



Akkujen kehittyminen ja lämmönhallinta

Akkuteknologiat paloturvallisuuden näkökulmasta
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Contents

- VTT energy storage technologies research
- Current battery technologies
- Emerging battery technologies
- Safety of lithium-ion batteries
- Thermal management of batteries

VTT energy storage technologies research

1. Experimental research on cell, module, and pack level

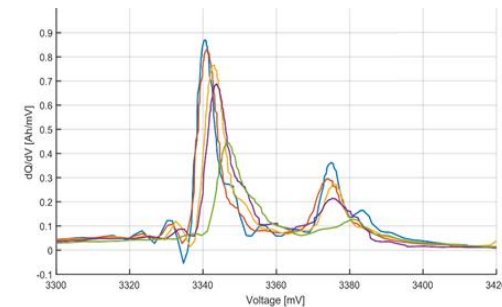
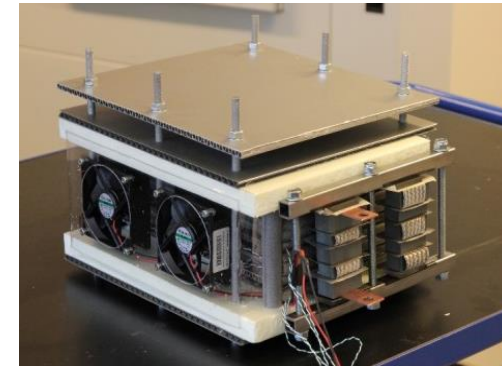
- Energy storage performance and lifetime testing, test methodology
- Impact of environmental conditions

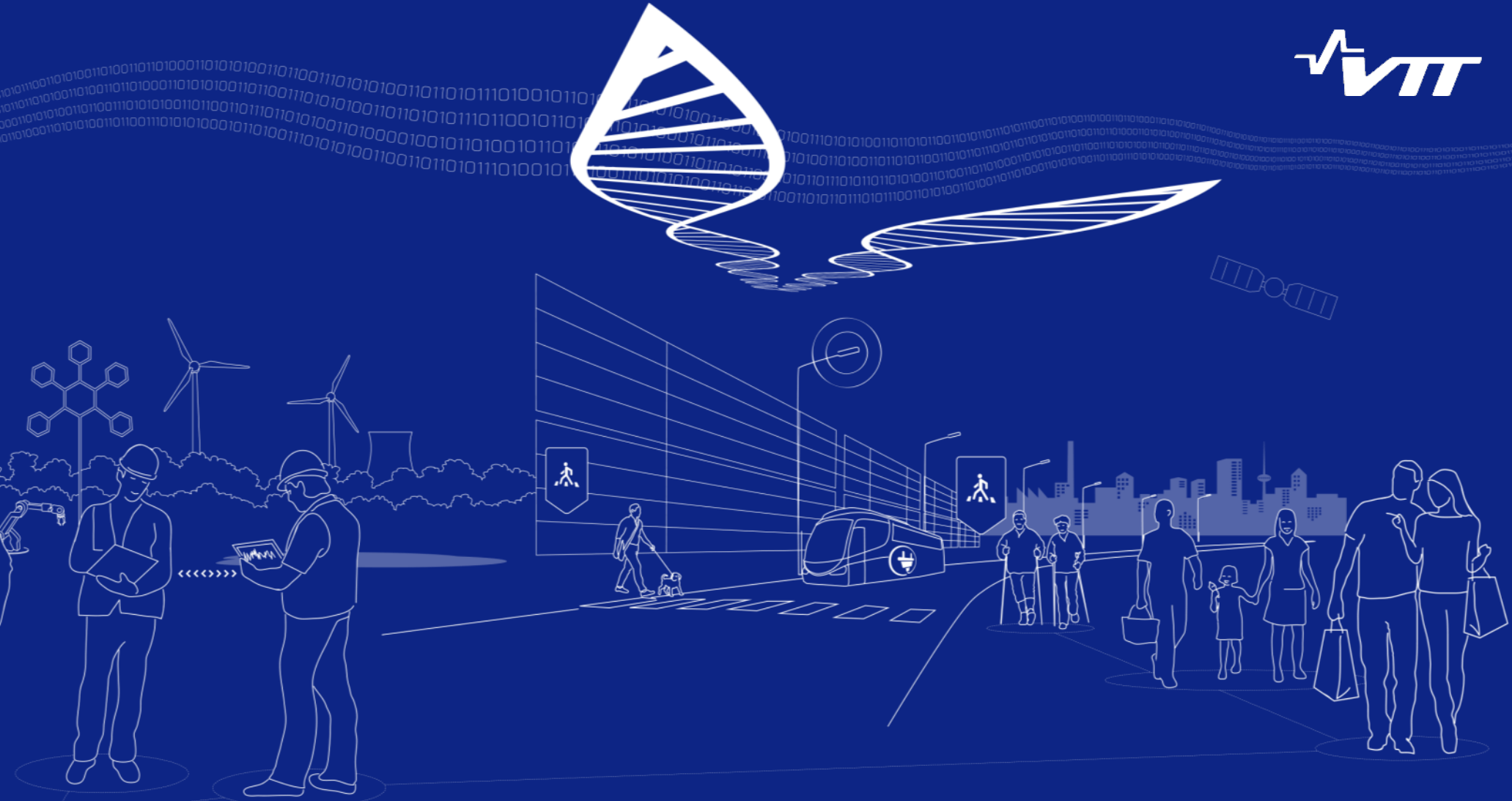
2. Design tools

- Electrical and thermal modelling
- Battery safety
- Lifecycle management, estimates, diagnostics
- Techno-economic evaluations

3. Energy storage systems and applications

- Battery management system (BMS) development
- Concepts of thermal management
- Technology choices and dimensioning

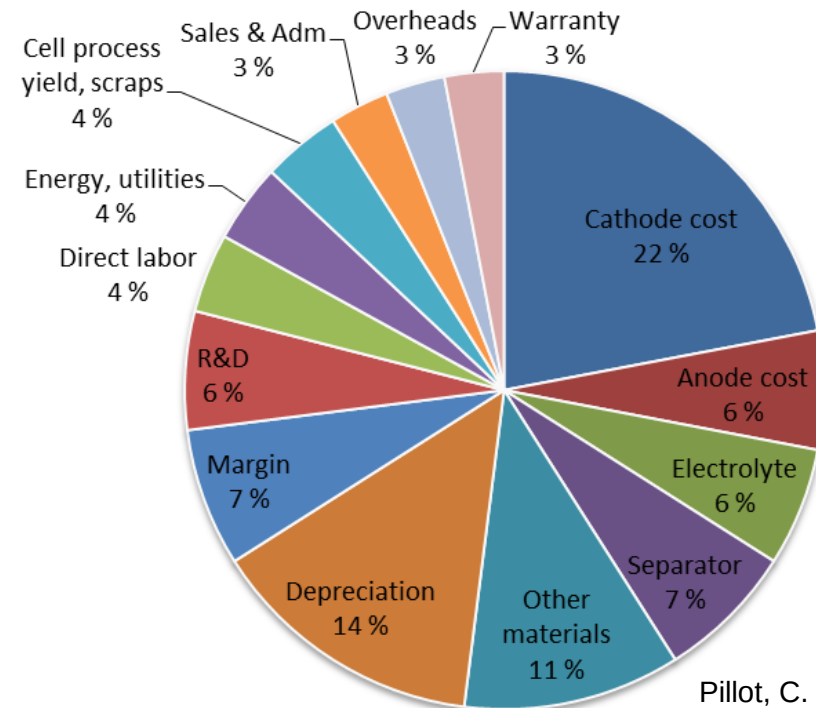
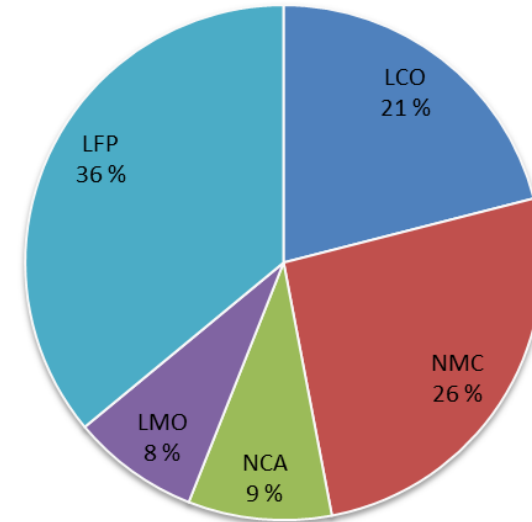




Current battery technologies

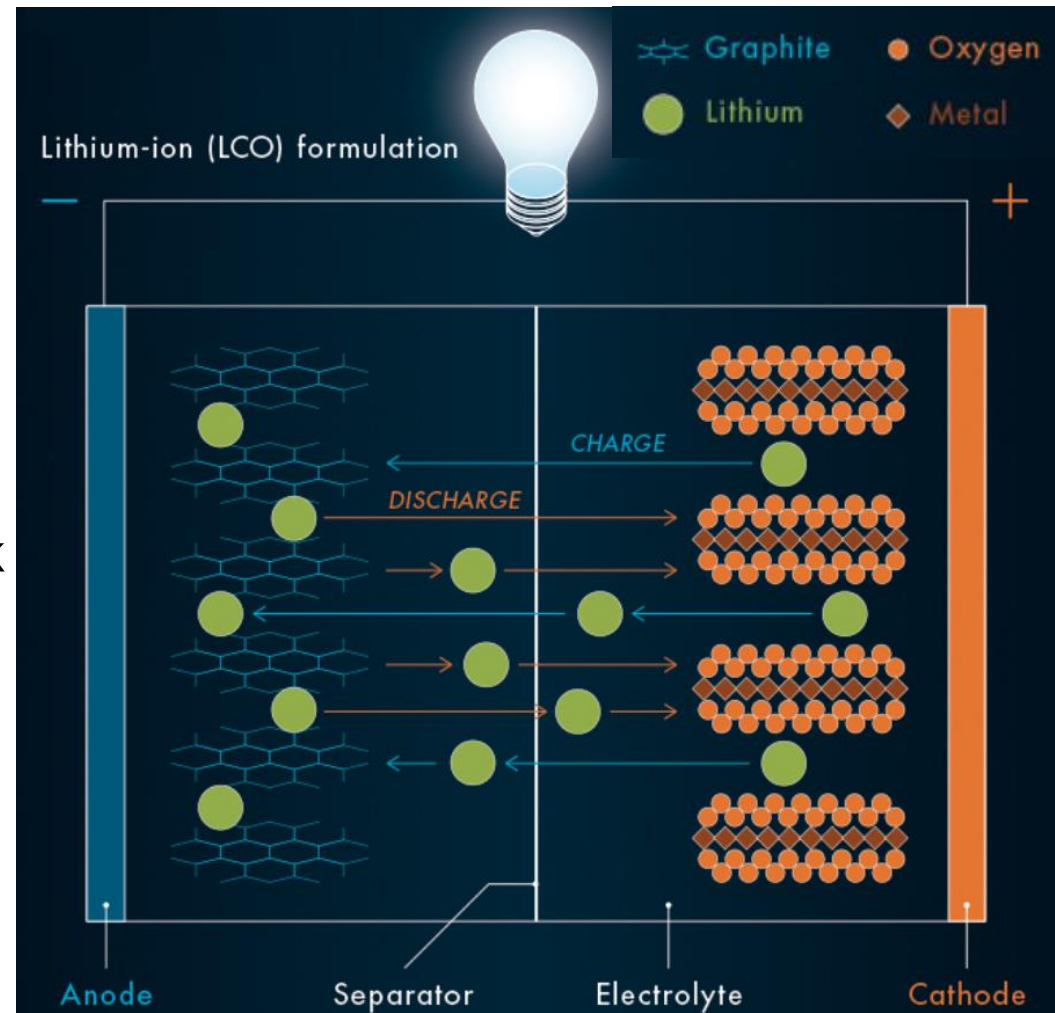
Current battery technologies

- Lead-acid
- NiMH
- Lithium-ion battery cathodes
 - LiCoO_2 (LCO)
 - $\text{LiNi}_{0.8}\text{Co}_{0.15}\text{Al}_{0.05}\text{O}_2$ (NCA)
 - $\text{LiNi}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3}\text{O}_2$ (NMC)
 - LiMnO_2 (LMO)
 - LiFePO_4 (LFP)
- Lithium-ion battery anodes
 - Carbon
 - Carbon-silicon alloys
 - $\text{Li}_4\text{Ti}_5\text{O}_{12}$ (LTO)

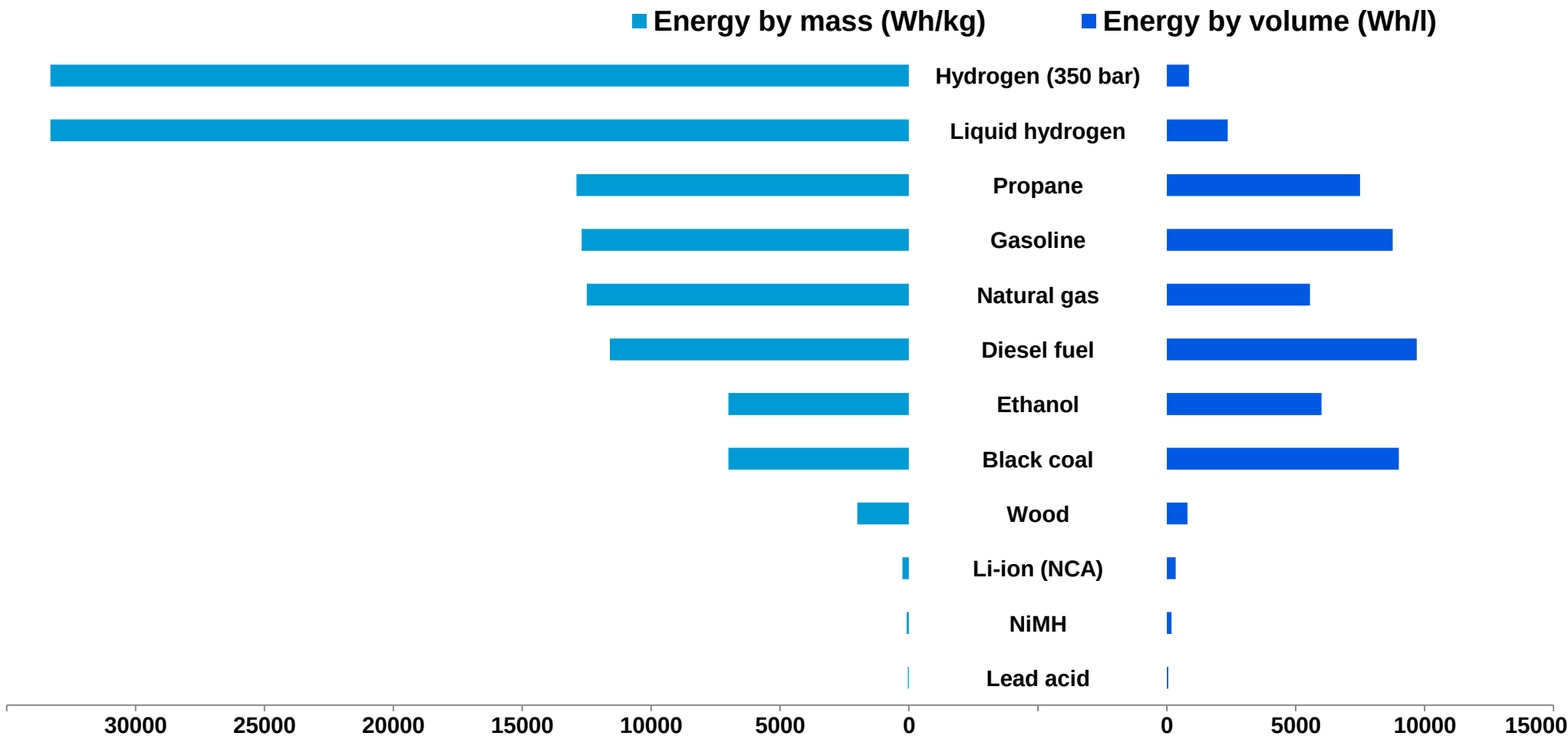


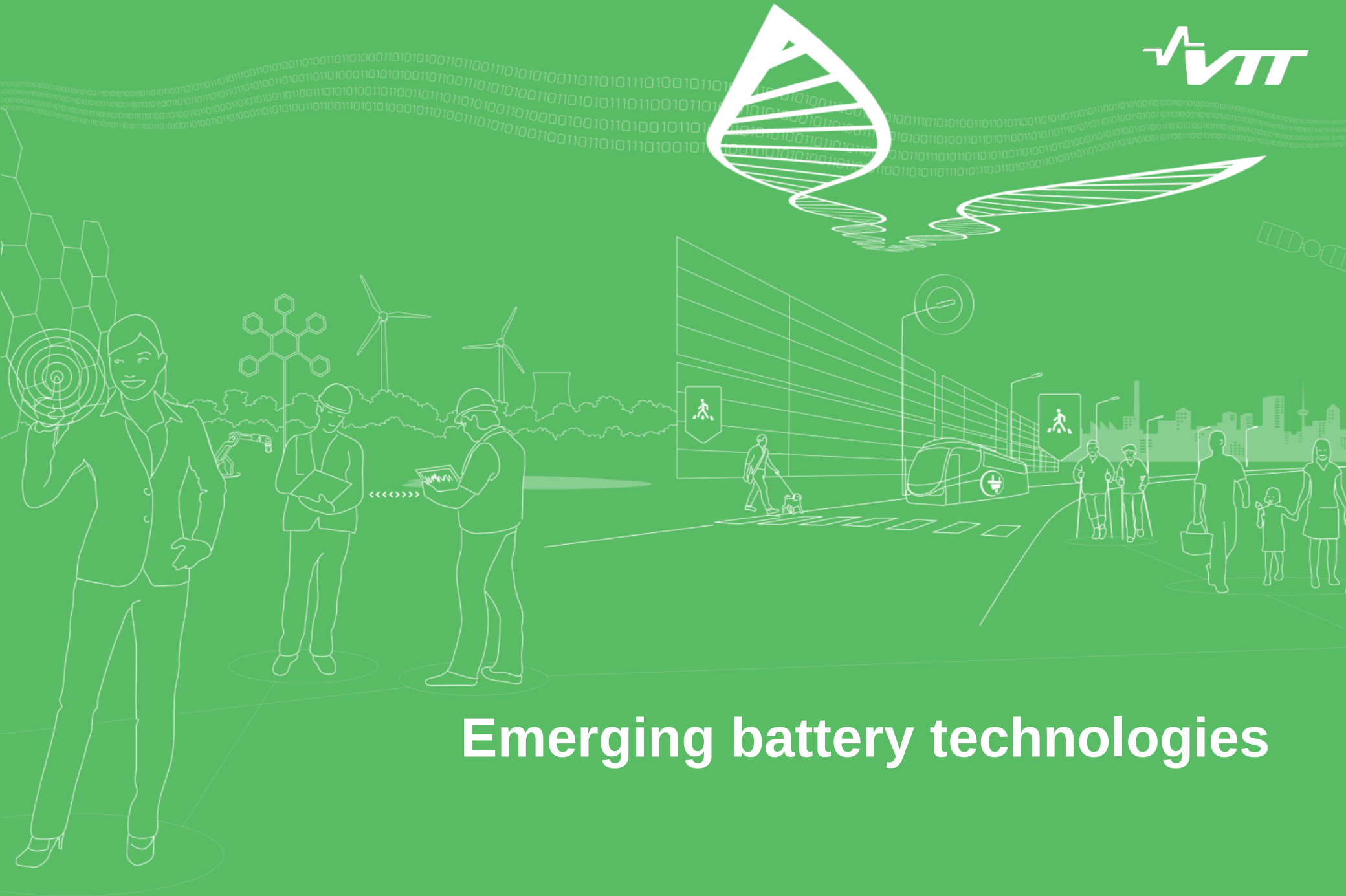
Current battery technologies

- Working principle
 - Intercalation reaction
“Rocking chair”
 - Charge: cathode gives up lithium-ions, which move to anode
 - Discharge: Li-ions move back
 - Current is produced by electrons moving in the outer circuit



Energy density

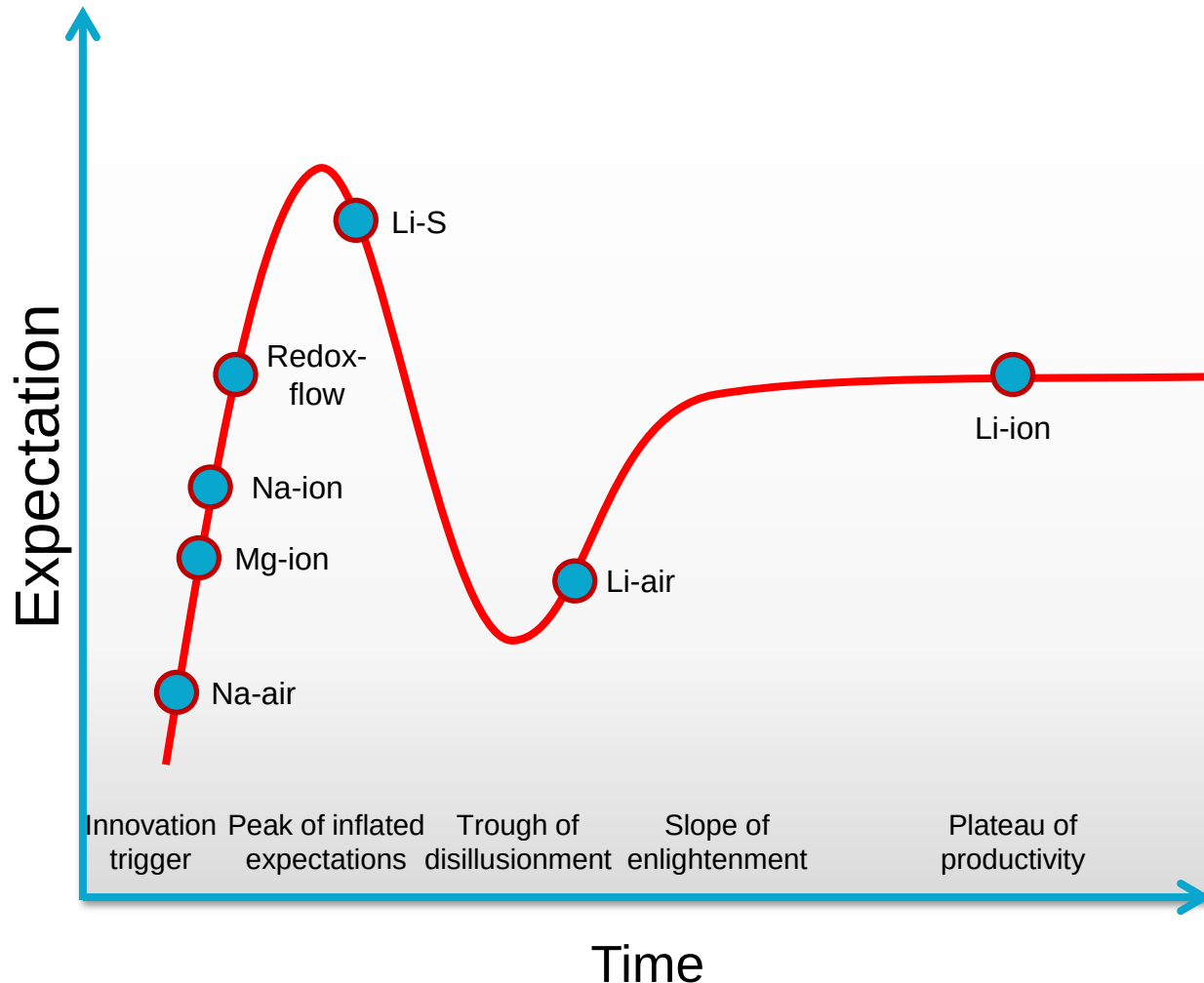


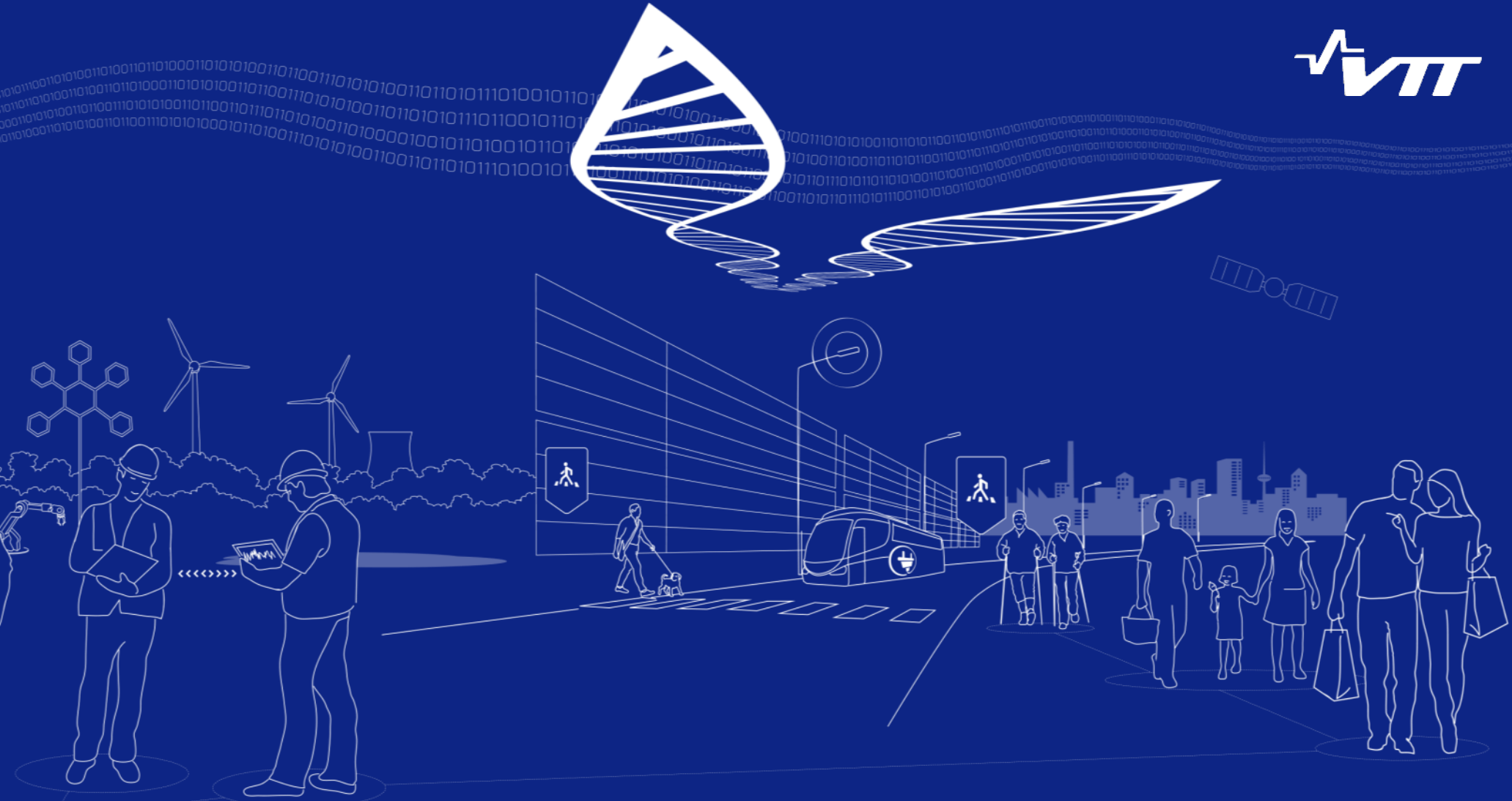


Emerging battery technologies

Emerging battery technologies

- Li-ion R&D going on for more than 35 years
- Li-S and solid state batteries to mature in 10-15 years
- Metal-air batteries not seen to be maturing within 15 years



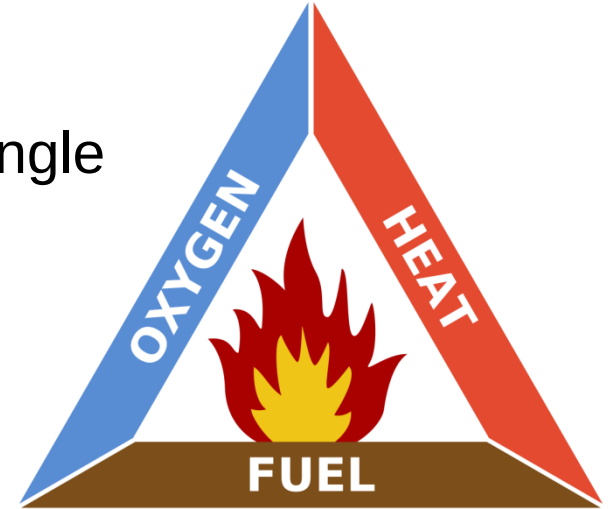


Safety of Li-ion batteries

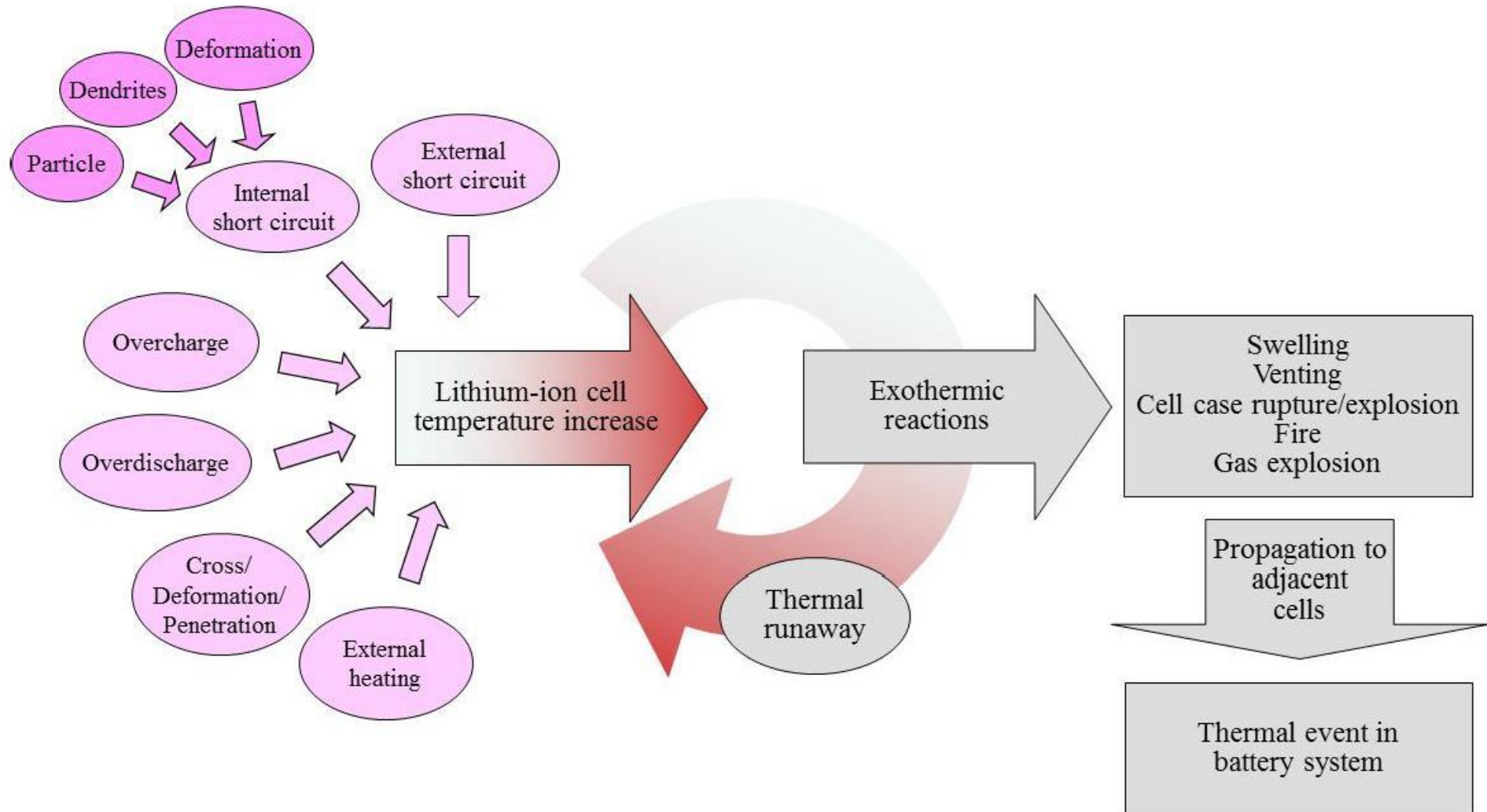
“There are no intrinsically safe Li-ion batteries”

Safety of lithium-ion batteries

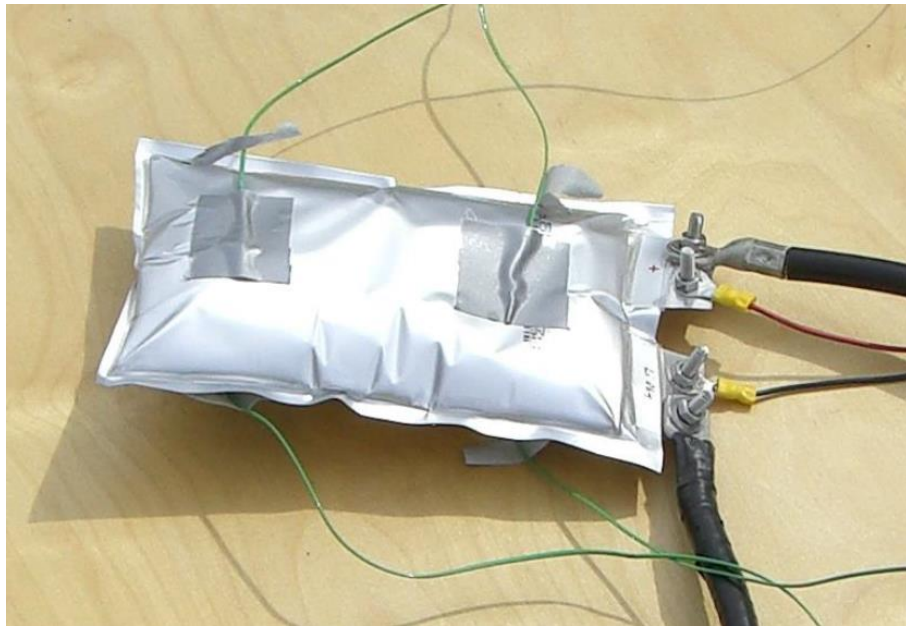
- Li-ion cell contains all three parts of the fire triangle
 - Heat
 - Combustible material
 - Released oxygen
- Internal temperature increase
 - ➡ exothermic reactions
 - ➡ thermal runaway
- Exothermic reactions can start at 30 °C, typically 120 °C
- Point of no return for thermal runaway 150-200 °C



Thermal runaway



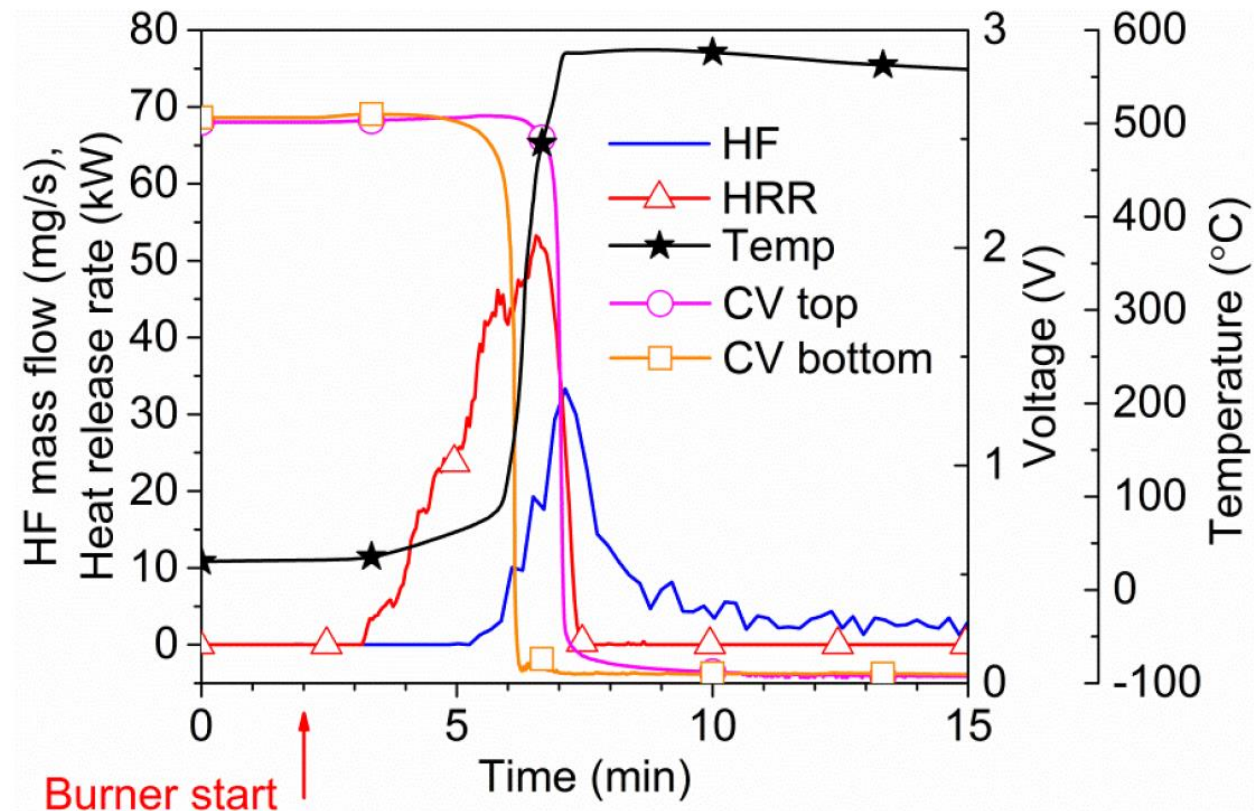
Thermal runaway



Larsson, F. PhD Thesis, 2017

External fire test results

- 16 kW propane burner
- Two 30 Ah LTO cells
- 100 % state-of-charge (SOC)
- Center temperature 600 °C
- 53 kW heat release rate
- 19 % weight loss
- Total HF 46-81 mg/Wh



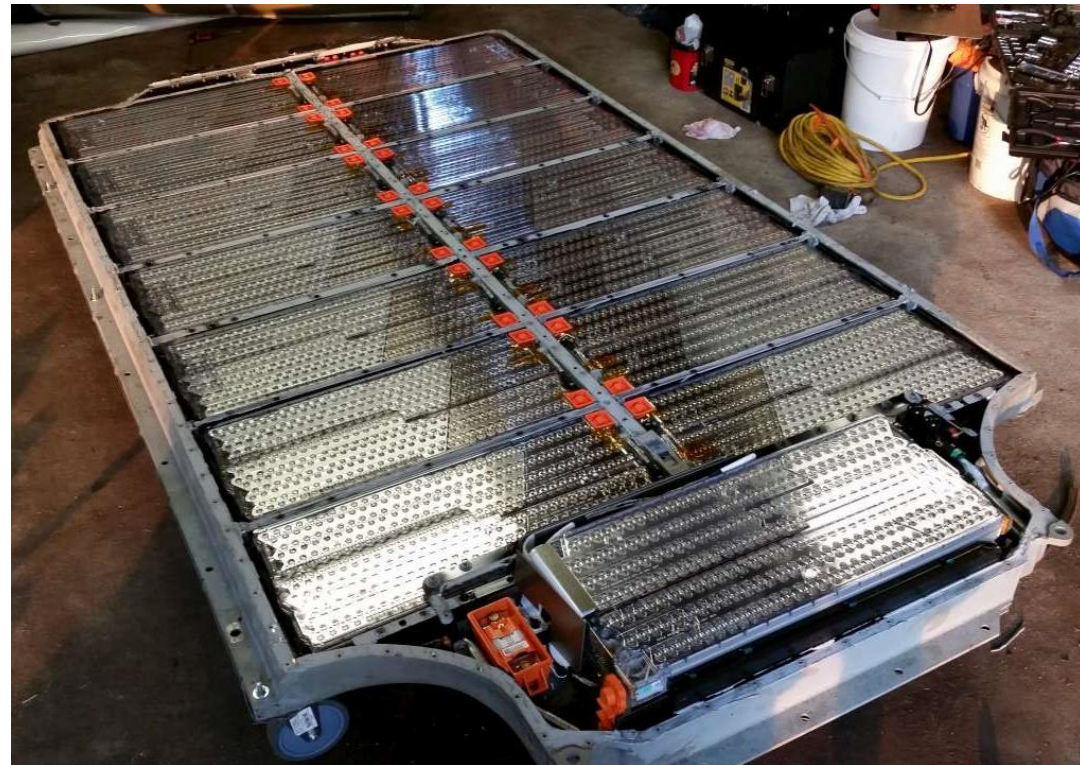
Worst case scenario

- 100 kWh battery pack
- 1200-8000 g of HF released
- Immediately Dangerous to Life or Health (IDLH) value for HF 0.025 g/m³
- 50 000 – 300 000 m³ air dilution
- 15 000 – 100 000 m² garage of 3 m height



Failure rate

- Lack of data
- Generally 1 ppm
- Large system with 1000 cells
 - → 1:1000
- Tesla Model S 60 kWh
 - Over 5000 cells
 - 2013-2016
 - Over 100 000 vehicles manufactured
 - 6 fires
- USA: 1 fire in 1000 vehicles/year



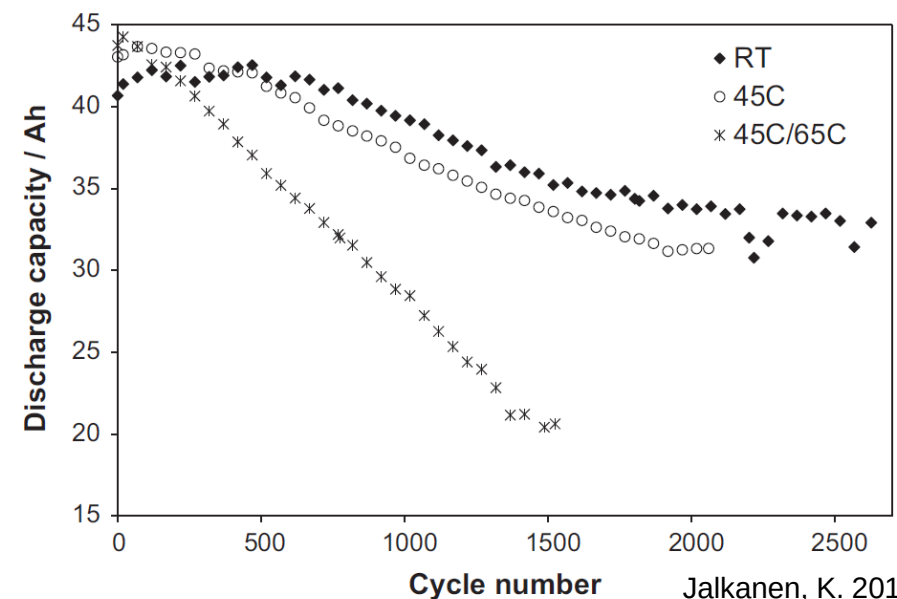
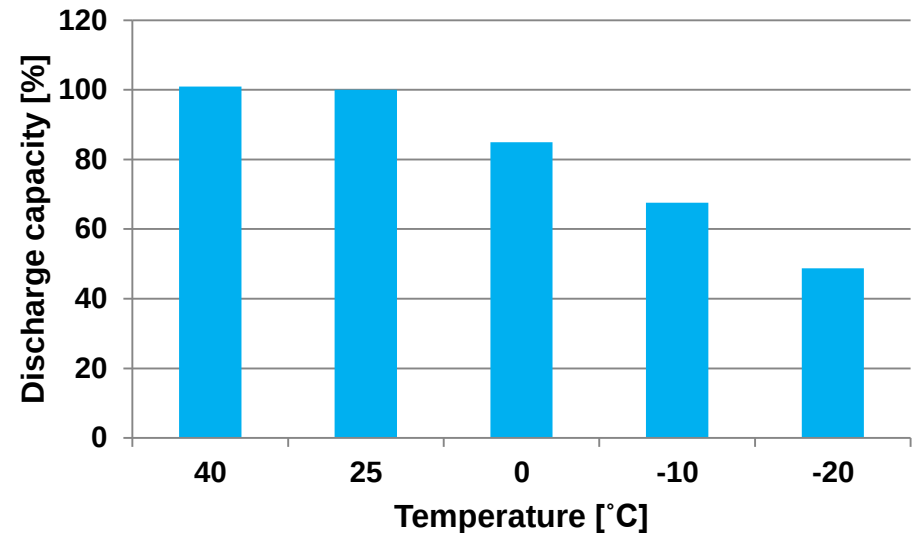
TMC



Thermal management of batteries

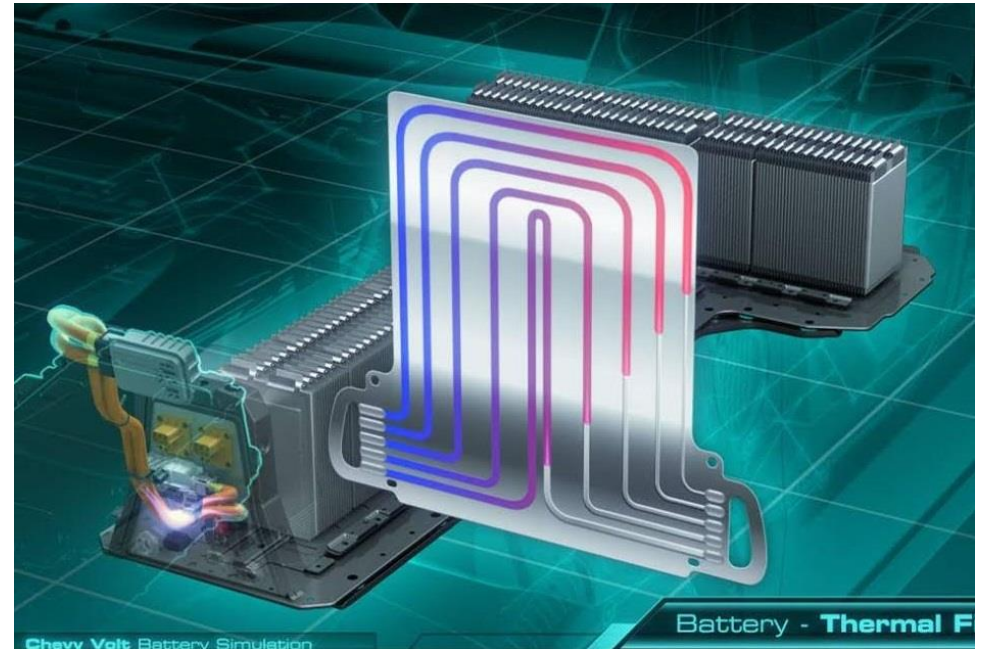
Battery temperature is important

- Temperature affects battery
 - Operation of the electrochemical system
 - Energy efficiency
 - Charge capability
 - Availability of energy and power
 - Safety and reliability
 - Life and lifecycle cost



Thermal management of batteries

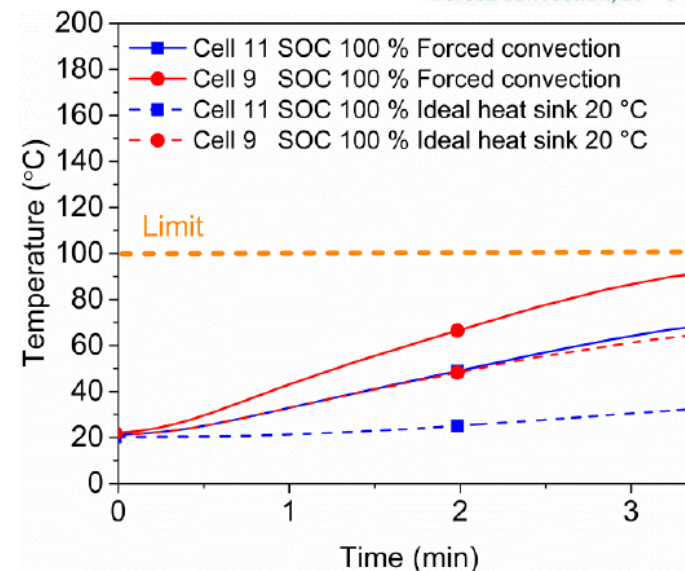
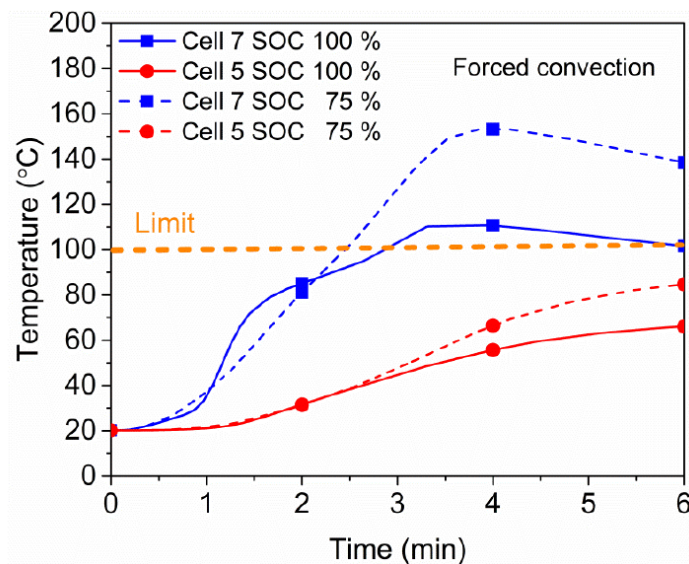
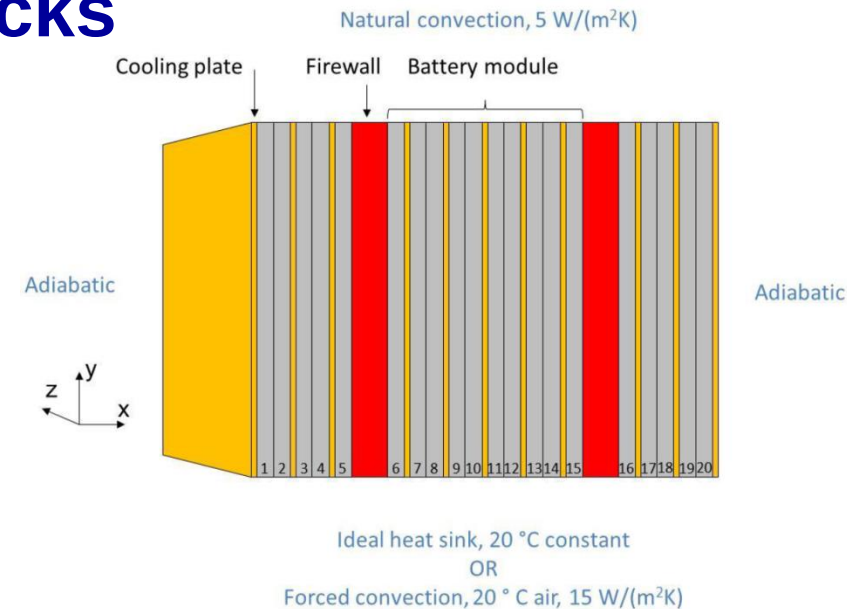
- Battery management system (BMS)
- Thermal management technologies
 - None
 - Air cooling
 - Liquid cooling
 - Phase change material (PCM)
 - Thermo-electric



GM

Fire propagation in battery packs

- There is a significant risk for fire propagation inside a battery pack
- Cell-to-cell propagation can be affected by cooling and use of firewalls



Yhteenveto

- Li-ion akut merkittäviä pitkään
- Uusia teknologioita tulossa 10 vuoden sisällä
- Li-ion akut vaativat turvallisuutta lisääviä toimintoja
- Syttyessä akku tuottaa paljon lämpöä ja ruokkii paloa itse
- Palon myrkkyyllisyys otettava huomioon
- Asiaan voi vaikuttaa suunnittelulla ja lämmönhallinnalla



TECHNOLOGY «» FOR BUSINESS

