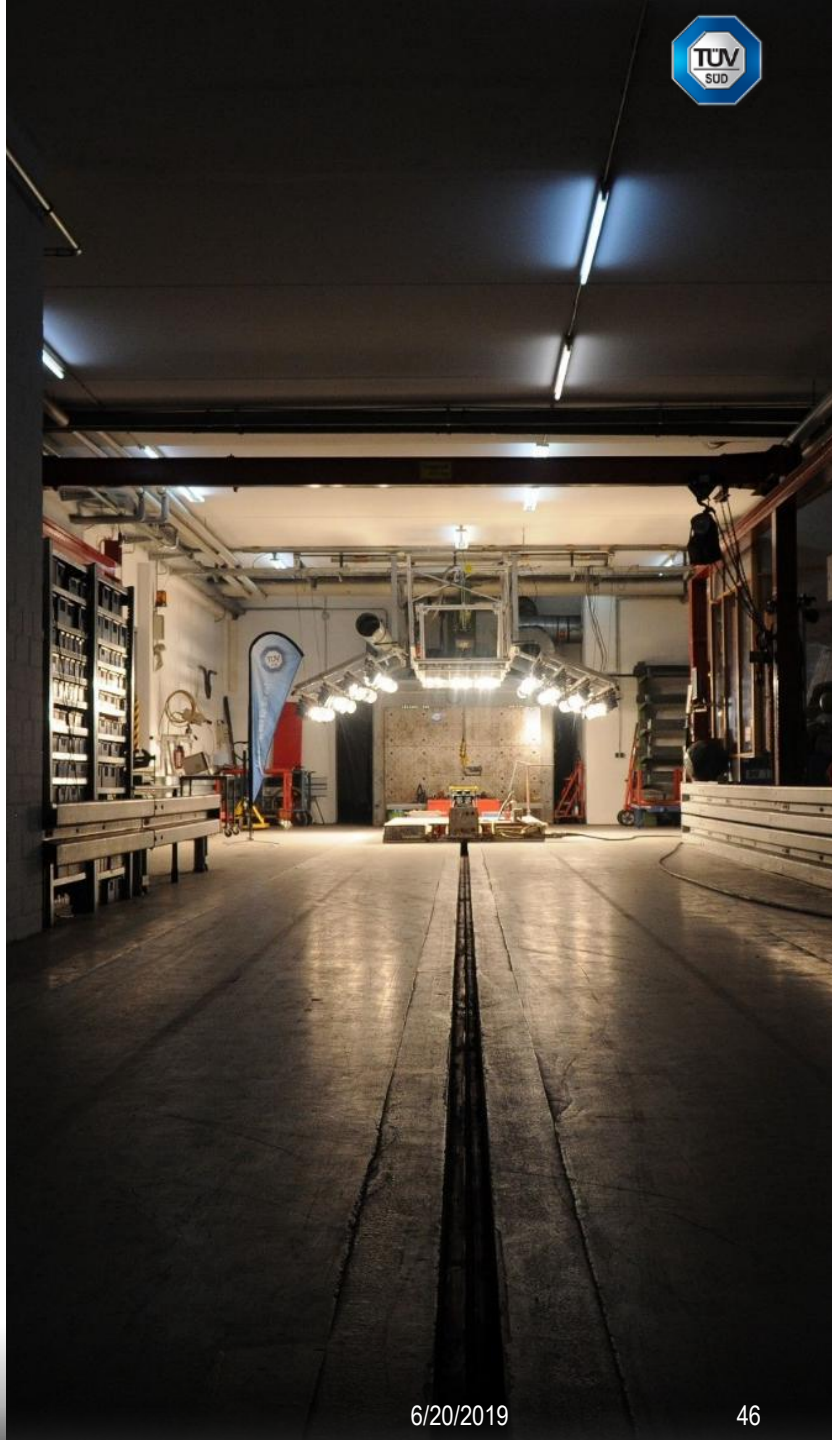
New Market, Toronto, Canada

Auburn Hills, Michigan, USA

Battery Testing goes beyond safety testing

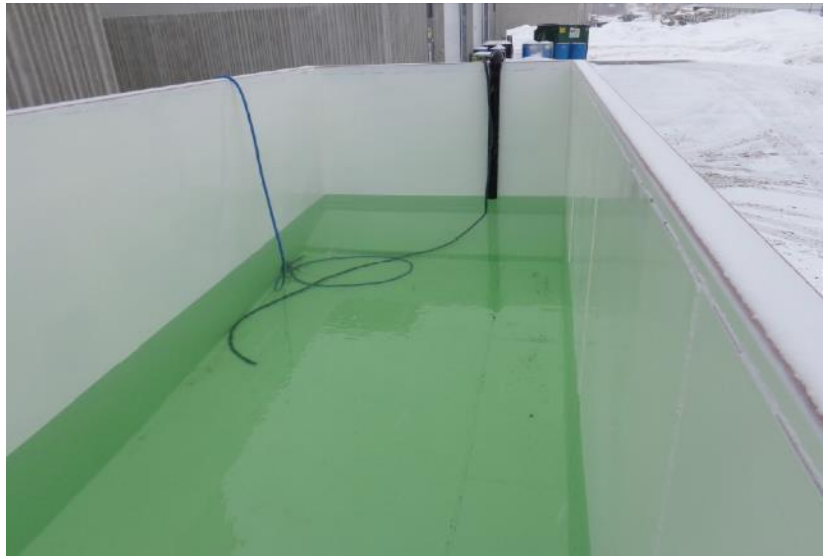
TÜV SÜD performed already many other services around testing the batteries:

- **Gas analysis** to investigate emissions during testing
- **Dynamic Shock Testing** of the battery with the car frame
- **EMC Testing** during cycling
- **Functional Safety and Certification** of the electronic components
- **Cyber-Security & Interoperability** with all the equipment around the battery (BMS, Charger etc.)
- **Advisory services** for designing verification plans based on standards
- **Post-Mortem-Analysis** of damaged batteries



TÜV SÜD is also a trusted partner of safety authorities – Tests for NHTSA

Full vehicle immersion test



Full vehicle propagation test

Discover the advantages of partnering with TÜV SÜD

Mehr Wert.
Mehr Vertrauen.

Add value.
Inspire trust.

Contact us:

www.tuv-sud.com/e-mobility

Volker.Blandow@tuev-sued.de

For a Safer and Greener Future!

@tuvsud
linkedin.com/company/tuvsud
youtube.com/tuvsud

Thank You!

EV-Battery – 2nd Life Pilot Project

Efficiency House Berlin, Battery System

Volker Blandow, TÜV SÜD China Holding

Choose certainty.
Add value.

Battery Storage System by:

LION Smart

TÜV SÜD Scope, Product Safety and Beyond…




Product Safety


Labour safety /
high voltage safety (800V +)


Rescue work


Recycling / Decomissioning

Definition 2nd life – 3rd life

1st life

EV or PHEV

2nd life

Revised battery / slightly reduced performance

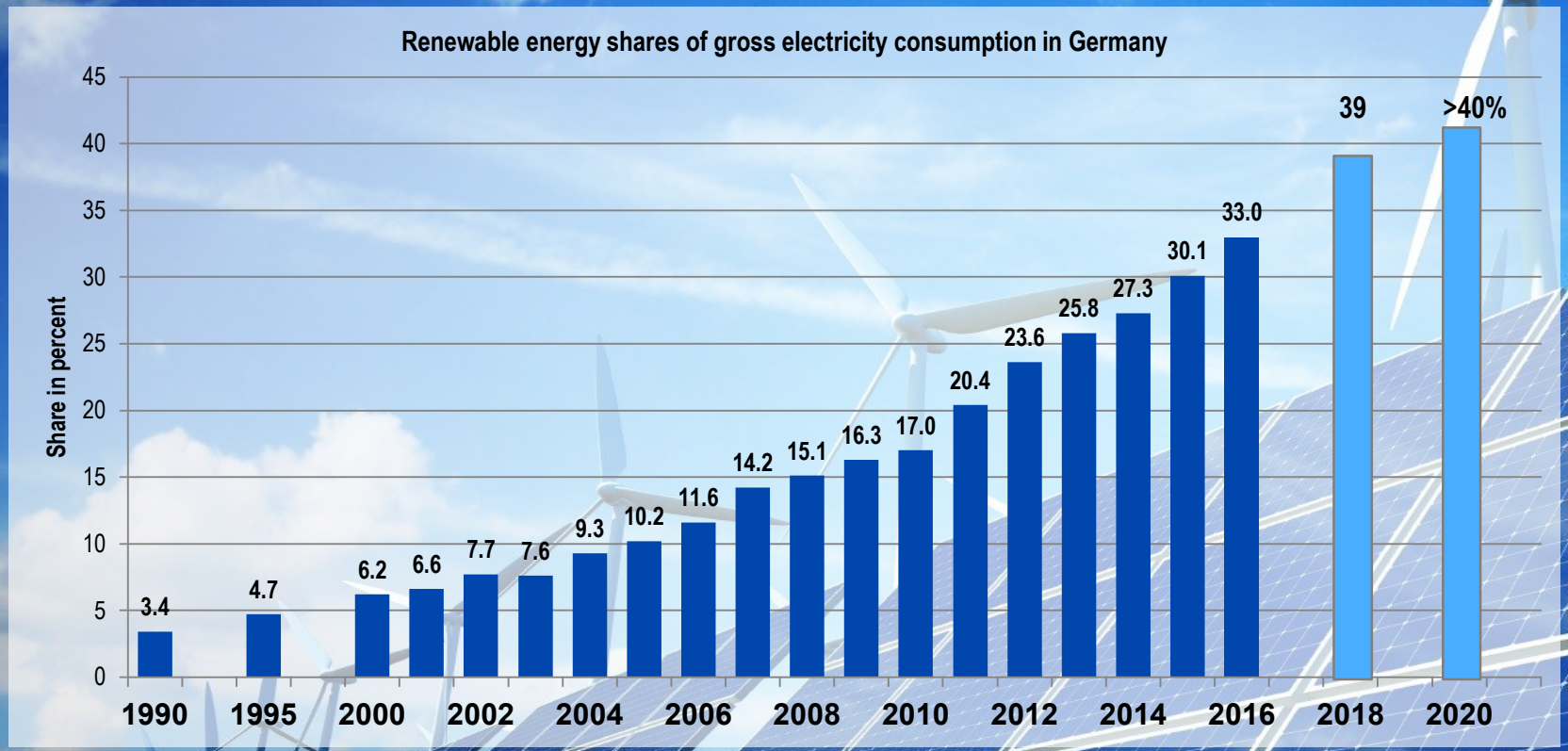
2nd or 3rd life

REES –grid connected or residential (outside)

End of Life

Recycling

Renewable energy share of gross electricity consumption Germany



@ 100%

Germany needs

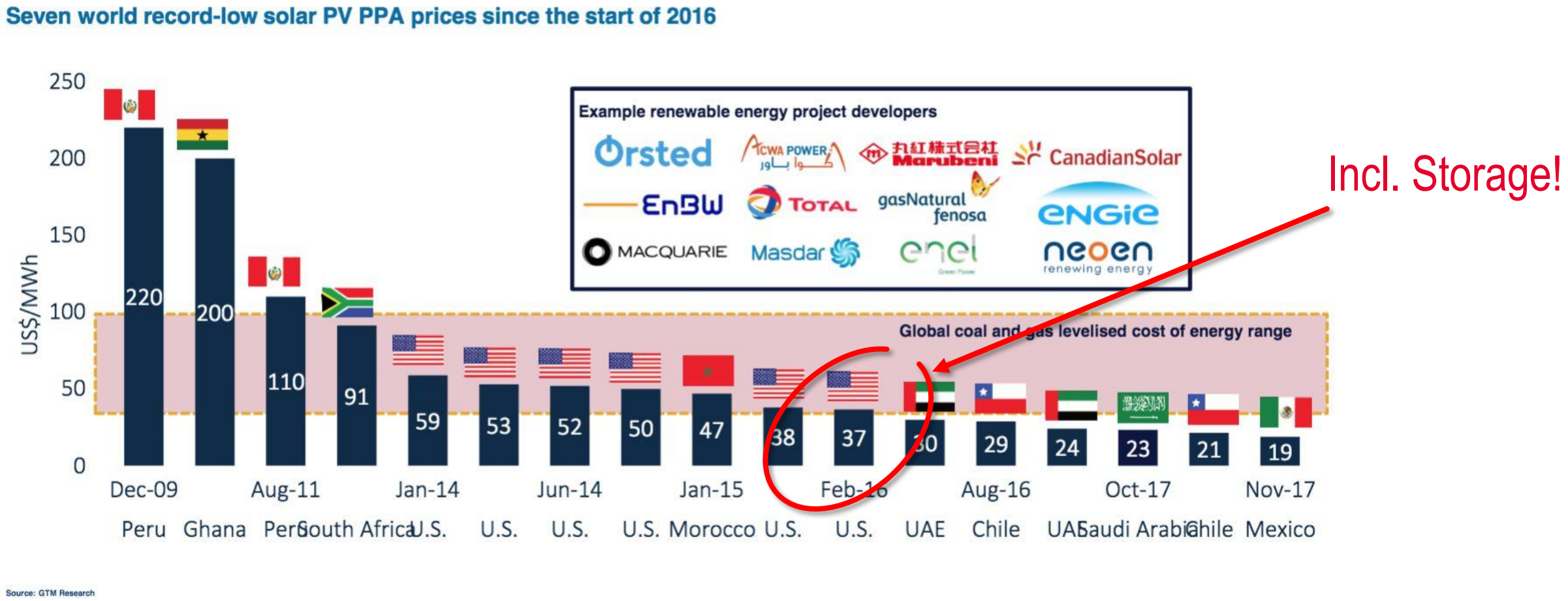
200-300 TWh storage capacity to cope with peak supply/ demand

Annual consumption 2018 Germany: 670 TWh

Tesla battery system Australia (7 MW / 729 MWh)

China did their „homework“!

(expanding production of: PV & REES & EV Batteries & EV & Charging Equipment)



600 Mini-e for California and Germany

Mini-E second life trial - Project goals:

- Try to implement an appropriate test set up for vehicle batteries to classify quality
  - by measurement
  - by statistical data (collect fundamental data to benchmark)

- Execute a **SOH investigation of about 104 modules**

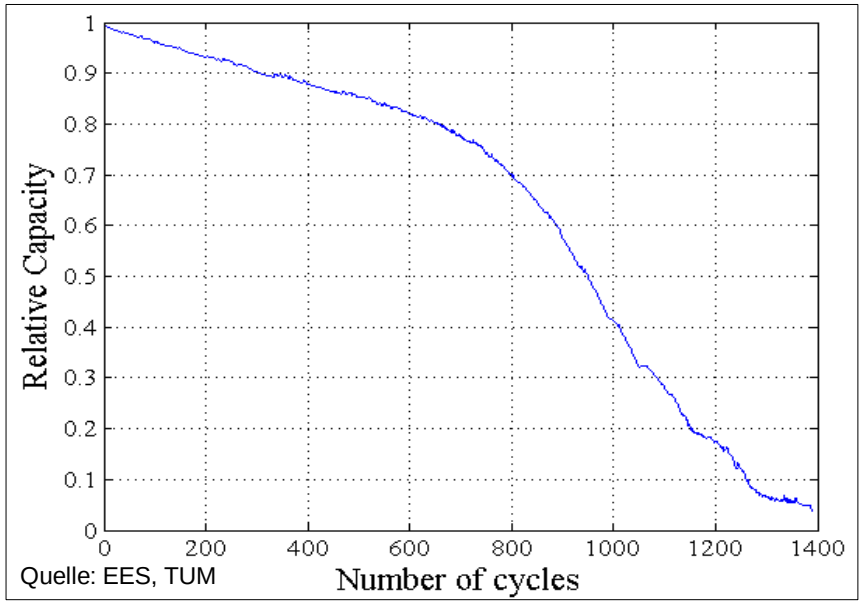
- Take 10 out of the 104 modules and perform a complete safety check by abuse testing
  - stability of SOH
  - risk assessment
  - performance

Border conditions:

- No information from BMS available
- Modules have been taken randomly from a number of cars
- No information at all about environmental conditions from car operation
- No information about no of cycles
- No scientific investigation of cells, tests must be quick and cheap

Theoretical behavior capacity vs. cycles

Example:18650 cell
shows non linear behaivior!



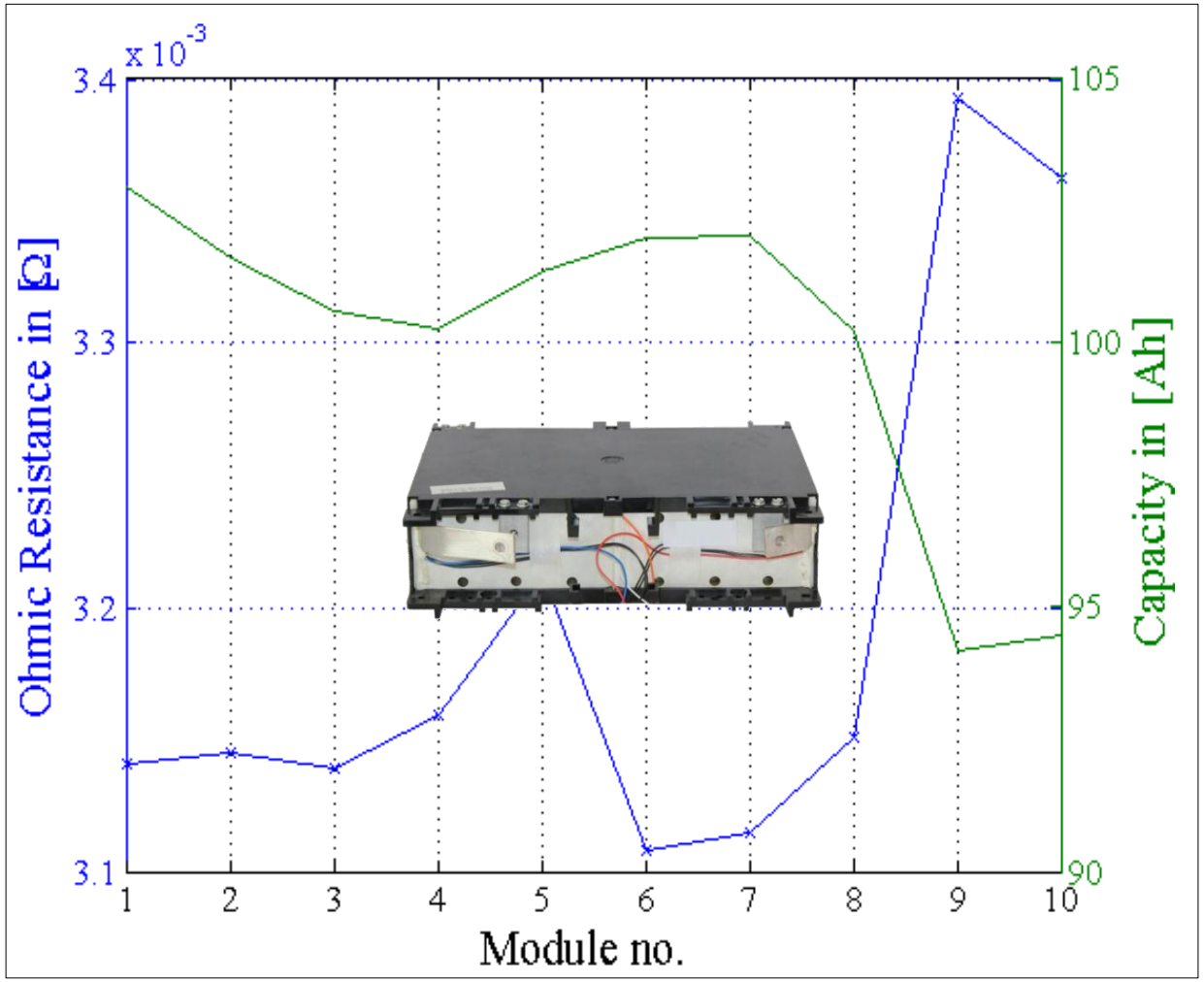
Quelle: EES, TUM

Different SoH lead to different aging characteristics, influenced by:

- Temperature
- C-rates (charge & discharge)
- Number of cycles and depth of cycles
- Unser behaivior (if not protected by the system, e.g. fast charging at very cold conditions)
- …

Results of the module tests

- **104 Modules under investigation- all of them showed >90% remaining capacity**
- **10 Modules have been tested in detail, resistance and capacity:**

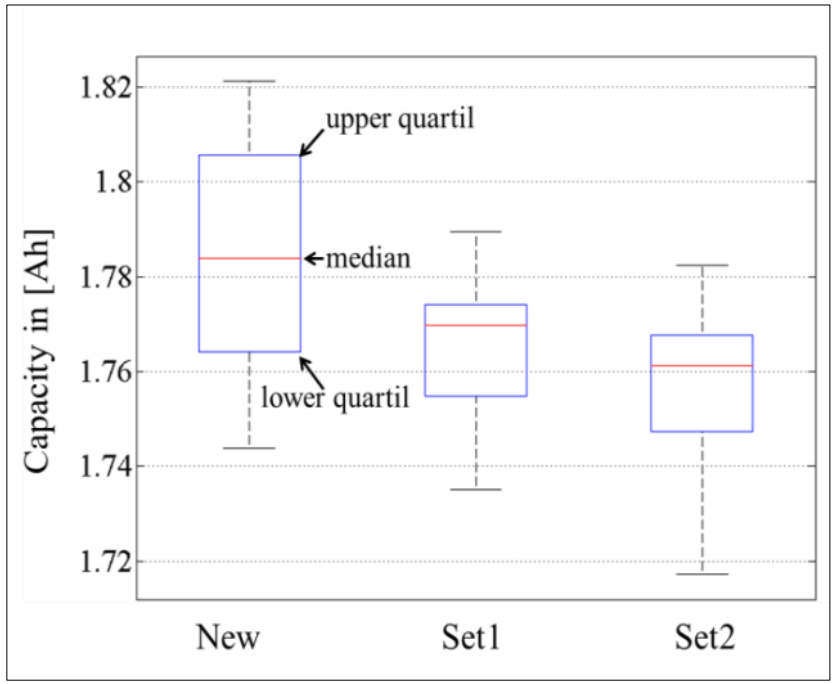


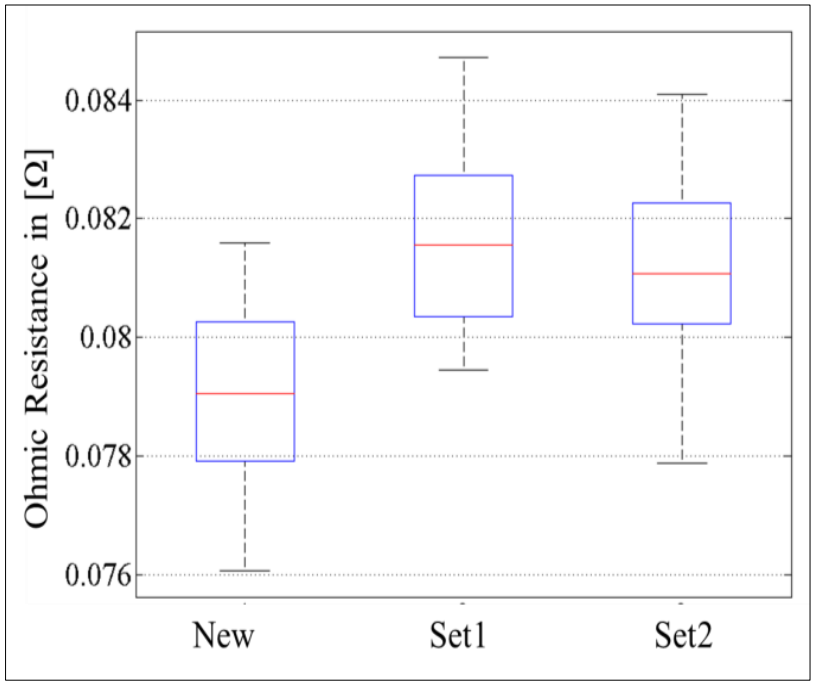
Quelle: EES, TUM

Comparison old vs. new cells

Quelle: EES, TUM

- Two different sets of old cells (53 pieces)
- Vs 25 new cells





Storage system in a „zero energy“ house

Tesla set a benchmark also for storage systems!

Tesla Power Wall Concept!

- 10 kWh system, 3 kWp
  - 3500 US$
- 7 kWh system, 3 kWp
  - 3000 US$

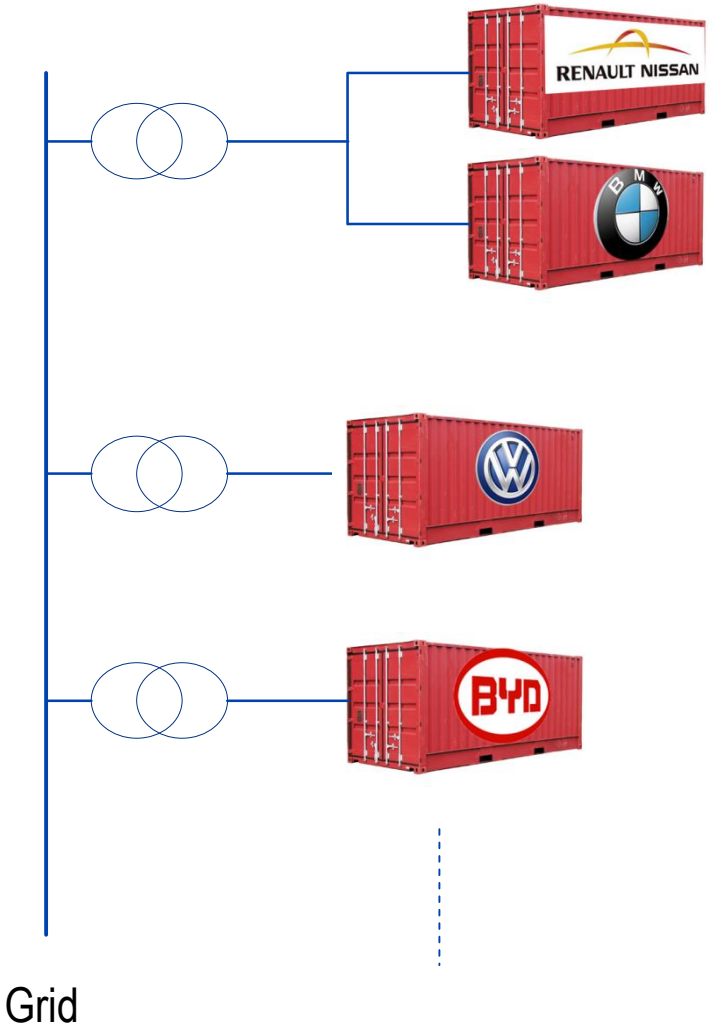
And Tesla even thinks big:

100 kWh system – 25k US$

Is there a market?

38,000 pre-orders after three days!

Proposal: Vehicle type specific battery storage systems



- Suitable for one specific battery type
- Plug and Play Connection / Communication
- Incl. Cooling system
- SOH check via BMS (incl. History)
- Activlely managed by special operator
- Only change complete packs (or modules)
- System should be close to vehicle decommissionig / wrecking
- Intermediate step before recycling
- Standardised systems 20-40 packs (1-4 MW)

„2nd Life“ of EV batteries

„USED“ Batteries coming from the Daimler Smart Electric EV

End of Life: Recycling is a must!

Governments should prepare regulations,

Exchange between China and Europe has started already!

May be ASEAN regulation?

Image: Umicore

Thank You!

Discover the advantages of partnering with TÜV SÜD

Mehr Wert.
Mehr Vertrauen.

Add value.
Inspire trust.

Contact us:

www.tuv-sud.com/e-mobility

Volker.Blandow@tuv-sud.hk

@tuvsud

linkedin.com/company/tuvsud

youtube.com/tuvsud

For a Safer and Greener Future!

Reference Projects (selection)

Approval of the Hamburg „Hafen City“ hydrogen re-filling station

Homologation and Certification of inductive charging systems (bus and vehicle project e-mil)

Certification and consulting services for charging infrastructure (Singapore, Berlin, Hamburg)

History: European type approval(Homologation) for the Tesla Roadster and the Mitsubishi IMIEV

Present: Homologation BMW i8 and i3