Watermist in a low carbon future

Ultra Fog Ltd.

IWMC, Berlin - 24th October 2019

ULTRA FOG®
FIRE EXTINGUISHING SYSTEM

Overview

- Battery technology, application, and market growth
- Fire risks, and suppression techniques
- Existing research and opportunity for watermist

Policies in response to climate change

- United Nations Framework Convention on Climate Change (UNFCCC)
  - Kyoto Protocol
  - Paris Agreement
- Germany’s federal council passed a resolution calling for a ban on new internal combustion engine cars by 2030.
- UK government has announced that sales of new internal combustion engine cars will be phased out by 2040.
- Volvo: “*In 2017 we made a commitment to electrify every car in our range in preparation for an era beyond the internal combustion engine. That era begins now*”.
- Jaguar Land Rover: “*will cease producing cars based around the internal combustion engine from 2020*”.
- Phasing out (closure or conversion) of coal fired power stations.
- Investment in renewables.

→ Increased demand for energy storage.

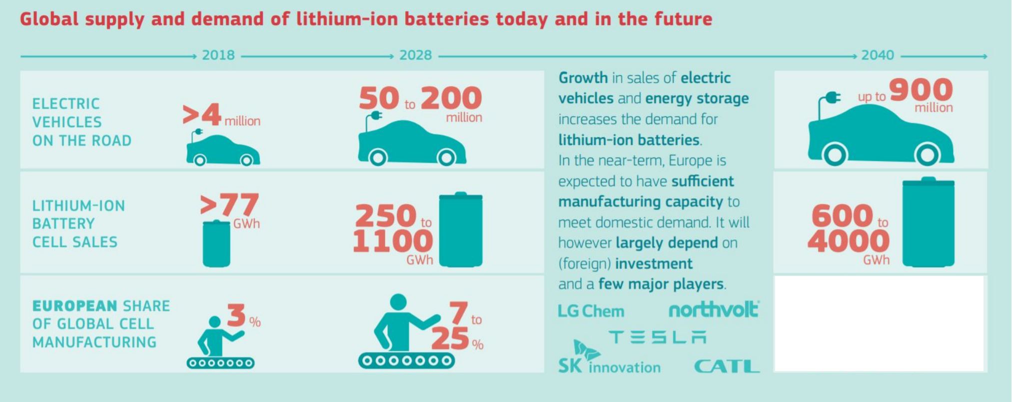
Battery applications

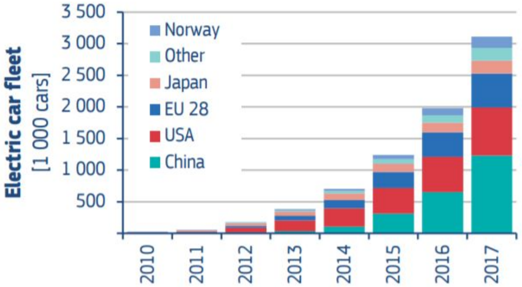
- EV *16-90kWh*
- EV (public transport) *70-400kWh*
- Shipping *6,100kWh (e.g., hybrid cruise ship)*
- Self-powered homes *6-14kWh modules*
- Grid energy storage *>2,000kWh*

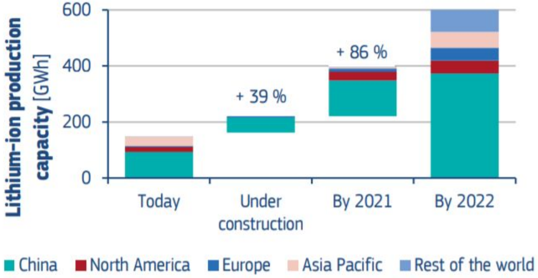
Rechargeable battery types

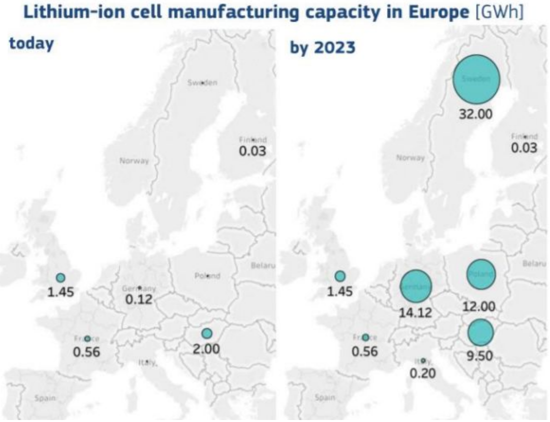
- Lead-acid
- Nickel-iron
- Nickel-cadmium
- Nickel-hydrogen
- Nickel-metal hydride
- Alkaline
- Lithium cobalt oxide
- Lithium iron phosphate ($LiFePO_4$)
- Lithium manganese oxide
- Lithium nickel cobalt aluminium oxide
- Low self-discharge nickel-metal hydride
- Lithium titanate
- **Lithium nickel manganese cobalt oxide (NMC)**
- Nickel-zinc

Market forecast (Li-ion batteries)









Source: European Commission fact sheet "Lithium-ion batteries for mobility and stationary storage applications SCENARIOS FOR COSTS AND MARKET GROWTH" 2018

Increased fire risk?

- Sensationalization within the press/media?
- Sources of risk: damage during use/misuse; manufacturing defects; aftermarket resales/servicing; counterfeiting.

Image source: PhoneArena.com, theregister.co.uk, Weibo

Causes of Lithium-ion / lithium polymer battery fires

- Thermal management failure
- External short circuit
- Internal short circuit
- Over-charging
- Excessive current (when rapid charging)

→ Leading to thermal runaway

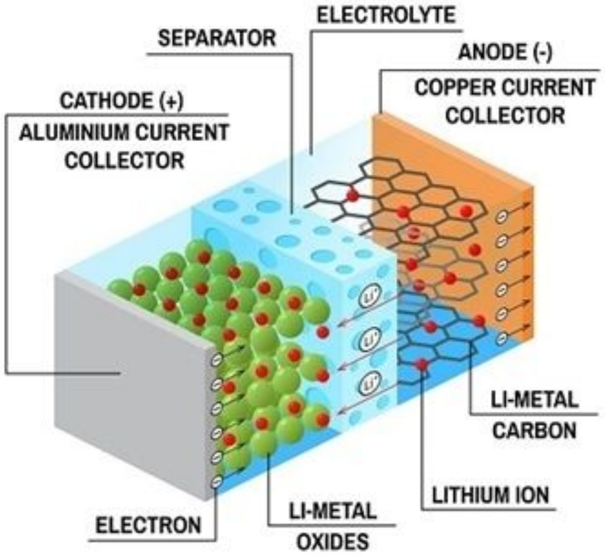


Image source: shutterstock.com/sivVector

Thermal runaway

- Thermal runaway = unstoppable chain reaction
- Norm operating temp <45°C. TR begins at 60°C. Critical at 100°C.
- Construction of lithium-ion batteries (especially lithium polymer batteries) susceptible to TR
- Thermal runaway occurs when a Li-ion cell gets so hot that it starts to generate its own heat.
- The separator – the polymer film that separates the anode and cathode – melts around 80°C.
- Can lead to internal short, allowing current to run unabated within the battery.
- This uncontrolled current leads to further heating.
- As the cell gets hotter the electrolyte starts to evaporate at 100°C, leading to a high pressure inside the cell, further increasing the temperature.
- At a critical temperature, the cathode begins to shed oxygen, making the cell combustible due to rapid reaction between the oxygen and electrolyte.
- For an LCO cathode, oxygen breaks away from the cobalt at 150°C.

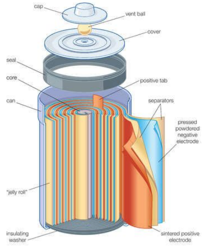
Fire suppression techniques

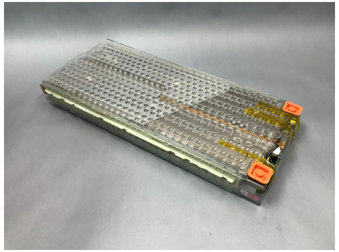
Lithium-ion batteries contain a highly flammable electrolyte, consisting of lithium salt in an organic solvent (lithium hexafluorophosphate).

- Class D fire extinguishers? (*Lithium-metal fires*)
- Foam, CO_2, ABC dry chemical extinguishers, powdered graphite, copper powder or soda (sodium carbonate)? (*Li-ion fires*)
- Aqueous Vermiculite Dispersion?
- **Water**

Effective control and suppression is dependent upon the construction and accessibility of the battery.

Battery cells, modules, and packs.





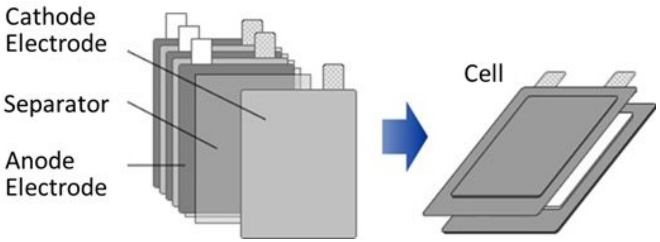


Image source: AESC.com

EV manufacturers’ recommended fire suppression approach

- *NFPA actively maintains a collection of Emergency Response Guides from 35+ alternative fuel vehicle manufacturers (https://www.nfpa.org/Training-and-Events/By-topic/Alternative-Fuel-Vehicle-Safety-Training/Emergency-Response-Guides)*
- *“...use large amounts of water to cool the battery. It can take approximately 3,000 gallons of water, applied directly to the battery, to fully extinguish and cool”. “Battery fires can take up to 24 hours to extinguish. Consider allowing the battery to burn while protecting exposures”. “Use fog streams to direct smoke and vapours”.* [Tesla]
- *“Extinguish fires using large and sustained amount of water to cool the high voltage battery. Do not extinguish fire with a small amount of water. Firefighters should not hesitate to pour large amounts of water on the vehicle”.* [Hyundai]
- *“The best intervention is to apply and continue to apply water to cool and quench the burning material. ABC extinguisher is not recommended”.* [FIAT]
- *“...use LARGE amounts of water if fire is present or suspected and, keeping in mind that fire can occur for a considerable period after the crash”.* [Ford]
- *“...extinguishing a lithium-ion battery fire will take a large and sustained volume of water”.* [Honda]

Examples of EV fire suppression techniques

- California, December 2018
- Towed to a garage. “Hissing” noise, followed by combustion.
- Fire department attended to extinguish fire.
- Towed to a depot. **Reignited** “hours later”.

Photo credit:
Brandweer Midden- en West-Brabant
Central and West Brabant, Fire Brigade, NL - March 2019

- Austria, October 2019.
- 2,000 litre water capacity from fire fighting appliance on scene
- 11,000 litres required to fully extinguish
- Up to 3 days monitoring / “quarantine”

Image source: tirol.orf.at/stories/3015765/ & https://www.ff-schwaz.at

Existing research - NFPA / SwRI EV (2014)

Key findings

- Water alone was able to suppress the battery fires each time.
- When battery size increased and/or when the battery was less accessible, there was a significant increase in the total volume of water necessary to extinguish the fire.
- Extinguishment varied from 6 to 49 minutes (excl. reignition which in one case occurred 22hr later).
- First responders should be prepared to conduct suppression efforts for at least an hour.
- Total water volumes were significantly greater in some tests than traditional ICE.
- Where a suitable water source is not available, and there are no threats to life safety or nearby structures etc., allowing the battery pack to burn to self-extinguishment may be a viable alternative (may require extended period of monitoring).

Existing research - DNV-GL (2017)

Considerations for Energy Storage System (ESS) Fire Safety

- Water demonstrated the highest cooling efficacy of all extinguishing agents tested.
- The use of water should only be considered if there is an acceptable risk of shorting additional cells or collateral damage to the remainder of the system.
- Water volumes for cooling can be minimized based on the expected duration of a failure event. Systems with adequate internal cascading protections will minimize the water volumes required for extinguishing.
- Staged extinguishing with fixed aerosol or gas suppression agents first, followed by water in the event of a cooling need, is recommended. It may be possible to use parallel water inputs on fixed suppression systems for containerized battery systems.

Reference: https://www.dnvgl.com/publications/considerations-for-energy-storage-systems-fire-safety-89415

Existing research - RI.SE (2018)

Lion Fire: Extinguishment and mitigation of fires in Li-ion batteries at sea

“The tests indicated that fire extinguishment of a battery cell fire inside a battery module is unlikely when using total compartment water spray or water mist fire protection systems. The water droplets are simply not able to penetrate the battery module and reach to the seat of the fire. Direct injection of the fire extinguishing agent inside the battery module is necessary.”

Limitations of test:

- “Total compartment” vs “direct injection” tests
-

Reference: RISE Research Institutes of Sweden AB, RISE Report 2018:77, ISBN: 978-91-88907-27-1

Challenges

- Requires large volumes of water
- Requires supervision (time consuming)
- Risk of re-ignition
- Restricted access to the seat of the fire
- Containment and control

An opportunity for water mist?

- Further research
  - Flow rates of sprinkler, deluge, and water mist systems. *Clear advantage of water mist? Less water? Higher rate of cooling?*
  - Direct injection.
  - Damage limitation to the cell/module/pack.

Summary

- Substantial (and increasing) demand for Lithium-ion battery production and use
- Presents new challenges for fire suppression
- Current experience and existing research supports the sustained use of large volumes of water to cool and prevent re-ignition
- Presents opportunities for water mist to
  - Cool more efficiently than conventional means
  - Reduce water consumption
  - Reduce the transmission of radiant heat to surroundings
- Limitations
  - Extinguishment of fire within a cell/module.
  - Potential loss of asset (battery)

Thank you.

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