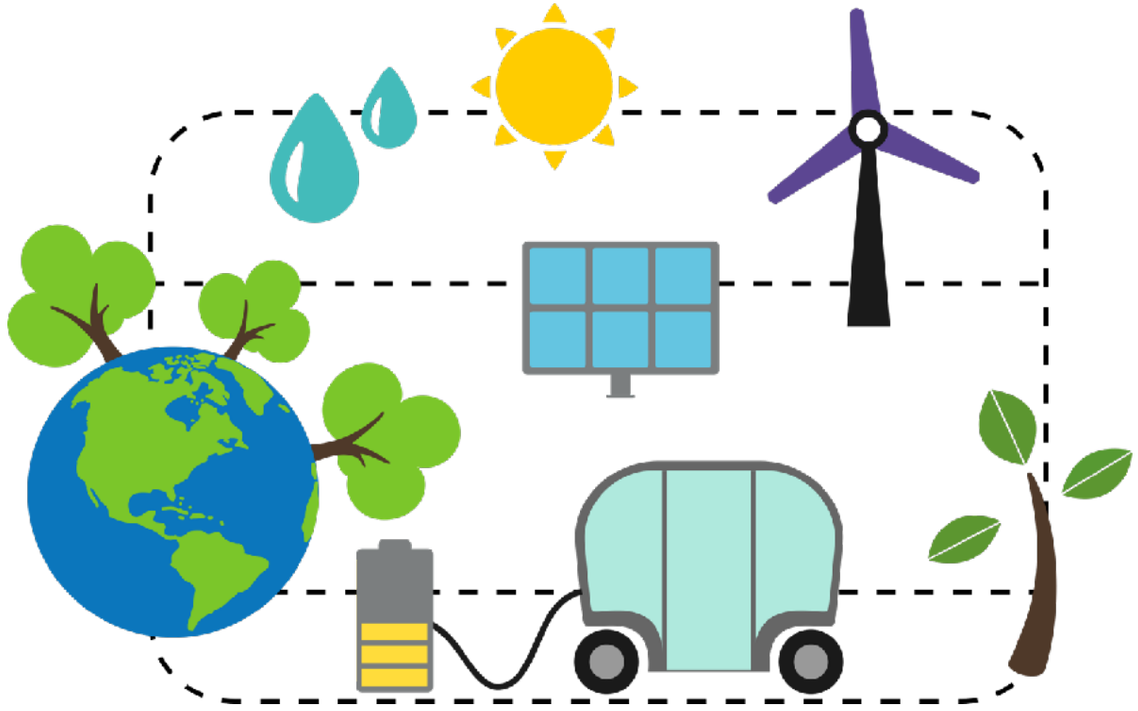
Kurt.energy:

The shift to green energy needs better batteries NOW

Evidence for

Carbon based hybrid power capacitors



Hybrid carbon based power capacitors

Similar energy density like lithium-ion batteries with the benefits of supercapacitors

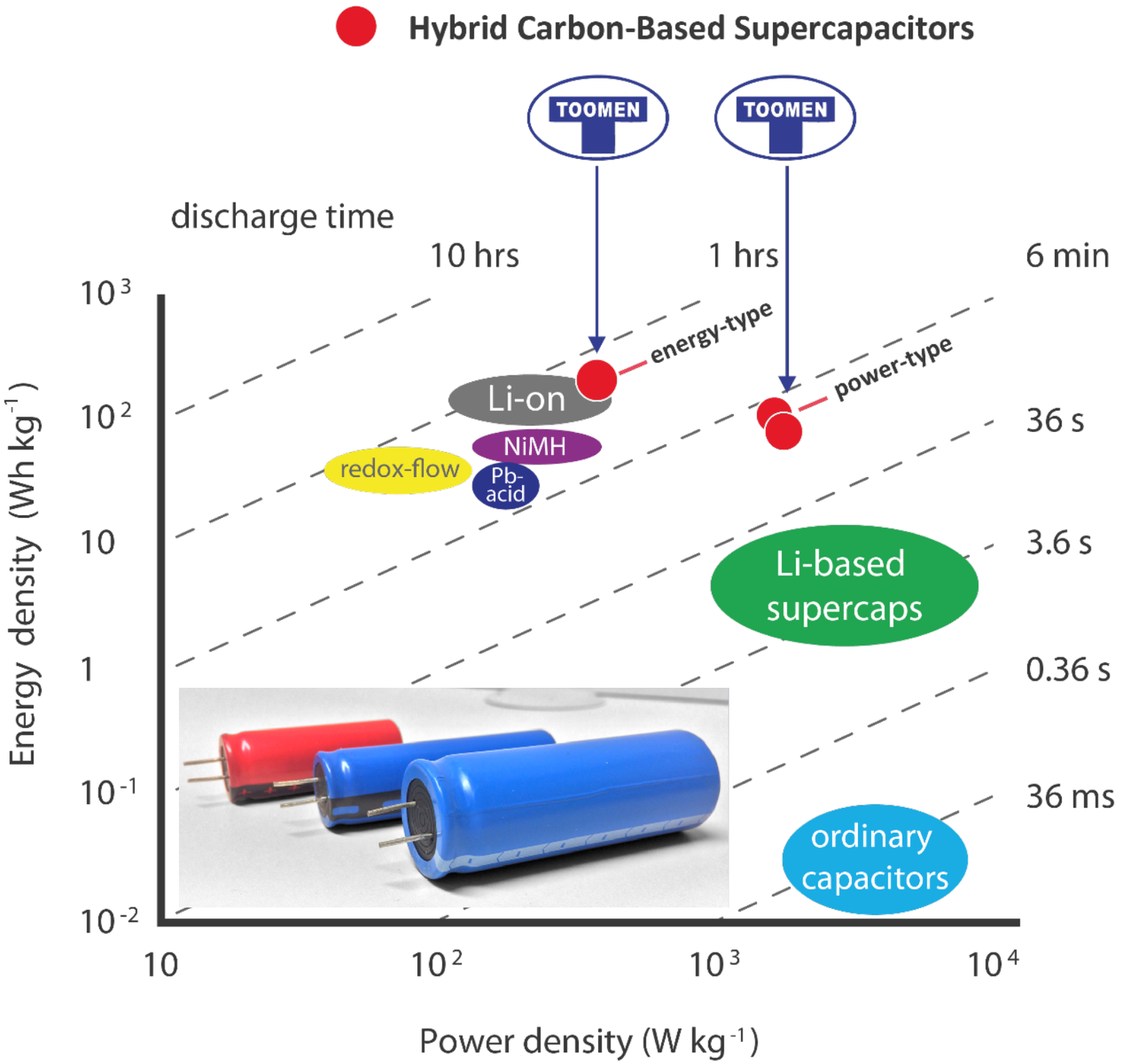
1. Carbon power capacitors **DO NOT BURN**
2. Sustained 10C to 20C **high peak power capacity**
   - **A 15 kWh battery can deliver 150 to 300 kW sustained (and more)**
   - **Very fast charging: 75% in 5 minutes**
3. Works from **-40°C to +80°C**
4. **Very long life: > 20000 cycles or 10 years**
5. **No BMS needed, no active thermal management needed**
6. Energy density cells from **80 to230 Wh/kg**

- While there is no ideal battery for all applications, a battery must have multiple parameters right and being in production
- Combination of energy density, high power density and safety provides a game-changing opportunity
- Lifecycle cost significantly lower

Comparison of batteries and C-powercaps

	LFP battery	NMC lithium battery	Lithium titanate battery	Lithium based super capacitor	Power-type C-powercap	Energy-type C-powercap
Energy density (Wh/kg)	90 - 150	180 - 250	70 - 95	4 - 6	**80 - 100**	**180 - 230**
Power density (kW/kg)	0.1 - 0.2	0.1 - 0.5	0.5 - 1	5 - 7	**1 - 1.5**	**0.3 - 0.5**
Typical charging/ discharging rates	1.0 C	0.7 - 1.0 C	1.0 - 5.0 C	100.0 - 200.0 C	**10.0 - 20.0 C**	**1.0 - 1.25 C**
Working temperature (℃)	-10 ~ 55	-20 ~ 45	-40 ~ 60	-40 ~ 65	**-20 / -40 ~ +80**	**-20 / -40 ~ +80**
Cycle life (times)	2000	2000	5000	> 500000	**> 20000 upto 50000**	**> 10000**
Safety	acceptable	not good	good	excellent	**excellent**	**excellent**
Complexity	Medium: BMS needed	High: BMS needed + thermal mgt	Medium: BMS needed	Low: no BMS, passive cooling	**Low: no BMS, passive cooling**	**Low: no BMS, passive cooling**

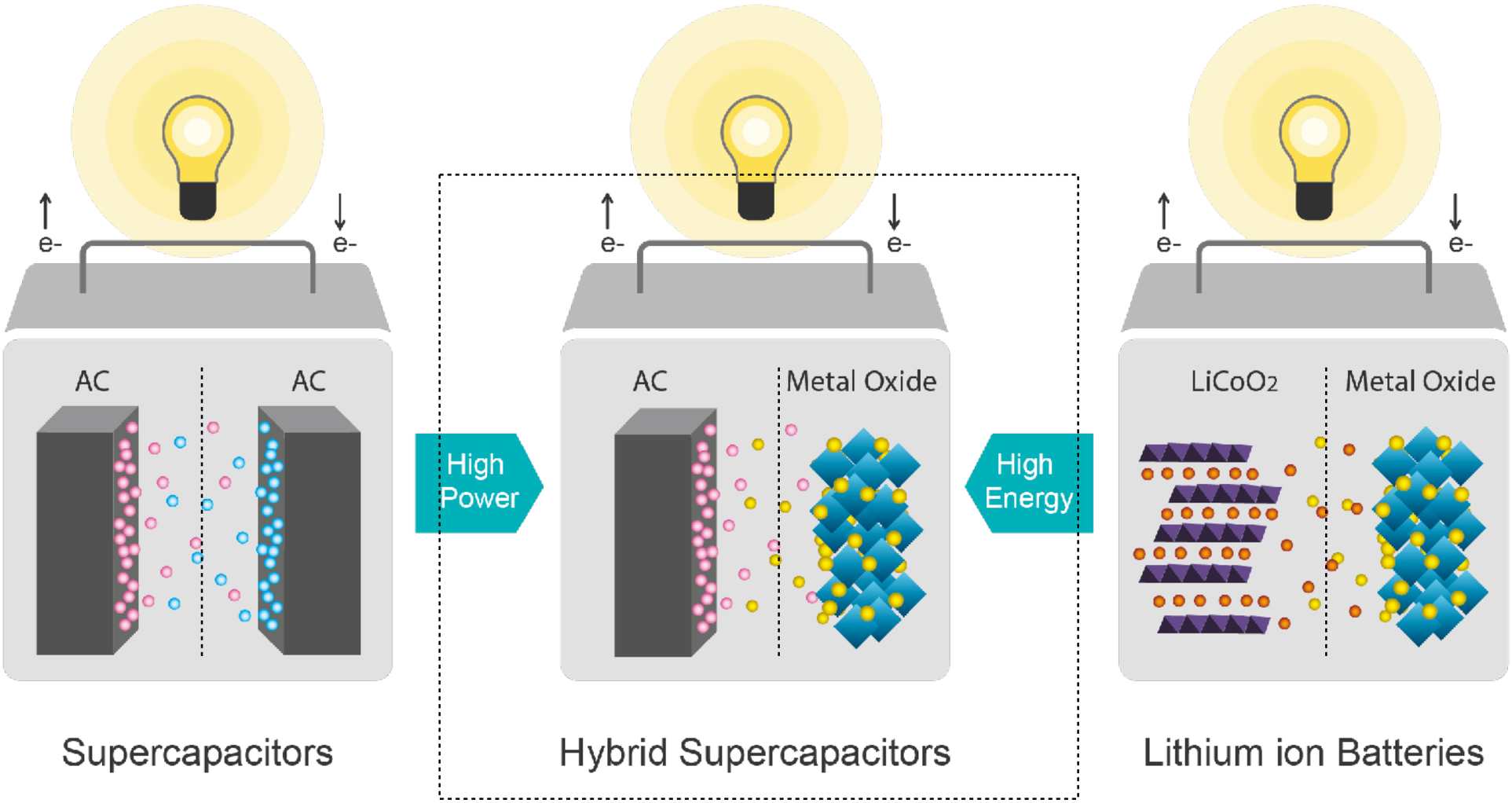
Argone chart: comparison



Comparison carbon power caps

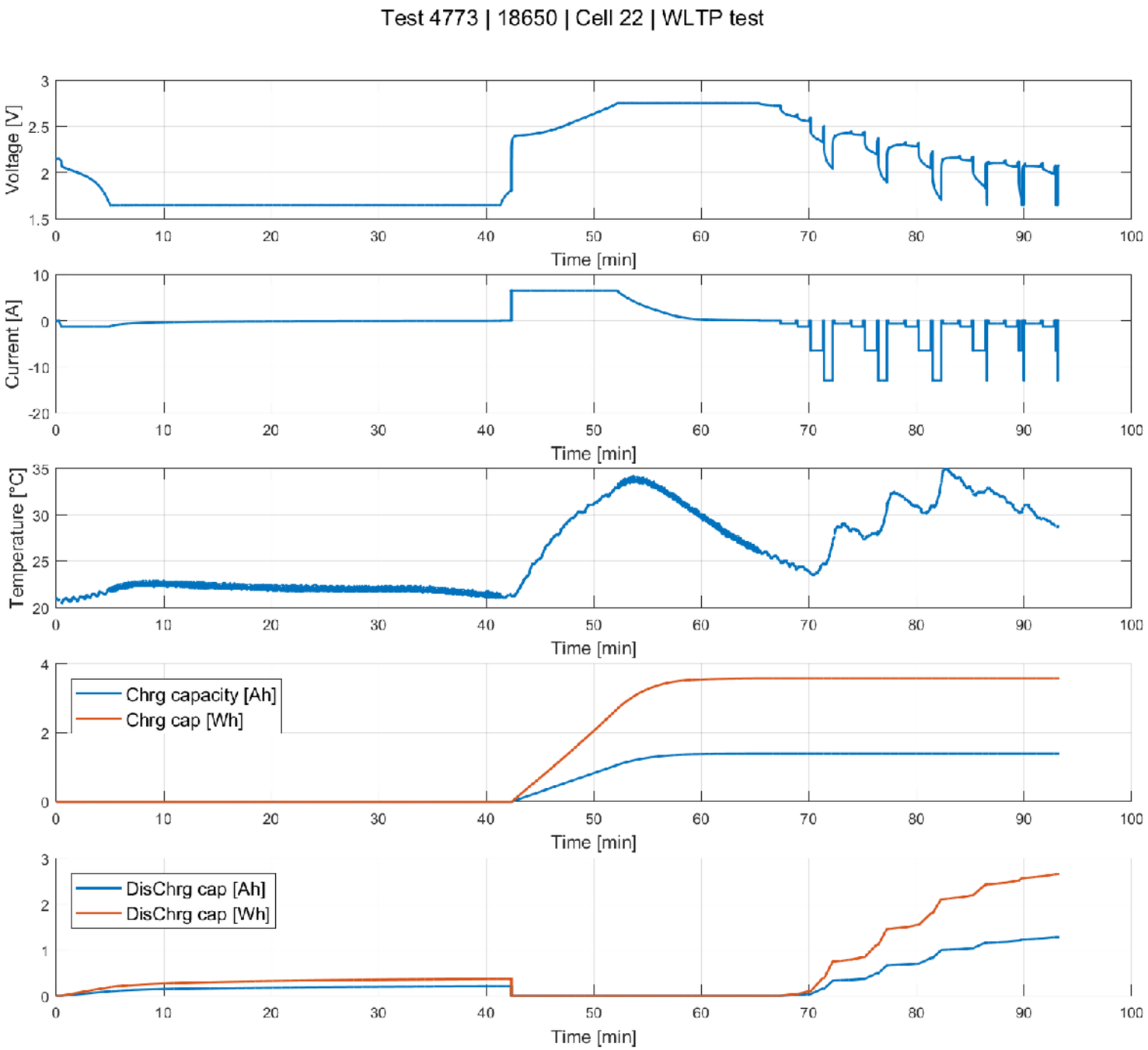
Type	Power-type	Power-type	Energy-type	Energy-type
Format	Cyl 18500	Cyl 18650	Cyl 23680	Pouch 120x200
Energy Wh/cell	3,2	3,5	16,0	70,0
Energy Wh/kg	100	80	200	230
Energy Wh/dm3	235	181	442	972
Max C-rate	10 C	20 C	1-1,25 C	1-1,25 C
Temperature range	-20 to +70 °C	-40 to +80°C	-40 to +80°C	-40 to +80°C
Lifetime	20000	> 20000	10000	10000
Max Ri (mOhm)	20	13	20	–
Status	Production	Production	pre-production	Prototype

Hybrid architecture: C-cap with a Li-side



- **Dominant component is activated nano-carbon**
- **No dendrites can form**
- **Low in electrolyte, absorbed by carbon**
- **Low in Lithium compounds (LPF, LTO, NMC like)**

Confirmed by external test & stress & abuse tests



Charging in 10 minutes to 75%

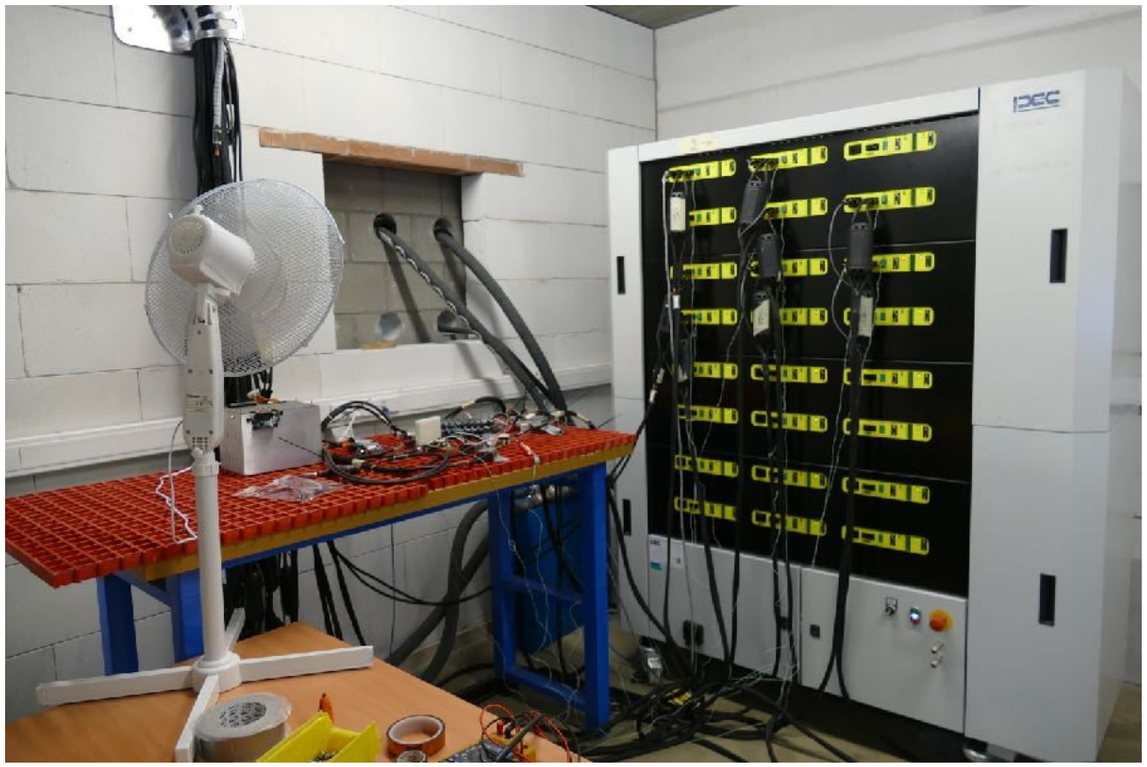
Discharging at 0.5, 1C, 5C, 10C

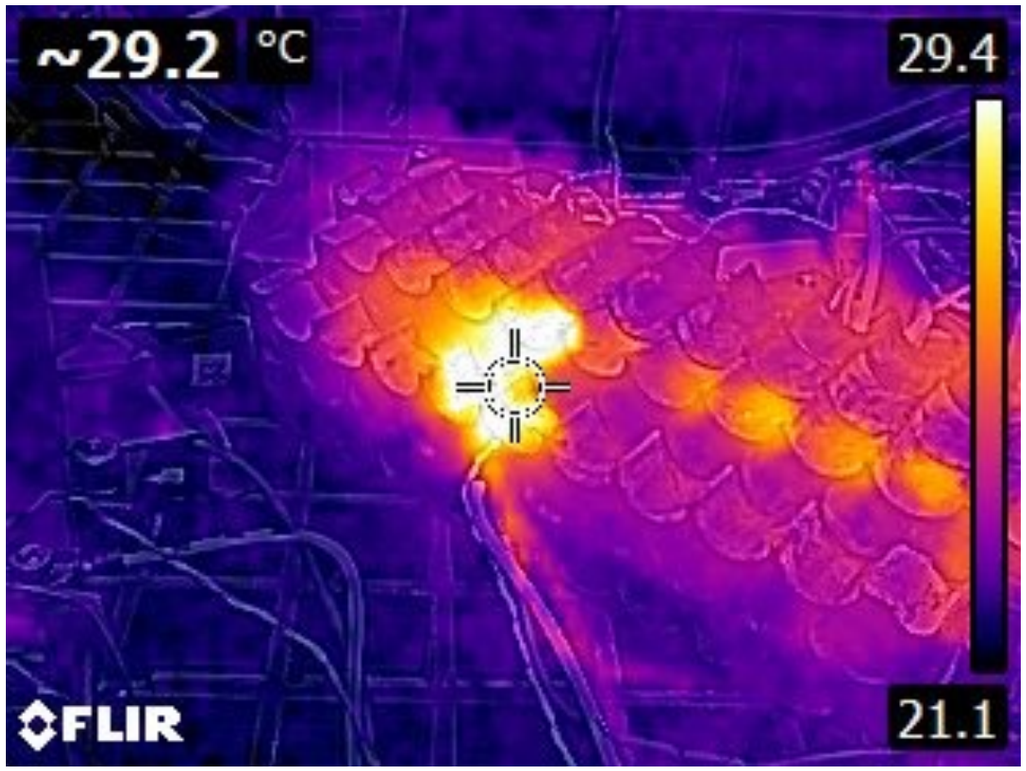
T < 35 °C in ambient air

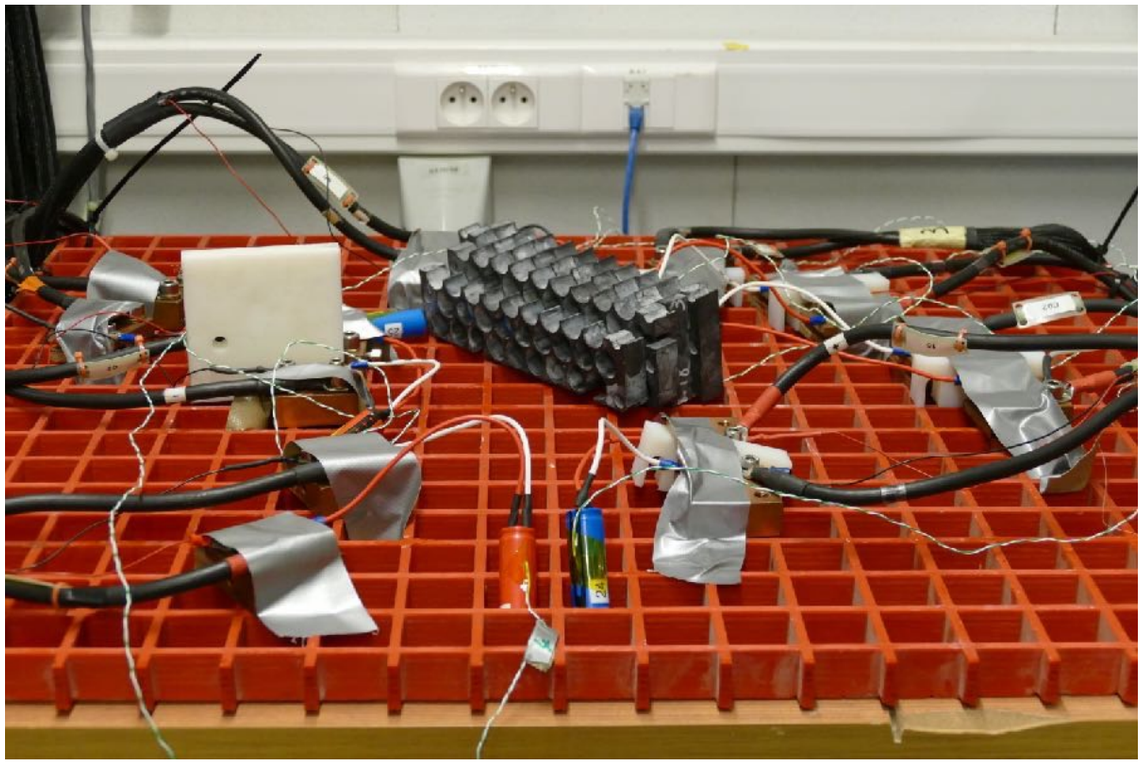
3.4 Wh charged & discharged

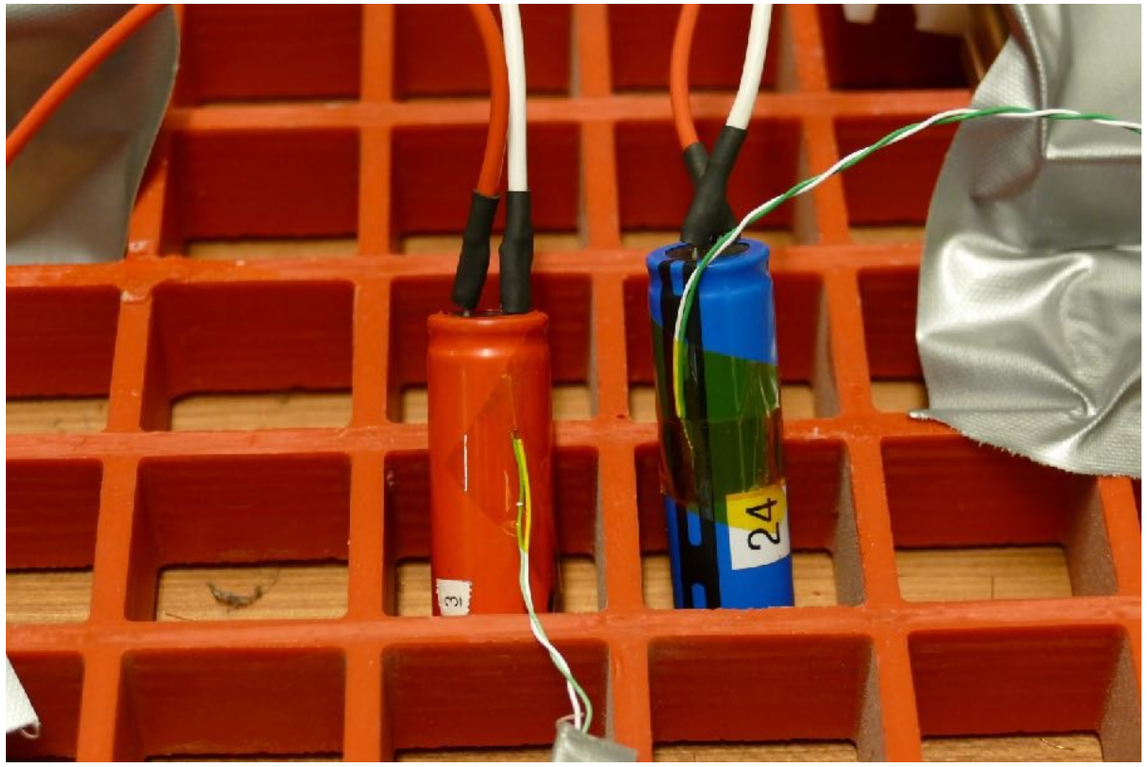
Charging at 5C (6.5 A), discharging at 0.5C, 1C, 5C, 10C, simulating WLTP cycle

Tests at FlandersMake Lommel

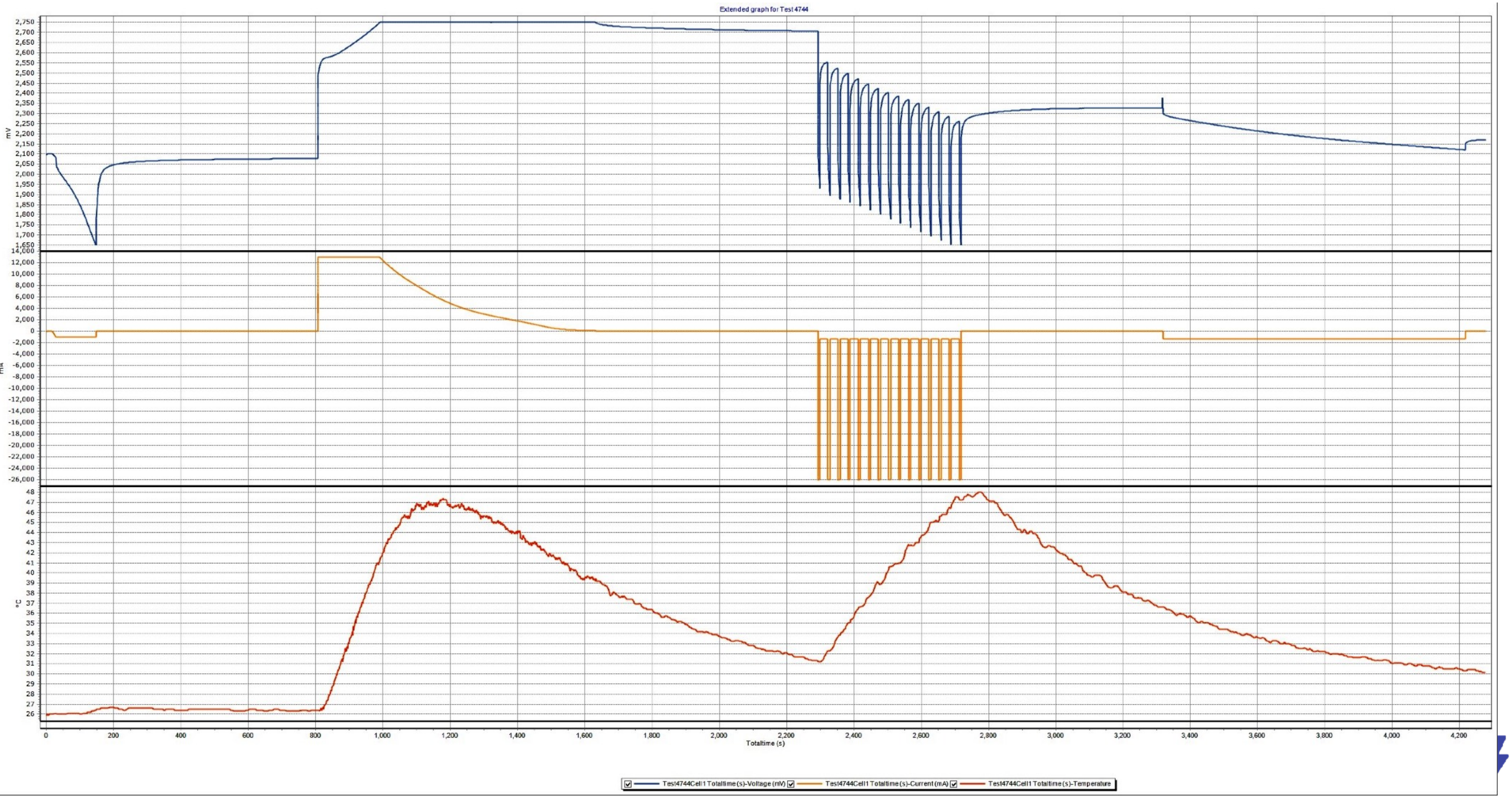


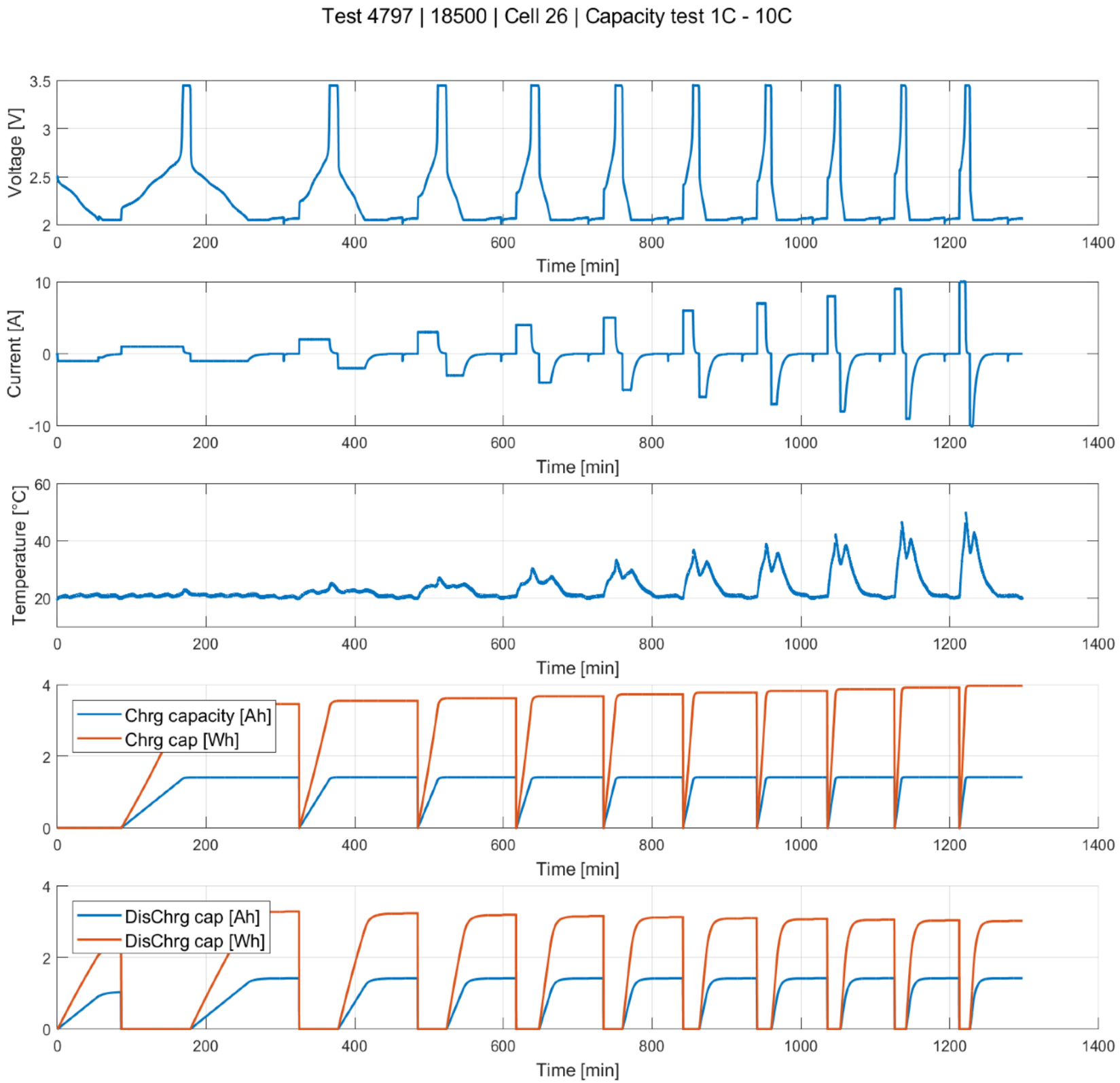






Stress test: charge at 5C, discharge 6 sec at 20C (26A), rest 24 sec in between.





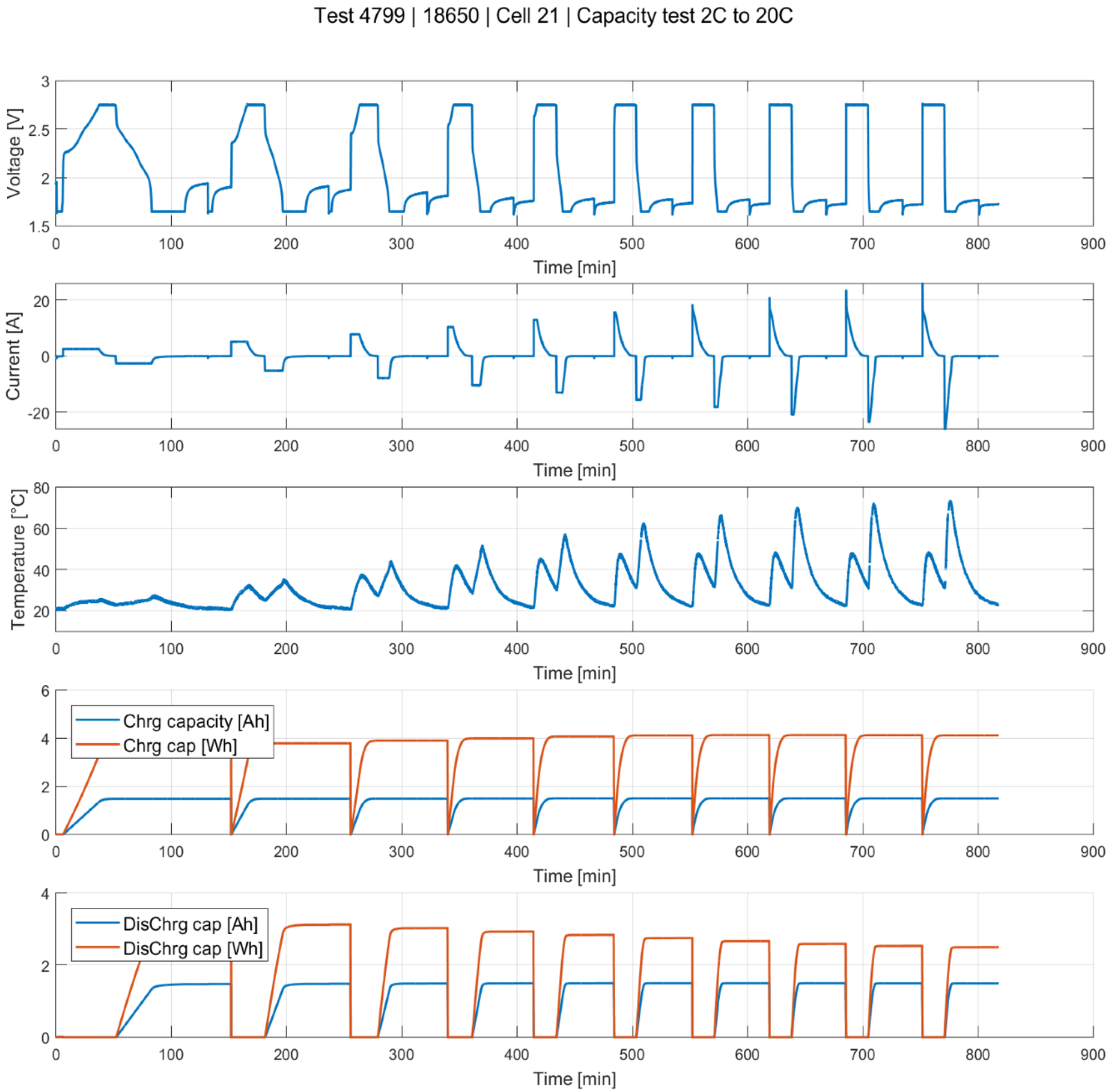
Charging in 22 minutes to 75%

Charging and discharging with 1.C (1.0 A) upto 10C (10.0 A)

Temperature peaks at 55°C remains below 30°C up to 5C

3,2 Wh charged & discharged

Stress test 18500 upto 10C (open air)



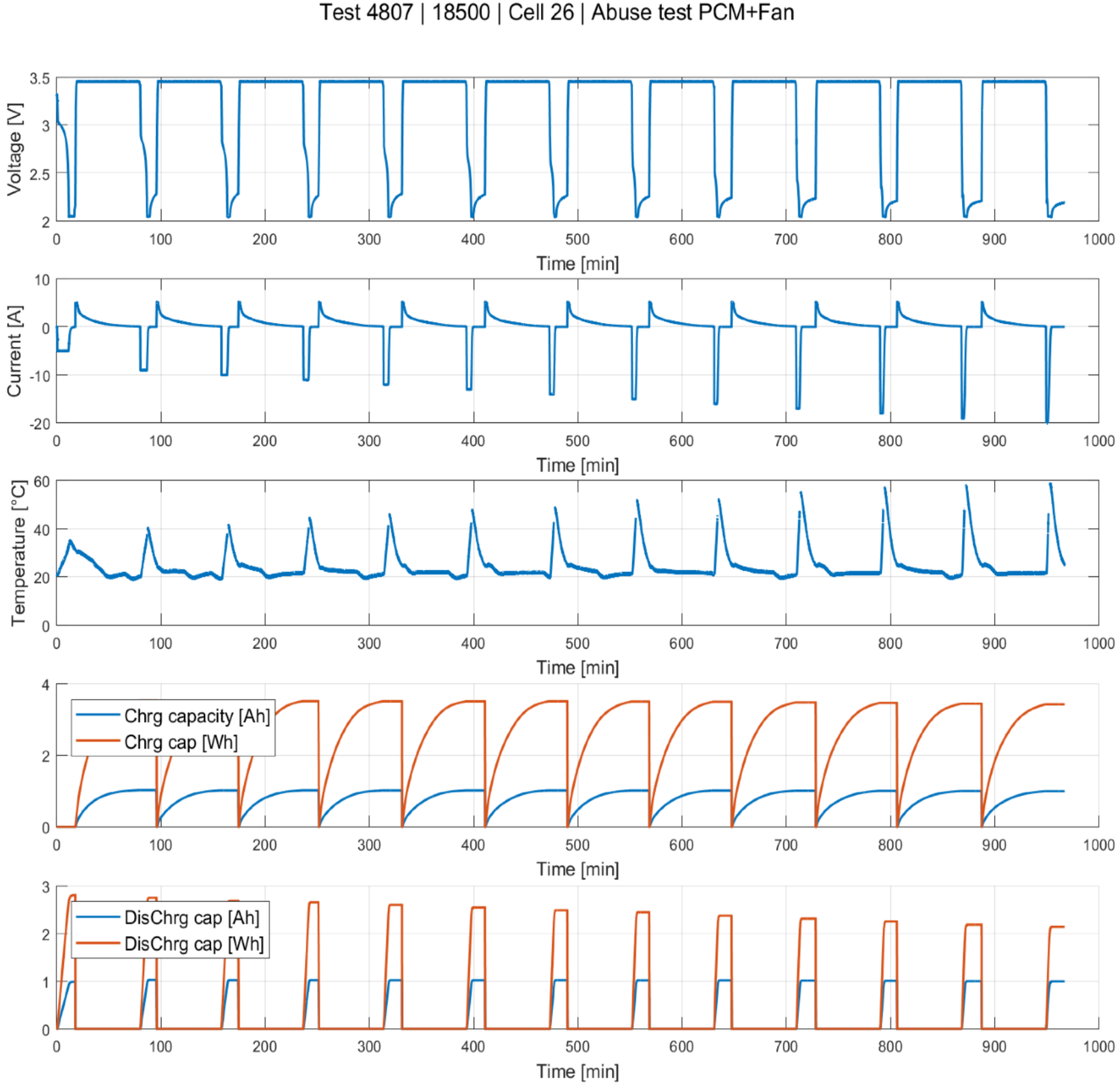
Charging in 5 minutes to 75%

Charging and discharging with 1C (1.3 A) upto 20C (26.0 A)

Temperature peaks at 75°C remains below 60°C up to 10C

3,5 Wh charged & discharged

Stress test 18650 upto 20C (open air)



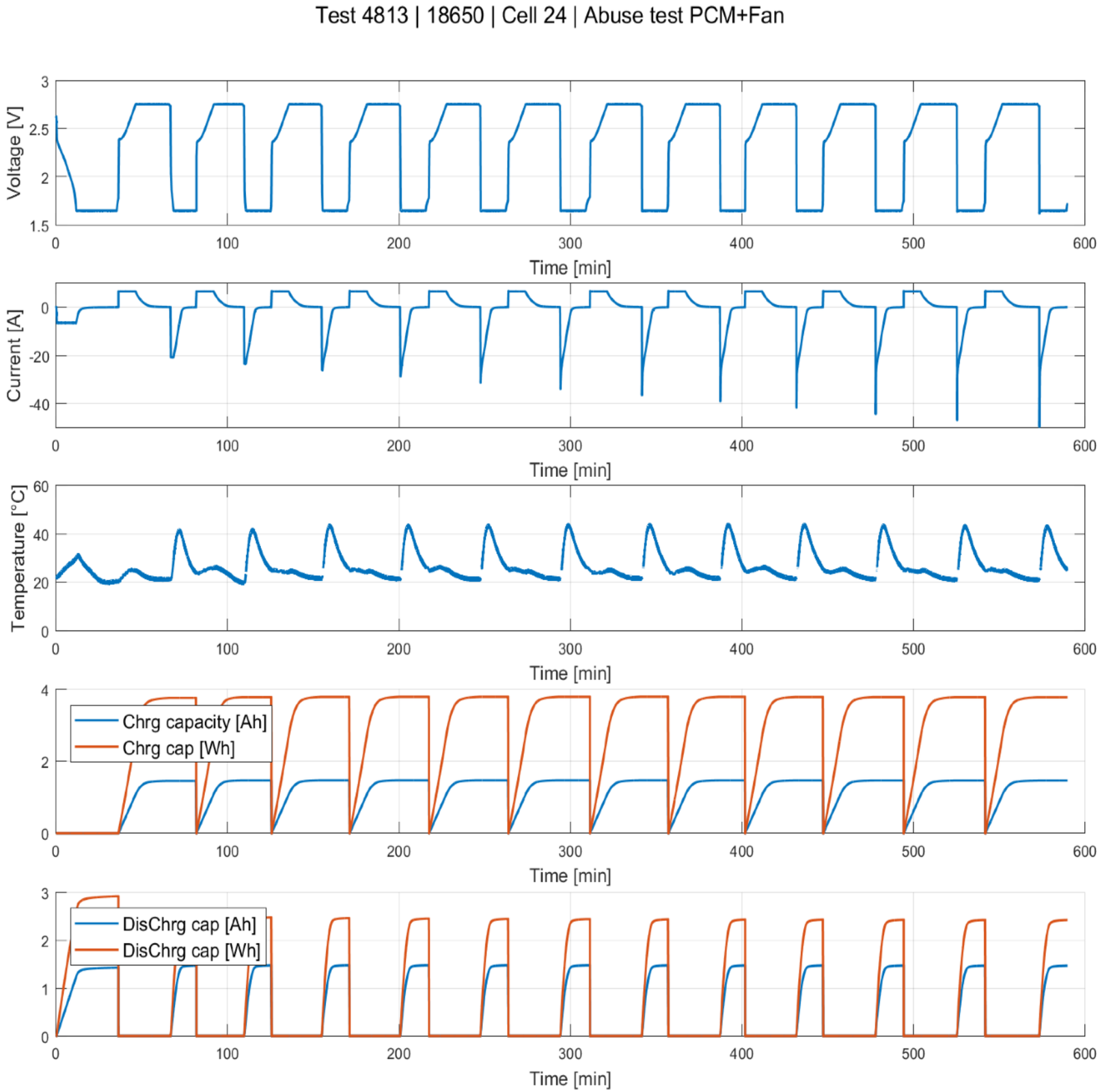
Charging at 5C in 22 minutes to 75%

Discharging from 9C (9.0 A) upto 20C (20.0 A)

Temperature peaks at 60°., Remains below 40°C till 10C

Charge capacity unaffected

Abuse test 18500 upto 2x10C = 20C (PCM + fan)



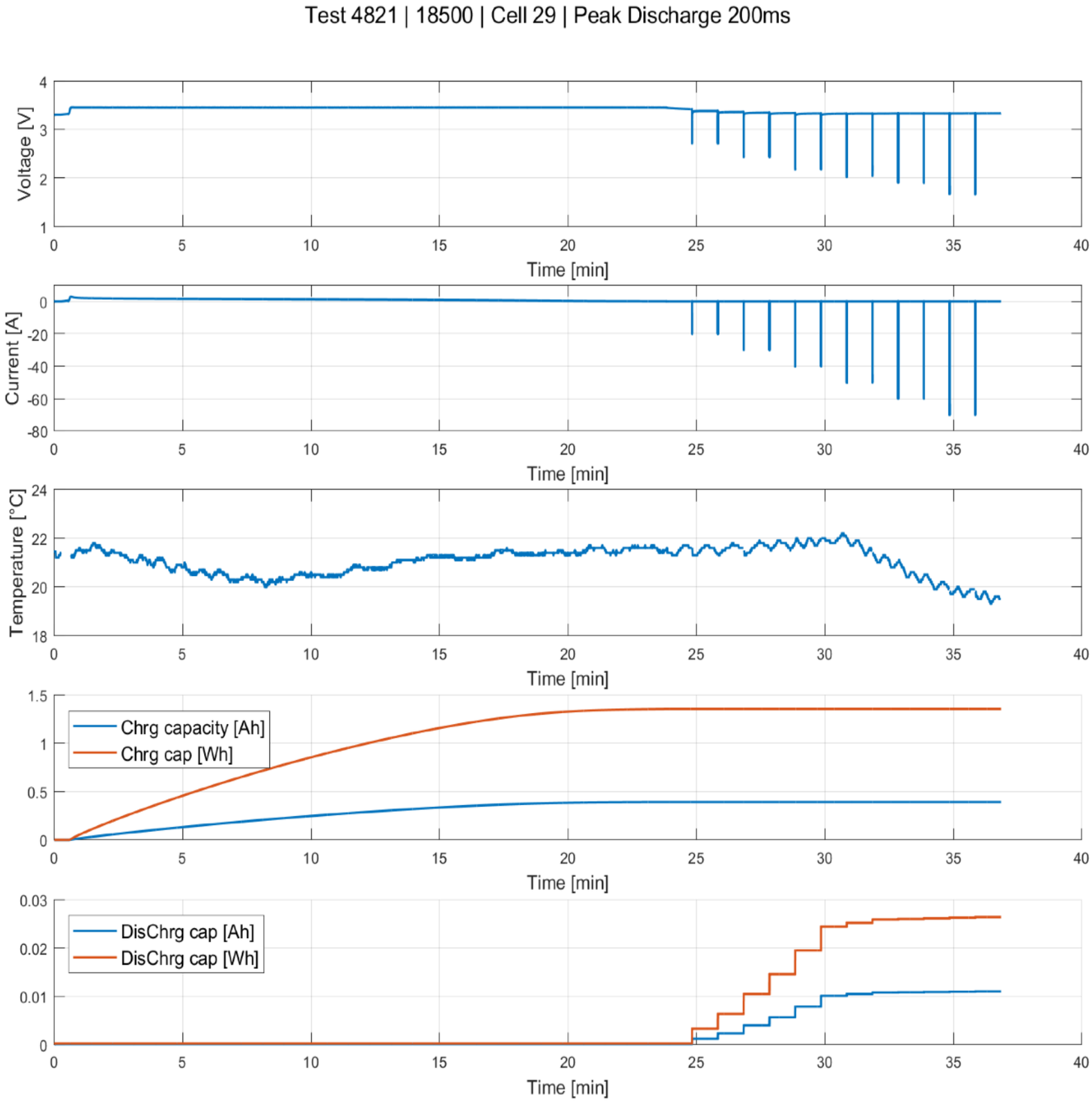
Charging at 5C in 5 minutes to 75%

Discharging from 16C (20.8 A) upto 38C (49.4 A)

Temperature peaks at 42°C, remains below 40°C upto 16C

Charge capacity unaffected

Abuse test 18650 upto 2x20C => 38C (PCM + fan)



Charging at 3C in 25 minutes to 50%

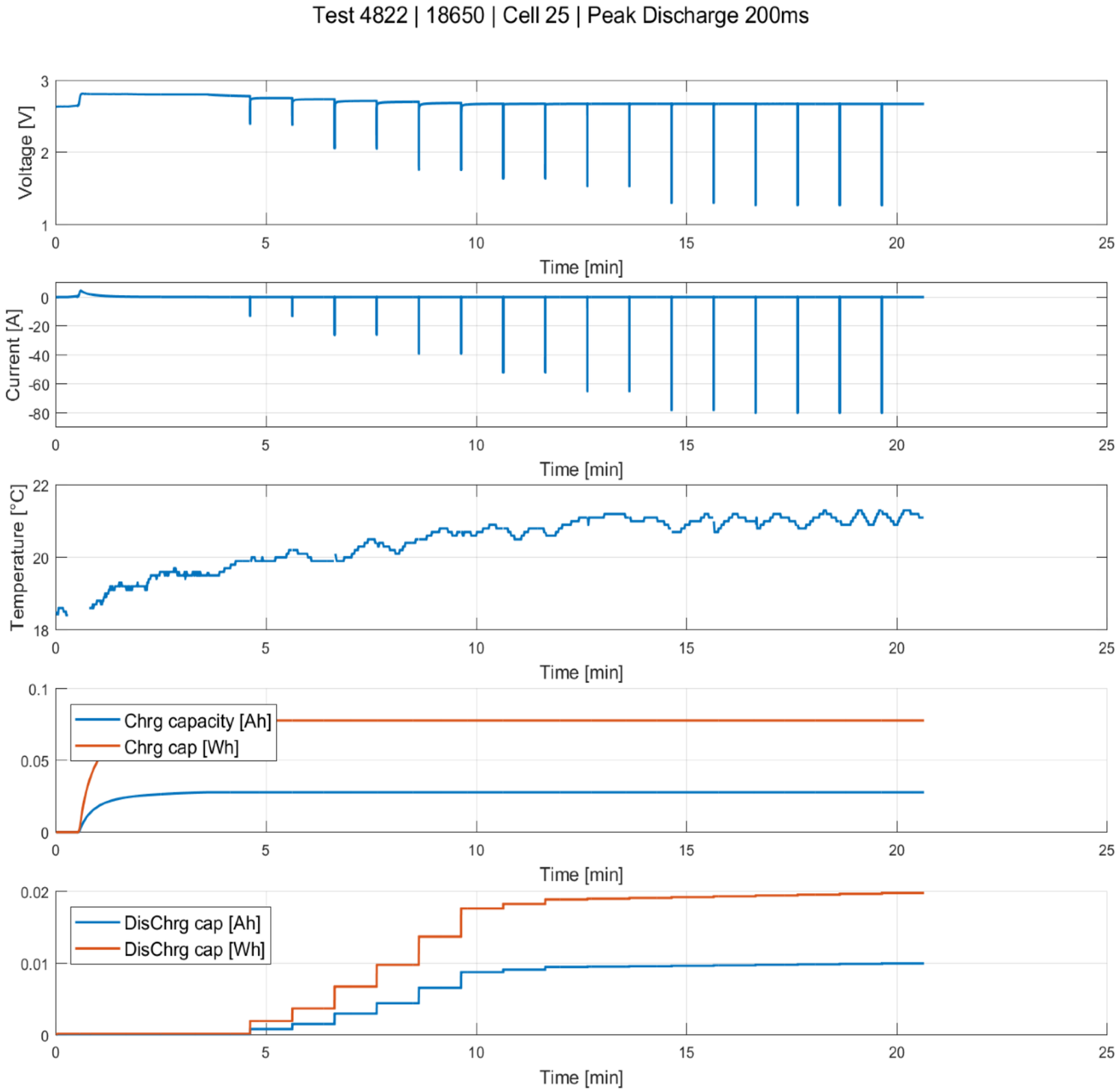
2X Pulse (200 ms) discharging from 20C (20 A) upto 70C (70 A)

No measurable temperature increase

Discharge capacity not affected

Note: tester limit 80A

Pulse abuse test 18500 upto 2x20C => 70C (PCM+fan)



Charging at 3C in 5 minutes to 75%

2X Pulse (200 ms) discharging from 10C (13 A) upto 60C (78 A)

No measurable temperature increase

Discharge capacity not affected

Note: tester limit 80A

Pulse abuse test 18650 upto 60C (PCM+fan)

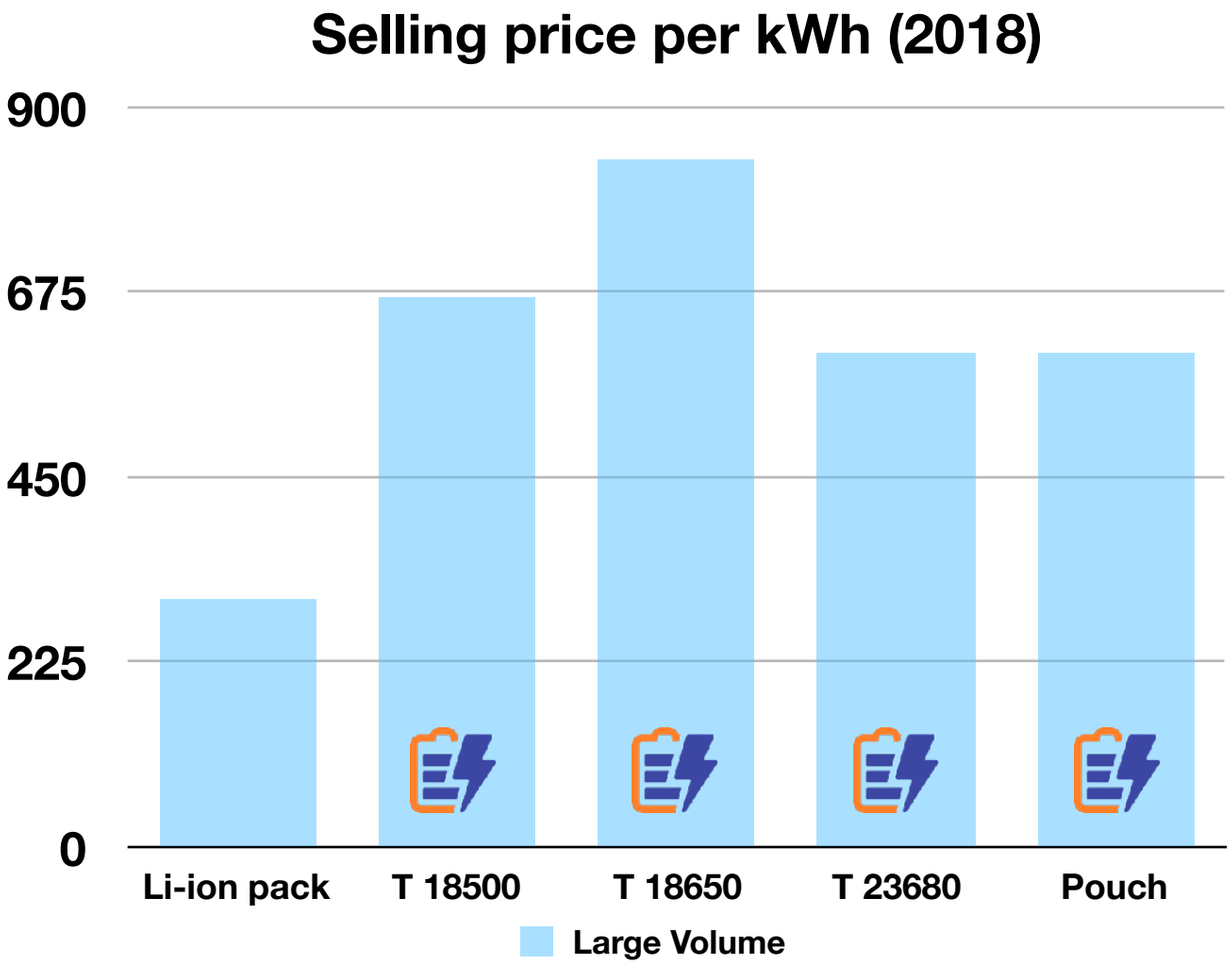
Extreme robustness

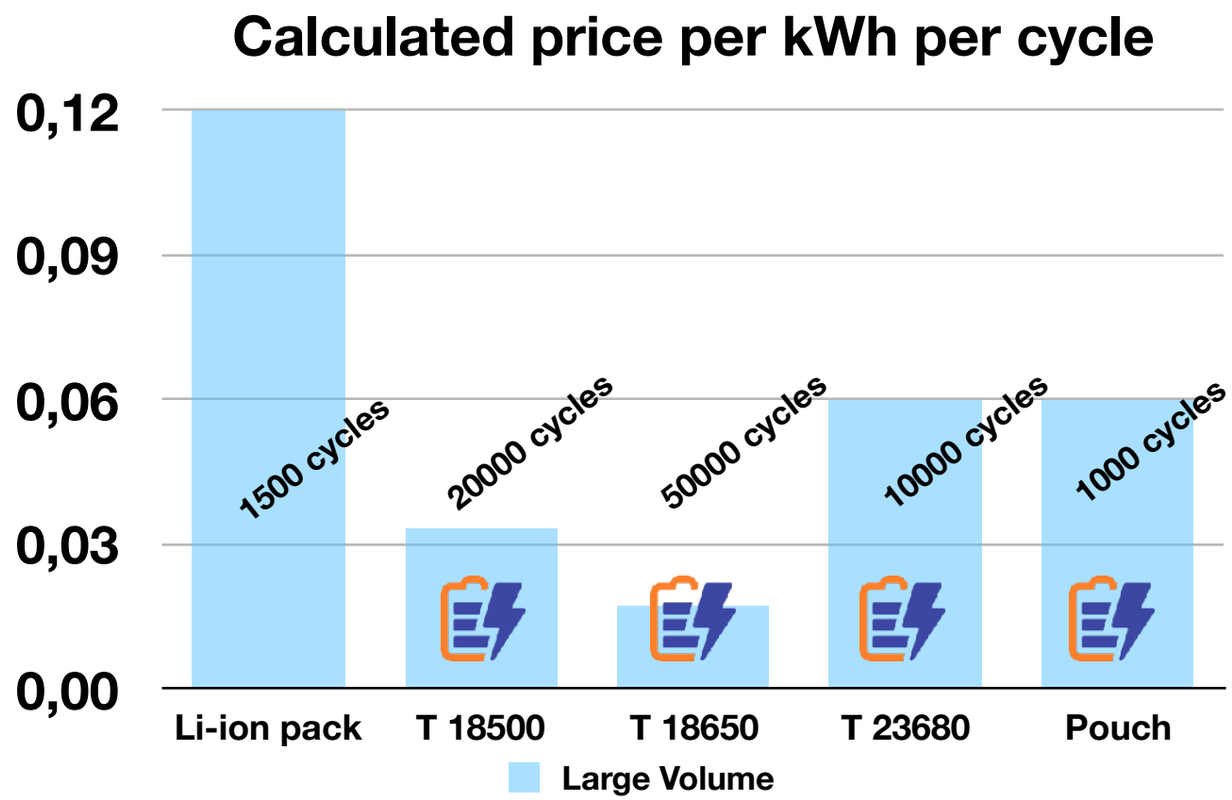
- What do these tests show:
  - Use beyond the datasheet specs gives no problem
    - No capacity loss,
    - No destruction,
    - No heat generation
  - Use with very high current only limited by voltage drop

- => Power capacitors are extremely robust

- In addition:
  - Failure mode is open-circuit, hence no thermal risk
  - Battery pack mesh architecture is failure resilient
  - Lifetime from 10000 to > 20000 cycles: lower cost / cycle

Costprice per kWh/cycle over (long) lifetime





Cycle = charge/discharge

Customer advantage:
10 years lifecycle (when monitored), maintenance cost very low
Often smaller power capacitor battery (1/3) with 10 to 20x more power
=> lower lifecycle cost

Why no BMS?

No Active balancing needed:

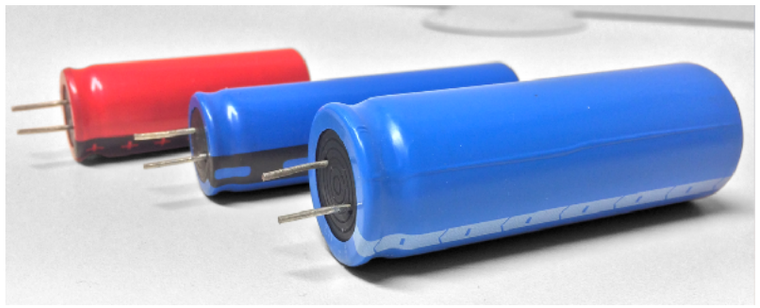
- **Cells are matched at assembly time**
- **Connected in “rectangular” S xP mesh**
- **Hence, no need for active balancing**
- **Benefits:**
  - **Much simpler, better use of space**
  - **Robustness: BMS has many parts that can fail and age**
- **Less “extra” weight**
- **If a cell fails:**
  - **(unlikely, only when penetrated or short circuit)**
  - **Fails as an open circuit**
  - **Battery remains operational**

Why no active thermal management system?

Powercapacitors remain cool

- **Low internal resistance**
- **Can tolerate low and high temperatures**
  - (high temperatures will affect lifetime, as for any technology)
  - No risk of thermal runaway
- **Good design practice:**
  - Keep C-rate < 5C for 18500, < 10C for 18650
  - Occasional higher rates are not a problem
  - Keep things “cooled” => enclose in heat absorbing package
- **Benefits:**
  - **Save a lot of complexity**
  - **Save a lot of weight**
  - **Reliability**

Construction of a power capacitor pack



Applications


Space


Heavy mining vehicles

Hybrid trucks


E-bike battery

Old-timer electrification


Energy storage


Grid stabilization


Street lighting


Car batteries


AGVs & forklifts


Hybrid vehicles


Trains

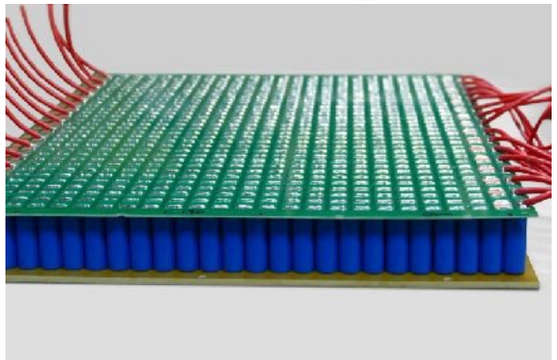

Welding equipment

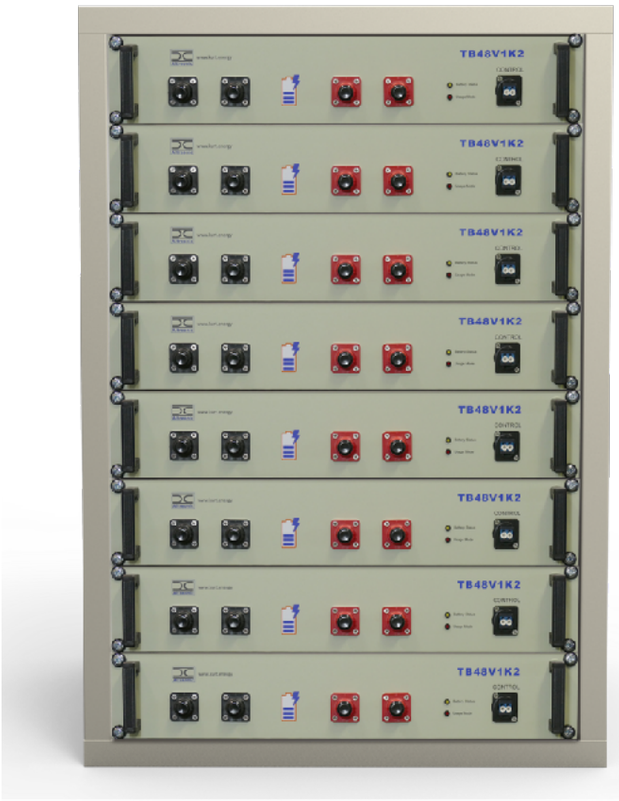

Hand-held power tools


Home energy system


Power mills

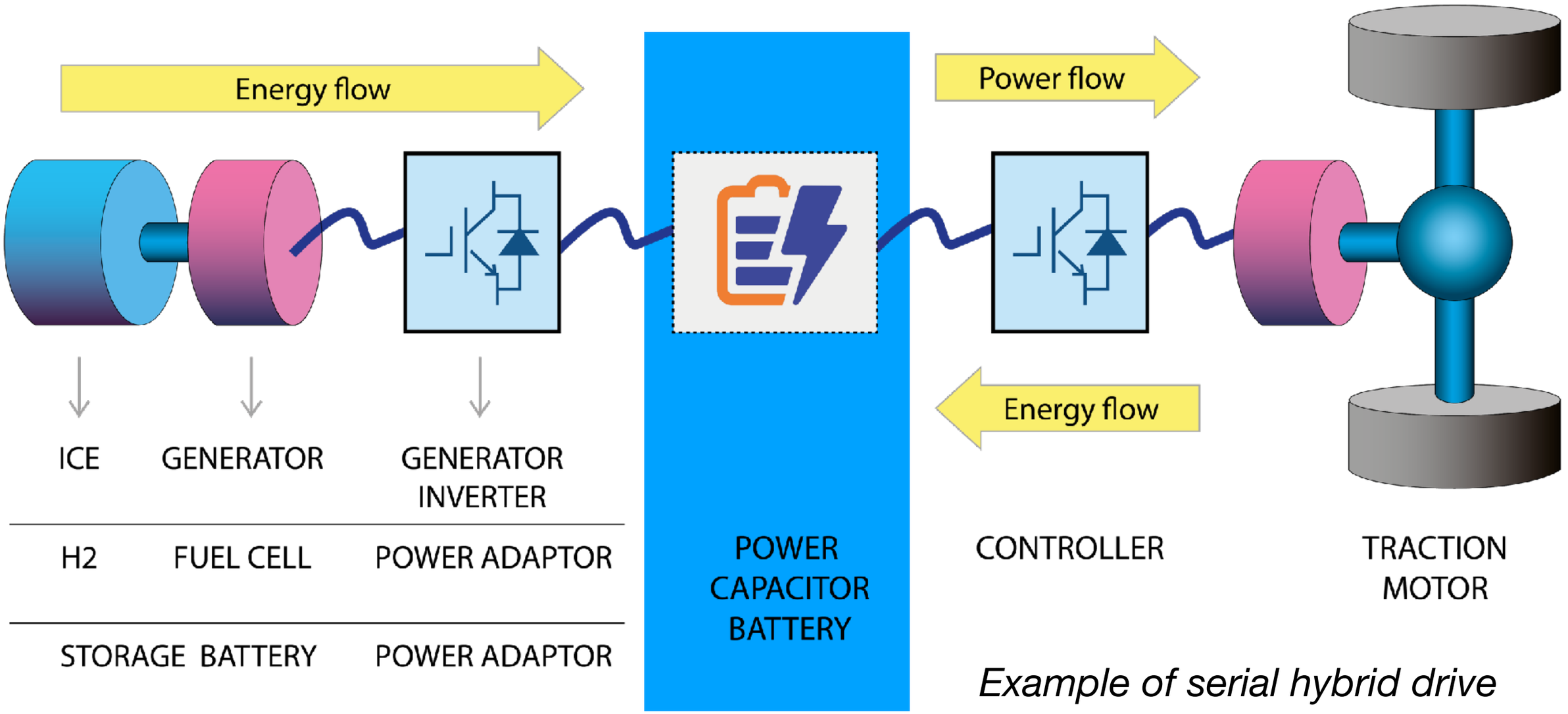
Applications of C-based supercaps





- Powerbanks (charging in (5 to 10 min)
- Starter batteries (for ICE vehicles)
- Hybrid batteries
- Serial hybrid vehicle drives
- Vehicle batteries:
  - Heavy duty vehicles (e.g. mining)
  - Fast charging vehicle batteries:
- Frequency grid adjustment
- Wind turbine blade pitch control
- Emergency power supply/ UPS
- Long life / high reliability batteries

Hybrid drives (serial - parallel)



Example of serial hybrid drive

Plug-in hybrid drives with 15 kWh battery can reduce pollution with 95% at a much lower cost than full BEV

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