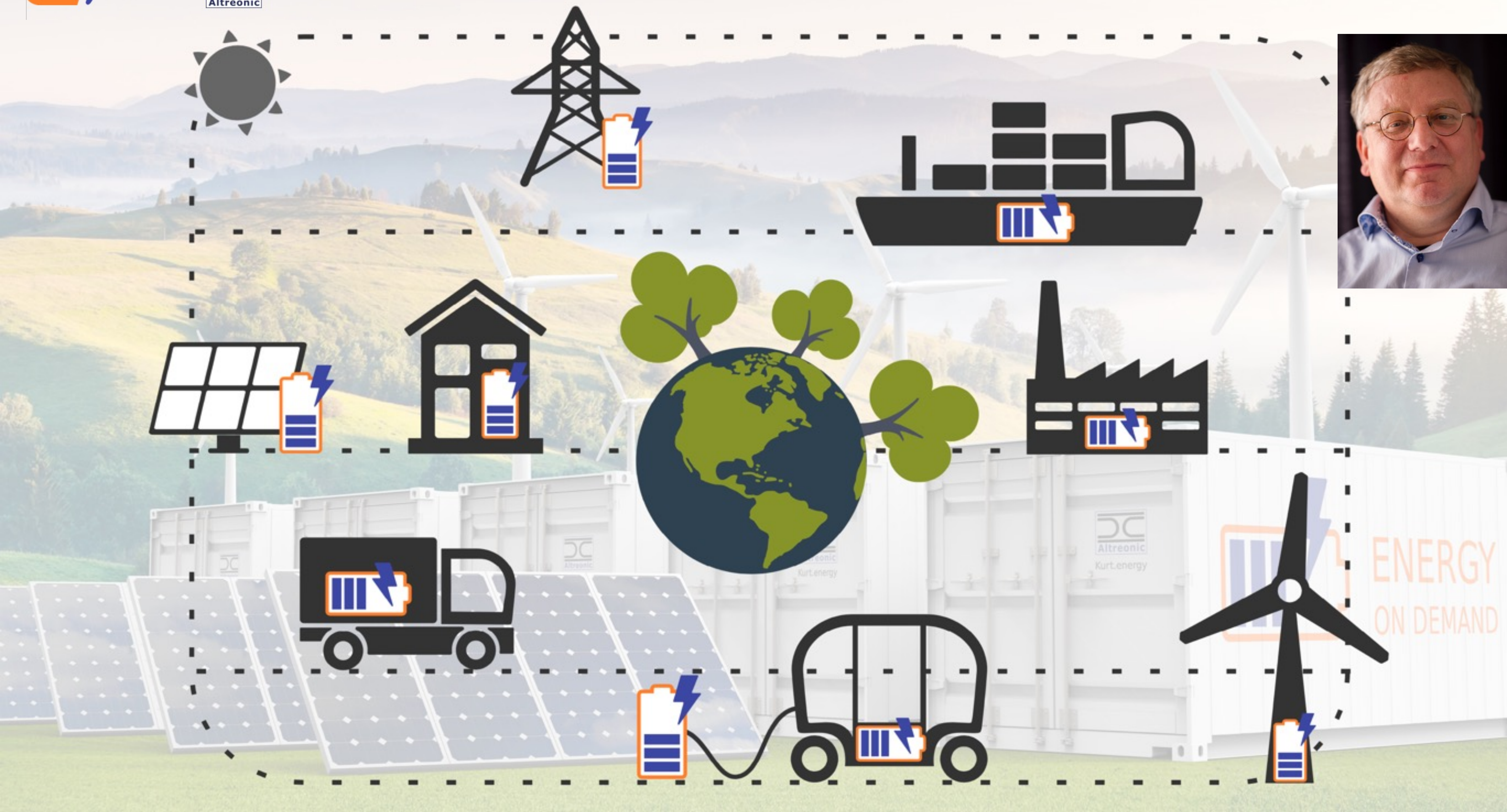
Kurt.energy

Altreonic

# ENERGY FOR LIFE, BLUE CELL POWER




Eric Verhulst, CEO/CTO

## THE SHIFT TO CLEAN ENERGY NEEDS BETTER BATTERIES NOW:
## We have them!

# Altreonic NV - previously Eonic Systems NV

- **30 years safety-critical embedded software**
  - **Trustworthy systems engineering**
  - **International technology focused SME**
  - **ESA: Virtuoso RTOS in Rosetta mission**
  - **5Gen unique fault tolerant VirtuosoNext RTOS**
  - **GoedelWorks**: Systems Engineering portal for certification
  - **KURT.mobi**: Light Electric Vehicle for urban use (inactive)

**Today: KURT.energy:**

**Customer specific batteries based on**

**Hybrid Supercapacitors and**

**Sodium-ion cells**

# Lithium-ion: Sustainable? Practical? Cost-efficient?

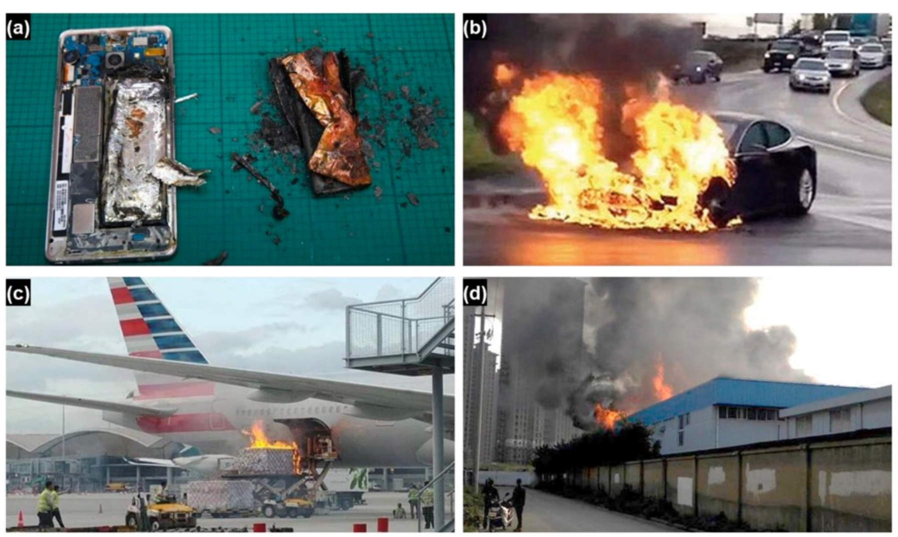
GM asks Chevy Bolt EV owners not to charge overnight or park inside after 2 more fires

Sean Graham - Jul. 14th 2021 1:59 pm PT

**SAFETY FIRST**

**Batteries are full of very inflammable products)**

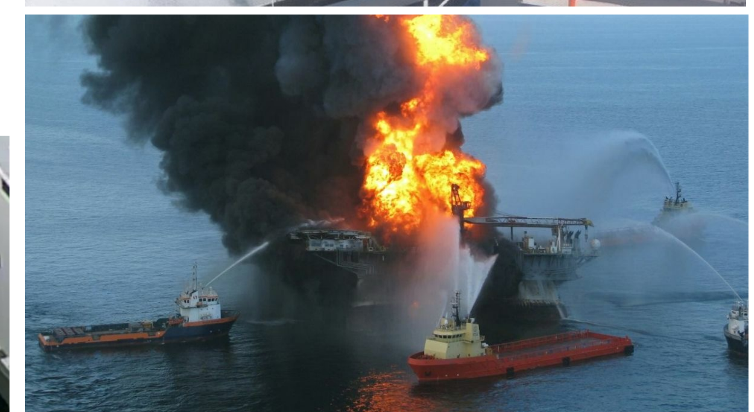
## Recall will cost 2 billion US$




**Toxic smoke 10 km away**

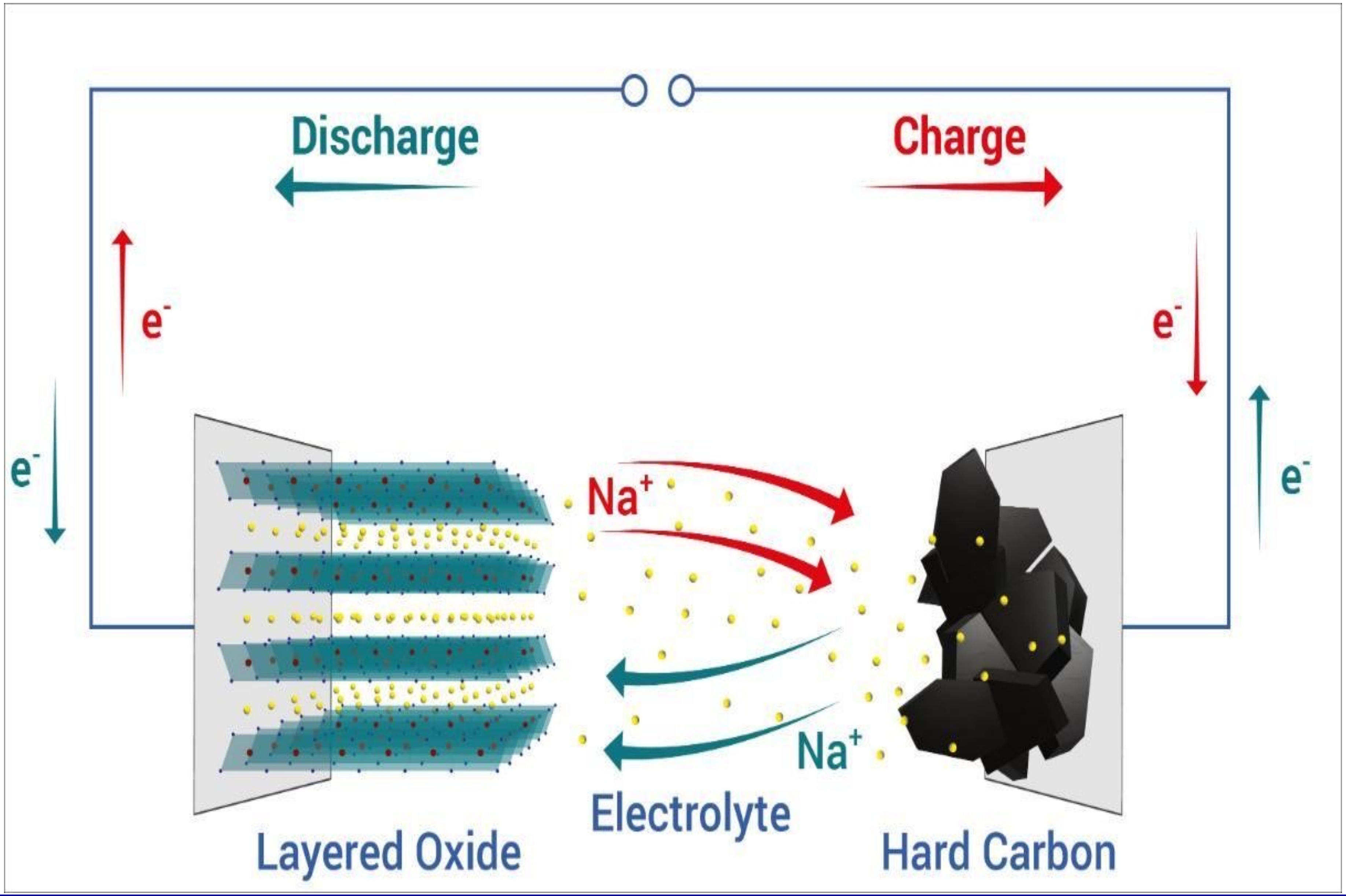
**From smartphones to warehouses**

**Our Seleced Hybrid Supercacitors and Sodium-ion cells are safe, and more…**

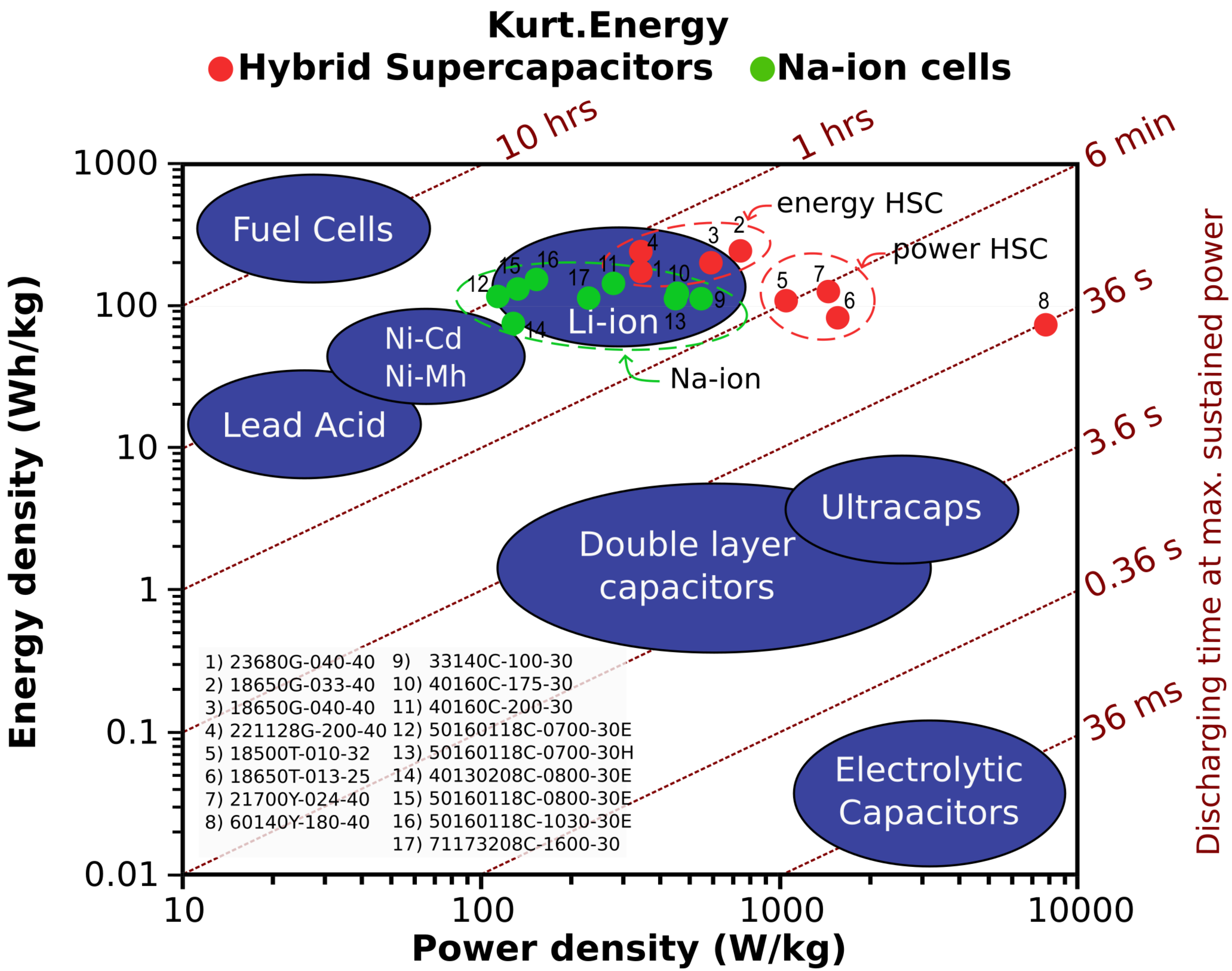


# The step beyond Lithium-ion batteries

- First Sodium-ion battery cells in 2023, no Lithium, no Nickel, no Cobalt
- Sodium-ion cells are safe and sustainable
- Customer and volume production ramping up
- From 100 Wh/kh to 130 Wh/kg upto 6000 cycles



# Hybrid supercaps and Sodium-ion technology map

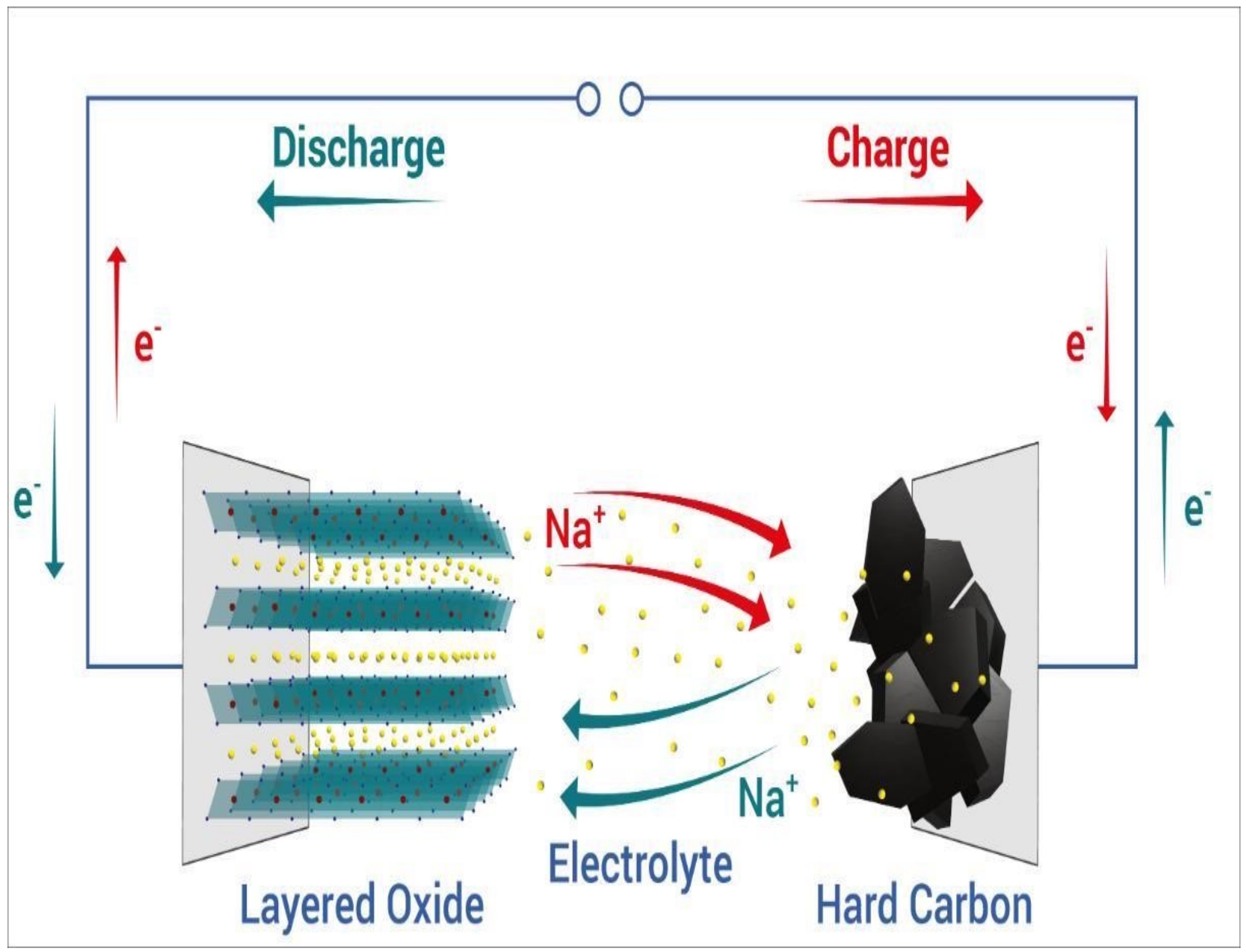


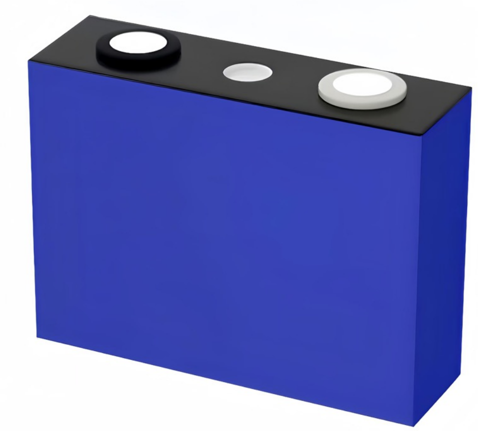
# Sodium-ion chemistries involved

**Anode:**
**Na-oxide: (NAxMO2)**
**Polyanion: (NaMPO4)**
**Prussian White/Blue (NaxPR(CN)6)**

**Cathode:**
**Hard carbon / 300-400 mAh/g**

**Capacity/cell:**
**From 1.3 Ah to 160 Ah**



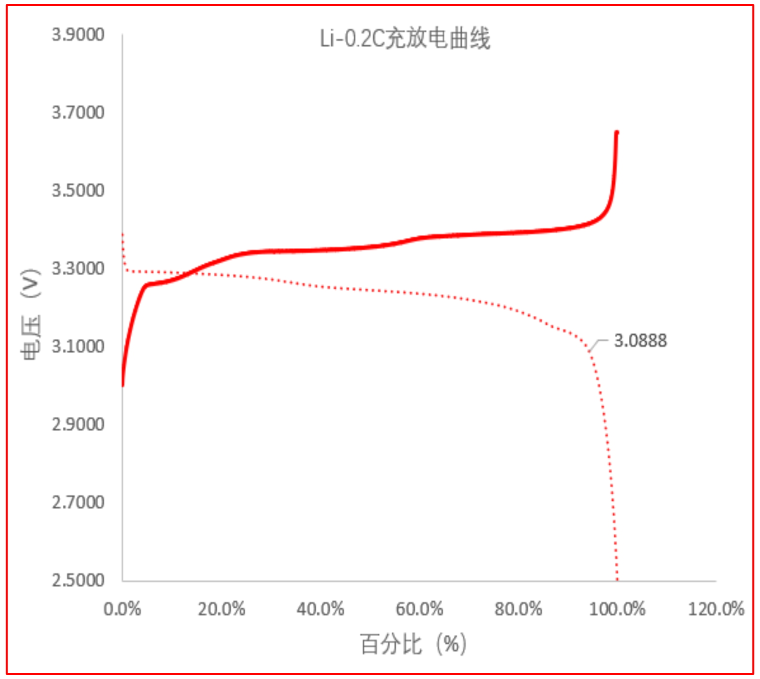
**Electrolyte:**
**Typically Sodium hexafluorphosphate**
**Current collector: Aluminum**
**Cylindrical or prismatic**

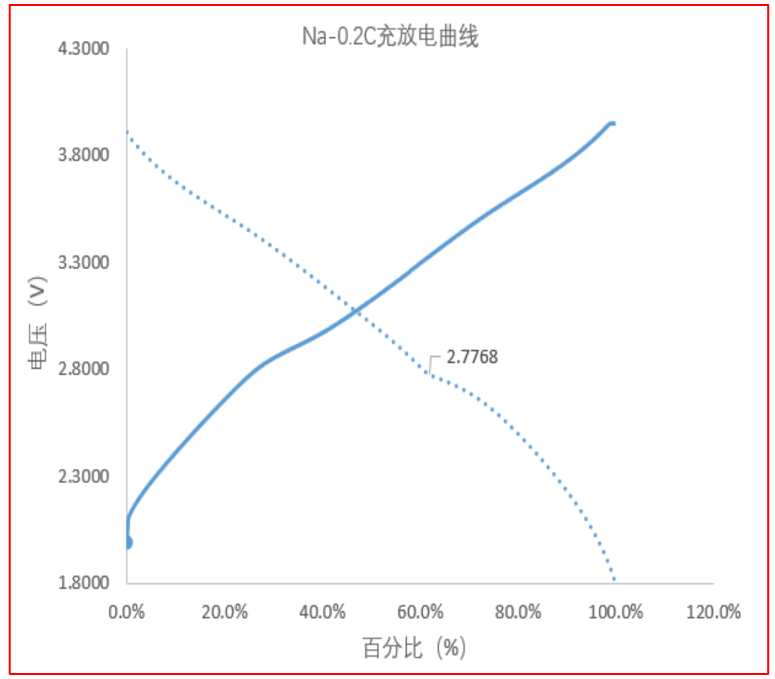
# Sodium-ion vs. Lithium-ion (LFP): overview

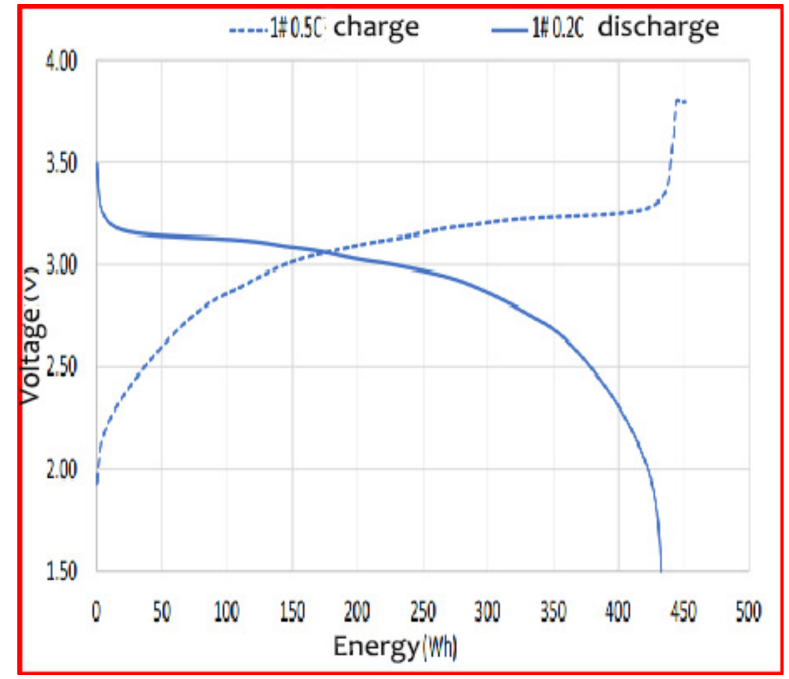
| | LFP | Sodium-ion (layered oxide) | Sodium-ion (polyanion prismatic) |
|---|---|---|---|
| Energy density (Wh/kg) | 150-180 | 120-150 | 100-110 |
| Cycle life (times) | 3000-10000 | 3500-4000 | 8000~10000 |
| Voltage range | 2.5~3.65 | 1.5~4.0 | （2.0）1.5~3.8（3.6） |
| Capacity retention -40℃ | n.a. | > 80% | > 70% |
| Average operating voltage | 3.2V | 3.0V | 3.0V |
| safety | Good | Very good | Very good |
| Resistance to discharge | medium | good | good |
| High temperature cycle | good | good | good |
| Power capability | medium | good | medium |
| System SOC estimation | approximate | accurate | acurate |
| -40℃ discharging | n.a. | yes | yes |

**Temperature range charging / discharging: tbd**

# Sodium-ion vs. Lithium-ion (LFP): Charge / discharge curves



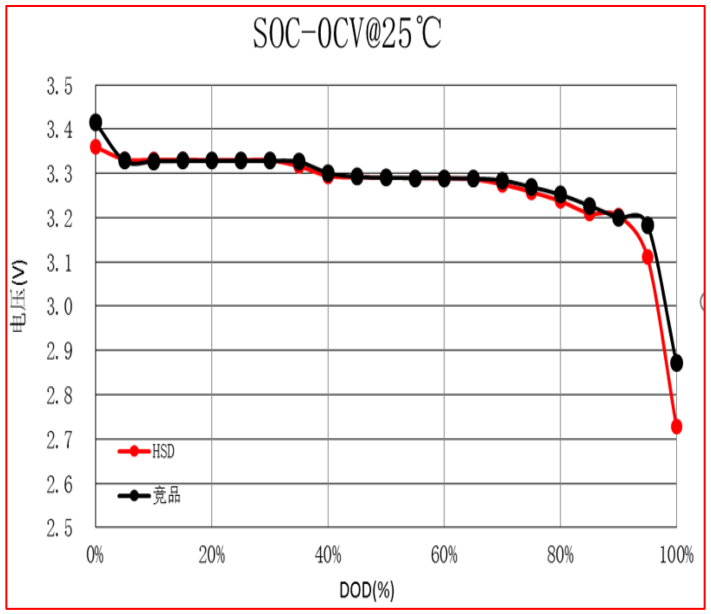




**LFP** **Na-ion (layered oxide)** **Na-ion (polyanion)**

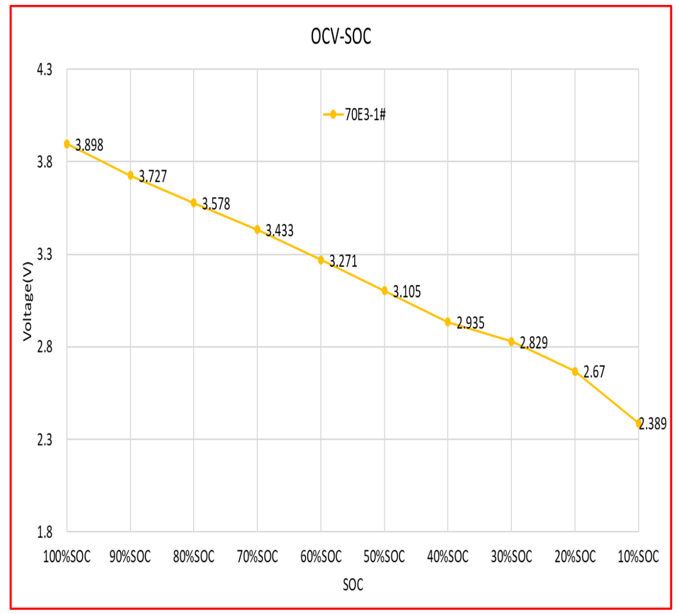
**Sodium-ion (layered oxide) more linear: easy to estimate SoC**

**Sodium-iom (polyanion) more like LFP**

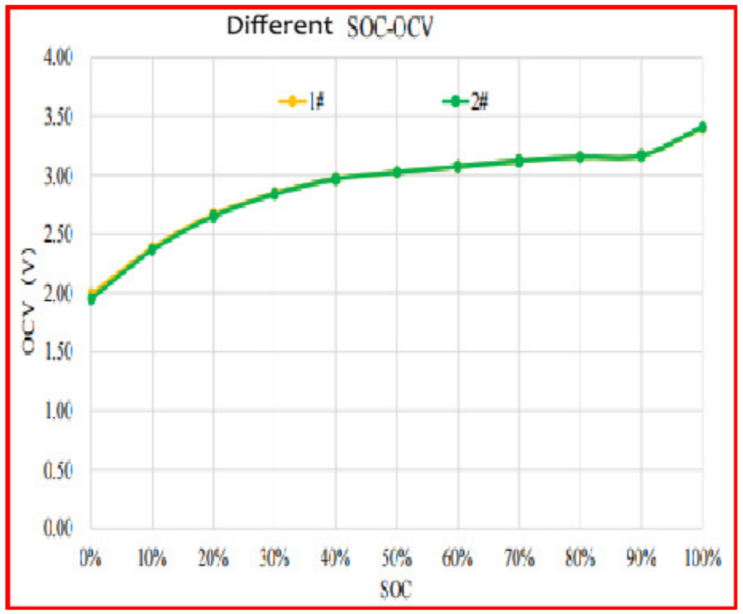
# Sodium-ion vs. Lithium-ion (LFP): SoC / OCV




LFP




Na-ion (layered oxide)



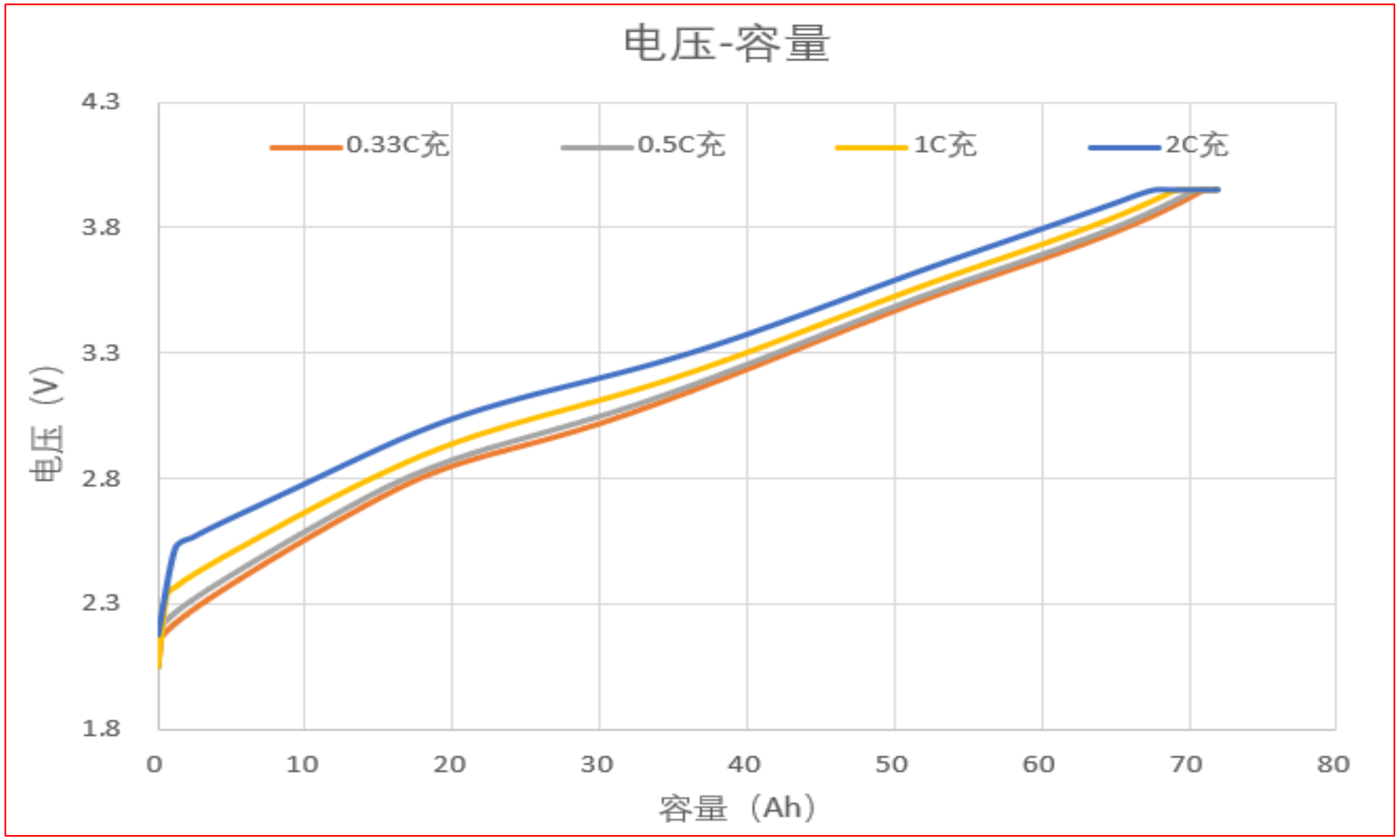

Na-ion (polyanion)

**Sodium-ion (layered oxide) more linear: easier to estimate SoC**

**Sodium-iom (polyanion) more like LFP**

# Charging capability Sodium-ion (layered oxide)

- Constant current – Constant Voltage charging profile
- Hard carbon cathode has higher energy density
- Temperature range: 5 – 60°C for fast charging, -10 to +5°C for 0.1C
- Max. rates are cell dependent (upto 20C)

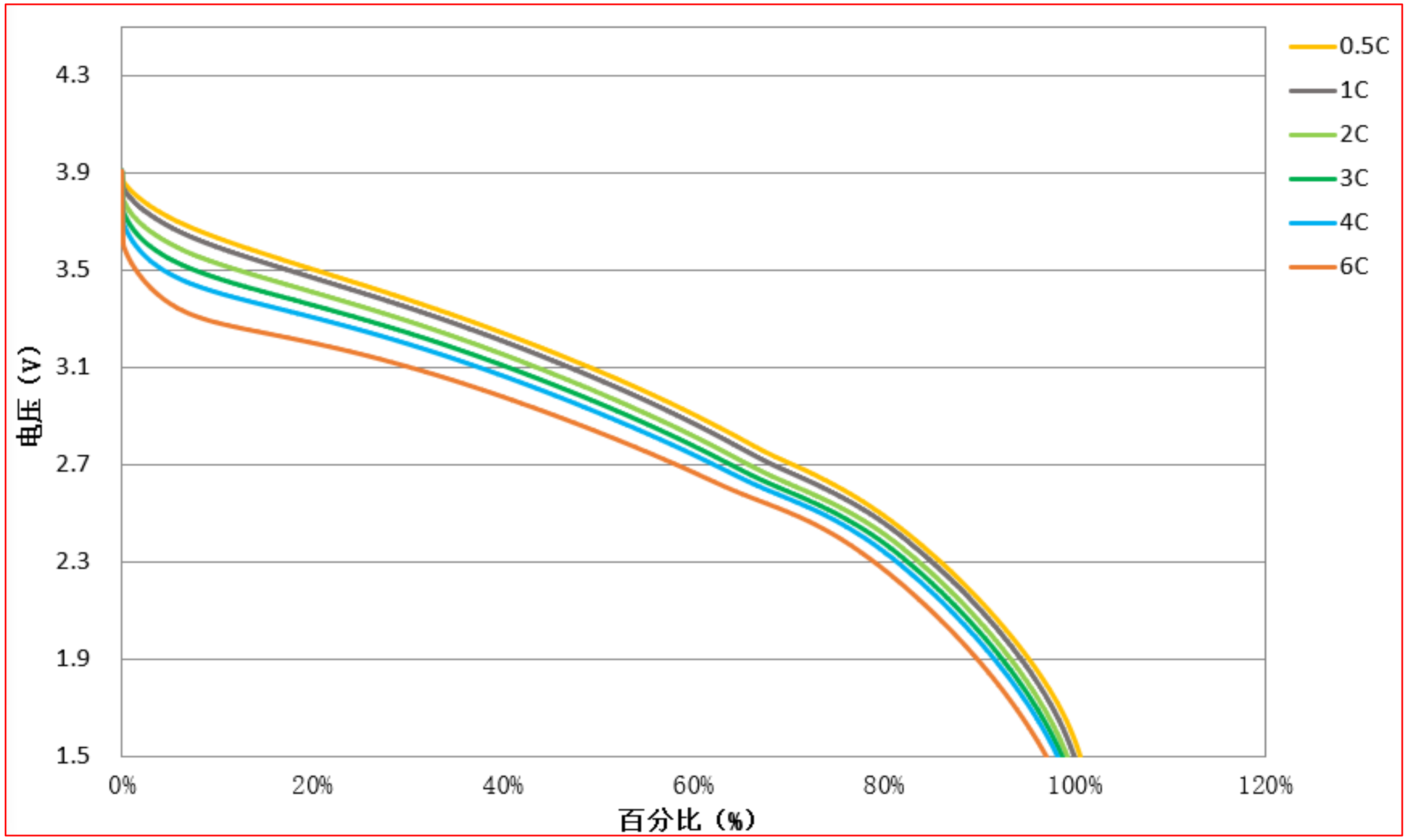



| C-rate | CC % SoC |
|---|---|
| 0.33 | 98.72% |
| 0.5 | 98.20 % |
| 1.0 | 97.16% |
| 2.0 | 96.07% |

**Test protocol:**
**Charging 0.5C to 3.95V**
**10 min. rest**
**Discharging 0.5 – 6.0 C till 1.8V**

# Discharging capability Sodium-ion (layered oxide)

- **Discharging possible till 0V, practically limited to 1.8V**

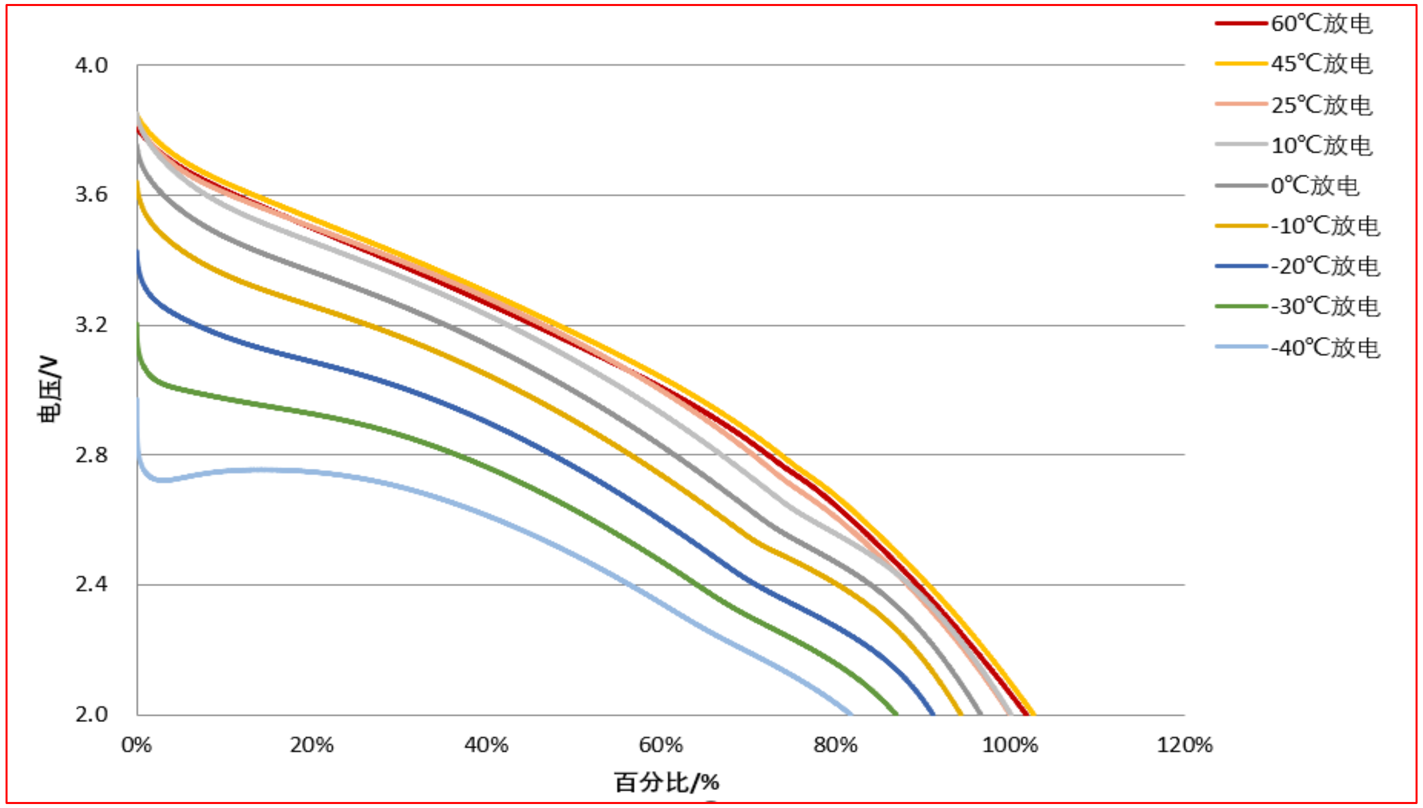



| Discharge C-rate | Capacity | % vs. 0.5C |
|---|---|---|
| 0.5 C | 74.37 | 100.0 |
| 1.0 C | 74.26 | 99.85 |
| 2.0 C | 73.72 | 99.13 |
| 3.0 C | 73.33 | 98.60 |
| 4.0 C | 72.98 | 98.14 |
| 6.0 C | 72.09 | 96.93 |

**Test protocol:**
**Charging 0.5C to 3.95V**
**10 min. rest**
**Discharging 0.5 – 6.0 C till 1.8V**

# Discharging capability Sodium-ion (layered oxide)

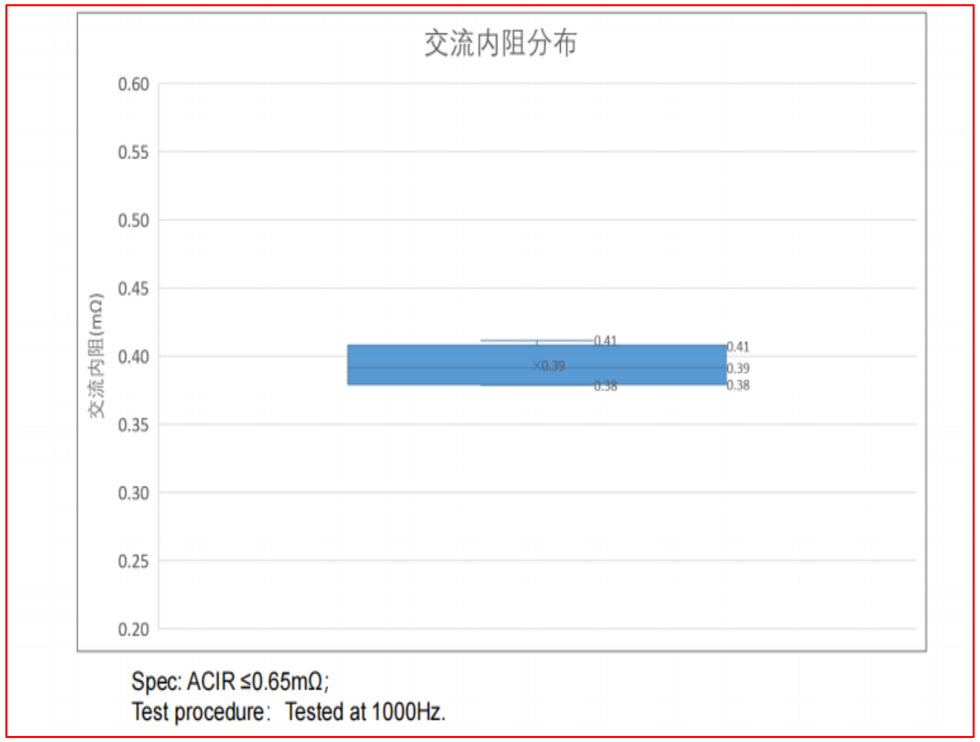
- **Can discharge from -40 to +60°C**
- **Still > 80 % capacity at -40°C (0.5C, 1.0C)**




| Temperature °C | Capacity % Na-ion | Capacity % LFP |
|---|---|---|
| 60 °C | 101.87 | 102.15 |
| 45°C | 102.72 | 103.15 |
| 25 °C | 100.0 | 100.0 |
| 15 °C | 100.12 | 93.49 |
| 0°C | 96.66 | 89.11 |
| -10°C | 94.39 | 85.02 |
| -20°C | 91.20 | 81.20 |
| -30°C | 86.96 | n.a. |
| -40°C | 81.77 | n.a. |

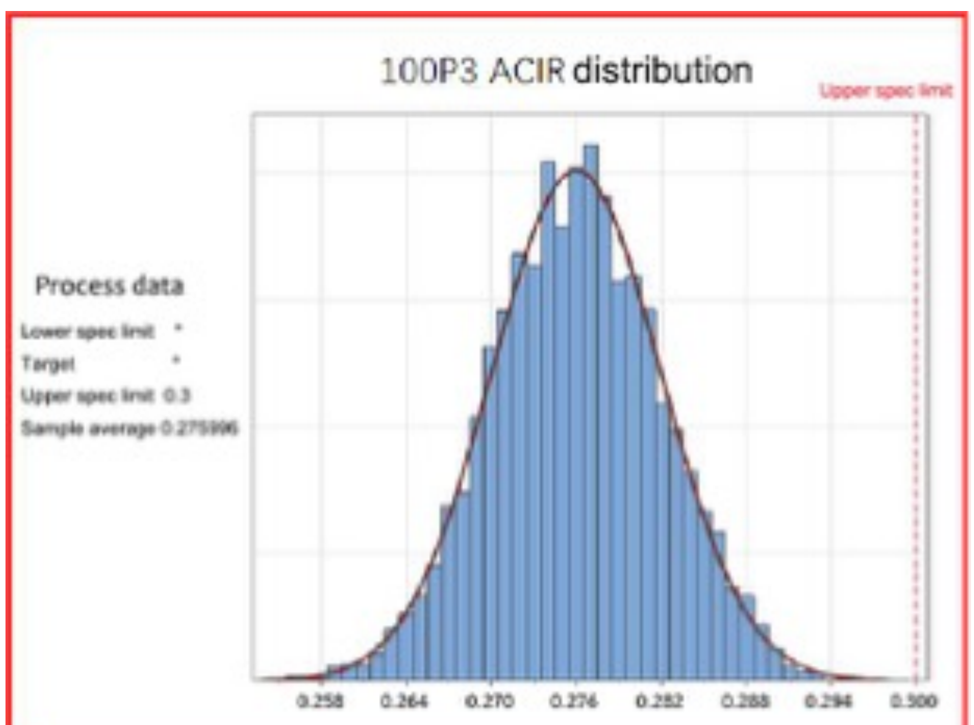
**Test protocol:**
**Charging 0.5C to 3.95V**
**10 min. rest**
**Discharging 0.5 – 6.0 C till 1.8V**

# Low internal resistance Sodium-ion (polyanion)




**Sodium-ion:**

**ESR < 0.2 to 0.4 mOhm**

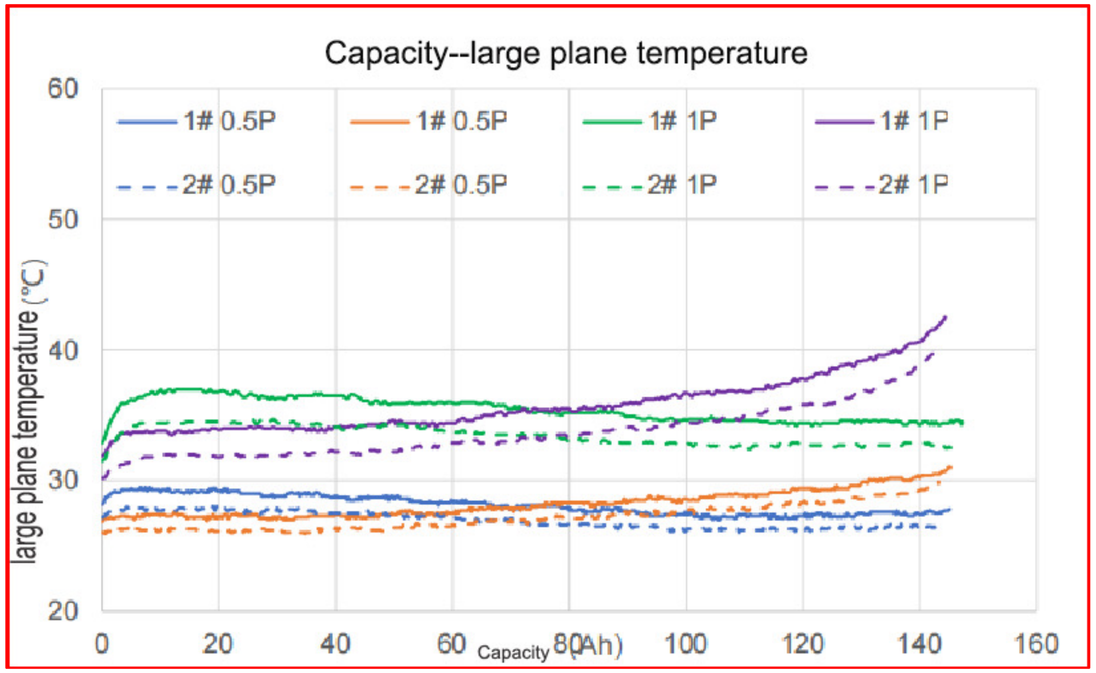



**LFP:**

**ESR < 0.25 - 0.294 mOhm**

# Thermal behavior of Sodium-ion (polyanion)

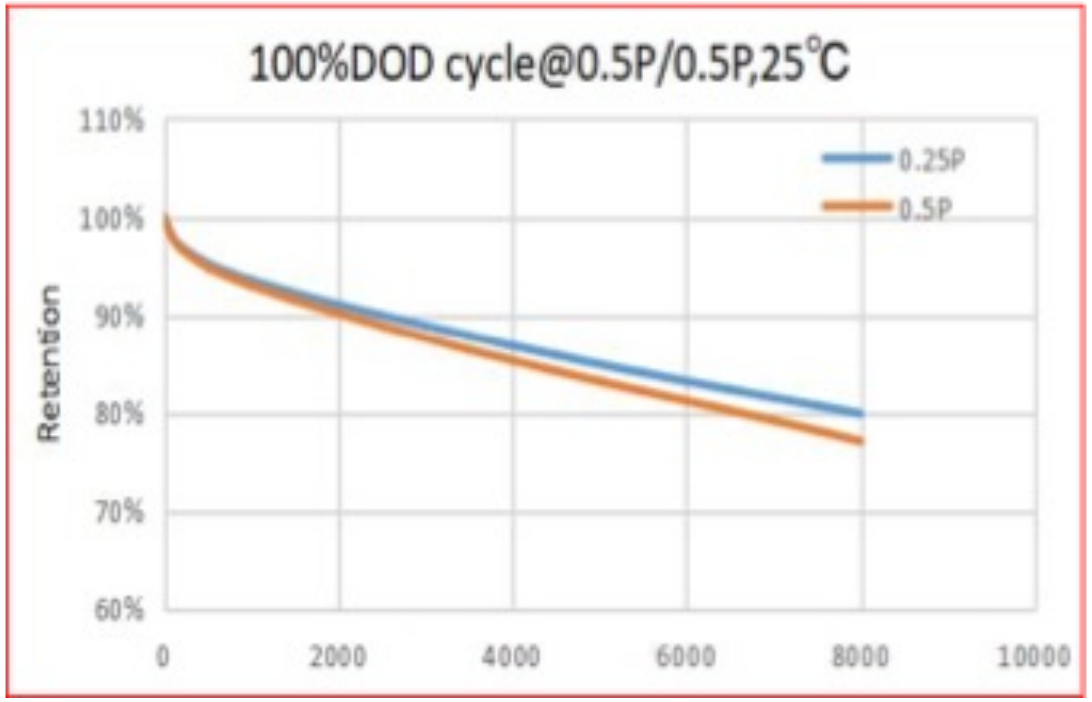
## Low resistance results in modest temperature rise




| Constant Power charging / discharging | Starting temperature(°C) | Ending temperature (°C) | Adiabatic temperature rise(°C) | Polyanion sodium ion /adiabatic temperature rise(C) |
|---|---|---|---|---|
| 0.5P power charging @25°C | 24.6 | 43.9 | 19.3 | -0.4 |
| 0.5P power discharging @25°C | 24.6 | 44.0 | 19.4 | 4.1 |
| 1P charging @25°C | 25.5 | 55.3 | 29.8 | 1.6 |
| 1 P power discharging @25°C | 25.5 | 56.9 | 31.3 | 10.6 |

# Cycle life of Sodium-ion (polyanion)

**Cycle-life @ 25°C comparable wit LFP**
**Note: temperature and current dependent**




**Cycle-life @ 25°C for good LFP cell:**
**8000 cycles till 80% capacity left**


**Cycle-life @ 25°C for Na-ion polyanion cell:**
**Estimated 6000 cycles:**
**394 cycles gives 95.4 % left**

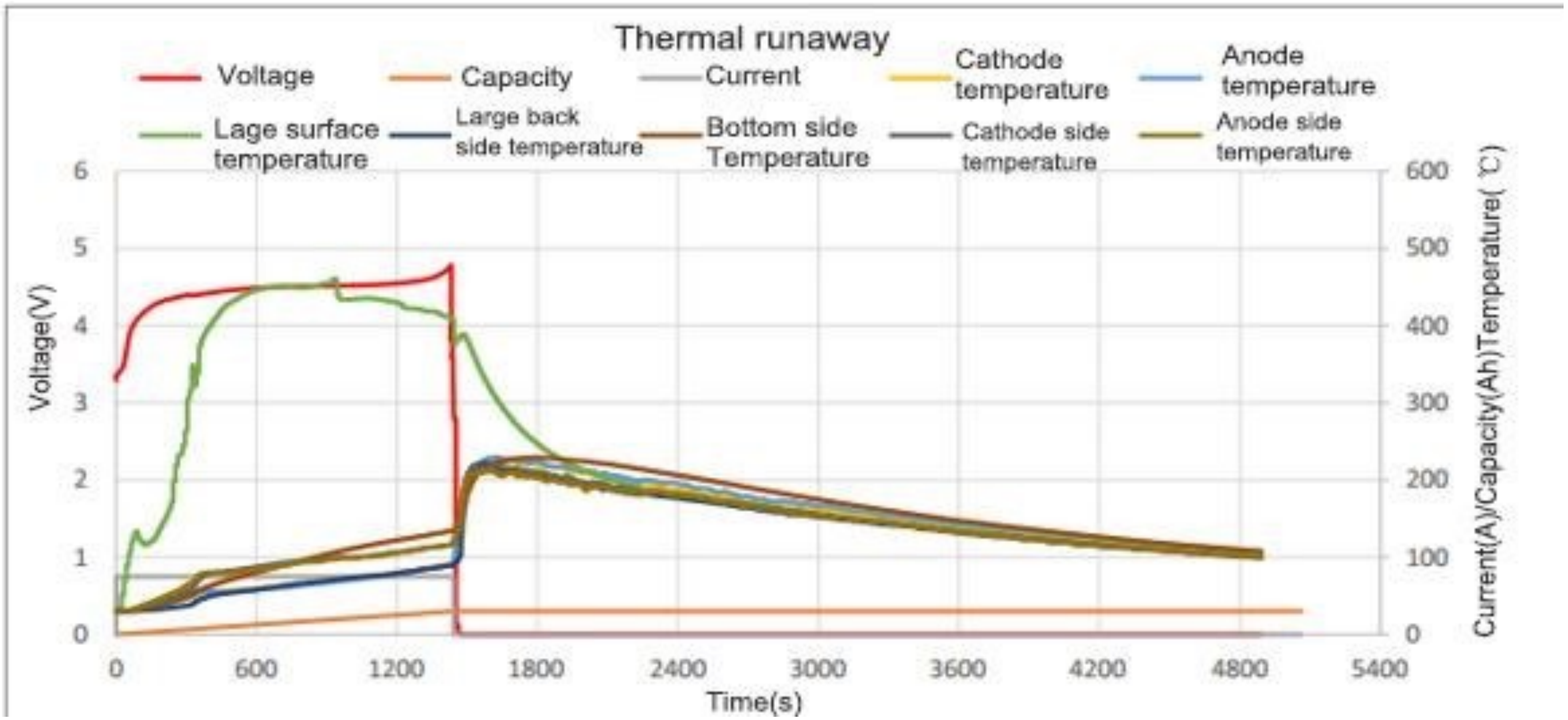
# Safety tests (polyanion)

| Test | | Specification | Result | |
|---|---|---|---|---|
| 1 | Short circuit | No explosion, no fire | Passed | |
| 2 | Over charging | No explosion, no fire | Passed | |
| 3 | Over discharging | No explosion, no fire | Passed | |
| 4 | Wide side extrusion | No explosion, no fire, no leakage | Passed | Crush test? |
| 5 | Humidity cycling | No explosion, no fire, no leakage | Passed | |
| 6 | Thermal abuse | No explosion, no fire, no leakage | Passed | |
| 7 | Decline | No explosion, no fire, no leakage | Passed | ??? Nail penetration? |
| 8 | Low pressure | No explosion, no fire, no leakage | Passed | |
| 9 | Vibration | No explosion, no fire, no leakage | Passed | |

**Reference to GB / T36276-2018**

**Lithium Ion Battery for Electric Energy Storage**

# Safety tests (polyanion): ): overcharging + heating

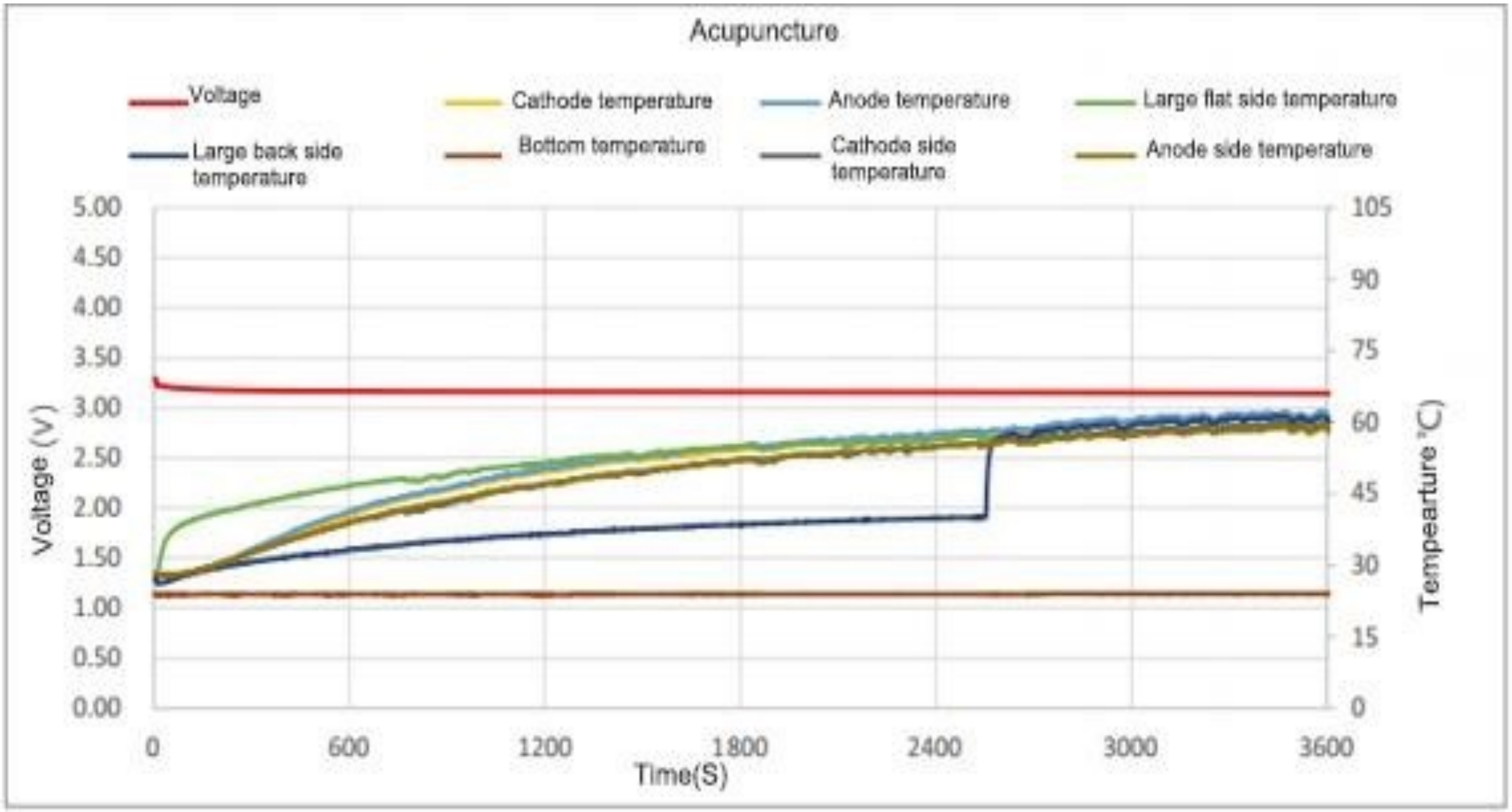



**Fully charged cell is overcharged + heated till thermal runaway (Voltage = 0)**

**Result No fire, no explosion**

**Thermal runaway temperature: about 220 °C**

# Safety tests (polyanion): nail penetration test

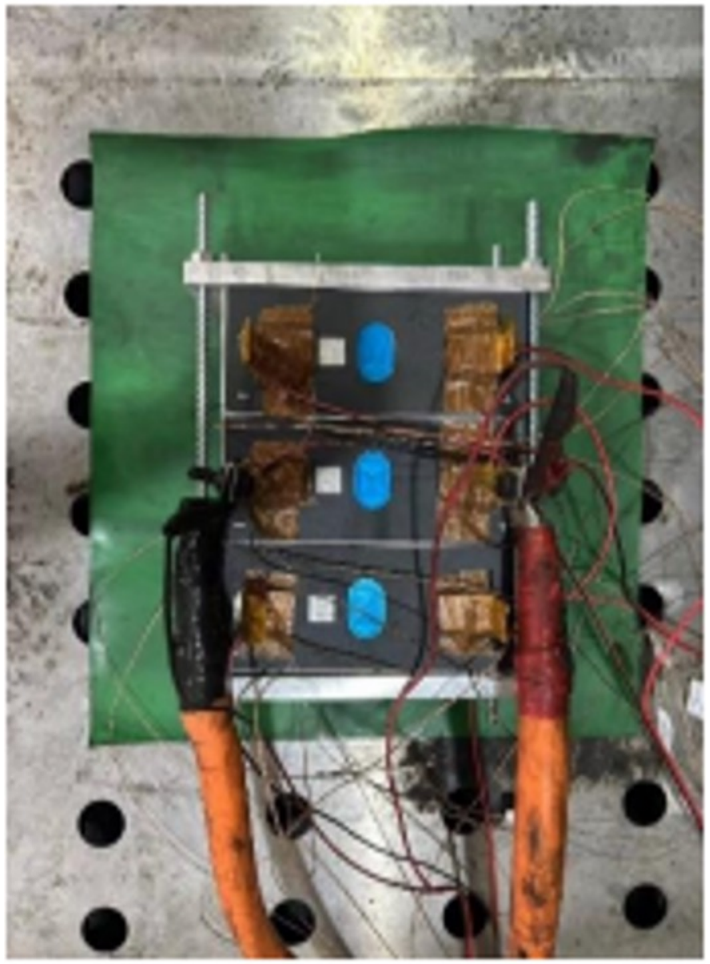


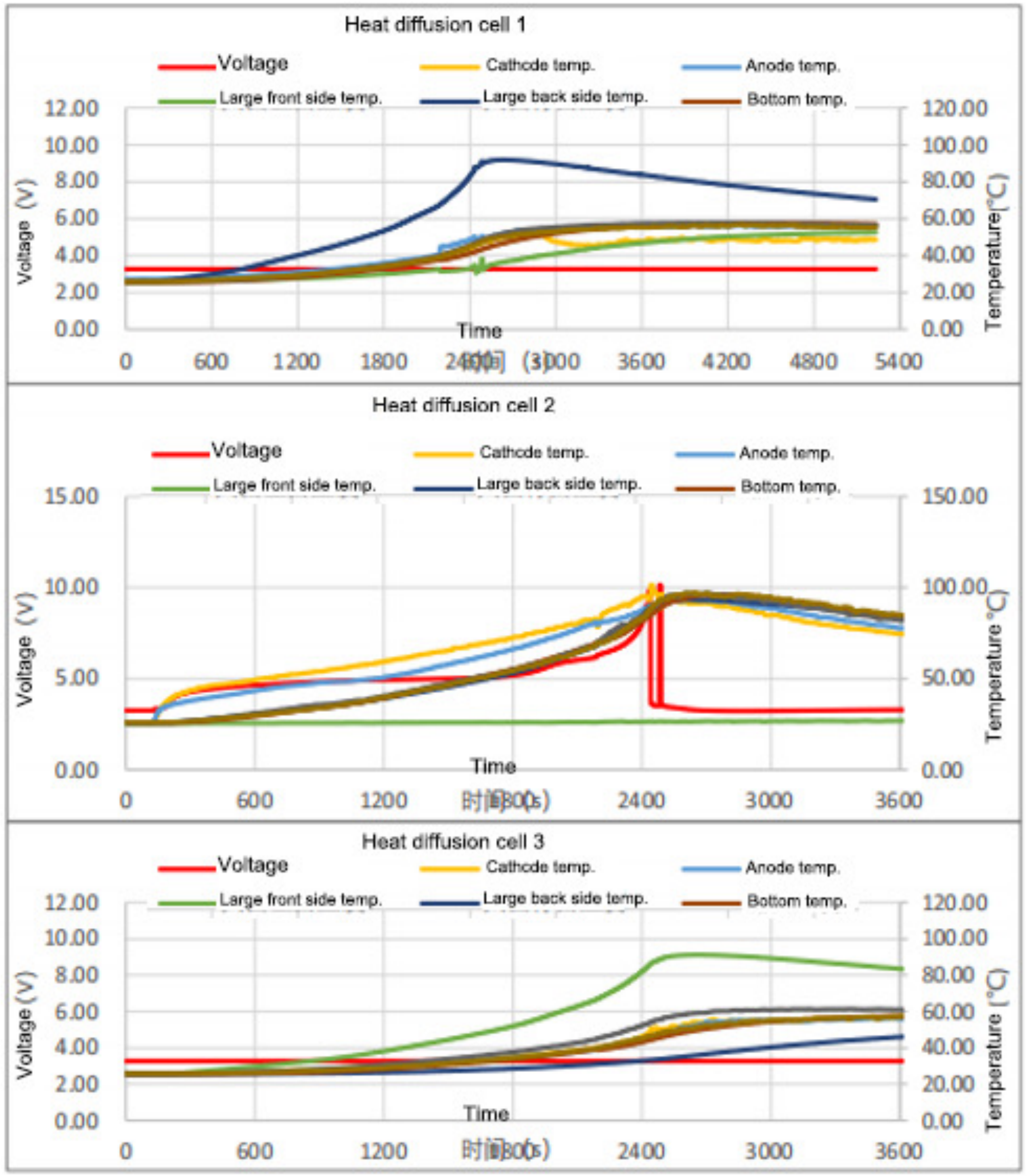

**Fully charged cell is nail penetrated during 60 minutes**

**Result No fire, no explosion**

**Temperature after 60 minutes: about 60 °C**

# Safety tests (polyanion): forced thermal runaway in battery modules






**3 fully charged cells in module**

**Overcharge middle cell till thermal runaway (V = 0)**

**Result No fire, no explosion**

**Temperature after 45 minutes: about 100 °C, 60°C for adjacent cells**

# Game-changing Sodium-ion batteries for sustainability

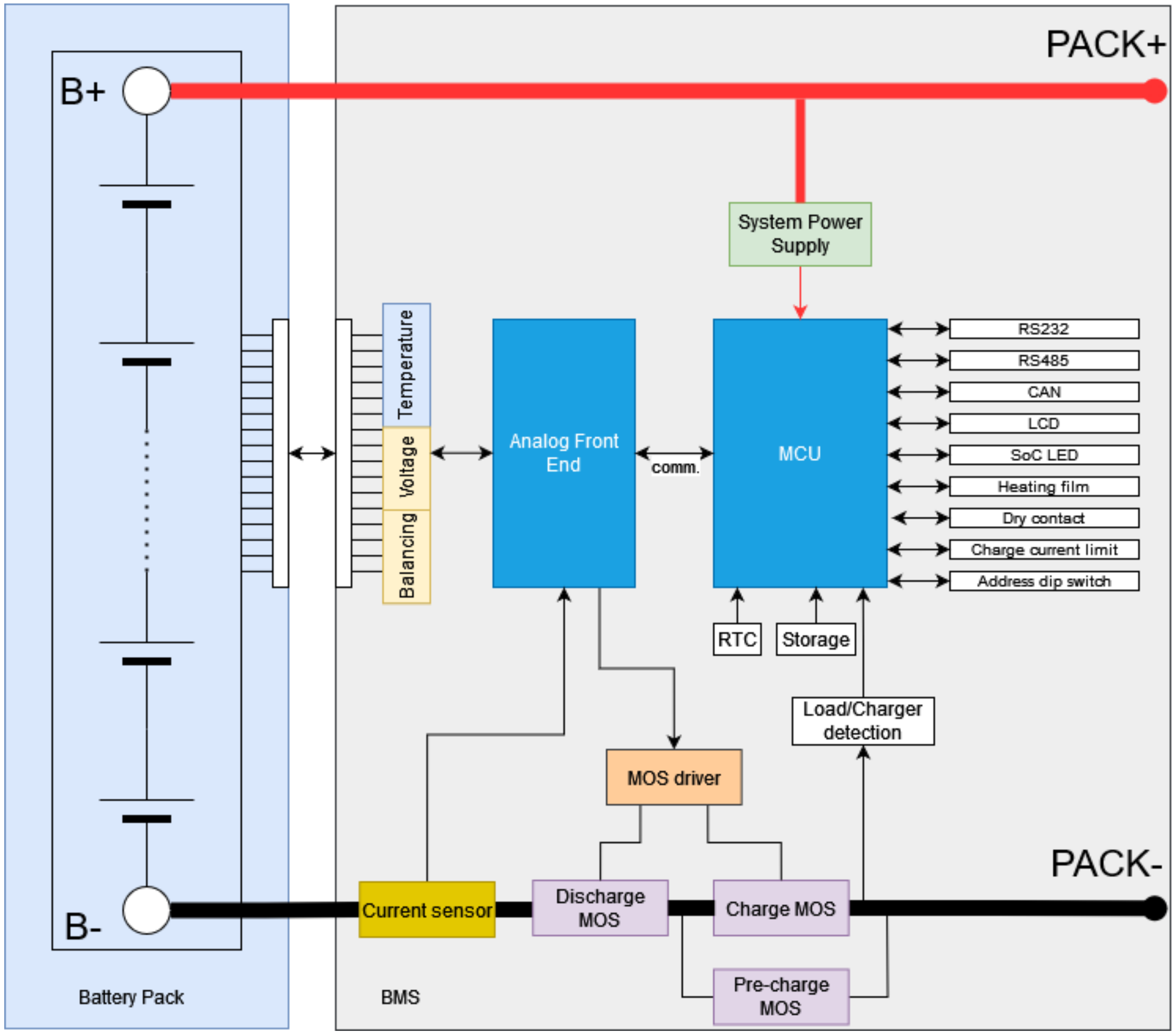
## A practical and sustainable battery must meet many criteria combined

| Lithium-ion battery cells | Sodium-ion battery cells |
|---|---|
| Fire risk | NO spontaneous fire risk |
| BMS | BMS, charger modulates pwer < 5°C |
| No charging < 0°C | Can charge at -10°C, current modulation < 5°C |
| Active cooling/heating | Often no need for active thermal management |
| Short time limited power | Higher power, upto 20C at all temperatures |
| Energy, 60 to 80 % usable | Energy, 100% usable |
| Limited temperature range | Works from -40°C to +60°C |
| Fast charging is problematic | Charging in 20-30 min possible |
| 3000 to 8000 cycles | 3000 to > 6000 cycles |
| Sustainable? | No Lithium, no Nickel, no Cobalt, easy recycling |
| Cost efficient | Cost efficient |
| Many announcements | In production since 2 years |

# Applications: solar energy storage


**Retrofitting existing systems**

# Battery construction




- Parallel first, then serial at module level
- BMS (active balancing)
- Battery Monitoring sufficient
- Paralel modules only at battery level to increase capacity
- Heat aborbing silicon gel inside
- Or forced airflow

*For illustration only*

# Process flow for customer specific solutions

- **Requirements collection:**
  - **Understanding the application and the system**
  - **Understanding the boundary conditions**
- **Feasibility study:**
  - **Selecting cell types**
  - **Initial battery configuration: (S xP), multi-module, …**
- **Load profile simulations**
  - **Beginning of Life – End of Life**
  - **Calendar lifetime calculations**
- **CAD design**
  - **Enclosure, safety devices, etc.**
- **Assembly and test**

# Kurt.energy division of Altreonic

## *Questions?*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