Customer-oriented Product Values

Super Safe

- Lifetime Safety Design Concept
- $LiFePO_4$ Chemistry Selected
- Advanced Material Design and Process Control
- Nail and Impact Test Passing to Ensure Safety

Long Lifecycles

- Design Optimization for Longer Lifespan
- Advanced Anode Treatment Process
- Balanced Stressing for Longer Life

High Reliability

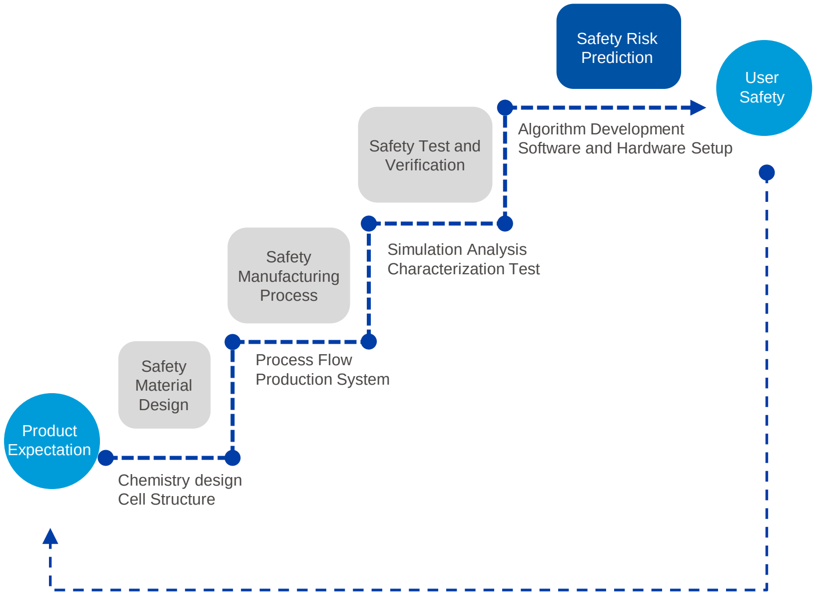
- A 100-day Test Equivalent to 10 Years' Operation
- Practical Life Cycle Modeling
- ESS Project reference after 9 Years with over 88%EOL

High Energy Density, High Power

- Lighter but with Higher Energy
- System Energy Density Equivalent with NCM
- Fast Discharging with Low Temperature Rising

Super Safe - Lifetime Safety Design Concept

Dowell develops comprehensive and multi-stage safety techniques from material/ design to final device usage.



Market Feedback and Continuous Improvement

Super Safe - LiFePO4 Chemistry Selected

ESS Fire Accidents: with NCM battery chemistry

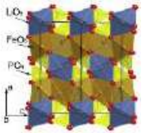
More than 26 energy storage stations got fire in the past 2 years in Korea, which seems to prove that NCM battery chemistry not so safe.

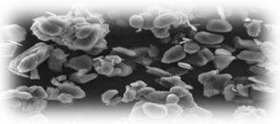

Battery Technology	LFP	NCM	LMO	LCO	LTO
Safety and eco-friendly	Best	???	Acceptable	Worst	Best
Cycling	Best	Acceptable	Worst	Acceptable	Best
Energy density	Acceptable	Best	Acceptable	Best	Worst
Power density	Best	Acceptable	Acceptable	Worst	Worst
Long-term testing	Best	Acceptable	Acceptable	Acceptable	Worst
Platform voltage	3.2V	3.7V	4.1V	3.8V	2.2V
Operating temperature	-20~55°C	-20~45 °C	<40 °C	<45 °C	-20~55 °C

LFP could be the most feasible and safest battery chemistry available for stationary energy storage application.

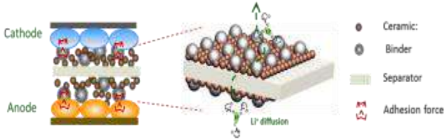
Super Safe - Advanced Material Design and Process Control

High Stability Material
LiFePO4 & Graphite

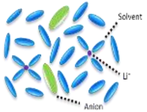


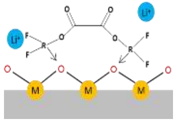


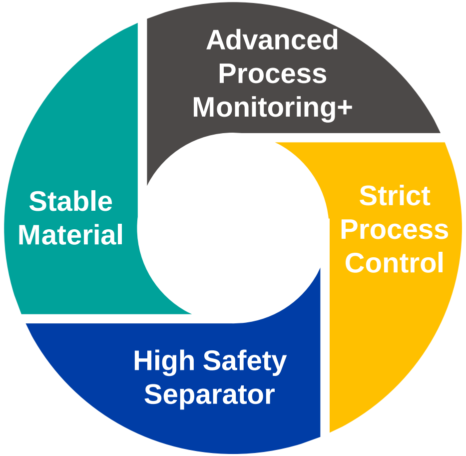
Advanced Coating Technology
for Sep.



Additive Electrolyte
with Excellent Cycle Life





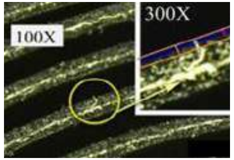


Exceed Customer Expectations

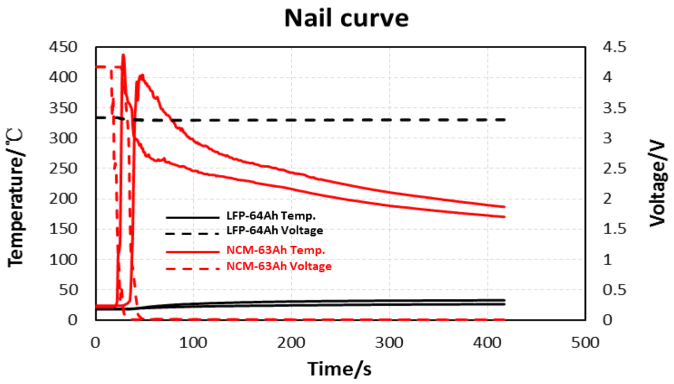
Online Process Monitoring

Strict Particle Control

Advanced Burr Control



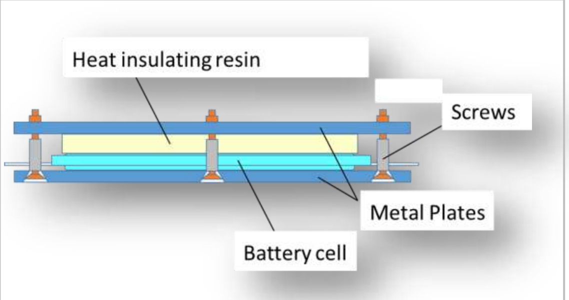
Super Safe - Nail Test Passed to Ensure Safety



LFP cell— 2/2 pass		Competitor's NCM— 0/2 pass	
Before	After	Before	After
			
			

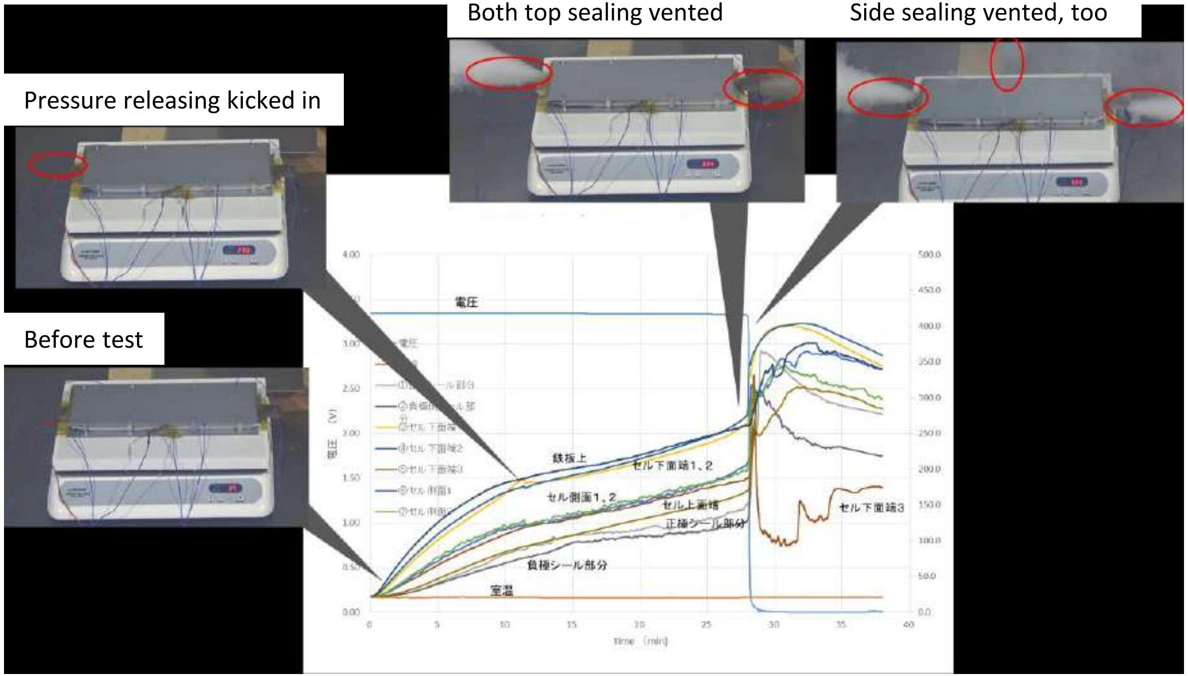
Super Safe – Thermal Conditions

64Ah 300℃ Heating Plate Test

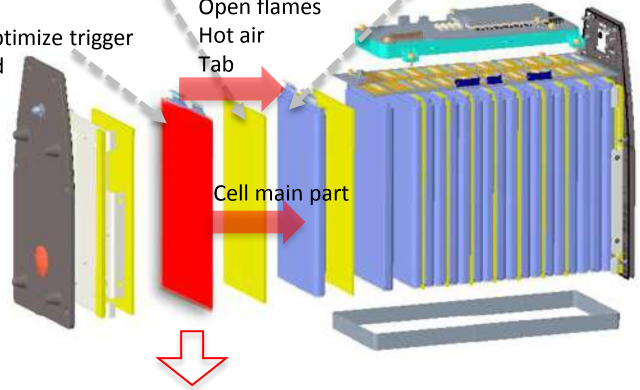


Finish-testing Cell: No Fire

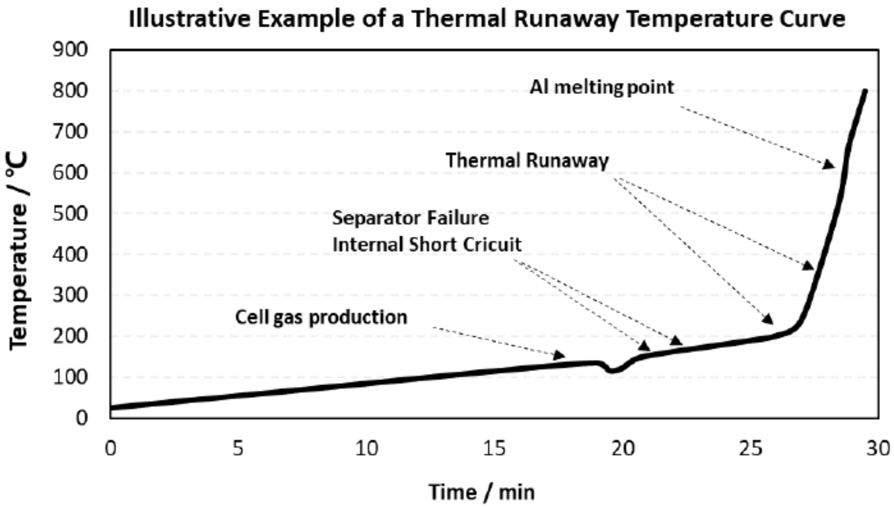
Safety Venting Under Extreme Thermal Condition



Super Safe



Fully charge the module to 100% SOC
use heating or external short circuit to cause thermal runaway of battery cells (1ea or more), and evaluate the spread of large-scale thermal runaway in battery energy storage systems.



Super Safe – Safety Throughout the Life Time

Life time safety management：All Fresh & EOL cell abuse tests passed

No.	Test Item	Test Condition	Safety standards	Fresh Cell Result	EOL	Test Result	Criterion	Remark
1	Hotbox	100%SOC, 130℃ 60min	UL1642		68.0%		NF,NE	Pass
2	Impact	100%SOC, Φ15.8mm rod, 9.1Kg hammer 61cm drop	UL1642		59.7%		NF,NE, NL	Pass
3	Drop	100%SOC, Height of drop:1m, 3 times	IEC62133		59.0%		NF,NE, NL	Pass
4	Nail	3mm thick steel nail (8cm/s)	JIS C8715		58.8%		NF,NE, NL	Pass
5	Short	100%SOC, 55℃ 5mΩ	UL1642		59.6%		NF,NE, NL	Pass

NF---No fire; *NE---No explosion;* *NL---No leakage*

Super Safe – Pouch vs. Prismatic

vs.

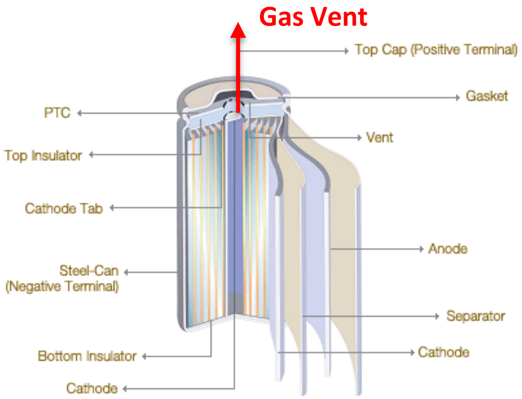
	Pouch	Prismatic	Cylindrical
Mechanical Strength	Acceptable	Best	Best
Corrosion/Leakage resistance	Best	Acceptable	Acceptable
Venting & Pressure-releasing	Best	Acceptable	Worst

Super Safe – Pouch vs. Prismatic

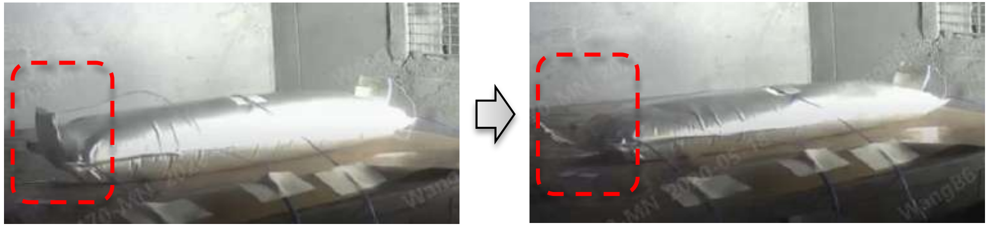
Built-in pressure releasing design with Pouch packaging

Pouch Cell

Prismatic Cell



Cylindrical Cell



- Lower pressure releasing threshold
- Avoid explosion
- No flying debris or flame beam

Super Safe – Pouch vs. Prismatic

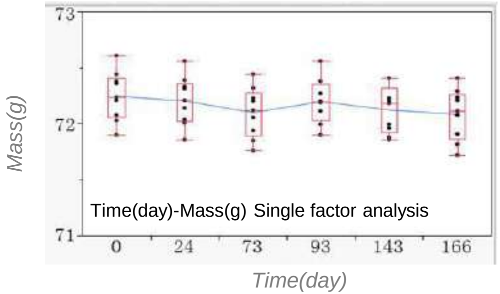
Water Vapor Penetration

$$\sum_{Cathode}^{Anode} EL\{Weight * (Threshold - Specification)\} = Safe\ water\ penetration\ content$$

Parameters	Design Mean	Design USL	Threshold
Top sealing width/mm	6	5	3
Side sealing width/mm	5.5	5	3.5
DEG sealing width/mm	5.5	5	3.5
Water vapor penetration /mg	21	30.9	53.5

- ◻ 15Yr water vapor penetration: 21mg(<53.4mg)

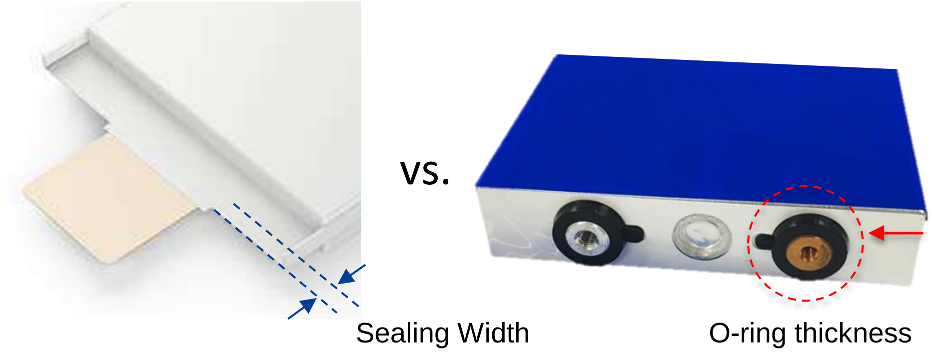
Electrolyte Leaking



- ◻ No leakage for 166days storage @ 60℃ 11.5kPa

Stronger Vapor Penetration Resistance

Item	Prismatic	Pouch Cell
Vapor penetration pathway	1~2 mm	5 mm

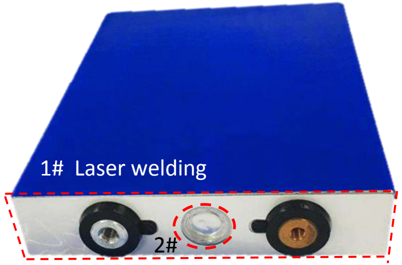


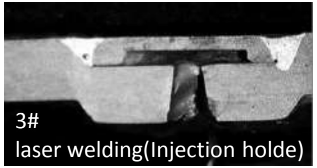
- ◻ Vapor penetration pathway is longer with pouch cell sealing design

Super Safe – Pouch vs. Prismatic

Stronger Corrosion Resistance

Item	Prismatic	Pouch
Manufacturing	**Welding slag** Higher risk of welding slag dropping due to the multiple-welding process	**No welding slag** Only 1 welding step before JR is entering the pocket
Structure	**Partial insulation** Risk of forming micro short circuit due to contact of falling active materials or jelly roll itself and inner Al-can, leading to accelerated corrosion.	**Complete insulation** PP layer insulates Al foil from electrolyte & active material





- Prismatic cell’s multiple laser & Ultrasonic welding process: 1#、2#、3#、4#

- Pouch cell fusion welding process: 1#

Electrical Safety： In Compliance to UL1973/IEC62619/VDE 2510-50/ISO 13849

1. Overvoltage protection：

- 4 level overvoltage protection (3 level firmware protection, 1 level hardware protection)
- Redundancy design for single point failure

2. Overcurrent protection：

- Short circuit detection at pre-charge phase.
- 4 level firmware and redundancy hardware detection for overcurrent protection.
- System overcurrent protection design with different actors(relay/MOSFET, breaker, fuse)

3. Fuse arrangement

- Robust 2 level fuse arrangement for high voltage system on DC bus.
- Fuse for BMS power/voltage sampling etc. to avoid overcurrent for low voltage PCB circuit.

Electrical Safety：In Compliance to UL1973/IEC62619/VDE 2510-50/ISO 13849

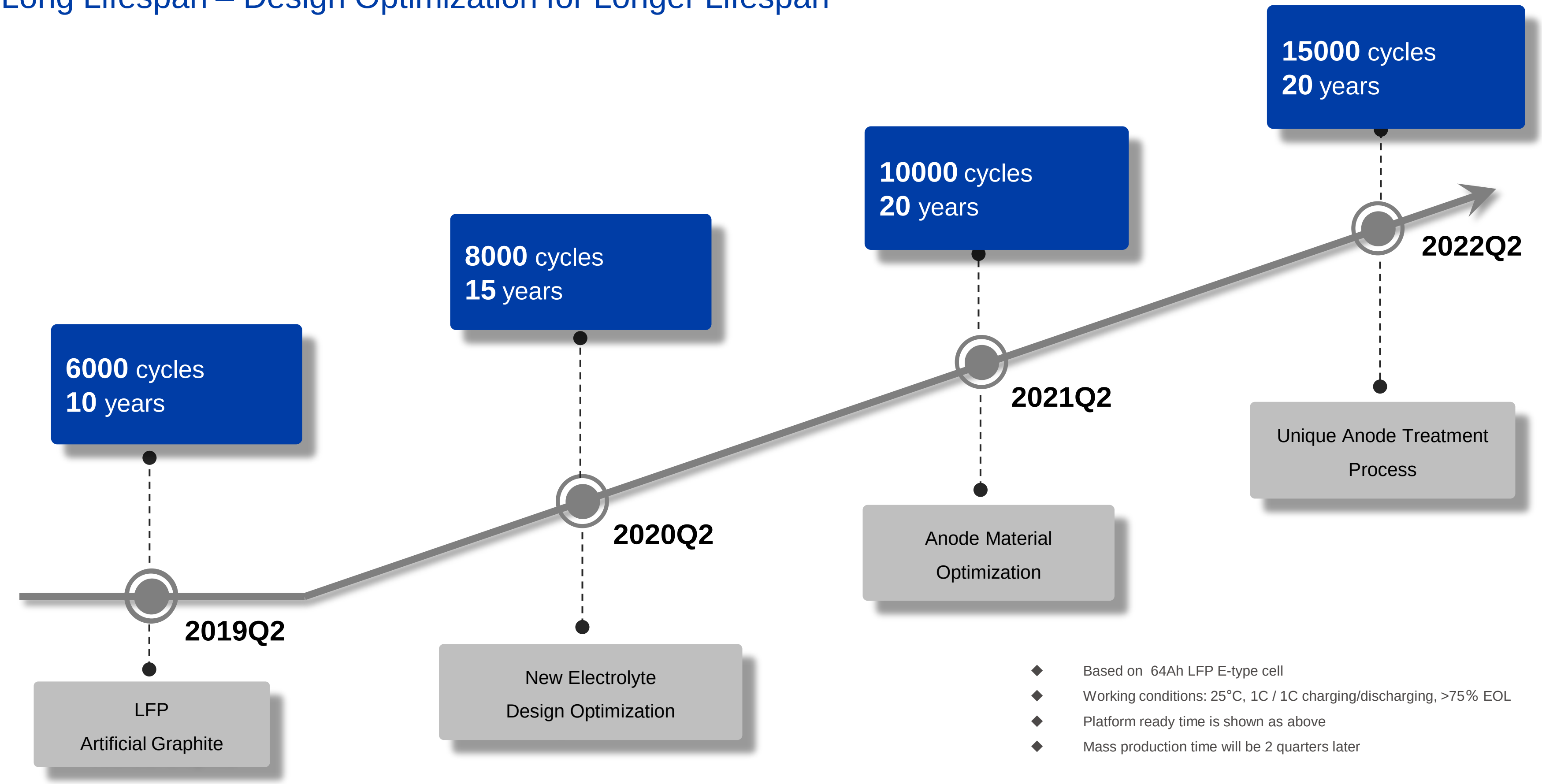
4. Insulation/electric strength

- Reinforced insulation design for secondary circuit and SELV circuit in compliance to IEC 60950/60664
- Insulation detection for high voltage system.

5. Grounding

- System design with high standard reliability testing to ensure good grounding between metal enclosures.
- Float grounding for low voltage BMS system.
- Isolated grounding for communication.

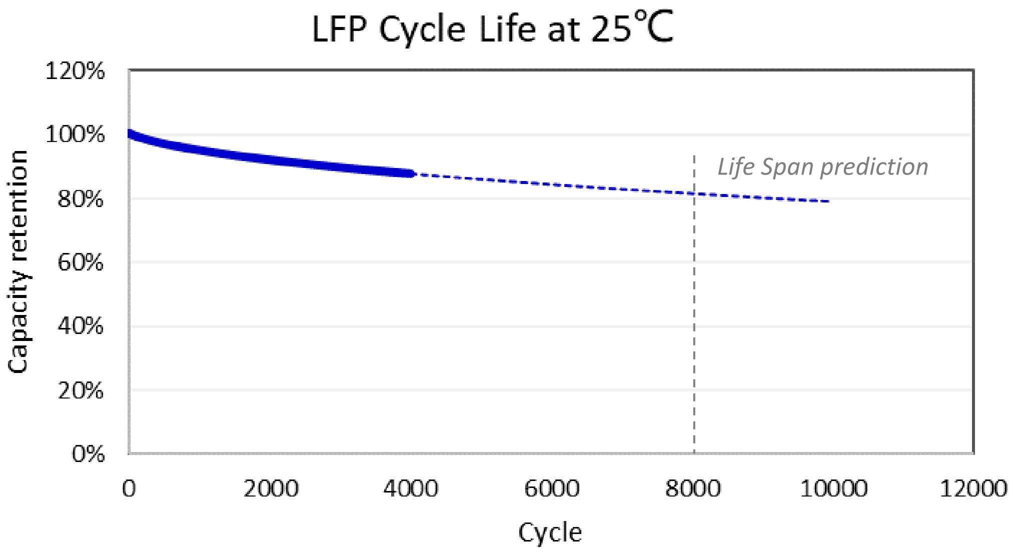
Long Lifespan – Design Optimization for Longer Lifespan

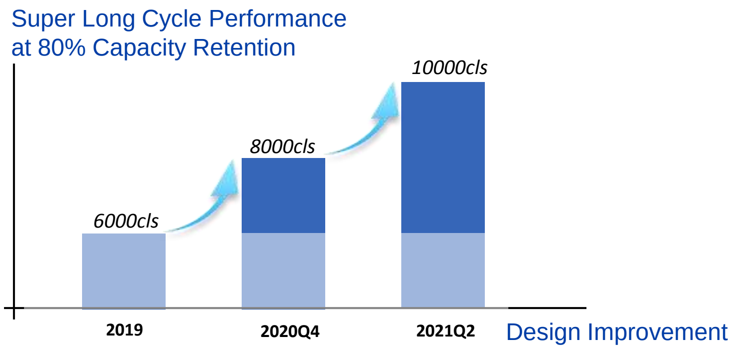


- Based on 64Ah LFP E-type cell
- Working conditions: 25°C, 1C / 1C charging/discharging, >75% EOL
- Platform ready time is shown as above
- Mass production time will be 2 quarters later

Long Lifespan – Keeping Optimizing to Achieve Longer Lifespan

Supports 8000cls or 15 Years of Warranty

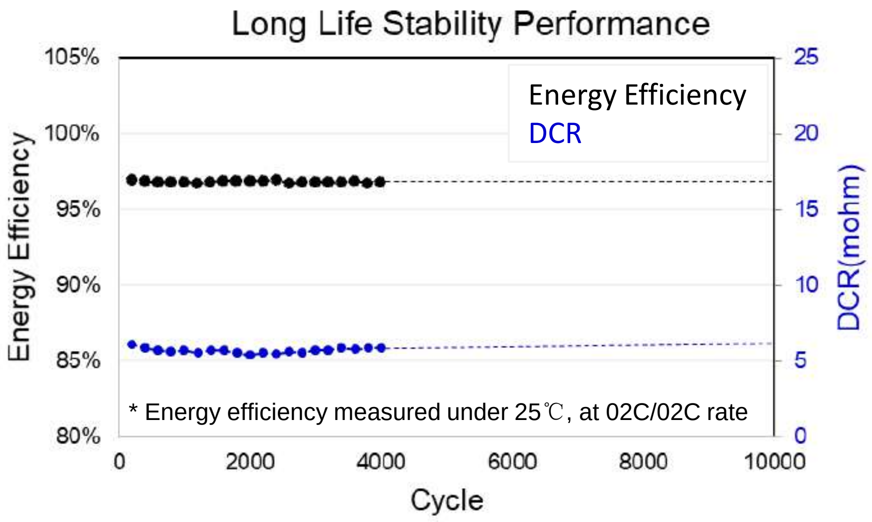


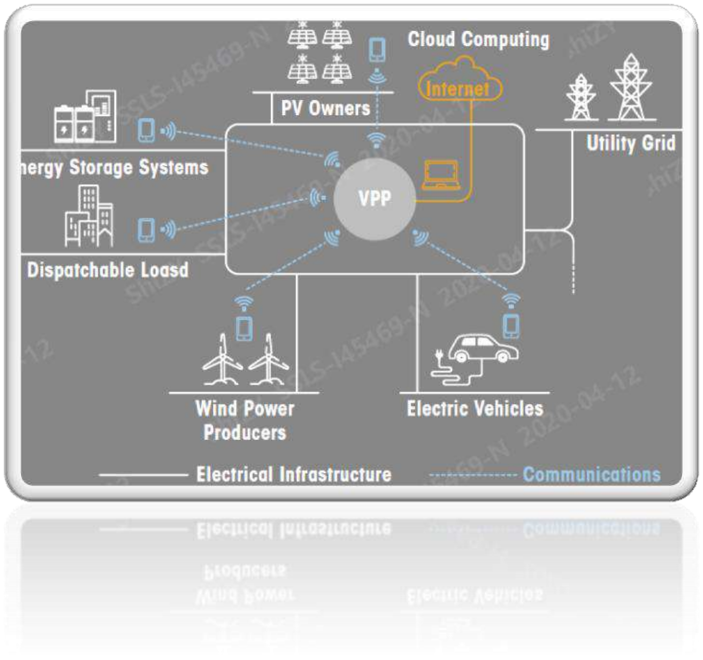


- Long-lasting electrode materials development
- Cell-structure design optimization

Long Lifespan – Keeping Optimizing to Achieve Longer Lifespan

Dependable Life-time Efficiency

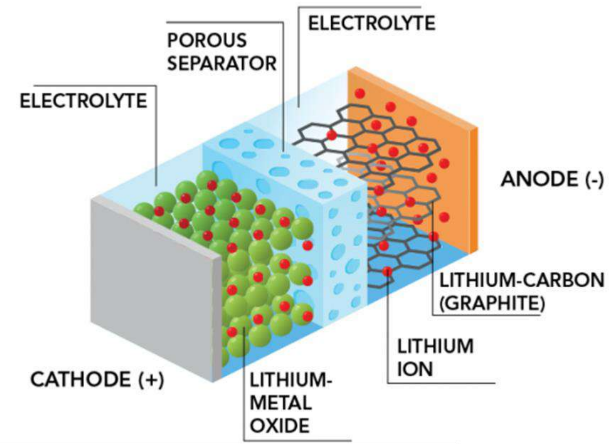




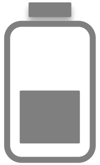
- Close-to-zero DCR growth during cycling
- Steady energy-efficient performance at 96.8%*

Long Lifespan – Keeping Optimizing to Achieve Longer Lifespan

One Battery, Double Life by Anode Treatment



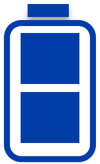
2019 Q4



6000 cls
10 years

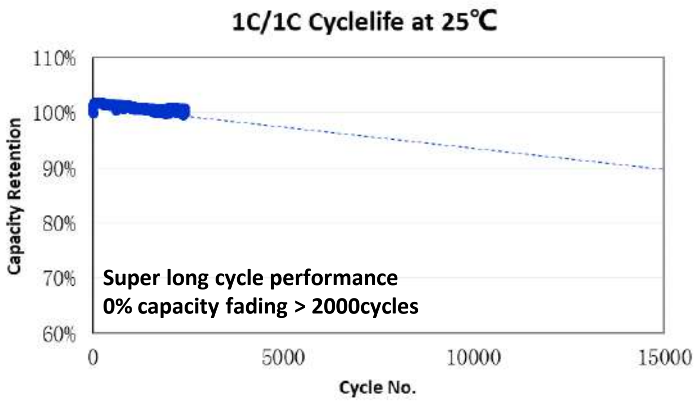
Base

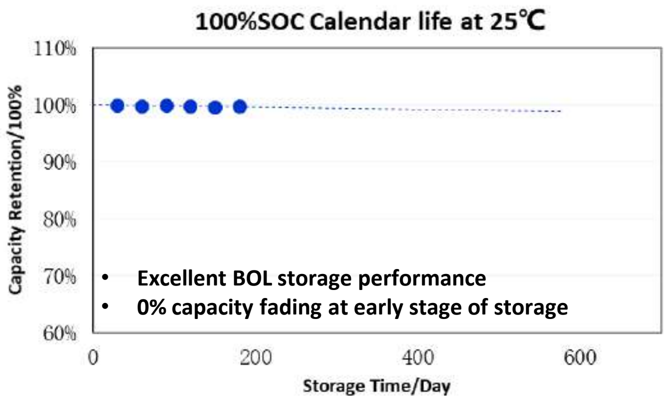
2022 Q2



15000 cls
20 years

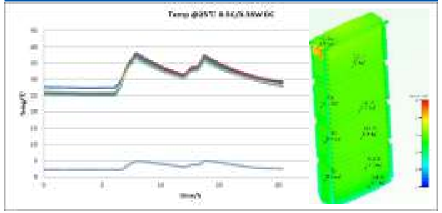
Anode Treatment





Long Lifespan-Pre-stressing for Longer Life

Voltage/ thermal balance

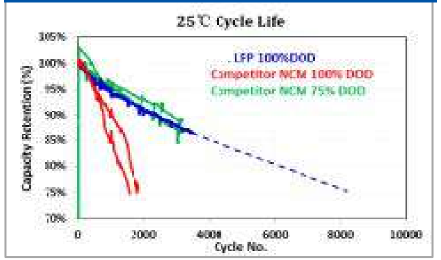


Smart balancing strategy

Advanced DoD algorithm

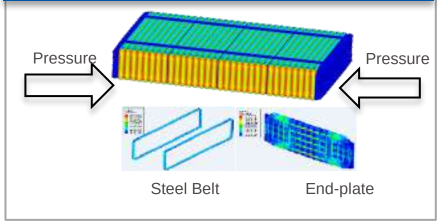
Long temp. rise and imbalance

cycle life > 6000 cycles



Deliver 75% retention with 6000+ cycles even with 100% DoD

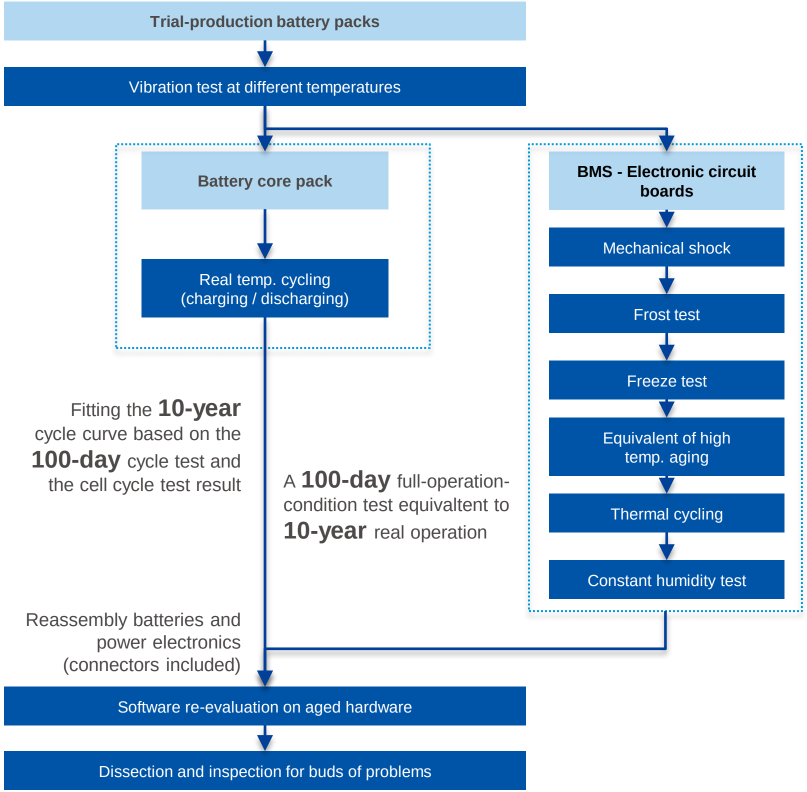
Constant pressure



Balanced stressing design to extend battery lifespan

High Reliability-Equivalent to 10 Yrs.' Operation

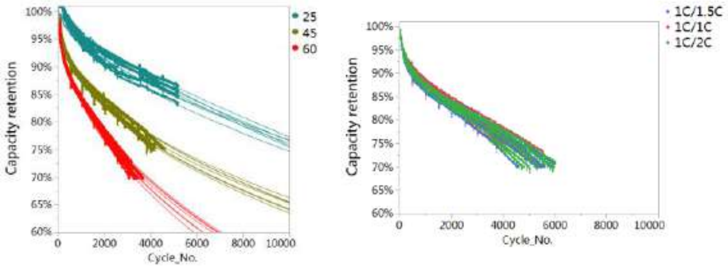
A 100-day full-operation-condition test is to equivalent to the 10-year real operation. It is exactly based on these dedicate reliability tests that we are confident to provide over 10 years' guarantee on the market.



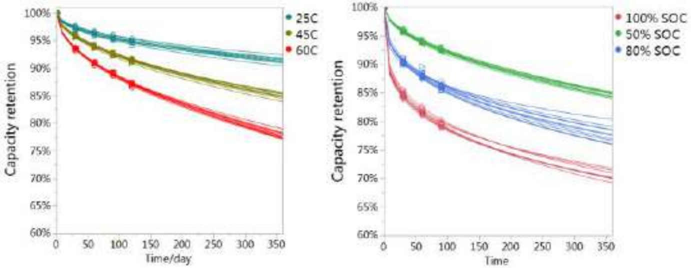
High Reliability-Practical Life Cycle Modeling

Cell Lifecycle Modeling

Cycle modeling for charging & discharging status



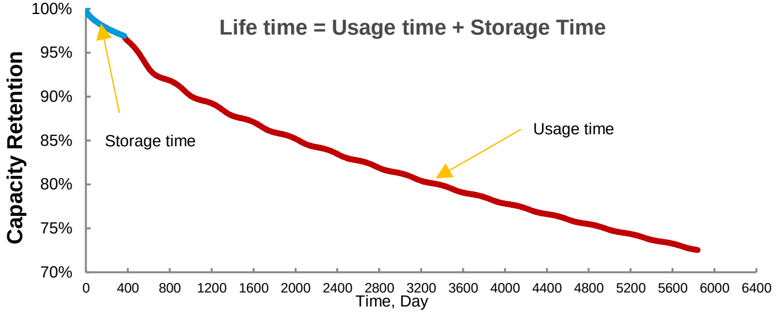
Cycle modeling for storage status



Accumulated damage in lifecycle: $D_{\text{life}} = D_{\text{usgae}} + D_{\text{storage}}$

From the real operation conditions, taking both the capacity fading under operation and storage status, which makes the cycling modeling more practicable.

Establishing the pack cycling model with the combination of cell model and Monte Carlo Methodology.



The measured data is consistent with the model **(1C charging / discharging,1 cycle per day, yearly 5%~6% capacity fading)**