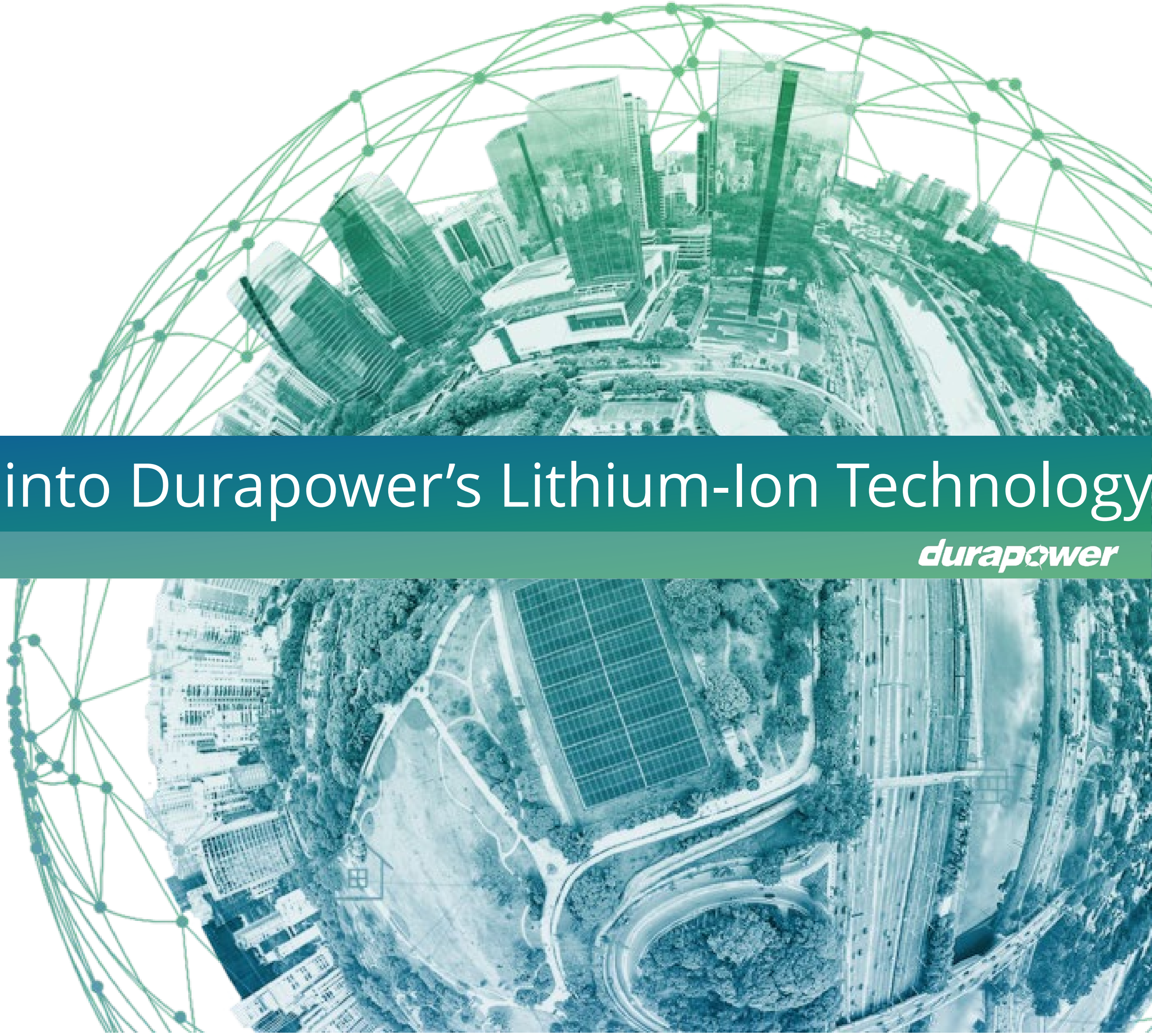


A Look into Durapower's Lithium-Ion Technology

durapower

Dr. Shen Nan
29th October 2020

01 MARKET POSITION

02 CURRENT PRODUCTION

03 R & D FACILITY

04 RESEARCH CHALLENGES AND FOCUS

01 **MARKET POSITION**

02 CURRENT PRODUCTION

03 R & D FACILITY

04 RESEARCH CHALLENGES AND FOCUS

WHO WE ARE

Established in 2009, Durapower offers a closed-loop, end-to-end energy storage solution for the electric mobility and renewable energy ecosystem. The company is focused on research and design of Lithium-ion battery (LIB) materials, battery cell manufacturing, and integration of battery systems, delivering state-of-the-art energy storage solutions for electric vehicles and renewable energy globally.

With professionals in the automotive and renewable industry of more than 15 years of experience and a wholly-owned battery cell manufacturing facility, Durapower is a tier-one supplier to vehicle manufacturers and has its battery systems integrated into thousands of Electric Vehicles (EVs), Hybrid Electric Vehicles (HEVs) and Plug-In Hybrid Electric Vehicles (PHEVs). The company has achieved a remarkable safety track record over the years, covering hundreds of million kilometers of operational mileage and deployed various scales stationary storage solutions for on and off Grid applications. Headquartered in Singapore and with subsidiaries in China, Europe, and Thailand, Durapower works closely with government agencies, blue-chip customers, and partners to deliver our solutions to over 20 countries and 45 cities globally.

Proud member of : EVAAP Electric Vehicle Association of Asia Pacific; SEAS Sustainable Energy Association of Singapore; Singapore Battery Consortium; SPECS Smart Grids + Power Electronics Consortium Singapore; European Battery Alliance EBA250

durapower

OUR VISION

Redefining Energy Storage Solutions

We envision a zero carbon emission and sustainable tomorrow for our future generations, by enabling global deployment of renewable energy through our innovative energy storage solutions

We Power the Future, Today

OUR MISSION

Empowering Lives and Transforming Future

We deliver world class energy storage solutions through innovation, empowerment and people development. We work closely with our partners around the world to transform the future by developing sustainable clean energy solutions to our customers globally.

durapower

OUR GROWTH HIGHLIGHTS

2020 and beyond
LAUNCHED AND CERTIFIED ESS FOR E-VESSEL APPLICATION – FIRST IN ASIA.

2019
- SETUP OF SUBSIDIARIES IN THAILAND AND EUROPE.
- WINNER OF WIPO IPOS AWARD 2019.
- LAUNCH OF NEW FACTORY.

2018
PRODUCT LAUNCH IN INDIA, PROVIDING BATTERY STORAGE SOLUTIONS AND BATTERY SWAPPING SYSTEM FOR ELECTRIC BUSES AND PASSENGER VEHICLES.

2017
- SIGNED LICENSED MANUFACTURING IN THAILAND.
- ATTAINED APEX SUSTAINABILITY AWARD, BY GLOBAL COMPACT NETWORK SINGAPORE, LOCAL CHAPTER OF UNITED NATIONS GLOBAL COMPACT.

2016
INAUGURAL FLEET OF ELECTRIC BUSES IN EINDHOVEN, NETHERLANDS, LAUNCHED WITH DURAPOWER BATTERY SOLUTIONS.

2015
MARKET ENTRY AND PRODUCT LAUNCH IN EUROPE AND SOUTHEAST ASIA.

2013
ATTAINED NATIONAL HIGH TECHNOLOGY CORPORATE CERTIFICATION AND NATIONAL HIGH TECHNOLOGY PRODUCT CERTIFICATION FROM THE CHINESE GOVERNMENT.

2012
SHIPPED FIRST BATCH OF BATTERY SOLUTIONS FOR HYBRID AGVS IN SEAPORT APPLICATIONS.

2011
- FACTORY SET UP COMPLETED
- LAUNCHED FIRST BATCH OF BATTERY SOLUTION FOR HEV BUSES.

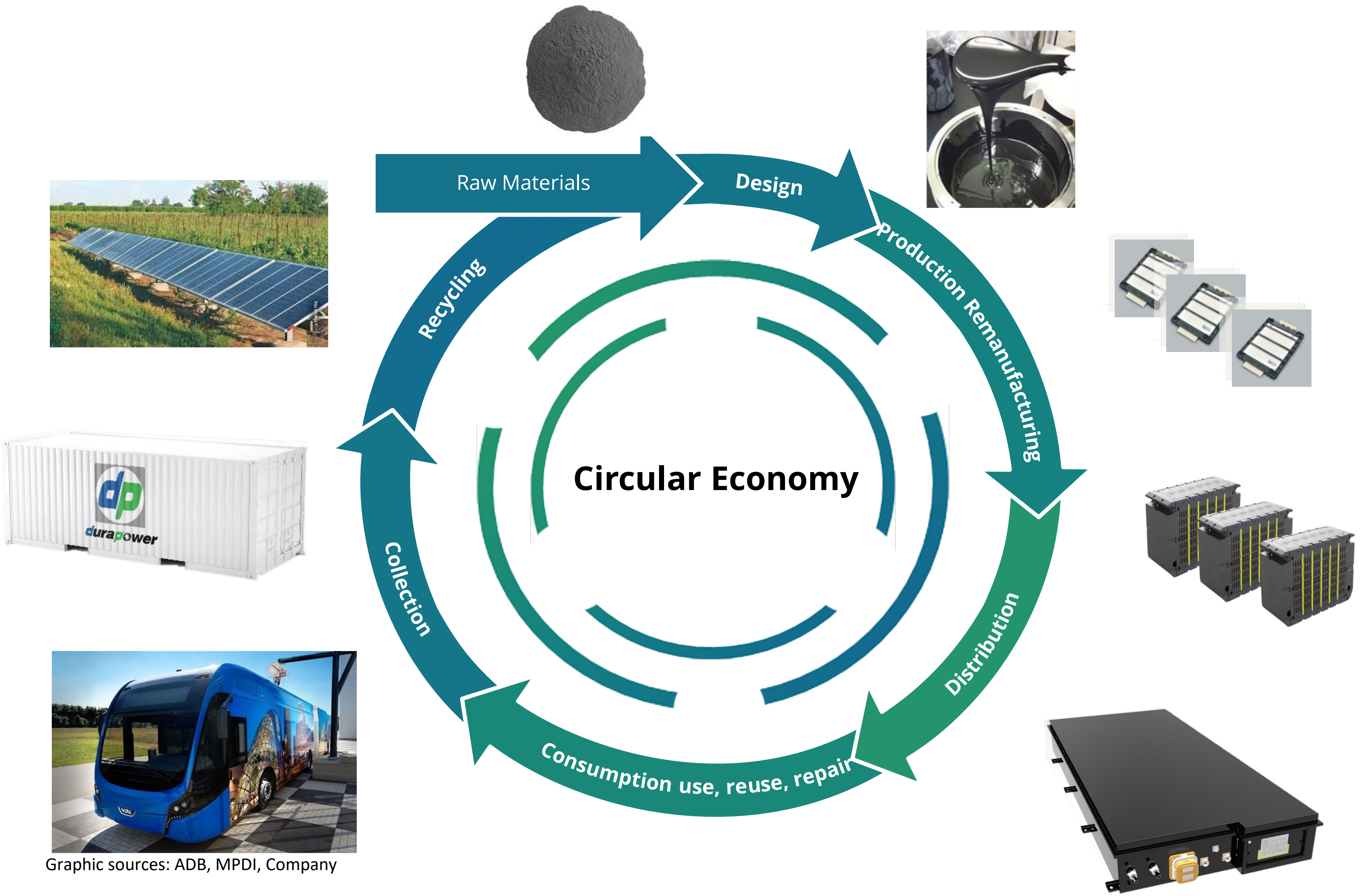
2010
SETUP OF CHINA SUBSIDIARY.

2009
COMPANY FOUNDED, HEADQUARTERED IN SINGAPORE.

OUR GLOBAL MARKET PRESENCE

20 Countries,
45 Cities & Growing

OUR COMMITMENT TO THE CIRCULAR ECONOMY



Graphic sources: ADB, MPDI, Company

FOCUS ON LARGE BATTERY SYSTEMS

durapower

37 – 80 kWh

200 – 400 kWh

600 – 1,000 kWh

500 – 4,000 kWh

1,000 – 50,000 kWh

Source: IDTechEx, DP Customer

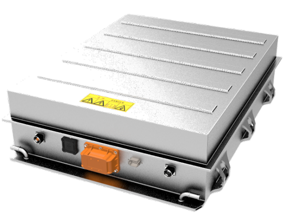
OUR MARKET SEGMENTS

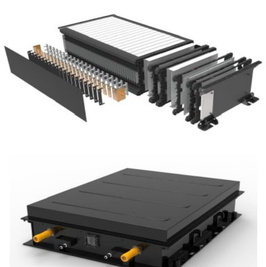
E-Mobility Platforms

Specialty Platforms

Stationary Applications

HYBRID AND ELECTRIC VEHICLES





- Low to **no emission**
- High drive train efficiency
- Compatible with **fuel cells**
- Opportunistic fast charging for **continuous operations**
- High Density for **space optimization**
- Air or liquid cooling for optimal thermal management
- **Low maintenance**
- Potential for battery swap
- Potential for second life usage

HYBRID AND E-FERRY

durapower

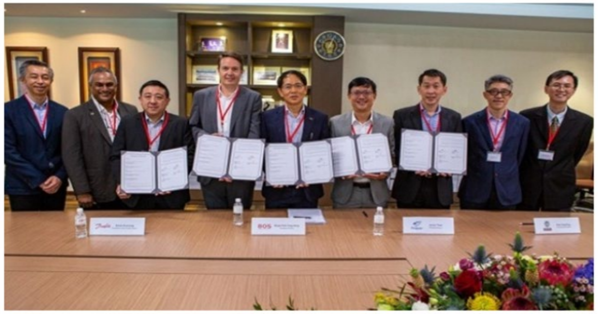
NEWS TRANSPORTATION

FIRST ELECTRIC FERRY LAUNCHED TO REDUCE POLLUTION

By Xinhua News Agency - August 6, 2020 1:30 pm

Image: BANPU

Partners to Develop Singapore's First Hybrid Electric Marine Launch



BY THE MARITIME EXECUTIVE 02-11-2020 05:42:21

BH Global Corporation Limited is pleased to announce that BOS Offshore & Marine, a 90 percent owned subsidiary of the Group, has entered into a MOU with strategic project partners Penguin International Limited, Danfoss, Durapower Technology (Singapore) and Bureau Veritas Marine (Singapore) (BV) for the joint design, development and construction of Singapore's first plug-in hybrid electric fast launch.

The scope of cooperation includes integrating hybrid electric solutions, testing and certification. The know-how generated will support Singapore's push towards the adoption of hybrid electric propulsion systems for its maritime industry.

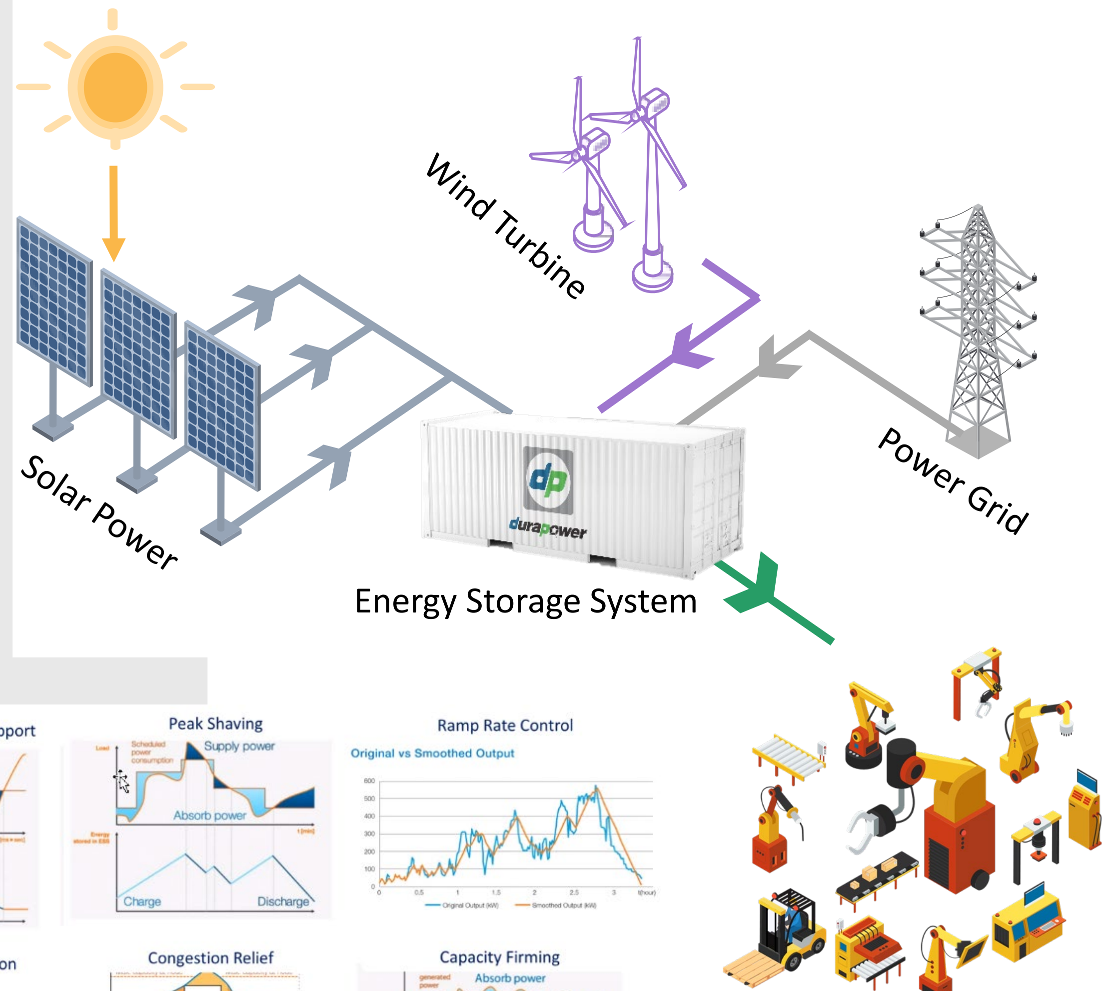
- Low to **no emission**
- Marine certified
- Fast charge during passenger's onboarding
- **Light weight** for vessel efficiency
- High IP Rating
- Low maintenance

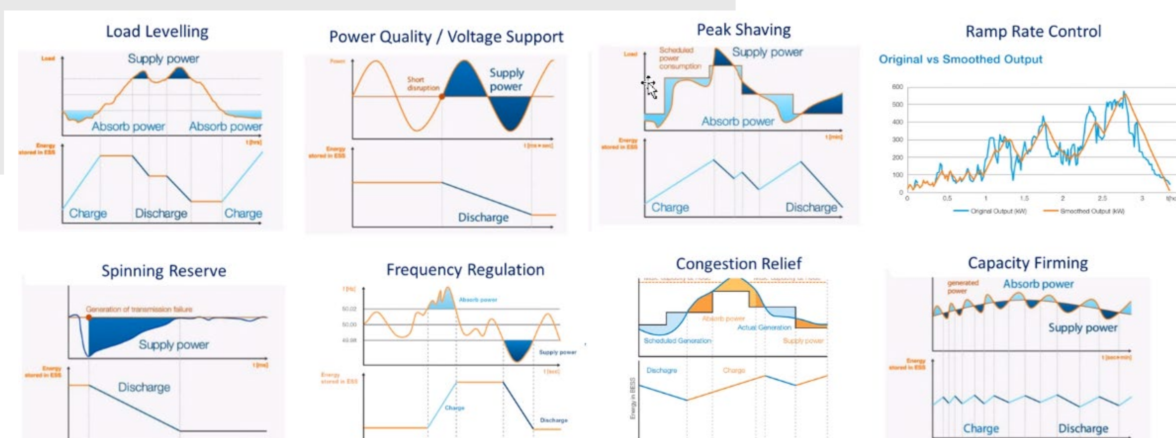
MICROGRID AND OFF-GRID

- Complements **renewable** energies
- Decrease reliance on Diesel Gensets
- Low maintenance supports **remote** applications
- Designed for operation in various **environmental conditions**

C&I, ON-GRID AND VPP

- Enables **Distributed Energy Resources**
- Supports intelligent **Energy Management System**
- Variety of value-creating operational modes
- Reduces peak generation
- Reduce reliance on demand pricing





Source: Eri@n

SECOND-LIFE DEPLOYMENT

- Battery packs retired from EVs have 70% **residual energy** retention.
- Such batteries can be repackaged into stationary storage system for power back up or peak shaving applications.
- This approach allows for **economically viable** extension of the value of the product.

BATTERY CHARGERS SYSTEM SOLUTIONS

durapower

Regional exclusive distributor for state-of-the-art battery chargers and battery swapping system to enhance the field application of Electric Vehicles. Wide range of battery charger products from low-power AC to high-power DC, 200V to 800V, and 7kw to 600kw.

CIRCONTROL
Mobility & eMobility

heliox

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NEW MANUFACTURING FACILITIES @ CHINA

durapower

BATTERY PACK PRODUCTION, SAFETY & RELIABILITY TESTS

Pack Assembly

- licensed factory for EV Cars
- inhouse factory for Bus & Trucks

Vibration Test

Humid Heat Constant & Thermal Cycling

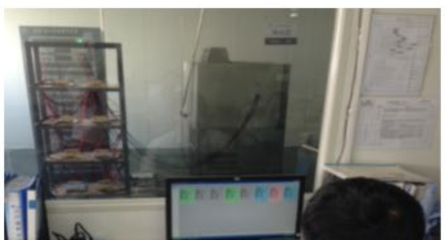
SAFETY & RELIABILITY TESTS

Nail Penetration Test

Press Test

Capacitance & Internal Resistance Test

Moisture Test



Cycle Life Test

Capacity Test

Temperature & Humidity Tests

Battery Pack Test

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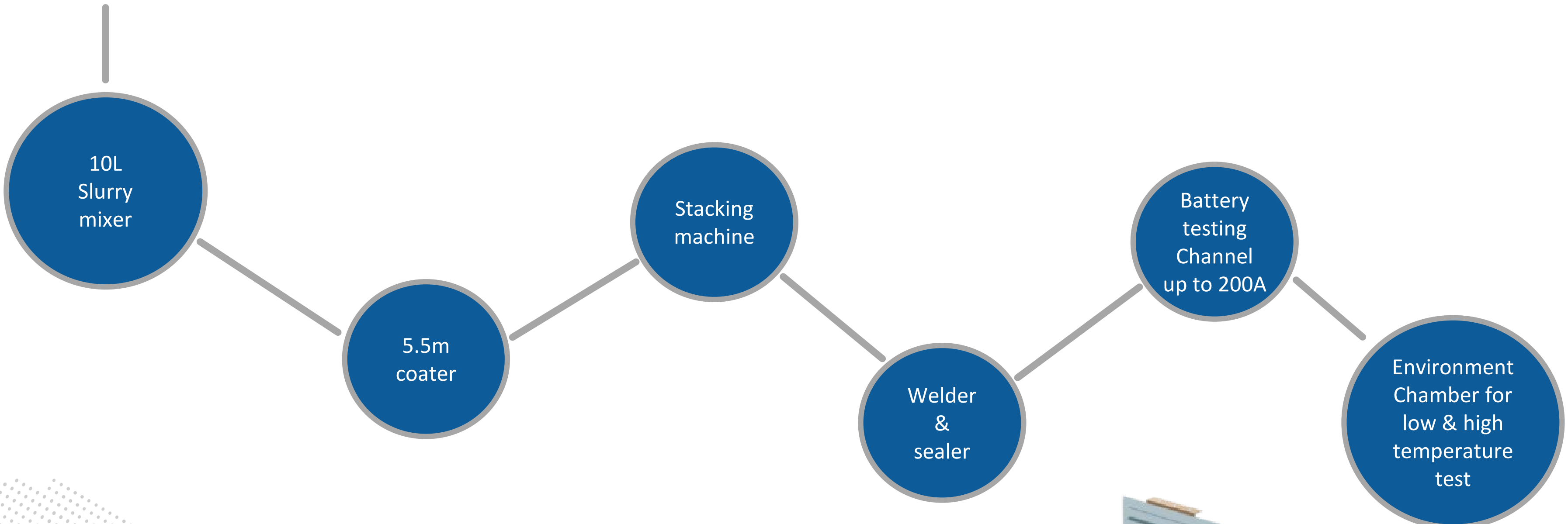
MANUFACTURING AND R&D FOOTPRINT

JOINT LAB – DP & NTU



Commercial Sized Cells (~30Ah)

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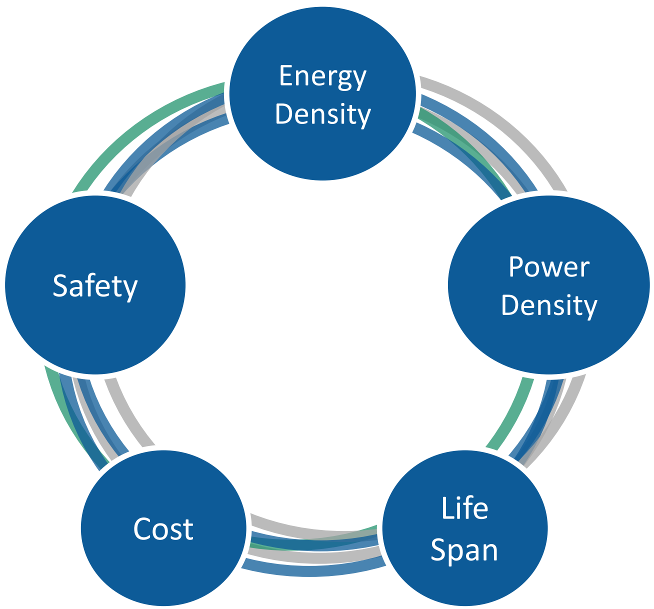
04 **RESEARCH CHALLENGES AND FOCUS**

RESEARCH FOCUS



- New Materials
- New Process & Equipment
- Improved Cell Design
- More Advanced Characterization Technics
- Algorithm Of BMS
- More Efficient Pack Design
- Modeling And Data Analysis

Lives Empowered, Future Transformed

Dr. Shen Nan
Assistant Manager, R&D

durapower

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Singapore 349324

+65 6846 0171
shennan@durapowergroup.com
www.durapowerbattery.com
Durapower Holdings Pte Ltd

Electrical measurement, inspection and characterization of LIBs

Mori, Takumi (森 匠)
Research engineer
HIOKI E.E. CORPORATION

29 Oct. 2020
SBC-Hioki Webinar

Contents

About us

HIOKI

Businesses/ Applications

A Manufacturer of Electrical Measuring Instruments Supporting the Development of Industry

Businesses

Automatic test equipment	Data recording equipment	Electronic measuring instruments	Field maintenance
			
Testing of electronic circuit boards and boards with embedded active and passive devices	Development of electrical devices and monitoring to detect equipment malfunctions	Testing of electronic components and batteries, energy conservation, and evaluation of power supply quality	Electrical work and maintenance and inspection of electrical equipment

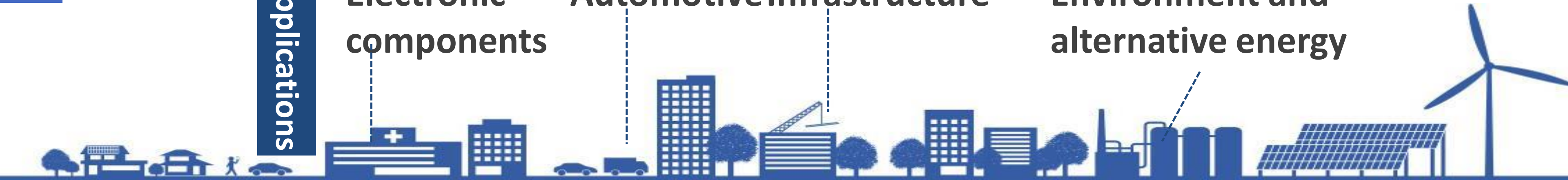
Applications

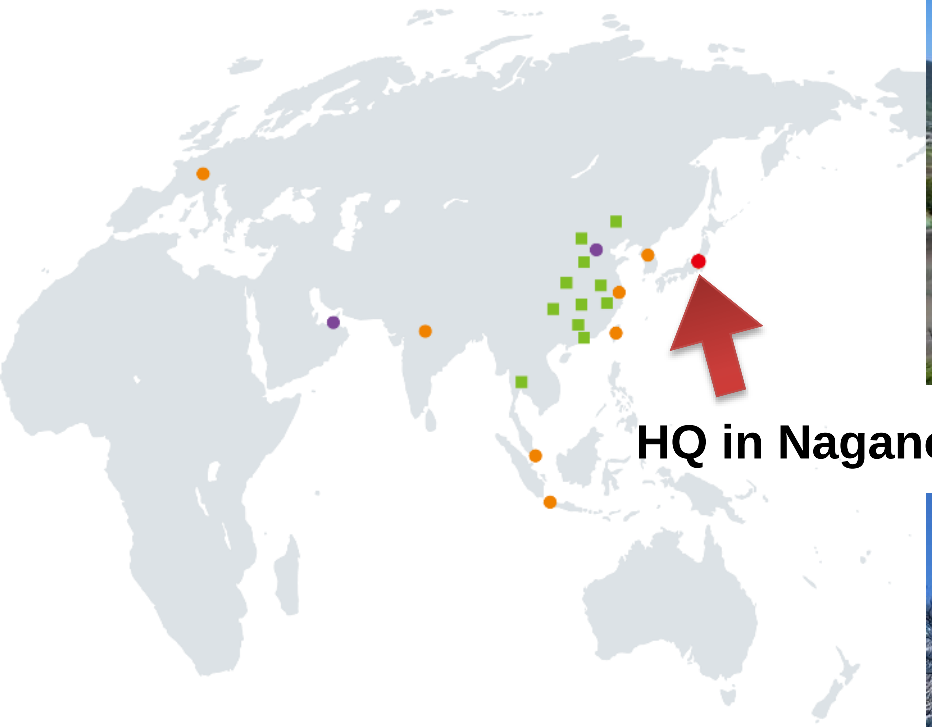
Electronic components

Automotive

Infrastructure

Environment and alternative energy

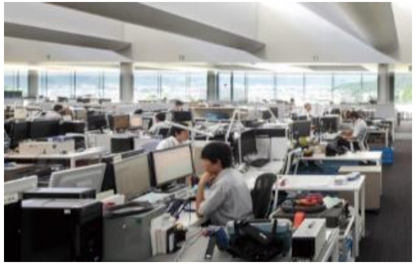


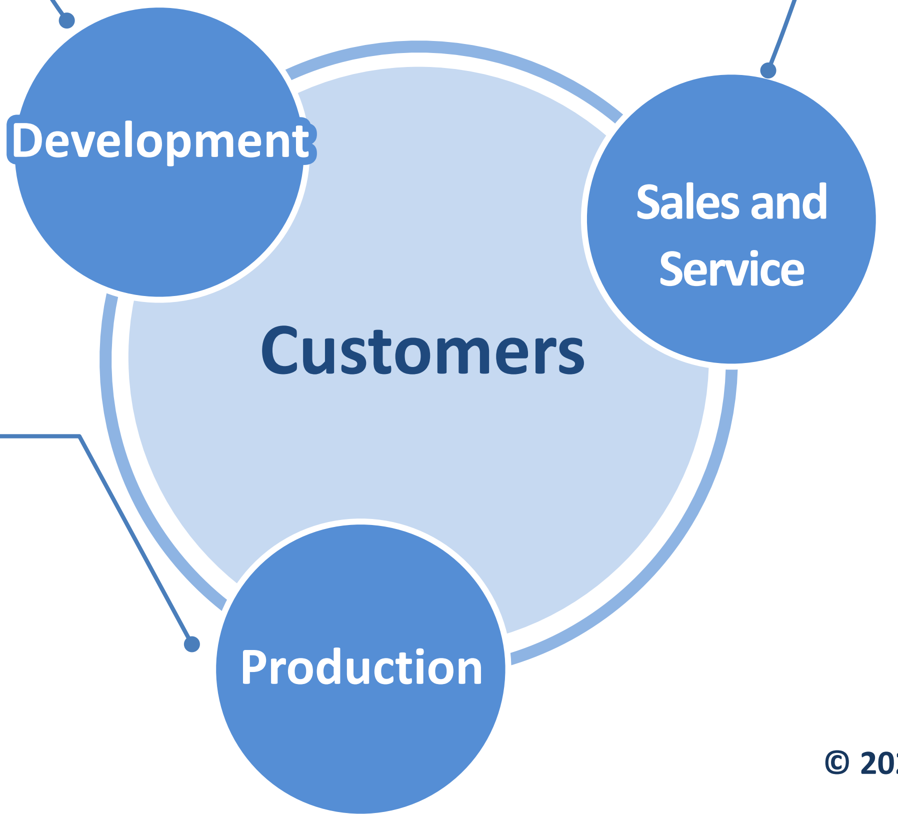


HQ in Nagano, Japan

All departments brought together

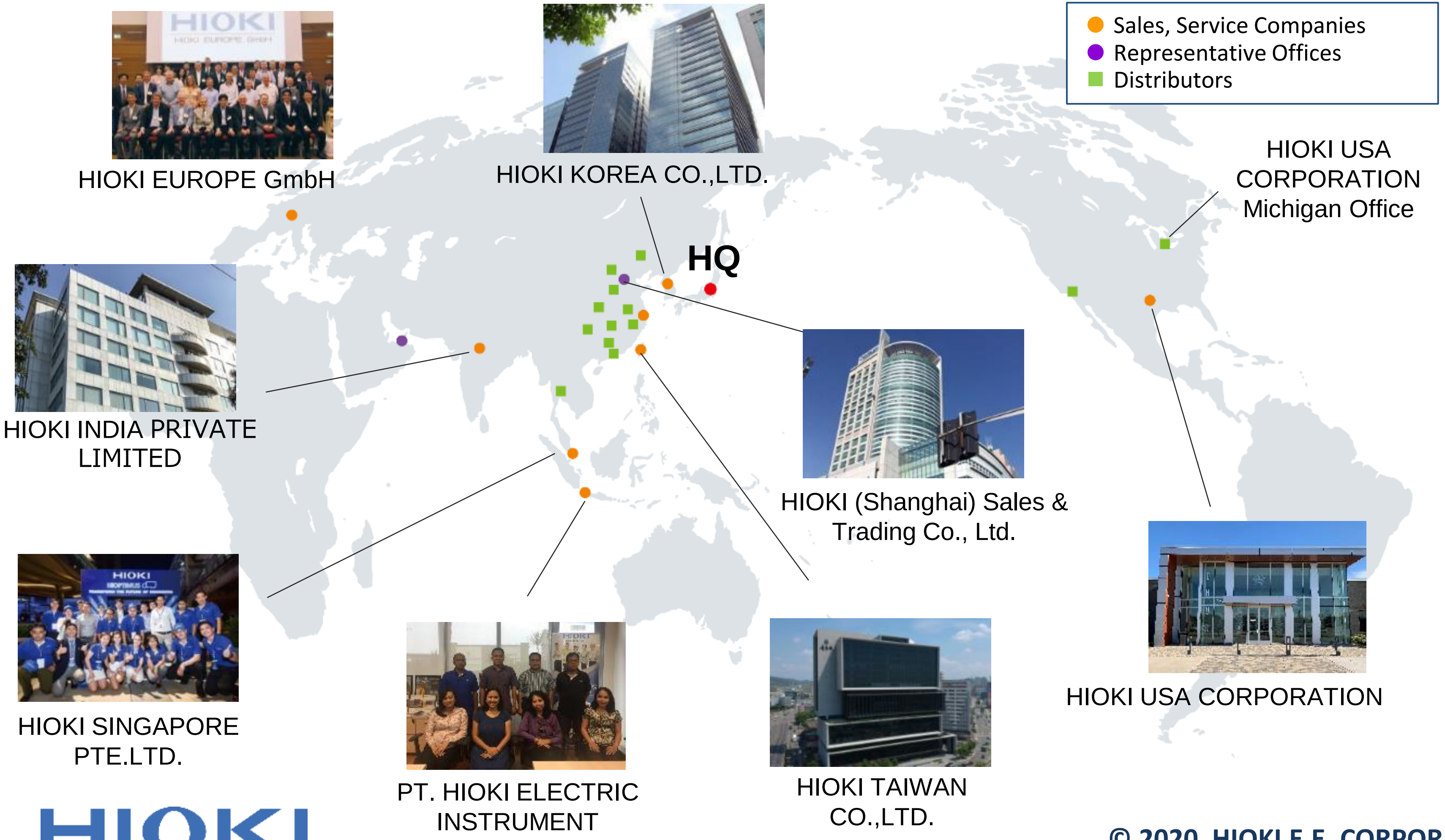
R&D-focused organization





Customer-focused sales

Pursuing agile production


Sales, Service Companies
Representative Offices
Distributors
HIOKI EUROPE GmbH
HIOKI KOREA CO.,LTD.
HQ
HIOKI USA CORPORATION Michigan Office
HIOKI INDIA PRIVATE LIMITED
HIOKI (Shanghai) Sales & Trading Co., Ltd.
HIOKI SINGAPORE PTE.LTD.
PT. HIOKI ELECTRIC INSTRUMENT
HIOKI TAIWAN CO.,LTD.
HIOKI USA CORPORATION

History

1946
Testers

1971
Clamp Meters

1974
Insulation Testers

1978
Clamp on
Power Meters

1983
Memory HiCorder

1986
In-Circuit HiTester

HIOKI, an R&D-focused company

HIOKI Innovation Center

(completed in 2015)

The HIOKI Innovation Center brings together technology and development teams so that R&D can be pursued in a way that maximizes the ability of employees to communicate

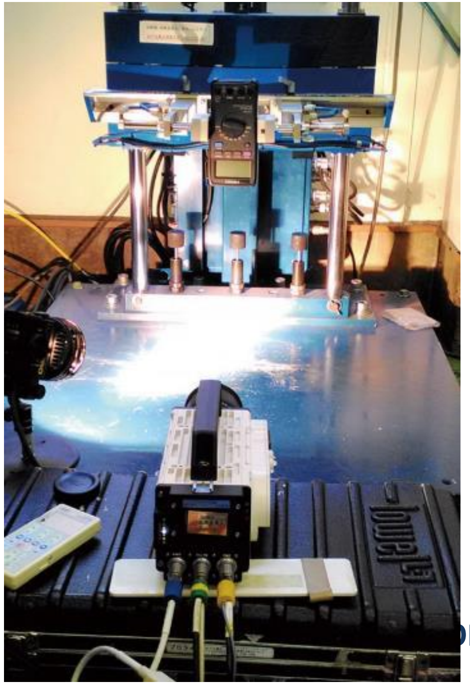
R&D-focused organization

Advanced testing systems ensure more highly reliable products

Anechoic chamber

Clean room

Drop testing system



The philosophies

Respect for Humanity

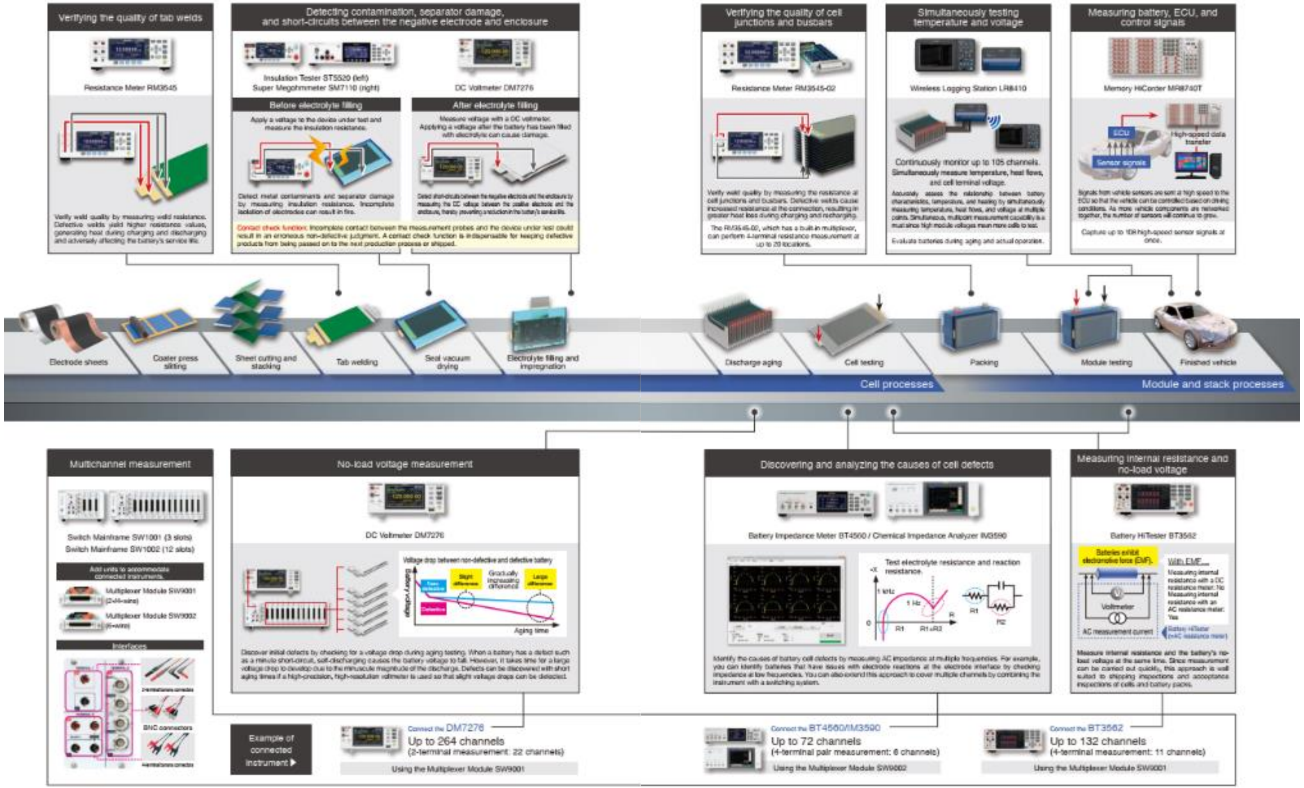
- A free-spirited environment that fosters individual creativity so that employees can realize their full potential
- The company as a place of self-realization where employees refine themselves and experience a sense of motivation and joy as they do their jobs
- Sophisticated harmonization of individual employees' potential with organizational goals (in other words, a connection between individual growth and the company's growth)

Contribution to Society

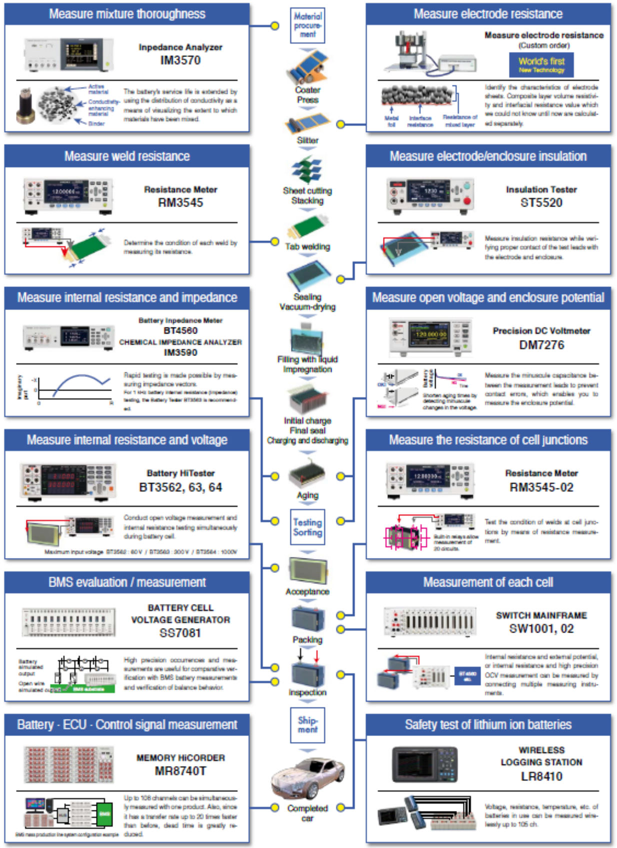
- Providing high-quality products and services
- Contributing to the development of the local community, for example through educational and cultural initiatives
- Actively undertaking environmental conservation activities

Our solutions for LIB industry

Everywhere in LIB production line



Everywhere in LIB production line

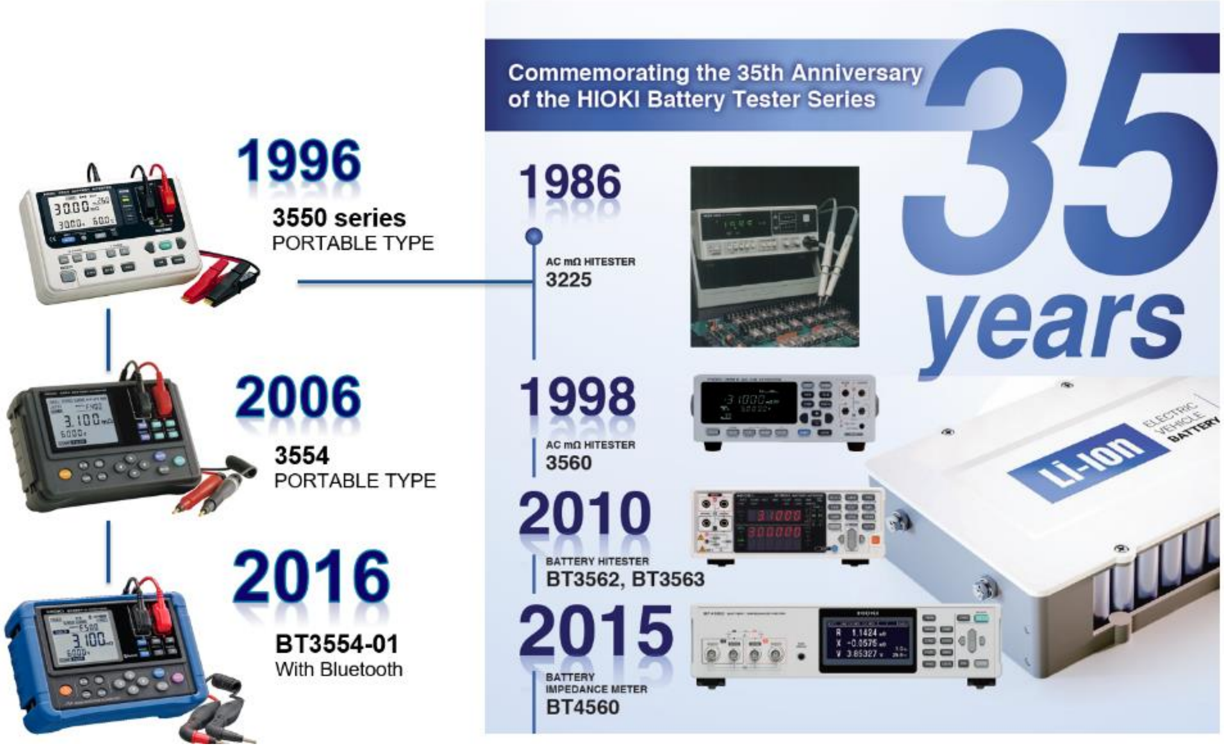


Battery (“Cell”) production

Battery module/pack production

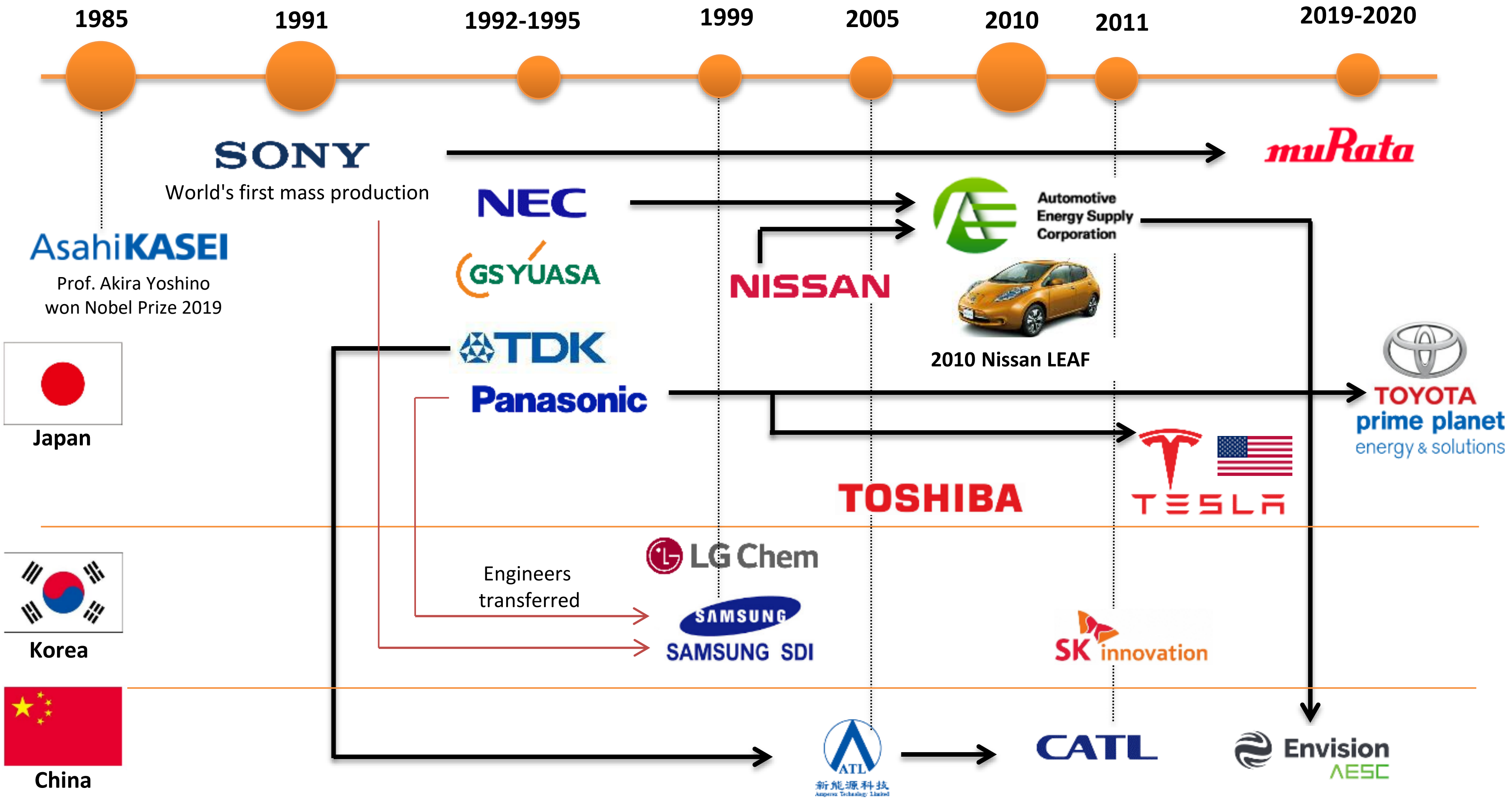
Assembling into products

History



HIOKI

History

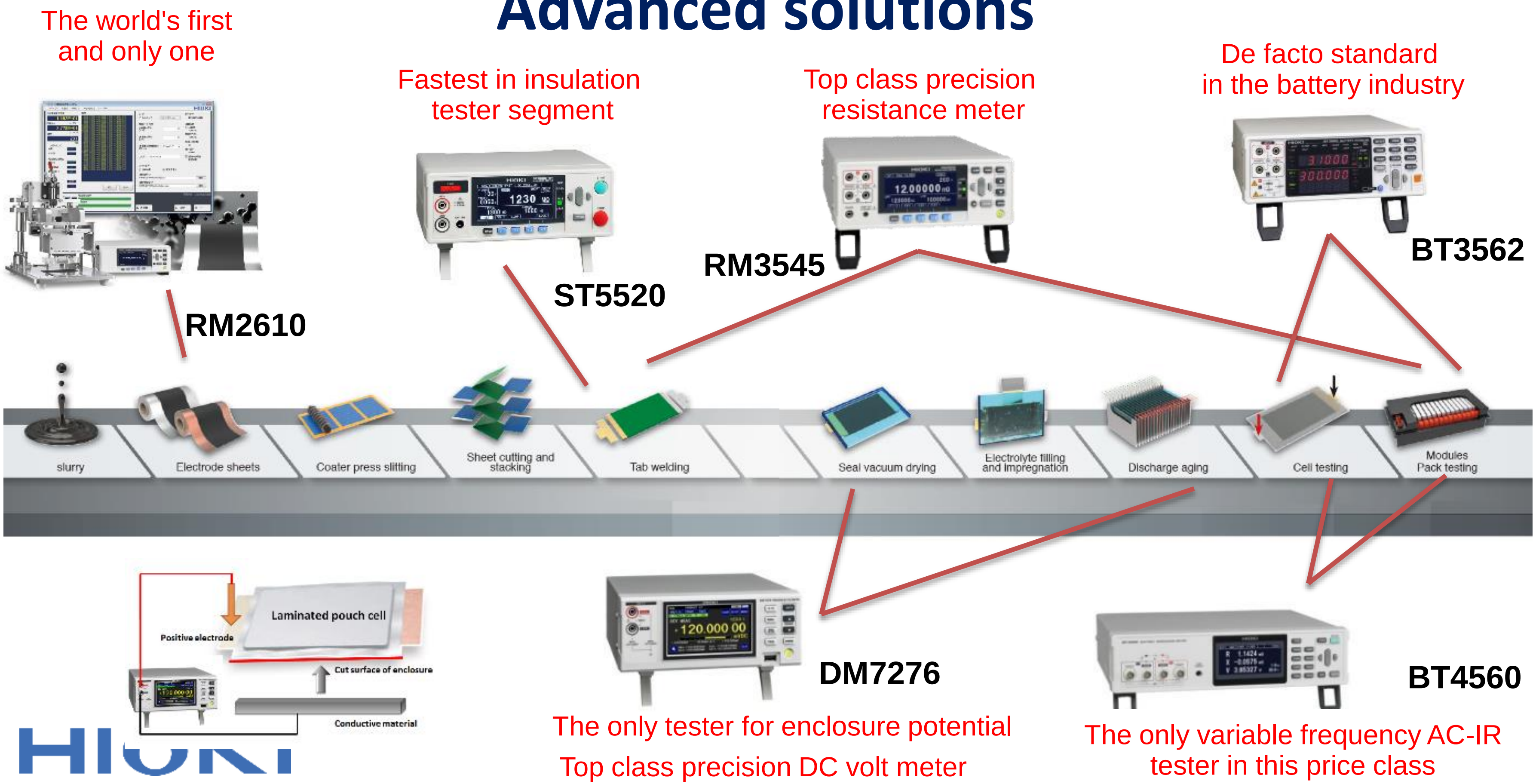

1985
1991
1992-1995
1999
2005
2010
2011
2019-2020
SONY
World's first mass production
muRata
NEC
Automotive Energy Supply Corporation
AsahiKASEI
Prof. Akira Yoshino
won Nobel Prize 2019
GS YUASA
NISSAN
TDK
2010 Nissan LEAF
Panasonic
TOYOTA
prime planet
energy & solutions
Japan
TOSHIBA
TESLA
LG Chem
Engineers
transferred
SAMSUNG
SAMSUNG SDI
SK innovation
Korea
ATL
新能源科技
CATL
Envision
AESC
China

History

For 35 years we have been developing products in conjunction with the world's top players

HIOKI

Advanced solutions



Pursuit reliability

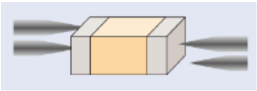
BT4560

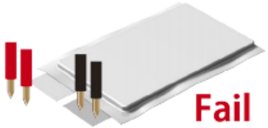
BT3562

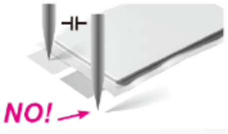
RM3545

ST5520

DM7276







Speedy and reliable probing

Ultrahigh accuracy

BT4560

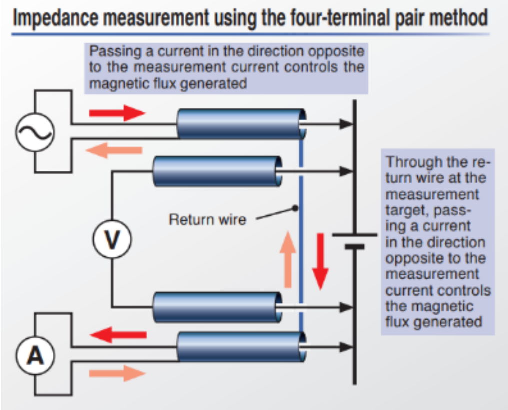
BT3562

RM3545

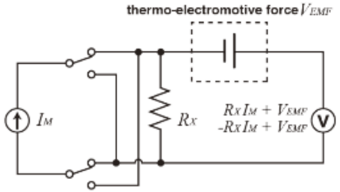
ST5520

DM7276

Ultra-low resistance measurement technology



BT4560 4-terminal pair method



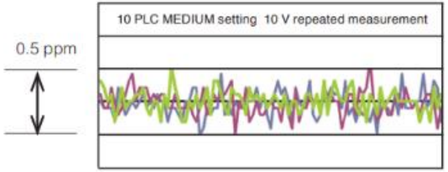
Cancellation of thermal electromotive force using the OVC function

$$\frac{(R_X I_M + V_{EMF}) - (-R_X I_M + V_{EMF})}{2 I_M} = R_X$$

RM3545 OVC function

High-speed insulation resistance measurement technology

High-accuracy voltage measurement approaching Reference Instruments



DM7276 HIOKI's Voltage Ref.

Multi instrument flexibility

All these tools are available to customers

BT4560

BT3562

RM3545

DM7276

SW1002 + SW9001/SW9002

Before and after production line

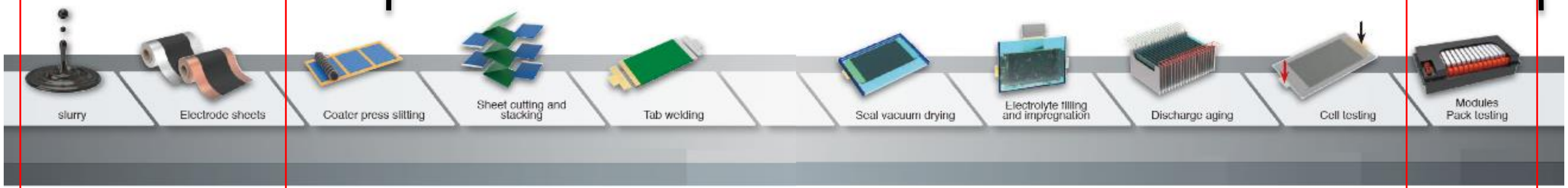
Material R&D

Non-cobalt research

Battery cells production lines

Pack design R&D and quality evaluation

For Evs and ESSs

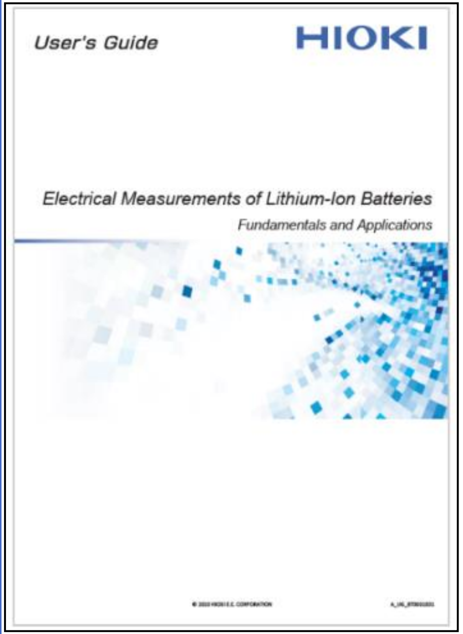


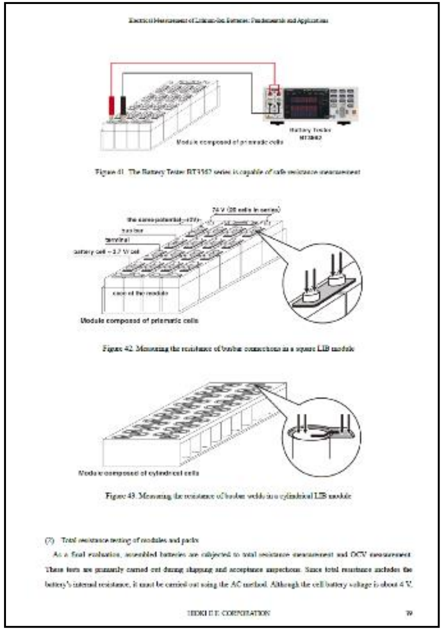
RM2610 for Electrode

SS7081-50 for Battery Management System

Inspection of high voltage Battery pack

Accumulated experience of LIBs measurement over 35 years
Pursuing reliability, accuracy and flexibility
We can strongly support all customers





Electrical Measurement of Lithium-Ion Batteries: Fundamentals and Applications

Module composed of prismatic cells

Figure 41. The Battery Tester BT3562 series is capable of safe resistance measurement

Module composed of prismatic cells

Figure 42. Measuring the resistance of busbar connections in a square LIB module

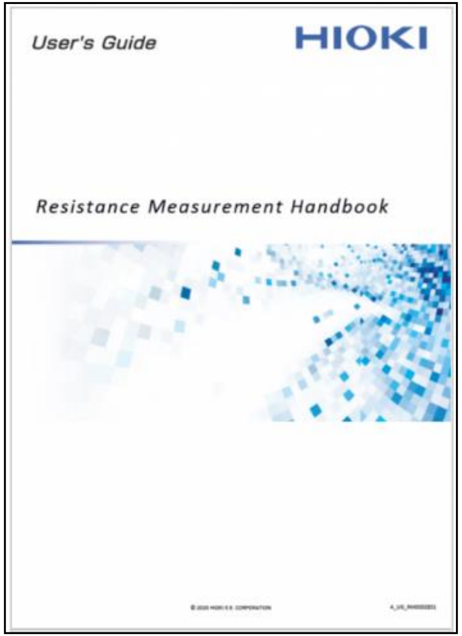
Module composed of cylindrical cells

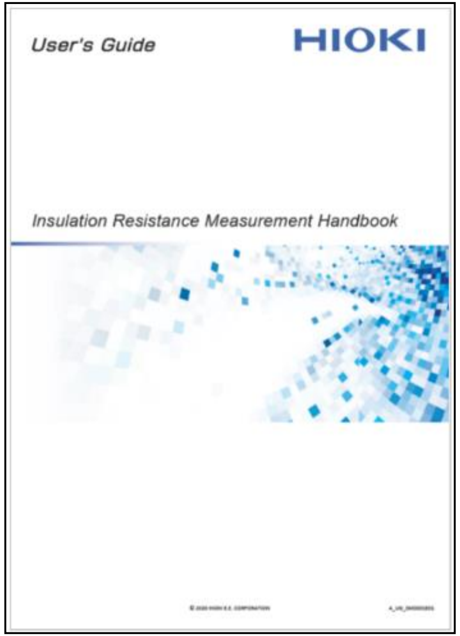
Figure 43. Measuring the resistance of busbar welds in a cylindrical LIB module

(7) Total resistance testing of modules and packs

As a final evaluation, assembled batteries are subjected to total resistance measurement and OCV measurement. These tests are primarily carried out during shipping and acceptance inspections. Since total resistance includes the battery's internal resistance, it must be carried out using the AC method. Although the cell battery voltage is about 4 V,

HIOKI E.E. CORPORATION





Measurement Handbooks about lithium Ion Battery / Resistance / Insulation Resistance

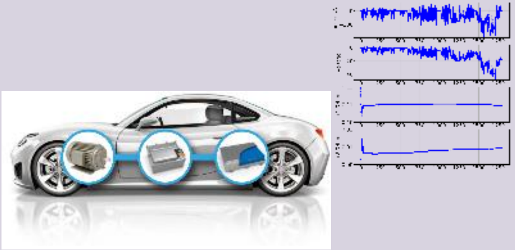
Introduction of an advanced research

Residual performance evaluation of LIBs based on impedance spectroscopy

HIOKI

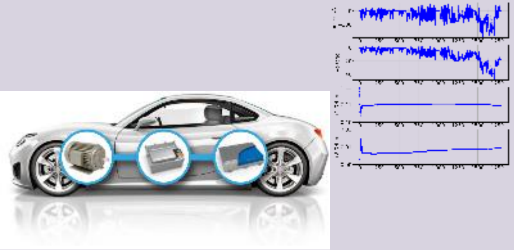
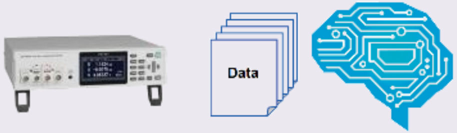
Overview

Still many challenges in estimating LIB performance

	online during operation	**offline** when removed from the device
Current performance “SOH” (state of health)	 ?	?
Future performance “Remaining life”		

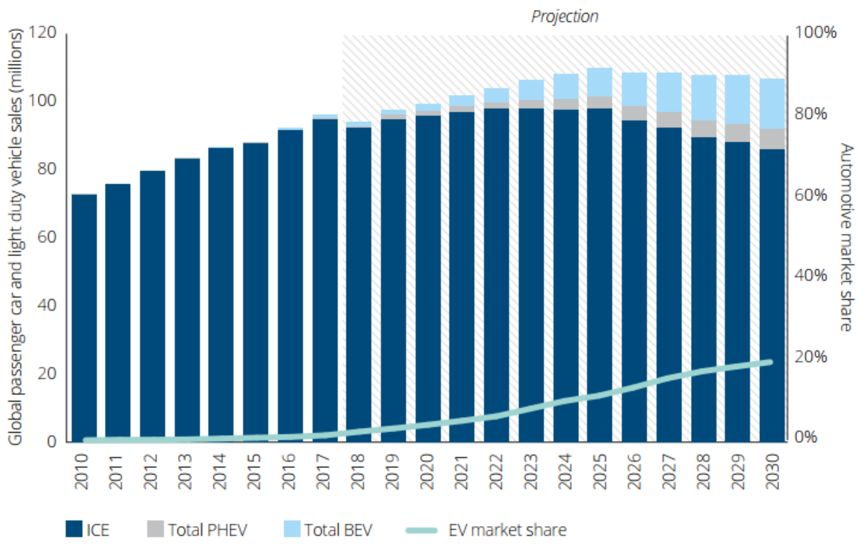
Overview

Still many challenges in estimating LIB performance

	online during operation	**offline** when removed from the device
Current performance "SOH" (state of health)		**Our focus**  **Offline measurement + Large-scale data analysis**
Future performance "Remaining life"		

Automobile electrification going on

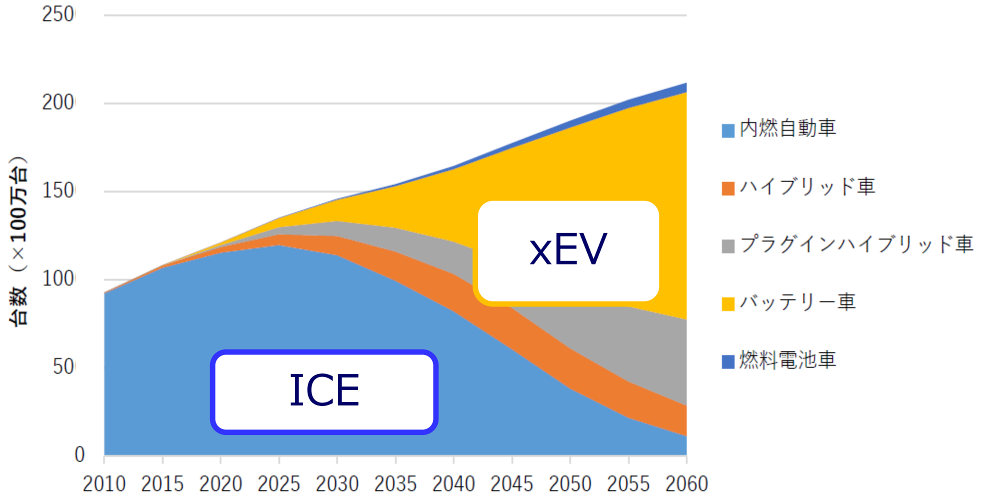
until 2017: actual number



Source: IEA, IHS, Deloitte analysis

Deloitte, New market. New entrants. New challenges. Battery Electric Vehicles

Prediction to achieve the B2DS scenario



出典：IEA「Energy technology perspectives 2017」[4]より財団が作成

公益財団法人 自然エネルギー財団, EV普及の動向と展望：気候変動対策の観点から

Reuse/repurpose of automobile LIBs

High performance battery for automobiles

- Safety
- Large current capability
- Large capacity
- Wide temperature range

Less demanding applications

- Stationary use
  - Emergency power supply
  - Efficient power grid
- Smaller e-mobility
  - Forklifts
  - Golf carts

HIOKI

Reuse/repurpose of automobile LIBs

High performance battery for automobiles

- Safety
- Large current capability
- Large capacity
- Wide temperature range

Less demanding applications

- Stationary use
  - Emergency power supply
  - Efficient power grid
- Smaller e-mobility
  - Forklifts
  - Golf carts

Repurposing enables more efficient exploitation of LIBs
-> Improve the economy of xEVs

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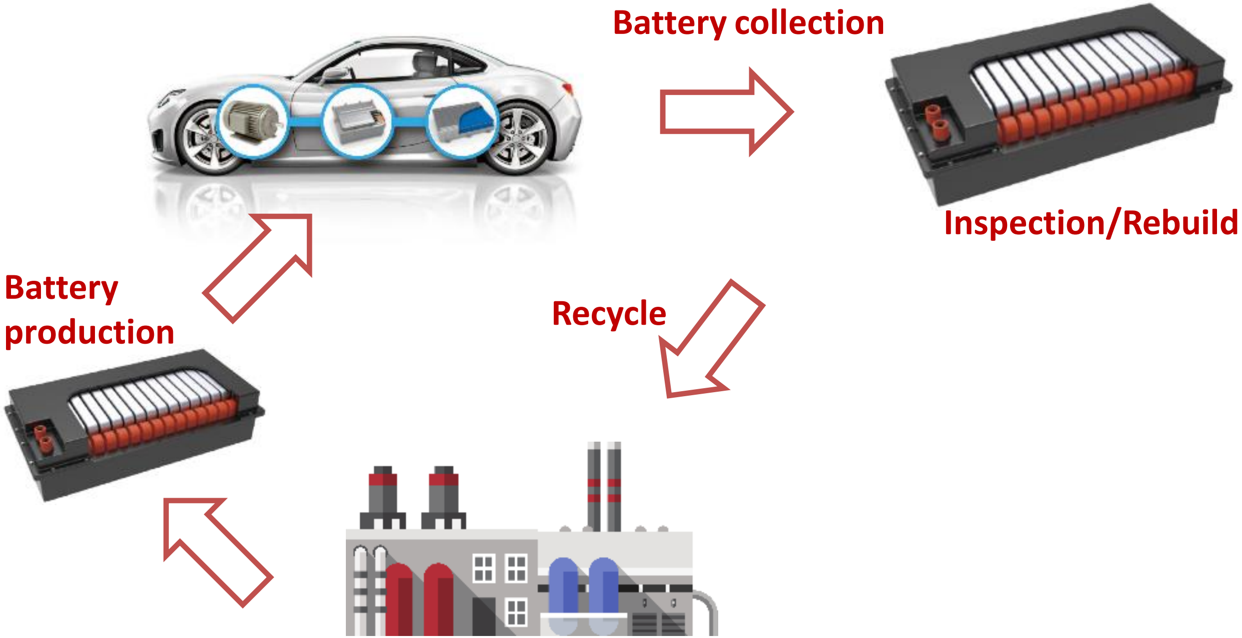
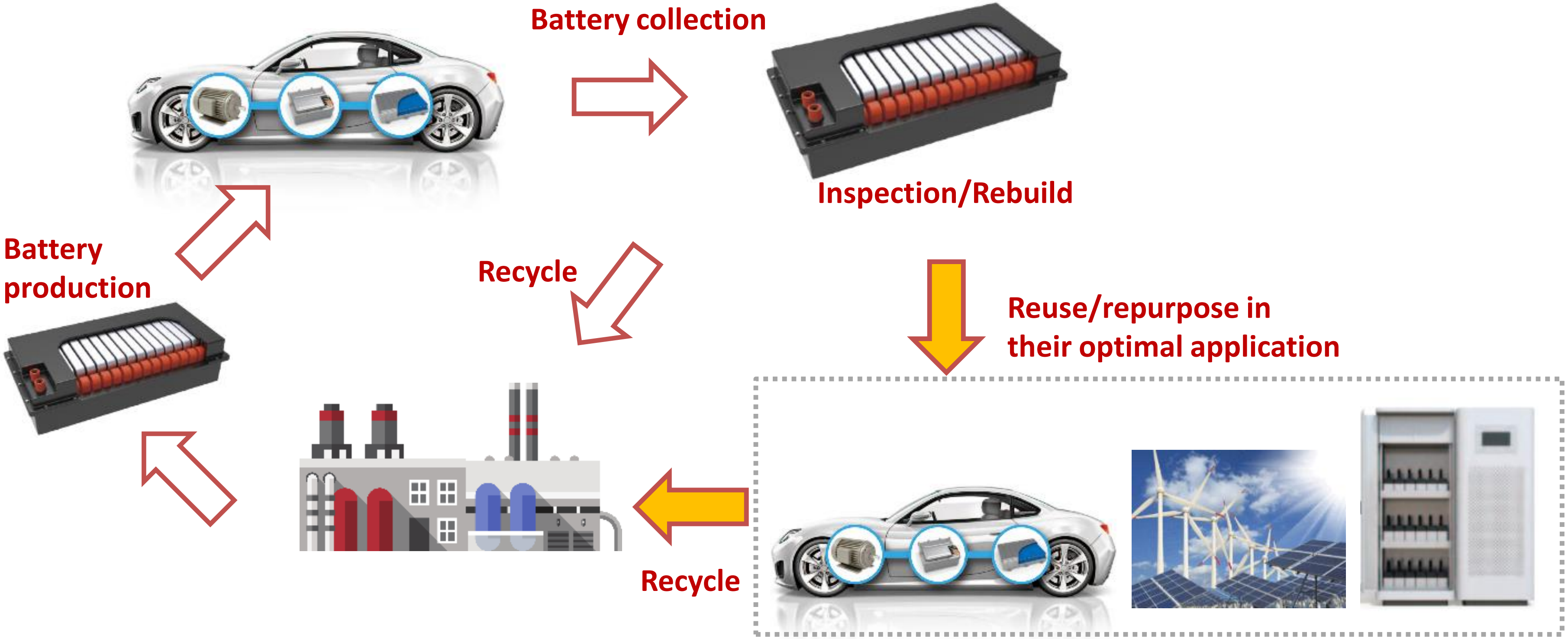
Life cycle assessment



Life cycle assessment



Issues in performance assessment

How to evaluate the SOH (State of Health)

SOH: the most popular LIB performance indicator

$$\mathrm{SOH} = \frac{\text{(full charge capacity at the time of measurement)}}{\text{(nominal capacity)}}$$

1. Stabilize the battery at room temperature
2. Discharge at a specified current down to a specified final voltage
3. Charge using the method declared by the manufacturer (usually CC-CV, C/3 or C/5)
4. Stabilize the battery
5. Discharge at a specified current down to a specified final voltage (usually 1C or C/5)
6. Calculate the capacity by integrating the discharge current of step 5.

IEC62660-1:2010
IEC61960-3:2017
JIS C8711:2013

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Issues in performance assessment

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IEC62660-1:2010
IEC61960-3:2017
JIS C8711:2013

- time-consuming (>24h)
- large equipment requisite

Issues in performance assessment

LIB pack	Assessment methodology for reuse	Issues
with data/information during operation	- ideally no need to any extra test	- a third party may need some test
w/o them	- standardized full charge/discharge	- time-consuming (>24h) - large equipment requisite
	- partial charge/discharge - electric measurement at specific SOC and temperature	- takes several hours - large equipment requisite
	- rapid electric measurement	- lack reliability

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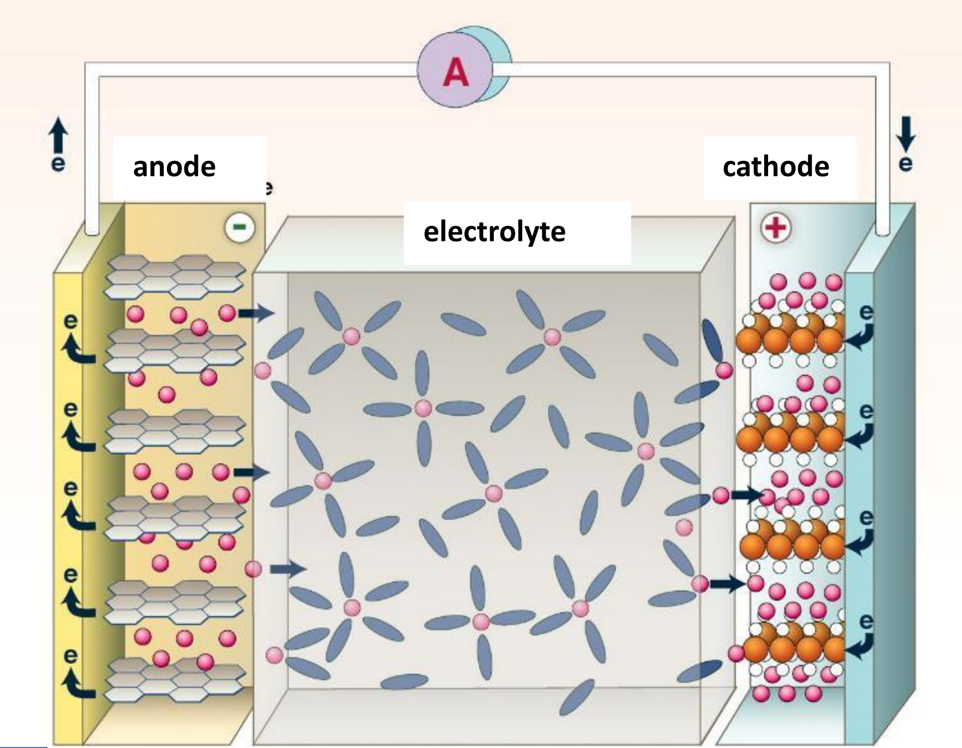
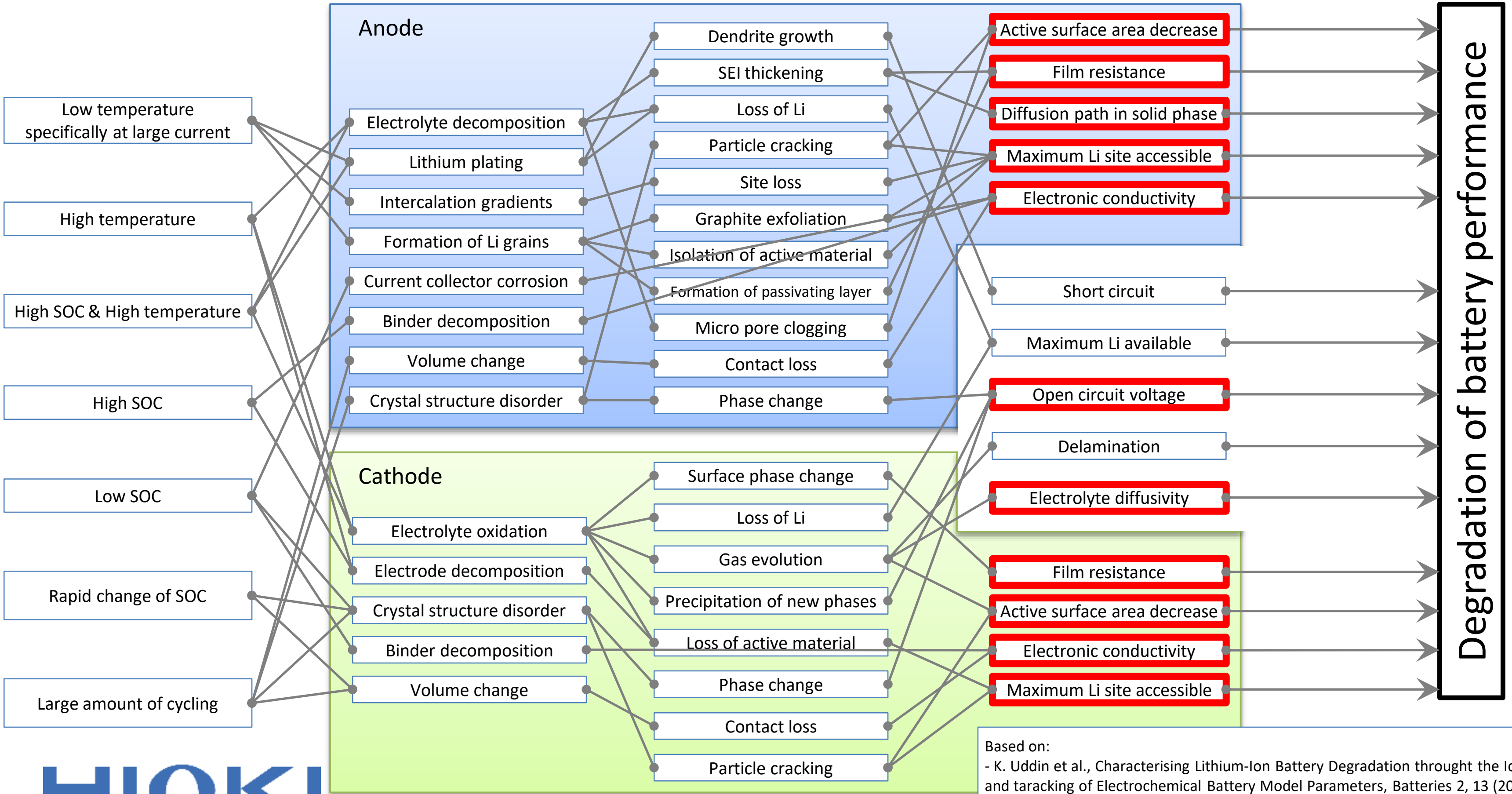
SOH estimation based on EIS



- Electrochemical impedance spectroscopy (EIS) reflects the internal state of LIBs
- EIS can evaluate the state of each battery component spectroscopically
- Traceable EIS value can be a common and comparable indicator of LIB performance, independent on the measuring hardware

B. D. et al., Electrical energy storage for the grid: A battery of choices

Degradation mechanisms



Based on:
- K. Uddin et al., Characterising Lithium-Ion Battery Degradation throught the Identification and taracking of Electrochemical Battery Model Parameters, Batteries 2, 13 (2016)
- N. Oyama, Performance and long-term reliability of lithium-ion secondary batteries, Science &Technology, M32 (2016), in Japanese

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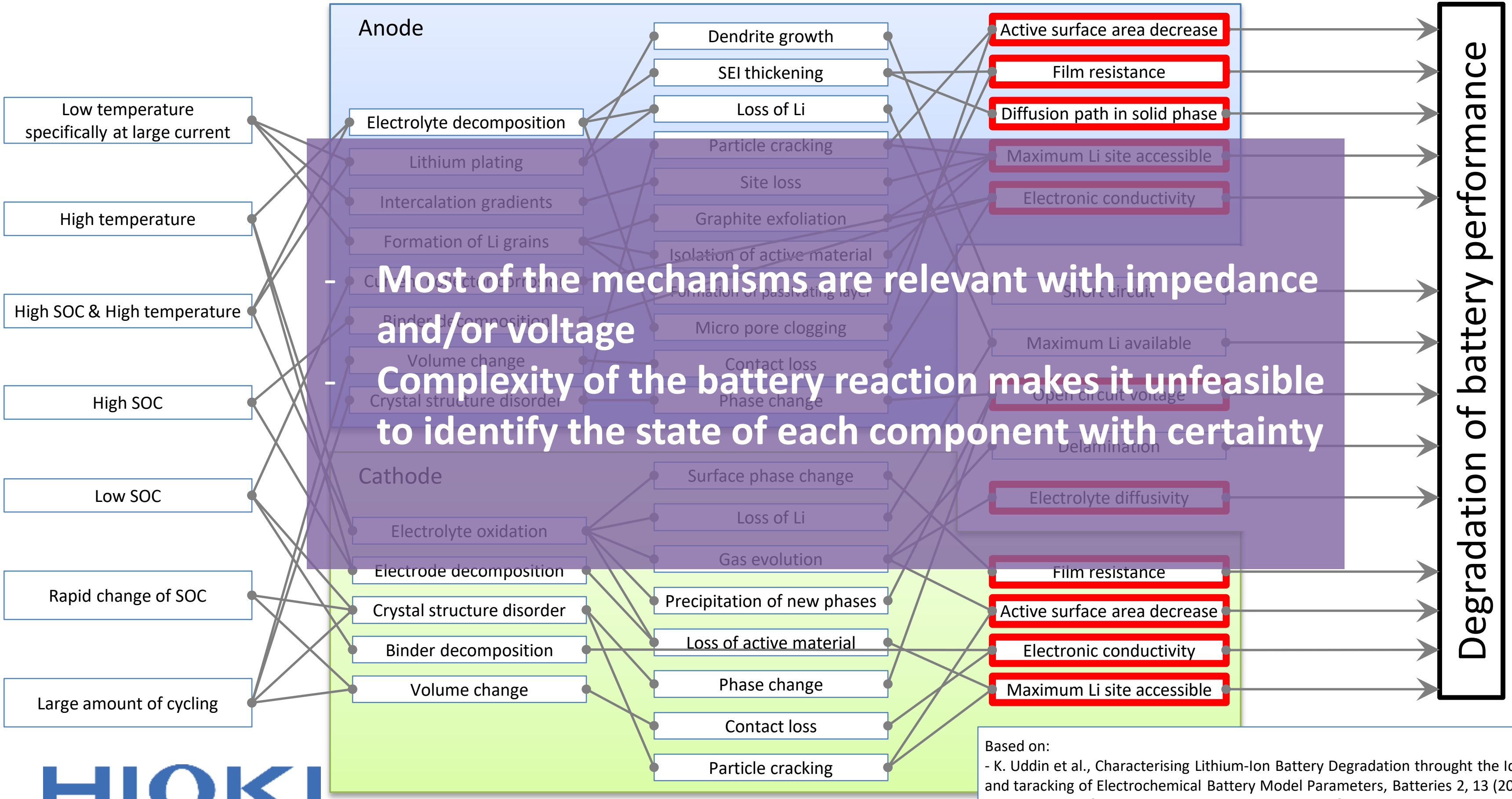
Degradation mechanisms

- Most of the mechanisms are relevant with impedance and/or voltage
- Complexity of the battery reaction makes it unfeasible to identify the state of each component with certainty



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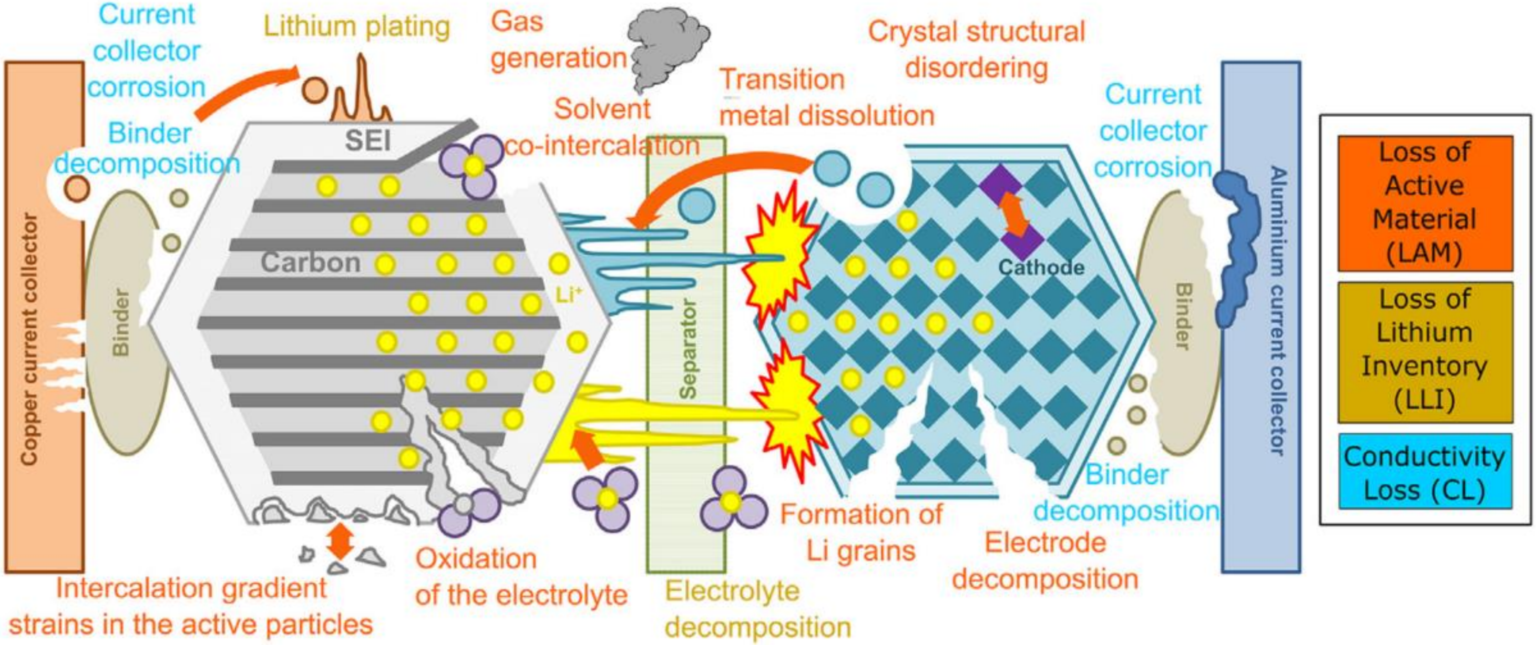

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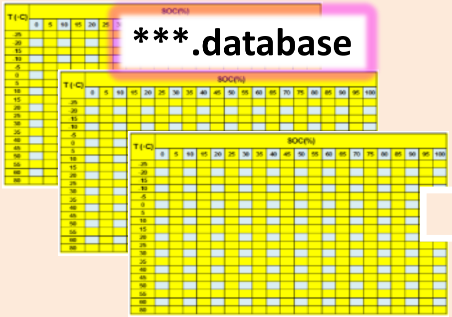
C. Pastor-Fernandez et al., A comparison between electrochemical impedance spectroscopy and incremental capacity-differential voltage as Li-ion diagnostic techniques to identify and quantify the effects of degradation modes within battery management systems, Journal of Power Sources 360, 301 (2017)

SOH calculation based on data-driven methodology

Database

***.database

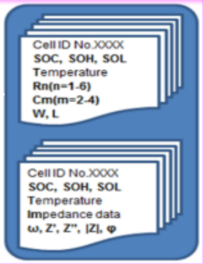


Z, OCV, Temp, SOH
under various conditions

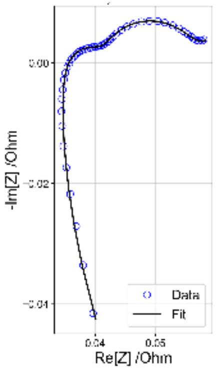
Data analysis

Calculate algorithm

***.algorithm



Battery with an unknown history of use (impedance, OCV, Temp.)



<u>Accumulate the characteristics data</u>

Calculation

<u>**Estimate SOH**</u>

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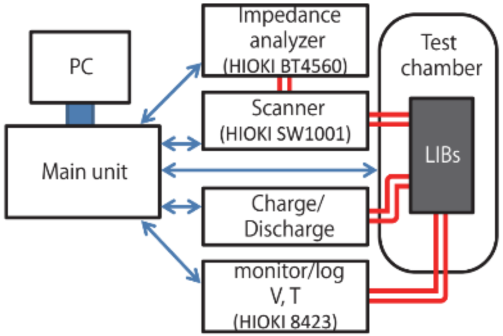
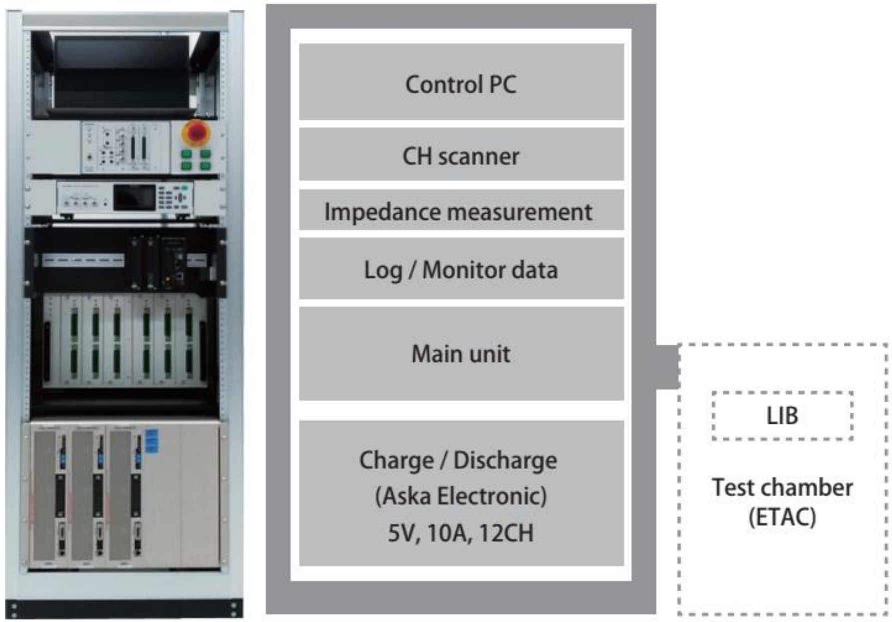
Developed data accumulation system

- Fully automatic control, ensuring strict safety
  - Charge/discharge
  - Temperature chamber
  - Measuring instrument





SOH estimation performance

- **Data**
  - **DUT: commercial 18650 type**
  - **# of spectrum: ~4000**
- **Algorithm: based on Gaussian process regression (GPR)**
- **Performance**
  - **Rms error of 1.72% -> +/-3.4% @95% CI**

rms error (Kfold, k=5)		to				
		1Hz	10Hz	100Hz	1kHz	10kHz
from	0.1Hz	2.96%	2.08%	1.89%	1.72%	1.87%
	1Hz	-	2.99%	2.49%	2.20%	2.13%
	10Hz	-	-	3.35%	2.96%	2.86%
	100Hz	-	-	-	3.92%	3.78%
	1kHz	-	-	-	-	4.78%

SOH estimation error: < +/- 5%
Optimal freq. range of 0.1Hz - 1kHz
-> ~2min. Including the measurement and the calculation

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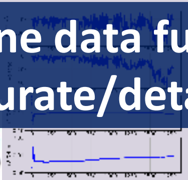
And more

	online during operation	offline when removed from the device
Current performance “SOH” (state of health)	 	 Offline measurement
Future performance “Remaining life”		

Online/Offline data fusion will enable more accurate/detailed analysis

EIS can also be the key of the offline remaining life estimation

Several cooperative researches are going on

EURAMET research program

HIOKI was invited to participate in the EU metrology research program

"Quality assessment of electric vehicle Li-ion batteries for second use applications"

EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

- **Our role: establishing traceability for low impedance measurement as a key technology to assess the used-battery**

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Coordination: PTB (Germany)

https://www.ptb.de/empir2018/libforsecuse/

Consortium

Metrology

Research

Industry

Stakeholders

Testing

Standardisation

First use

Batteries

JRP-i25
LiBforSecUse

Quality assessment of electric vehicle Li-ion batteries for second use applications

NEED

Resale market for growing amount of second use Li-ion batteries

STATE OF THE ART

Lack of reliable, fast method for residual capacity measurement and premature failure detection is hampering effective reuse

At present the majority of automotive batteries are incinerated after removal from electric vehicles.

Overall OBJECTIVE

Development of effective measurement method, resting on impedance based measurement and analytical methods

Immediate IMPACT

Best Practice Guides

- Low impedance calibration
- Harmonised Life Cycle Test and impedance measurement procedures
- Residual capacity measurement of second use battery cells and modules

European calibration infrastructure

Entries of Calibration and Measurement Capabilities in BIPM data base

CEN-CENELEC Workshop Agreement

Input to CLC/TC 21 and IEC/TC 21, i.e. IEC 62660-1

Papers, conference talks, workshops, website, online training

In-house training at stakeholders premises

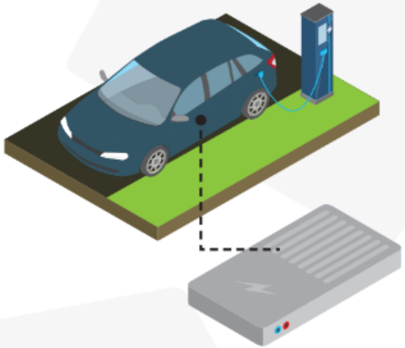
Wider IMPACT

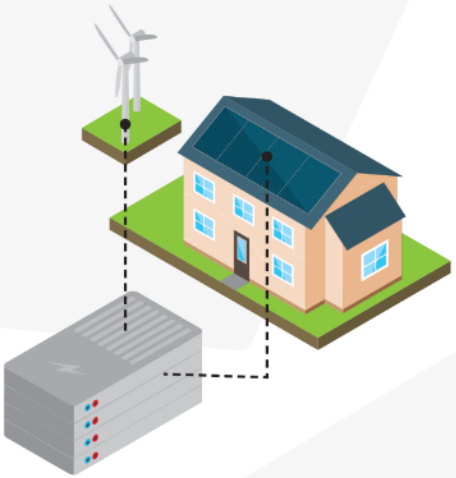
Emerging market for 200 GWh of second use batteries

30 % cost reduction for second use applications (e.g. energy storage for PV systems)

Investments in energy storage capacity is kept in Europe

Support of electromobility to reduce CO_2 emission and air pollution





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WP1 – Impedance Standards

Development and characterisation of low impedance measurement standards and agreed calibration procedures

Scientific excellence / Challenge

mΩ – range with uncertainties < 1%

WP2 – Impedance based LCT Measurements

- Harmonisation of Life Cycle Test (LCT) and impedance measurement procedures
- Development of comprehensive LCT measurement database for various types of Li-ion cells and modules using a range of standard and novel techniques
- Post mortem analysis data

Scientific excellence / Challenge

Metrological sound, reproducible impedance based measurement results with uncertainties around 1%

WP3 – Method Development

- Application of impedance based analytical methods to LCT results from WP2
- Correlation of derived ageing parameters with conventional capacity measurement
- Feasibility study to detect premature sudden death

Scientific excellence / Challenge

Development of fast method to measure residual capacity of second use battery cells and modules with uncertainties around 3 %

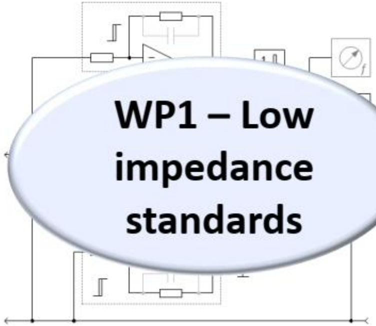
WP4 – Method Validation

Various tests to substantiate methods of WP3

Scientific excellence / Challenge

- Variation of cell types and ageing conditions
- Upscaling to battery packs
- Definition of appropriate Round Robin test
- Test of stakeholder batteries
- Battery modelling
- Correlation with post mortem analysis data

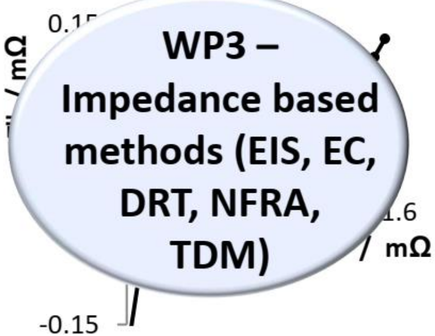
Main Objective/Activities of LiBforSecUse



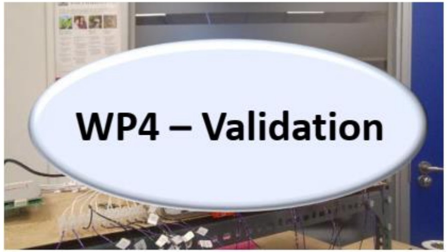
WP1 – Low impedance standards

Method to measure the residual capacity of second use battery cells and modules more effectively and based on metro-logically sound principles

WP2 – Life cycle tests



WP3 – Impedance based methods (EIS, EC, DRT, NFRA, TDM)



WP4 – Validation

Characterisation of Second Use Batteries

- must be effective for economical reuse
- often they are ineffective
- ambiguous definitions and results
- large or unknown uncertainties

Our method of choice
based on nondestructive, fast impedance measurements

Activities of WP 1 (Impedance standards)

Development of optimal **calibration procedure**

Development of **impedance standards**

Metrological characterisation of the standards (**impedance values, uncertainties**)

Comparison measurements

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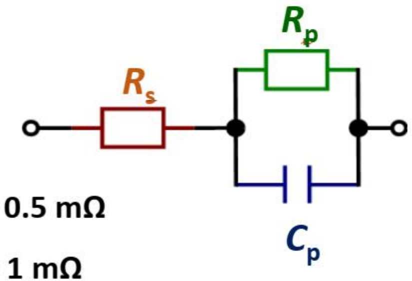
Impedance standards

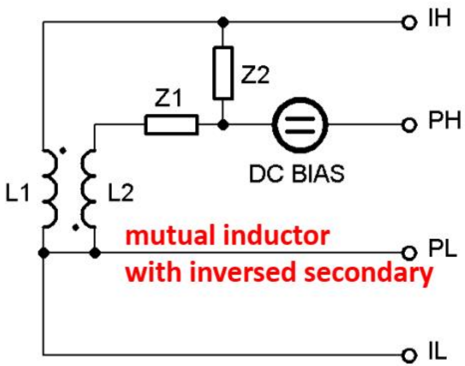


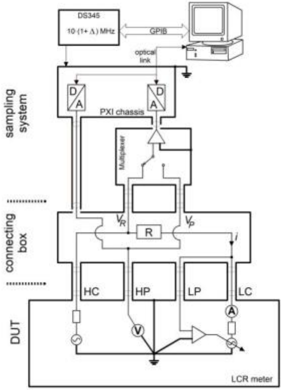
R_s = 0.5 mΩ

R_p = 1 mΩ

C_p = 4 F

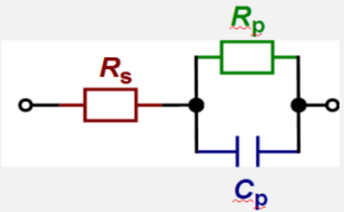
various passive standards
w and w/o bias





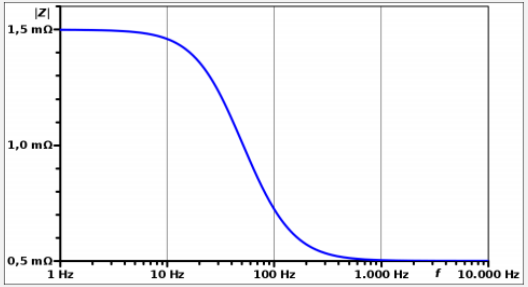
digital
impedance
simulator
(full phase
angle)

Characterisation of impedance standards



$|Z(f)| = U_{eff} / I_{eff}$ measured

Fit of $|Z(R_S, C_p, R_p, f)|$ to $|Z(f)|$

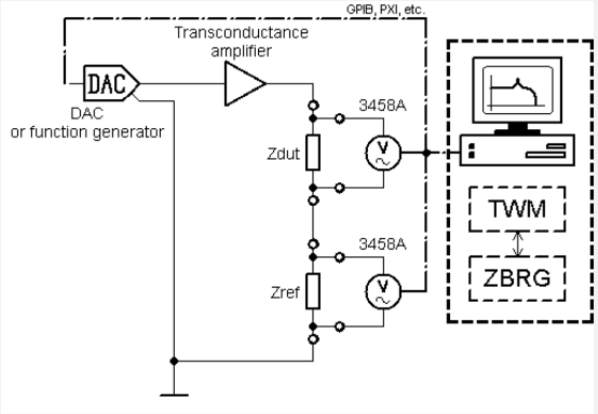


Low frequency, low impedance bridge

Dual Agilent 3458A DMMs for digitizing

DMMs and calculation by open source tool:
https://github.com/smaslan/TWM

Frequency 10 mHz to 10 kHz.
Current 2 A ac + 2 A dc.
Allowable DC bias up to 5 V



Activities of WP2 (LCTs)

Conduction of LCTs under various conditions

Provision of LCT measurement data
(EIS, non linear impedance, OCV, capacity, a.o.)

Definition of reproducibility parameters
(LCTs and impedance measurements)

Quantification of measurement uncertainty

Comparison measurement

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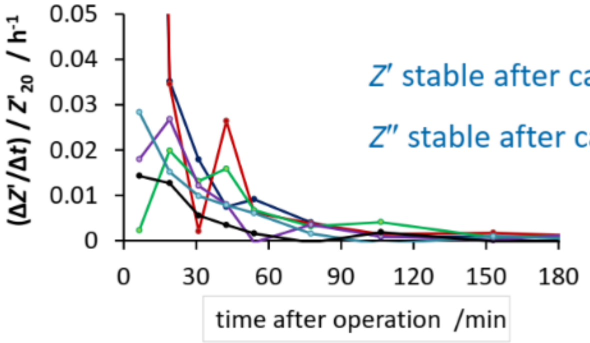
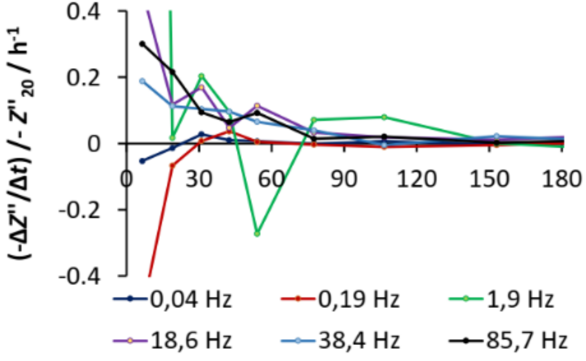
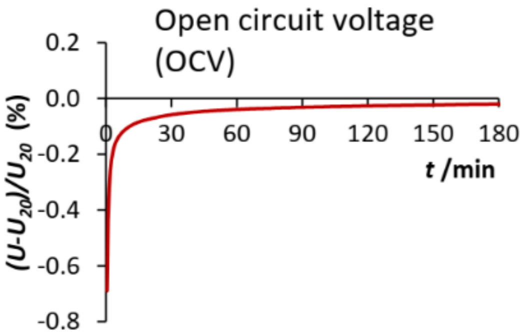
Example: steady state / relaxation time



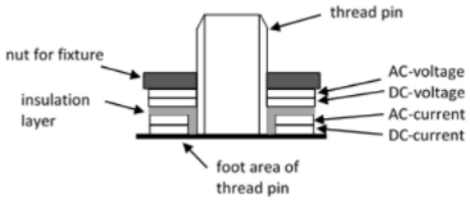
Z' stable after ca. 60 min < 1 %/ h

Z'' stable after ca. 150 min < 2 %/ h





LCT & Measurement conditions



Wiring

Cell positioning and fixture

Temperature

Currents (charge/discharge/impedance, capacity, OCV)

Charge/discharge patterns

SoC adjustment (current or voltage based)

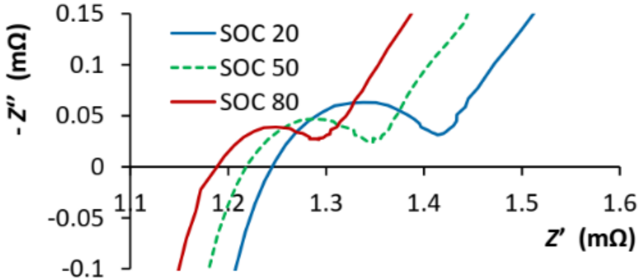
Frequency ranges

Noise levels

Relaxation times

Causality test

LCT test procedure



WP3 Activities

- Residual capacity from impedance based analysis
- Feasibility study to detect risk of sudden death

Methods to be applied

- Impedance spectrum analysis (EIS)
- Equivalent circuit analysis (EC)
- Distributed relaxation times (DRT)
- Nonlinear frequency response analysis (NFRA)
- Time domain measurements (TDM)

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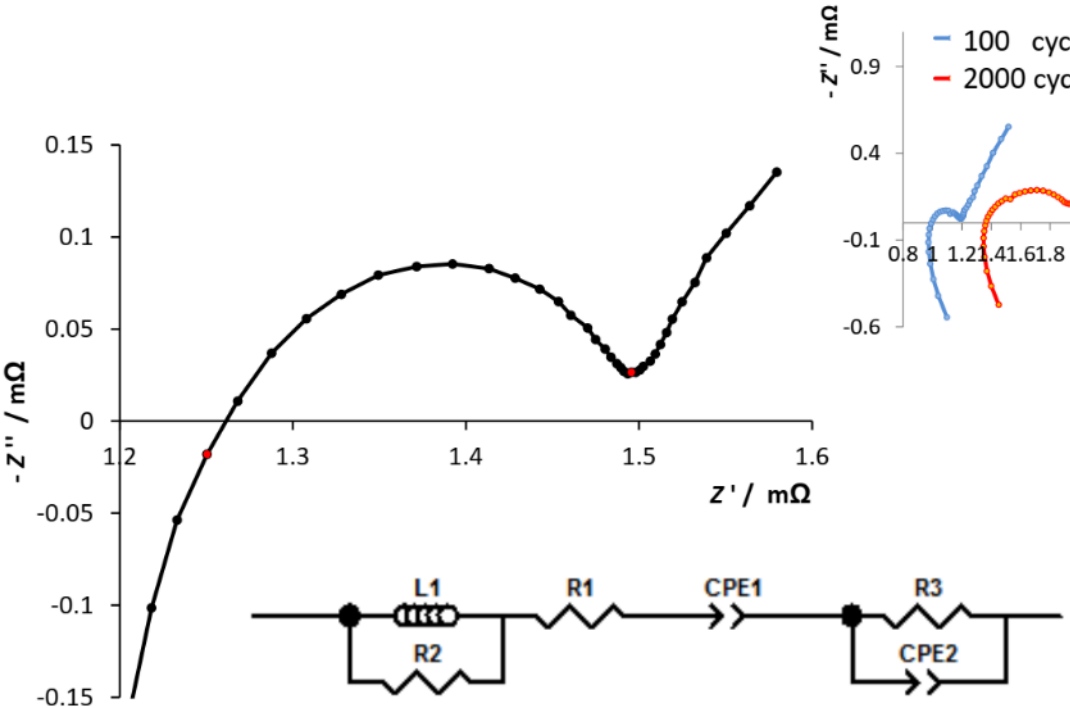
Equivalent circuit/ impedance analysis



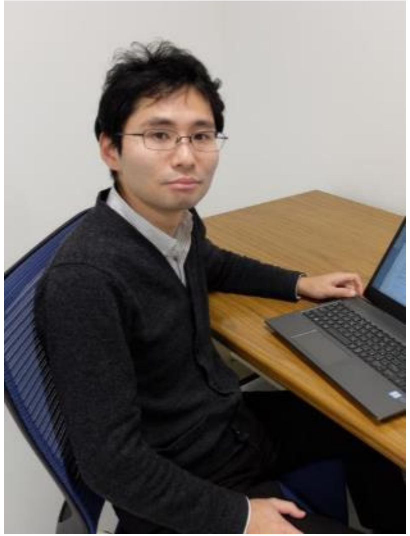
Summary

Summary

- We have developed a variety of electrical measuring/inspection instruments in conjunction with the evolvement of LIBs. They are widely used in industry and academia in Asia and all over the world, playing a significant role for their ongoing evolvement.

- Based on our outstanding measurement technology, some novel solutions are under development. Above all, the methodology to evaluate the residual performance of LIBs for their reuse is one of the most promising, hopefully opening up the acceleration of automobile electrification.

Thank you !



Mori, Takumi (森 匠), Ph. D.
Research engineer
EM unit, HIOKI E. E. CORPORATION
takumi.mori@hioki.co.jp

HIOKI

SINGAPORE BATTERY CONSORTIUM

HIOKI

Lithium Ion Battery Safety

(Safety Standards and Testing)

Andreas Hauser

Singapore, 29th October 2020

VDE

Introduction VDE Renewables Asia

VDE Association structure - overview

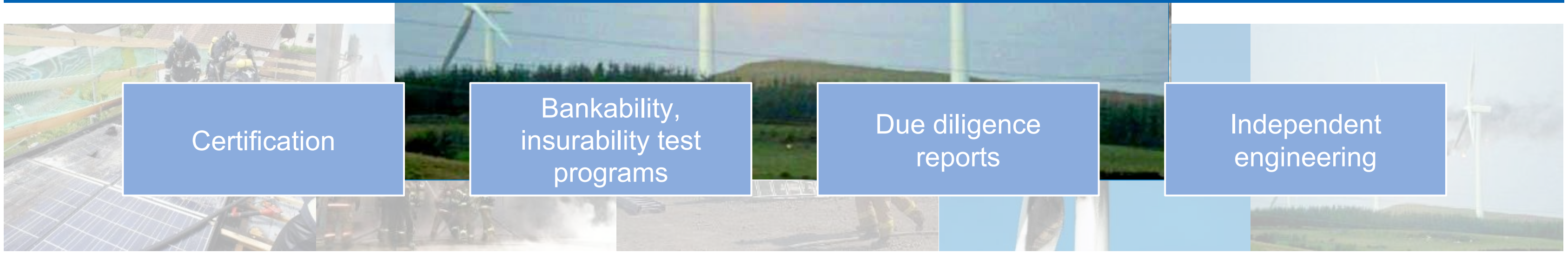
Professional network	Technology services	Standardization services	Professional education
36,000 Members 1,300 Corp. members 6,000 Students 250 Universities 1,800 Employees 5 Expert Societies Energy, ICT, Automation, Microelectronics, Biotechnology	VDE Innovation & Technology Services VDE Renewables with VDE Prime Labs VDE IT Security CERT, Smart Technologies VDE Digital Platform VDE Global Services VDE Americas	DKE German commission for standardization (IEC) FNN Network for applications rules in grid technology and operation Testing & Certification Institute	VDE Publishing VDE Conferences & Seminars VDE Academy

Immeasurable technical and financial risks
➔ No compromises with quality assurance!

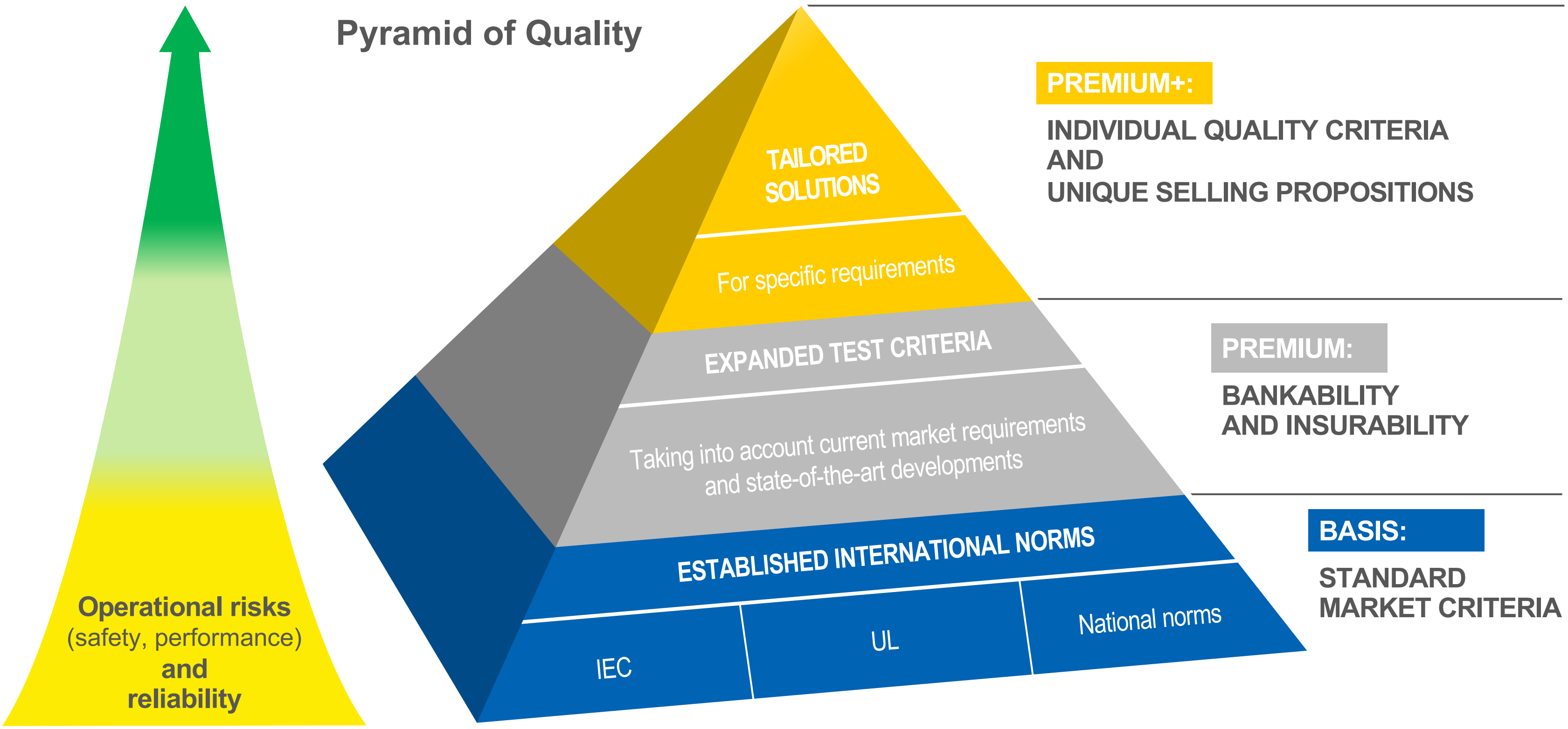
Evaluation of all essential test criteria

Remaining at the forefront of state-of-the-art technologies and techniques

Recognized by courts of law



Bankability and Insurability



Technical and financial risk minimization for energy storage systems

Independent product quality assurance through global competence centers

Important manufacturing markets – today and tomorrow:

Japan | South Korea | China | Southeast Asia

- Batteries / cells (small to large-scale)
- Power tools, portable appliances
- Stationary energy storage
- E-mobility - Components and systems

- Consultancy on international and national standards as well as market access requirements
- Support in creating requirement specifications
- Technical support in the assembly of storage systems
- Development and implementation of in-house quality criteria
- Tailored analyses of battery cells and packs
- Premium certifications based on international standards
- Support in achieving bankability and investability criteria
- Regular and unannounced audits at manufacturers
- End-of-line tests at production lines
- Conducting accident forensics and error analyses with recommendations for risk minimization

VDE Energy Storage PrimeLab Singapore

Key activities:

- R&D for industrial clients
- Prototyping of energy storage systems (ESS)
- Testing & certification on cell, module, and pack level
  - Performance and lifetime testing with 200+ test channels for various system sizes (all chemistries)
  - Safety testing in specially designed testing bunker
- Consulting, due diligence and development support

VDE Energy Storage PrimeLab Singapore

Bridging research, commercialization and financing

- Accompanying client products on all stages from ideation to market introduction
- Dedicated senior experts with decades experience in Batteries and ESS
- Creating strong ties and collaboration supported by a globally interconnected VDE PrimeLab network and our academic and industrial partners
- Tailored premium certification for bankability and insurability together with our global network of banks and insurance companies

Safety of lithium-ion cells & -batteries

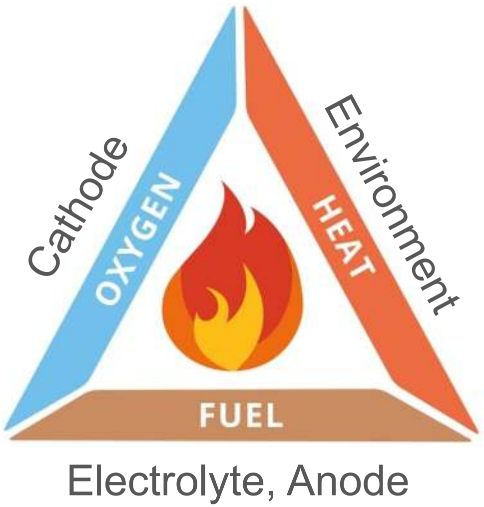
Safety of lithium-ion cells & batteries

Possible risks of lithium-ion cells

Required	Located where
Oxygen	Cathode: LMO, NMC, NCA, etc. Environment: Air oxygen
Combustible substance (fuel)	(Liquid) electrolyte, separator, carbon / graphite (anode)
Heat	Inside or outside of cell

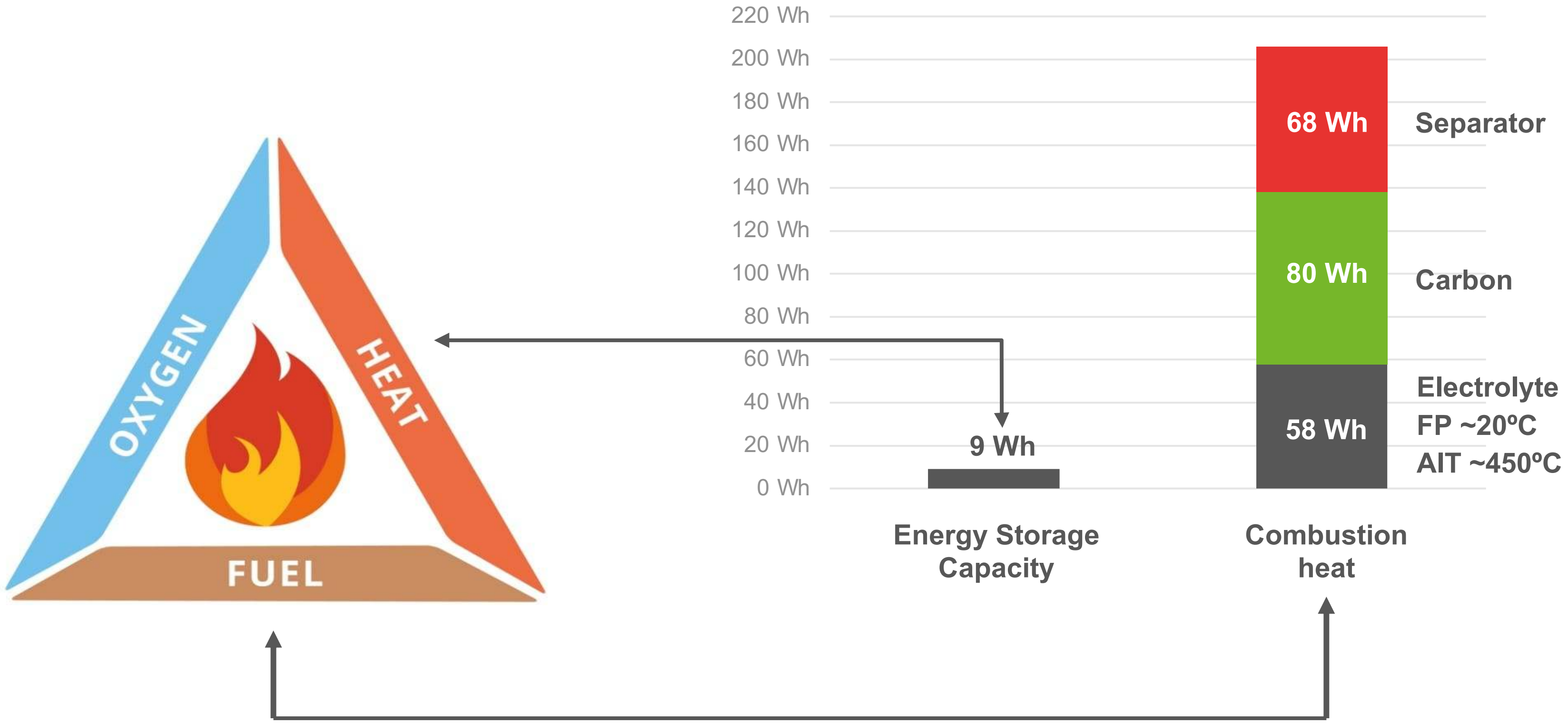
- Lithium-ion cells contain a) oxygen chemically bound in cathode and b) combustible substances in other components, e.g. electrolyte solvents

➡ During normal operation within manufacturer specifications, Lithium-ion cells are generally safe, as long as heat sources are absent
(Note: Heat can be created internally by e.g. damage, misuse, internal short)



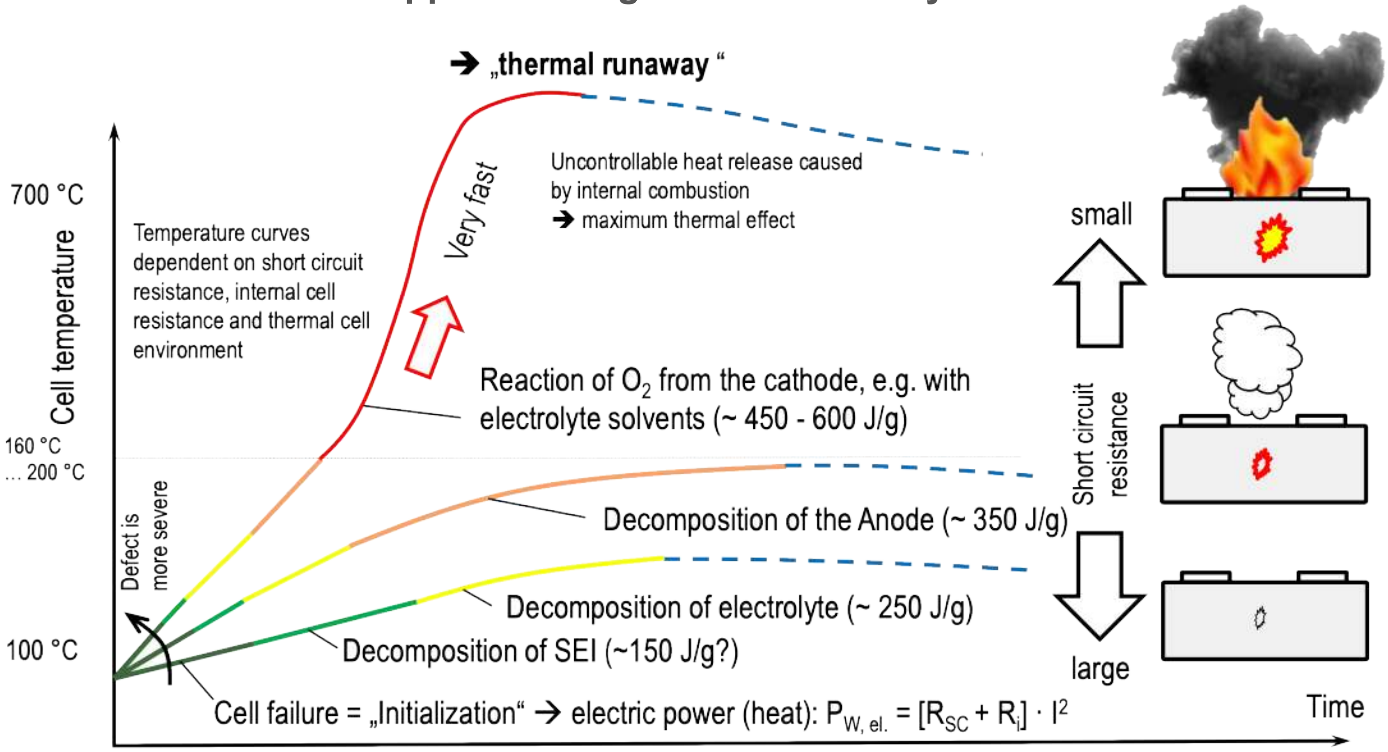
Raw image source: High Speed Training

Safety of lithium-ion cells & batteries



Safety of lithium-ion cells & batteries

What happens during thermal runaway?



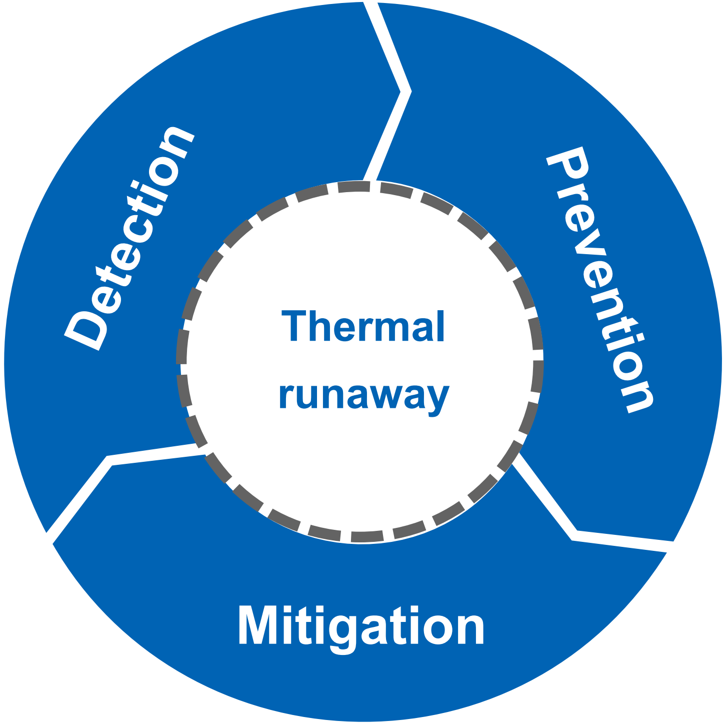
Source: S. Scharner – "Quantitative Safety Characterization of Li-Ion Cells", 2018

Safety of lithium-ion cells & batteries

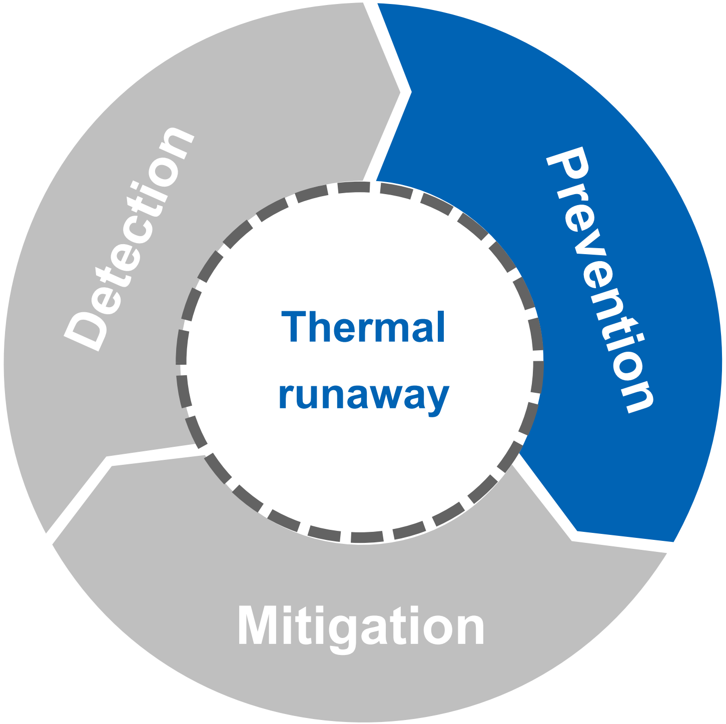
Location	Heat generator	Reason	Countermeasures
Cell external	External short circuit	Failure of external fuse	Cell-internal fuse
		Short circuit between cells	Improved isolation of cells, fusible links
	External fire	Different reasons	Thermal isolation
Cell internal	Li-Dendrites	Fast charge, low temp. charge	BMS: Current & temperature monitoring
	Cu-Dendrites	Deep discharge	BMS: Voltage monitoring
	Decomposition	Overcharge	
	Crush, puncture	Crash / traffic accident	Mechanical design
	Quality defects	Different reasons	Inspections and assessments

➡ Quality defects cannot be predicted nor can consequences be prevented by BMS!

Safety of lithium-ion cells & batteries



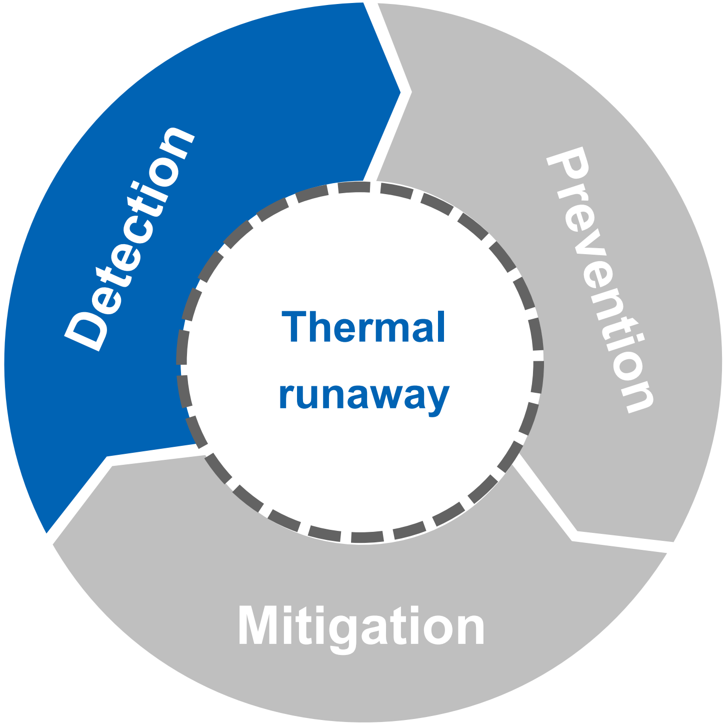
Safety of lithium-ion cells & batteries



Prevention by quality control, BMS & EMS

- Quality control
  - Usage of certified components
  - Factory- / facility inspections & assessments
  - Trained personnel (also at installer)
- Constructive measures
  - Thermal- and mechanical design
- BMS & EMS
  - Monitoring of voltages, temperatures and currents
  - Control of cooling strategy
  - Energy management, e.g. predictive load reduction
  - Access control & Cybersecurity

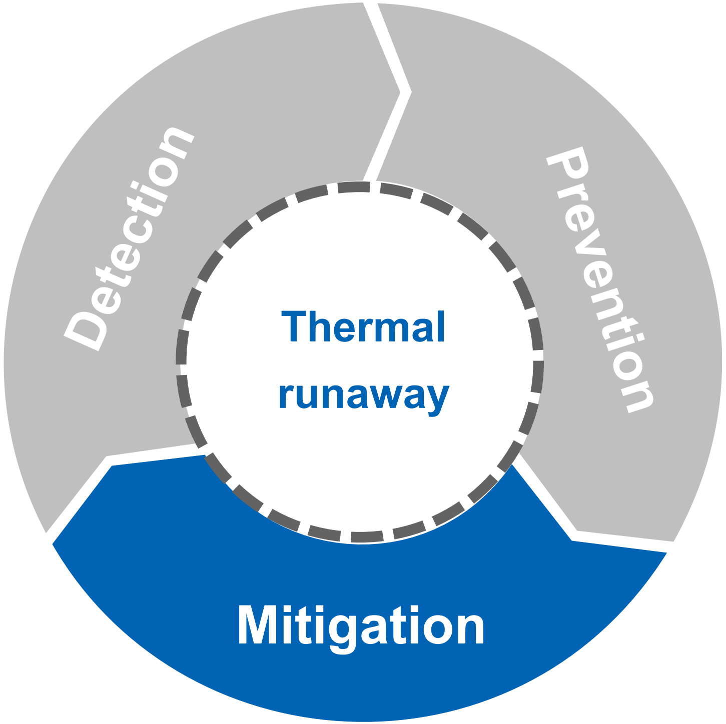
Safety of lithium-ion cells & batteries



Detection by Battery Management System (BMS)

- Cell-, module- and system voltage abnormalities
- Cell temperatures outside operating window
- Thermal management system status checks
- Ground fault detection / insulation resistance measurement
- Contactor status / Safety interlock
- Smoke / gas detection

Safety of lithium-ion cells & batteries



Mitigation by active & passive measures

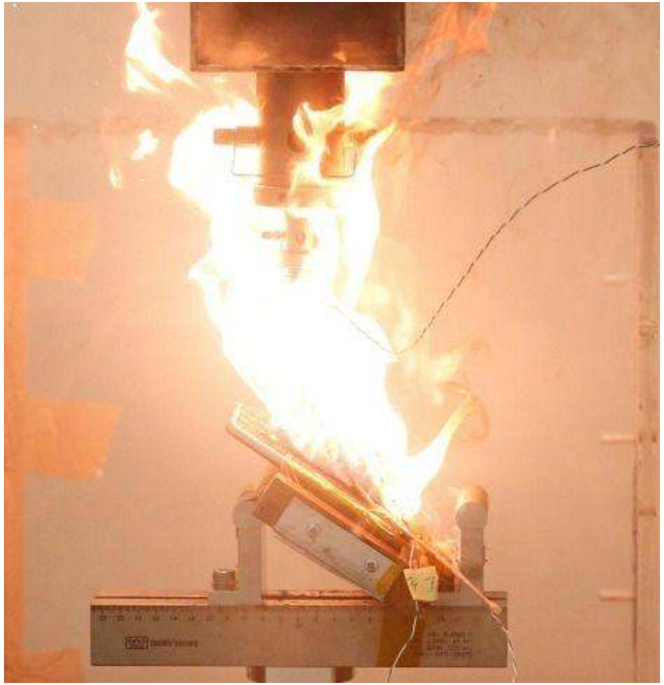
- Passive (constructive) measures
  - Thermal insulators between cells / modules (anti-propagation measures)
  - Overpressure venting system (e.g. burst disc)
- Active measures (fire extinguishing)
  - N2 / CO2 / Water
  - Fire retardant chemicals
  - Specialized aerosols / gas mixes (e.g. Inergen gas)

Safety testing of cells & batteries

Safety testing of cells & batteries

What is safety testing?

- Testing with the aim to evaluate the behaviour of a cell / battery during foreseeable misuse, accidents, failures caused due to production / design issues, etc.
- Tests include (but not limited to):
  - Overcharge / deep discharge
  - Overheating / thermal shock
  - External short circuit
  - Nail penetration / Nickel particle (simulated internal short circuit) / Blunt nail indentation
  - Fire exposure tests
  - Crush / Shock / Vibration / Drop / Impact / Bending
  - Propagation testing
  - BMS tests with connected cells



Safety testing of cells & batteries

- Lithium ion batteries can be used safely but can have various failure modes when misused or when systematic design / production faults occur
- Definition of failure modes & hazard levels (EUCAR):

Hazard Level		Classification Criteria, Effect
0	No effect	No effect, no loss of functionality
1	Passive Protection activated	No defect, no leakage, no venting, no fire or flame, no rupture, no explosion, no exothermic reaction or thermal runaway, cell reversibly damaged, repair of protection device needed
2	Defect Damage	No leakage, no venting, no fire or flame, no rupture, no explosion, no exothermic reaction or thermal runaway, cell irreversibly damaged, repair needed
3	Leakage > 50%	No venting, no fire or flame, no rupture, no explosion, weight loss ≤ 50 % of the electrolyte weight electrolyte = solvent + salt
4	Venting > 50%	No fire or flame, no rupture, no explosion, weight loss ≥ 50 % of the electrolyte weight
5	Fire or Flame	No rupture, no explosion, i.e. no flying parts
6	Rupture	No explosion, but flying parts, ejection of parts of the active mass
7	Explosion	Explosion, i.e. disintegration of the cell

Safety testing of cells & batteries

Electrical tests

- Abnormal charge, continuous charge, overcharge
- Forced discharge (polarity reversal)
- External short circuit
- Insulation resistance & internal resistance
- (Internal short circuit) & propagation testing

Thermal tests

- Thermal cycling (e.g. -40 °C to +70 °C)
- Thermal stress (up to +130 °C)
- Low temperature operation (e.g. for Aerospace)
- Molded case stress test
- Projectile & external fire

Mechanical tests

- Crush
- Vibration
- Shock
- Impact & drop (free fall)
- Bend tests (pouch cells)

Others

- High altitude (low pressure)
- Functional safety testing of BMS
  - Over- & undervoltage and overcurrent
  - Overtemperature

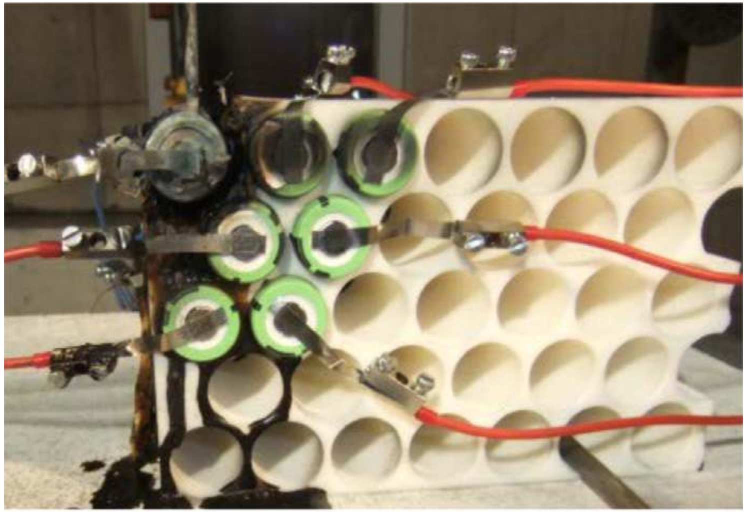
Safety testing of cells & batteries

Of special importance - Propagation testing

- Critical to ensure battery system hardened against random thermal runaway events → Quality defects!

- Reason for thermal runaway not relevant for test & analysis
  - Cell in the centre of the battery stack is triggered using a suitable trigger method
  - Suitable methods include overheating (heat patch / laser), overcharge, nail penetration, etc. (but not external short!)

- Test fails if
  - Fire / thermal runaway spreads to surrounding cells in battery stack
  - Fire / thermal runaway spreads to another cell module in same system



Source: M. Hartmann, "Temperature Adjustable Thermal Management System with Thermal Runaway Protection for Li Ion Packs"

Safety testing of cells & batteries

Electrical safety testing – BMS

- BMS testing still not included in most standards (exception: IEC 62619:2017)
- Simple tests to determine BMS response to:
  - Overtemperature
  - Overvoltage
  - Overcurrent

→ **Tests do not cover edge cases or random faults (only systematic faults)**

- BMS should be evaluated using functional safety methods and processes (FMEDA / FMEA, fault tree analysis, etc.)
  - IEC 62619 requires functional safety analysis of BMS, but not certification based on IEC 61508 family of standards (or similar)

Safety testing of cells & batteries

Video Link: 18650 cell safety test – https://youtu.be/YJNsmnVrAJo

Standards for safety testing of lithium-ion cells & batteries

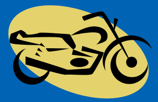
Standards for safety testing of lithium-ion cells & batteries

Standardization in a (small) nutshell

- Important nomenclature in (most) battery standards:
  - cell = individual, stand-alone cell without additional components
  - battery = system consisting of one or multiple cells with casing, connectors, electronics, etc.
- On international level, standards developed by multiple working groups coming from different angles, so overlapping standards, no common framework
- Long development time of standards → standardization behind state of the art of technology
- Most international standards / norms generally not mandatory, exceptions for specific purposes and industries:
  - UN 38.3 Transportation tests (all sectors)
  - ECE R100 rev. 2 / ECE R136 (electromobility)
- Standards can be grouped in performance- and safety standards

Standards for safety testing of lithium-ion cells & batteries

- **ISO 12405 series** Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems
- **IEC 62660 series** Secondary lithium-ion cells for the propulsion of electric road vehicles
  Part 1: Performance testing ; Part 2: Reliability and abuse testing
- **ECE R100 rev. 2** Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train



- **ISO 18243** Electrically propelled mopeds and motorcycles -- Specifications and safety requirements for lithium-ion traction battery systems
- **EN 50604-1** Secondary Lithium batteries for LEV (light electric vehicle) applications
  Part 1: general safety requirements and test methods
- **ECE R136** Uniform provisions concerning the approval of vehicles of category L with regard to specific requirements for the electric power train

- **IEC 61960 series** Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications
- **IEC 62133 series** Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells / batteries, for use in portable applications

- **IEC 62619** Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
- **IEC 62620** Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for use in industrial applications

Standards for safety testing of lithium-ion cells & batteries

- **IEC 63056** Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems
- **IEC 62485 series** Safety requirements for secondary batteries and battery installations
  Part 5: Lithium-ion batteries for stationary applications
- **IEC 62933-5** Electrical energy storage (EES) systems - Safety considerations for grid-integrated EES systems
- **VDE-AR-E 2510-50** Stationary battery energy storage systems with lithium batteries – Safety requirements

- As already mentioned, transportation usually requires testing based on the UN Manual of Tests and Criteria, part III, subsection 38.3 (or UN 38.3 in short)
- Required by e.g. IATA DG (air), IMDG Code (marine), etc.
- Apart from UN regulations, IEC and ISO standards there are also national and regional standards (e.g. EN standards [Europe], DIN standards [Germany], UL standards [US], etc.)
  - IEC standards available as UL-harmonized version
- Standards released by standardization organisations (e.g. VDE, UL, DNV-GL, RTCA etc.) often very similar to IEC standards (e.g. UL 1973, UL 2054) or fill voids in standardization landscape (e.g. VDE-AR-E 2510-50 [Home storage], UL 2272 [PMDs], UL 9540A [Fire protection of large-scale ESS])

Standards for safety testing of lithium-ion cells & batteries

- Testing based on international standards has limitations, notably:
  - Progression to “design for test” cells and batteries
  - Potential safety issues get worse with cell ageing, but often no testing of aged cells
  - Standards lack behind technology → some tests “outdated” (e.g. low short circuit currents)

- Misuse can be reduced by technical measures in the application, but quality issues may cause type-tested cells to fail (e.g. Samsung Note 7, ESS fires in US & Korea)
  - Safety of cells not purely defined by design, quality control plays an important part

- Other aspects of ESS not (or insufficiently) controlled / tested:
  - Assembly, installation, maintenance, decommissioning, recycling
  - Additional components, e.g. BMS
  - Propagation of thermal runaways in multi-cell systems

Q & A

Q & A – Part 1 / 1

Q: It is understood it is possible to quantify how much heat is being released during an abrupt reaction upon thermal runaway of battery cells, but is it possible to test the specific heat capacity during normal operation conditions?

- Yes, the specific heat capacity (c_p) can be determined in a laboratory setting (at VDE Renewables Asia for example, where we have the required equipment for that) with various measurement setups, such as calorimeters.
- It is however not possible to measure the c_p while the cell / battery is in use in a target application, i.e. in an energy storage system

Thank you for your attention!

We shape the e-dial future.
Experience it with us.

Your contact:

Andreas Hauser

Deputy Head, Energy Storage Systems

Phone: +65 9151 1798
andreas.hauser@vde.com

Our services:

- *R&D for industrial clients*
- *Testing & certification on cell-, module-, and pack / system level (including BMS)*
  - *Performance and lifetime testing with 200+ test channels for various system sizes (all chemistries)*
  - *Safety testing in specially designed bunker*
- *Inspections (Factory, ESS sites, pre-shipment)*
- *Accident investigations (battery forensics)*
- *Consulting, due diligence and development support*

Powertrain for Electric Motorbikes: Opportunities and Challenges in Singapore and Southeast Asia

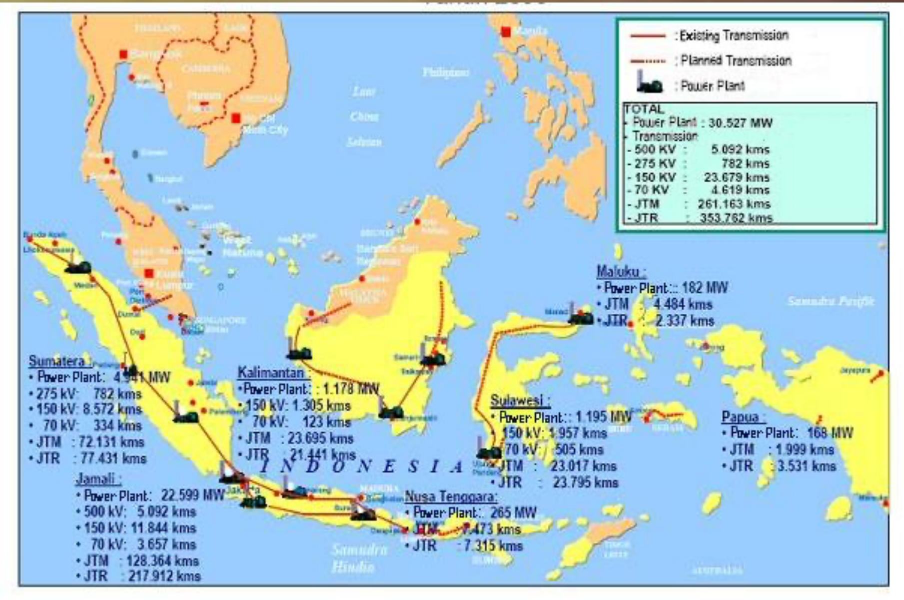
by James Chan
Co-founder & CEO of ION Mobility

Design vs Reality:

<u>It’s a jungle out there!</u>

The Road to (Petrol-fueled) Hell is paved with good (Electric) Intentions:

<u>Many roads can lead to Rome, but which pathway should we take?</u>




Z28
Z27
生产部
台铃
E-Bikes = Electric Bicycles
EV Motorbike = Electric Motorbikes (UK)
EV Motorcycle = Electric Motorcycles (US, China)

Motorcycle Value-Chain Transformation from Gasoline to Electric is Needed in Order to Deliver Cleaner Air and Better Value to Customers.

Motorcycles have poor well-to-wheel CO2 emissions, skewed to its use more than production.

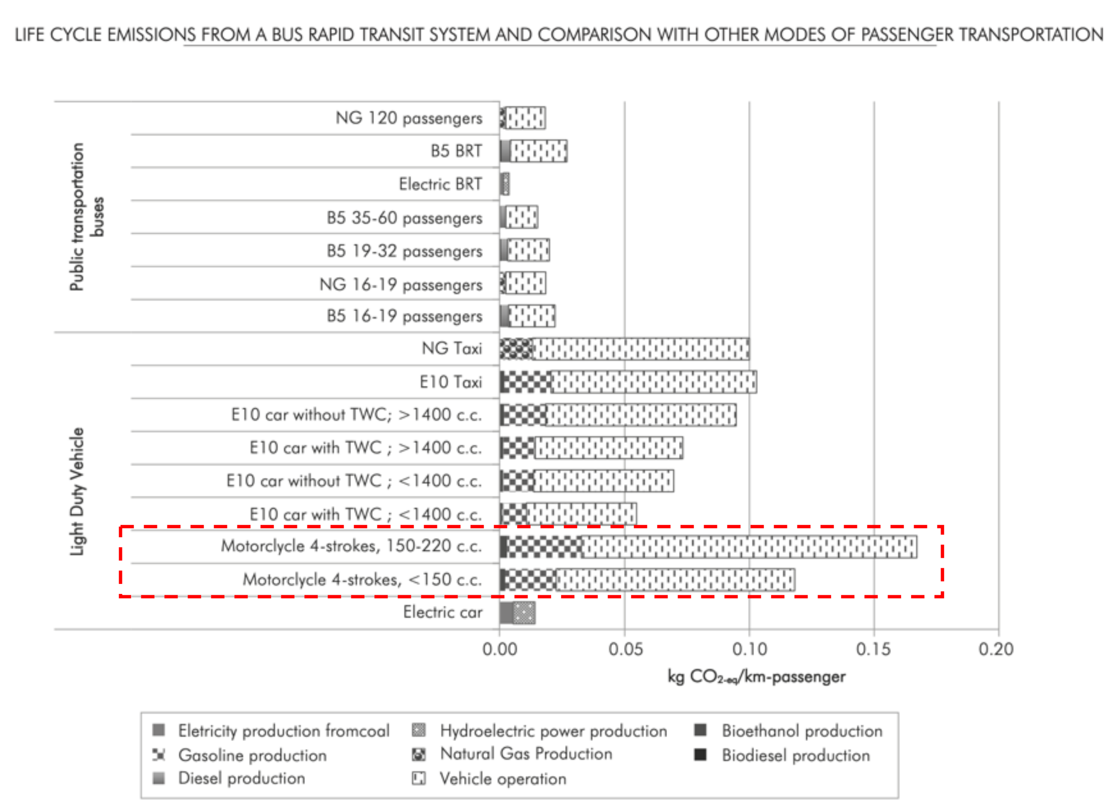


Figure 4. Well-to-wheel CO2-eq emissions from selected energy sources of the vehicle categories. (kg/km-passenger). NG: natural gas; BRT: Bus Rapid Transit; B5: blend 5% biodiesel-diesel; E10: blend 10% bioethanol-gasoline; TWC: Three-way catalyst.

Jakarta had 3rd-worse air quality in the world in Jul 2019.


JAKARTAGLOBE NEWS | BUSINESS | LIFESTYLE | TECH |

Switzerland-based pollution mapping service AirVisual revealed that Jakarta had the world's worst air quality on Friday last week. It was listed as the world's second worst on Wednesday evening. (Antara Photo/Muhammad Adimaja)

Jakarta Air Quality Among World's Worst

BY :ANTARA & NUR YASMIN
JULY 03, 2019

Jakarta. Switzerland-based pollution mapping service AirVisual revealed that Jakarta had the world's third-worst air quality on Wednesday, when it was categorized as "very unhealthy," while air quality in the Indonesian capital was described as the worst globally on Friday last week.

AirVisual bases its listings on the United States Air Quality Index (US AQI), which serves as a yardstick, running from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health risk. According to the AirVisual website, Jakarta had an AQI score of 154 on Wednesday evening, second only to Santiago, Chile.

Greenpeace Indonesia said air quality in Jakarta was only considered healthy on 29 days in 2017, while

Andono Warih, acting head of the province's environmental department, said transportation is the main source of pollution in Jakarta and that he had drawn up a roadmap to reduce air pollution. "Transportation is the main source, and all efforts to control air pollution have been included in the Jakarta Cleaner Air 2030 roadmap," Andono said on Tuesday, as quoted by Antara news agency.

Jakarta Globe – Jakarta Air Quality Among World's Worst, 3 Jul 2019

Luis Carlos Belalcazar - Lifecycle Emissions from a Bus Rapid Transit System ad comparison with other modes of passenger transportation, Apr 2016

Problem Statement

ICE Incumbents will not have the motivation to cannibalise their own petrol-heavy supply chain

HONDA

Honda CEO's views on full-electric vehicles in Dec 2019:

"Are there really customers who truly want them? I'm not so sure because there are lots of issues regarding infrastructure and hardware. I do not believe there will be a dramatic increase in demand for battery vehicles, and I believe this situation is true globally…But I don't believe it will become mainstream anytime soon.

December 26, 2019 05:56 AM

Honda CEO expects hybrids to outshine EVs

HANS GREIMEL

TWEET SHARE SHARE EMAIL PRINT

Honda's Hachigo "I don't have any timeline or any vehicles decided for Level 3 autonomous driving."

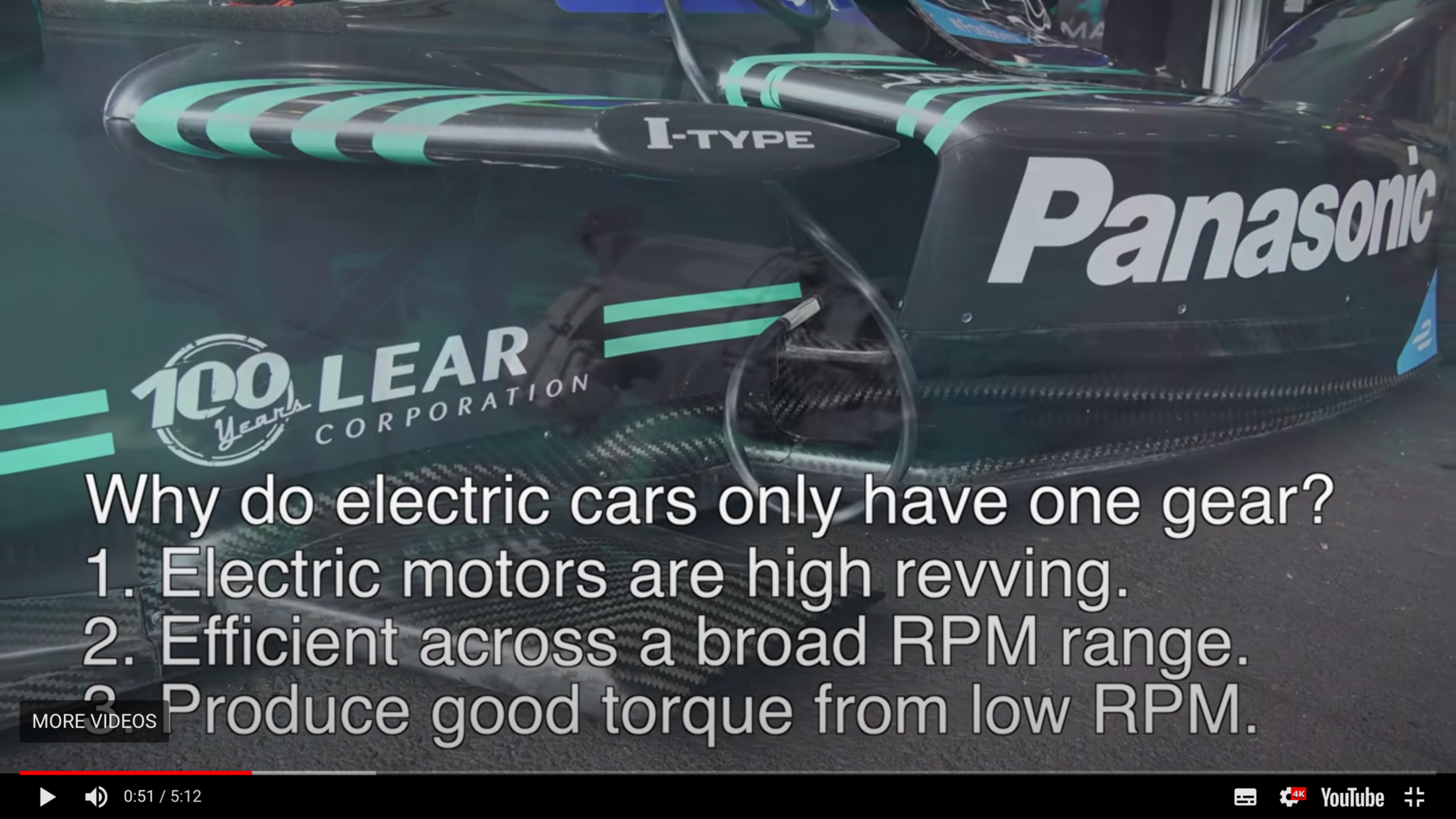
TOKYO -- Changing times mean changing tactics. To keep earnings flowing Honda Motor CEO Takahiro Hachigo is overhauling everything from product development to production. The effort means forging more loose partnerships to tap new technologies, while passing on capital tie ups that might undermine Honda's independence. Hachigo, speaking through an interpreter, talked with *Automotive News* Chief Content Officer Jamie Butters and Asia Editor Hans Greimel.

Honda wants two-thirds of its global sales to come from electrified vehicles by 2030. What is your road to electrification when demand for hybrids and EVs is still undeveloped?

I believe hybrid vehicles will play a critical role. The objective is not electrification, per se, but improving fuel efficiency. And we believe hybrid vehicles are the way to abide by different environmental regulations.

What about full-electric vehicles?

Are there really customers who truly want them? I'm not so sure because there are lots of issues regarding infrastructure and hardware. I do not believe there will be a dramatic increase in demand for battery vehicles, and I believe this situation is true globally. There are different regulations in different countries, and we have to abide by them. So it's a must to continue r&d. But I don't believe it will become mainstream anytime soon.


I-TYPE
Panasonic
100 Years
LEAR
CORPORATION
Why do electric cars only have one gear?
1. Electric motors are high revving.
2. Efficient across a broad RPM range.
3. Produce good torque from low RPM.
MORE VIDEOS
0:51 / 5:12
YouTube

Rear hub motor = unsprung weight problem

Adding transmission = drivetrain power efficiency loss

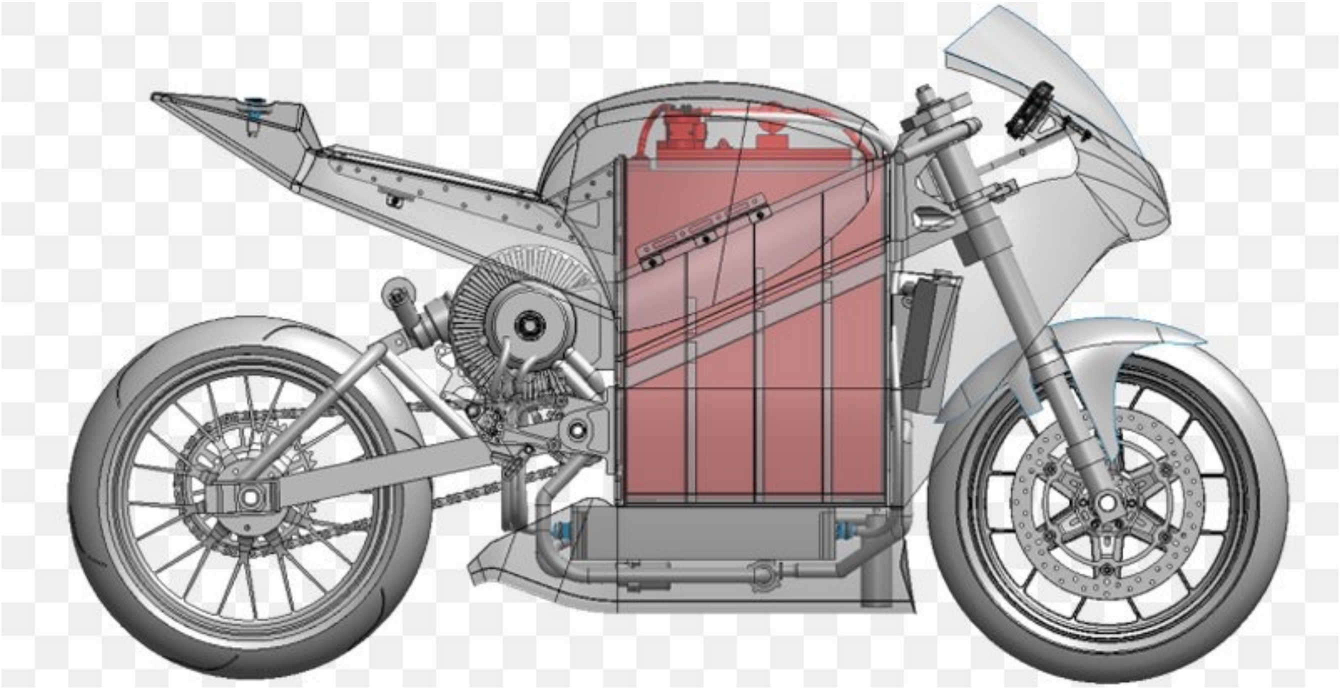
The holy grail? Multiple gear ratios while maintaining 90% efficiency

Hub Motor

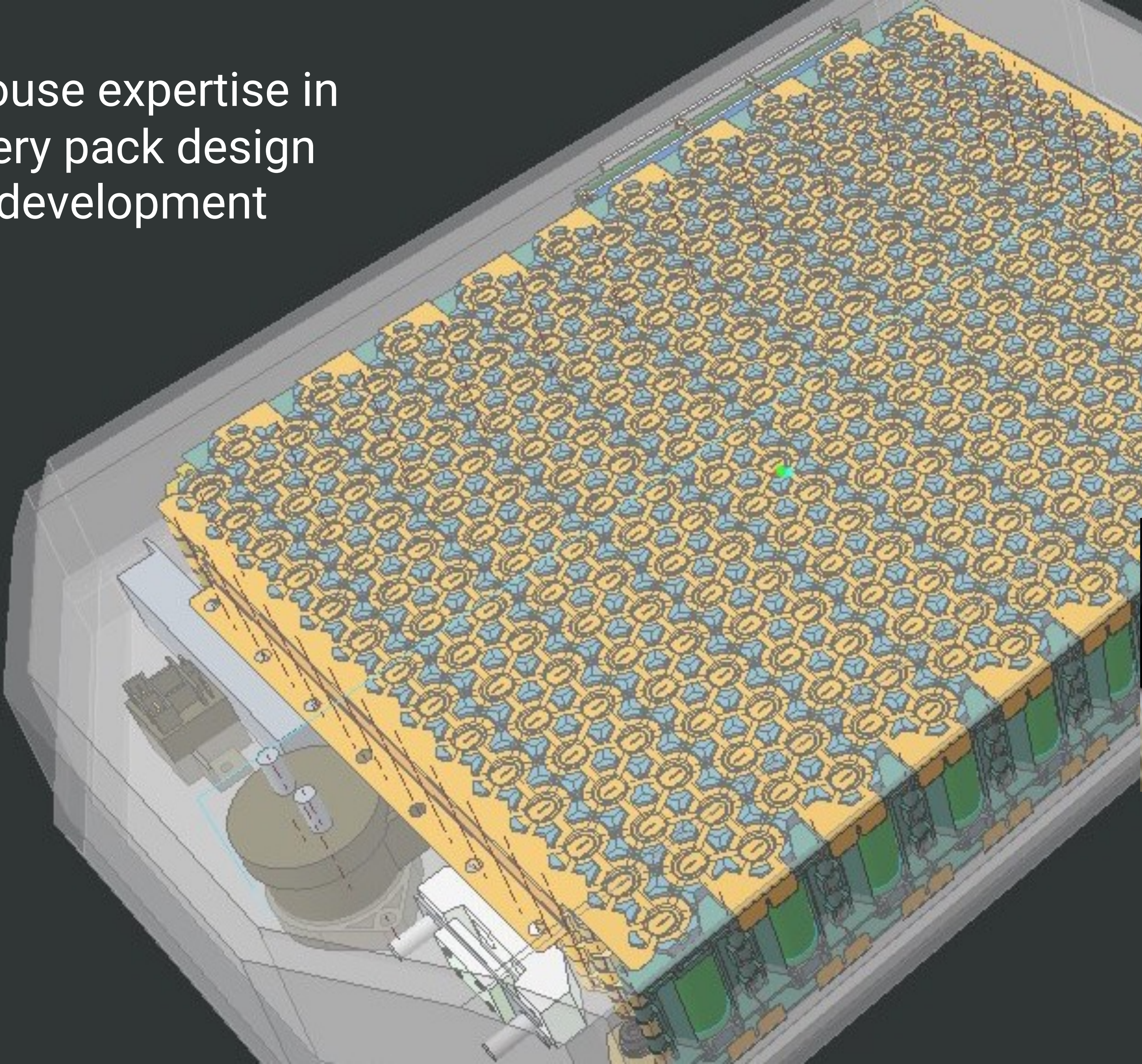
Making tradeoffs between drivetrain efficiency across riding profiles and single-charge usable range

Mid-mounted belt/chain Motor

Battery volumetric constraints are a key consideration in designing for sufficient real-world range in electric step-through scooters, so as to minimize range anxiety and achieve mainstream adoption.



In-house expertise in battery pack design and development

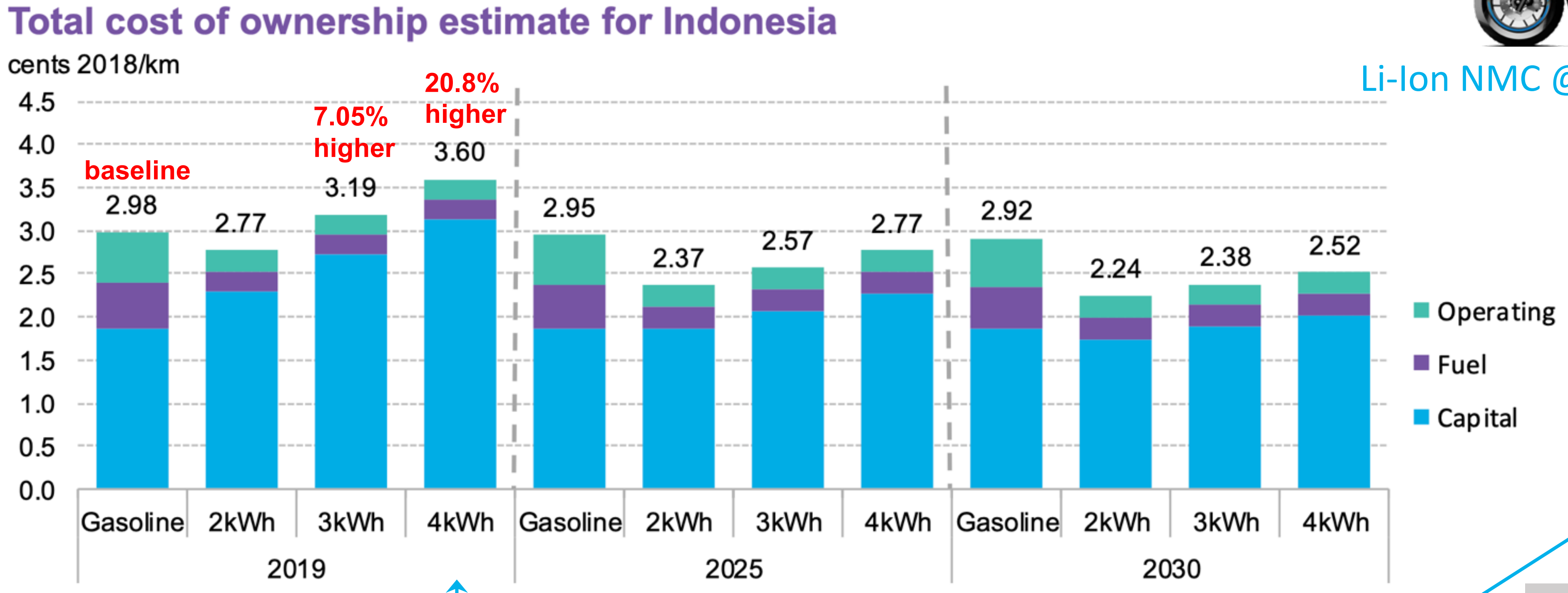


Li-ion NMC 811
2170 cylindrical cells
In-house BMS

Bloomberg claims 3 - 4kWh is not yet cost-comparable vs gasoline until 2025; but we will achieve this with Model 1 (Model 0 as reference).

Source: (L) Bloomberg NEF report "Southeast Asia's EV Push Needs More Focus on Two-Wheelers", Mar 2019

Electric motorcycles are cheaper on a total cost of ownership basis



Li-Ion NMC @72V55aH = ~**4kWh**

Model 1 to offer 125cc-equivalent TCO while delivering performance and features superior to 150-155cc popular gasoline comparables

Competition


Teams in Singapore,
Shenzhen & Jakarta
FINISHER
ION

Teams in Singapore, Shenzhen & Jakarta

James Chan

CEO & CFO

- Polymath investor-entrepreneur with diverse experience in product-business strategy-feature and investor-customer operations across 3DP, robotics & software disciplines, in the fields of consumer internet, fintech & social domains
- CMU B.Eng in Electrical & Computer Engineering; Stanford M.Sci in Management Science & Engineering; EDB Singapore Inc. scholar
- VC fund with Joi Ito at Neoteny Labs; US$5M seed-stage tech fund since 2010 returned 1.66x w/ 27+M AUM left by year 9
- GreyOrange, Silicon Straits, Wecash exits as operator

Joel Chang

COO & CMO

- GM of BMW M Singapore from 2005-2010 operating a 100-pax team
- Group CEO for BMW Regional Dealer covering China & Southeast Asia with annual turnover of US$500M and over 500-pax team; raised US$100M equity & debt to setup dealership distribution across China and Singapore
- Co-founder and COO of EV 2-wheeler startup Scorpio Electric 2017 - 2019

Xianyi Wu

Chief Design Officer

- Seasoned designer & entrepreneur with broad range of experiences in design and product creation spectrum; CMU B.Sci Mechanical Eng, Stanford M.Sc Mechanical Eng
- Co-founder of d.light, affordable off-grid solar systems which raised US$197M since 2007
- Lead Product Design & Development for GreyOrange from 2015 – 2018
- Head of Design for fintech Wecash since 2018

Calvin Cheng

Director (Software)

10+ year startup hands-on software CTO-architect-scrum coach with product & dev exp. across hardware/ software fields

Thomas Phan

Automotive Engineer

Ex-Tesla Automotive Engineer from 2016 – 2019; quality, diagnostics and repairs for interiors & exteriors of Model S & X

Chris Riether

Chief Vehicle Officer

American; co-founder & CTO of Evoke Motorcycles since 2014; in China for past 20 yrs, familiar w/ China supply chain, capabilities & limitations; prototyped 2 EV platforms, shipped 2 EV models to world from China.

Adhithya Srinivasan

Principal Engineer (Battery)

- IIT Madras graduate in Mechanical Engineering
- 5+ year veteran in Ather Energy of India; designed the battery pack for Ather 450 from early prototype to production, thermals, electronics integration cell connections and power transmission, battery testing and safety

Annie Liu

Director (Procurement & Supply Chain)

21-year hands-on industry veteran with 18 years in Foxconn handling servers, computing and mobile devices from ground-up, end-to-end sourcing to production and logistics across Asia

Road Map

2-wheeled Motorcycle products are the start; 3-wheeled autonomous and beyond can be the future!

3-wheeler EV “trike” (driven/autonomous)

2-wheeler EV motorcycle (driven)

?

Industrial Design
Electric Motor & Controller
Battery Pack & Management
Display, Vehicle Computer & Comms
Vehicle Integration & Assembly
Software, Billing & Collection
Marketing & Retail
Aftersales

Emerging market motorcycle-dense paradigm

10-year vision for the soul!

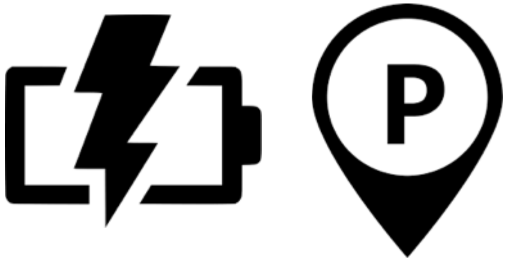
DKI Jakarta Assembly Line

Millenium Online Marketing

OTOMOTIFNET.COM

Experience Centres

Post-Sales Support

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Thank You! Questions?

james@ionmobility.asia