Thermal management for batteries in E-mobility applications

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on behalf of Batenburg Mechatronica

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PRIATHERM

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1931 Congrescentrum Den Bosch

POWER ELECTRONICS 2018

Company overview – relator presentation

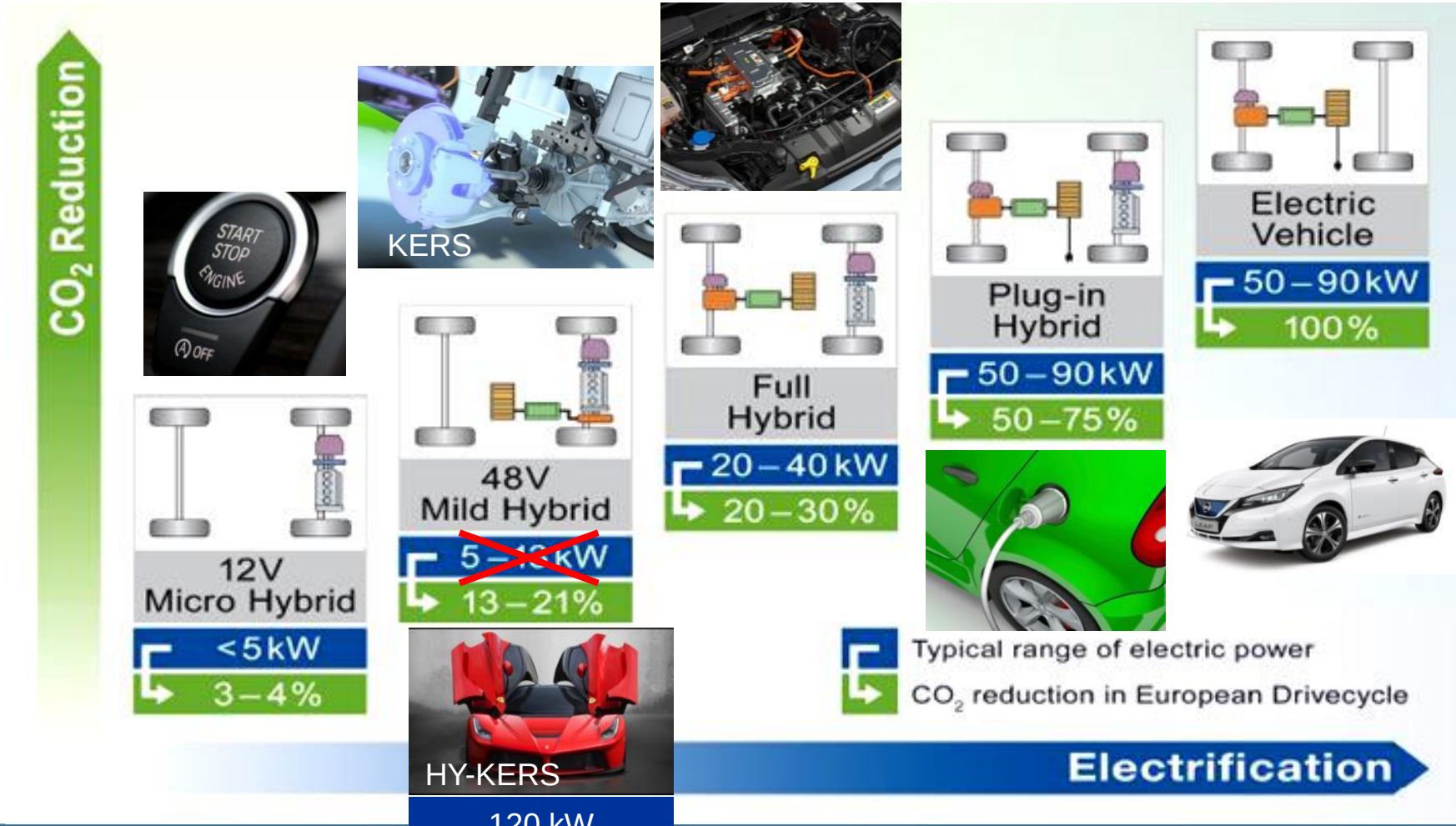
- **Batenburg Mechatronica**
  - Focus on smart components:
    - Precision resistors and capacitors
    - Sensors and connectors
    - Thermal management (cooling & heating – foils, etc.)
  - www.batenburg-mechatronica.nl (Rotterdam & Zaventem)

- **Priatherm**
  - Thermal management solutions:
    - Product manufacturing (air and liquid cooling)
    - Engineering services – simulations - testing
    - Technology development - innovation
  - www.priatherm.com (Ferrara - IT)
  - I'm ALESSANDRO BIZZARRI, General Manager, Thermal Engineer

Hybrid and Electrical Vehicles

- Micro Hybrid (start / stop)
  First introduction in a commercial car by Mahindra & Mahindra (India, May 2000)
- Mild Hybrid (support to thermal engine → K.E.R.S.)
  Suzuki Baleno, Audi A7 and A8 Sportback, La Ferrari (HY KERS)
- Full Hybrid (medium hybrid capabilities + electric launch)
  Toyota Prius, Ford Escape
- Plug-in Hybrid (full hybrid capabilities + electric range)
  BMW i3 , Mercedes-Benz C350e, VW Golf GTE
- Full Electric Vehicles (No thermal engine)
  Nissan Leaf, Renault ZOE, Tesla Model S

Hybrid and Electrical Vehicles



Source: Continental Automotive

Energy storage – Cells shape

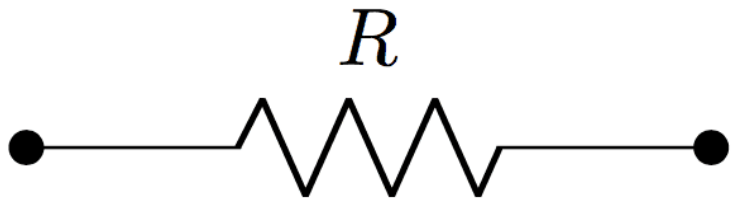
Overview of cell types for HEVs

	Large - Prismatic	Large - Pouch	Small - Cylindical
Pros	Best scalability; High cycle life	Form factor	Cheap & commoditized
Cons	Currently expensive	Expensive and hard to scale	Need sophisticated BMS
Main cell maker	Samsung SDI, Panasonic, BYD, EnerDel, ATL, PEVE, LEJ	AESE, LG Chem, SK Innovation	Panasonic
Market share (volume)	26%	49%	25%
Market share (sales)	33%	54%	13%
Main auto OEM	Toyota, Mitsubishi, Honda, BMW, VW, Audi, Chrysler, BYD, Ford	Nissan, GM, Ford; Renault, Daimler, Hyundai, Volvo	Tesla

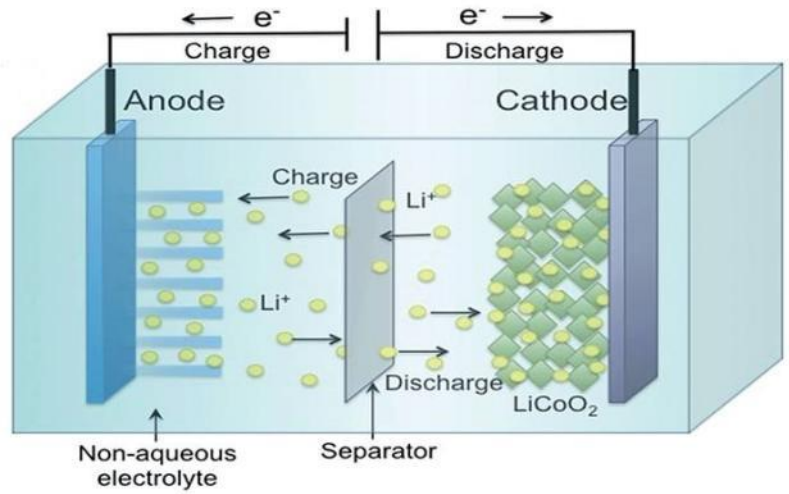
Battery Thermal Management

Heat in a battery cell is produced by:

1. The resistance of the various cell components (electrode, cathode, anode, etc.); Joule heating, which can be minimized by cycling the cells at low currents



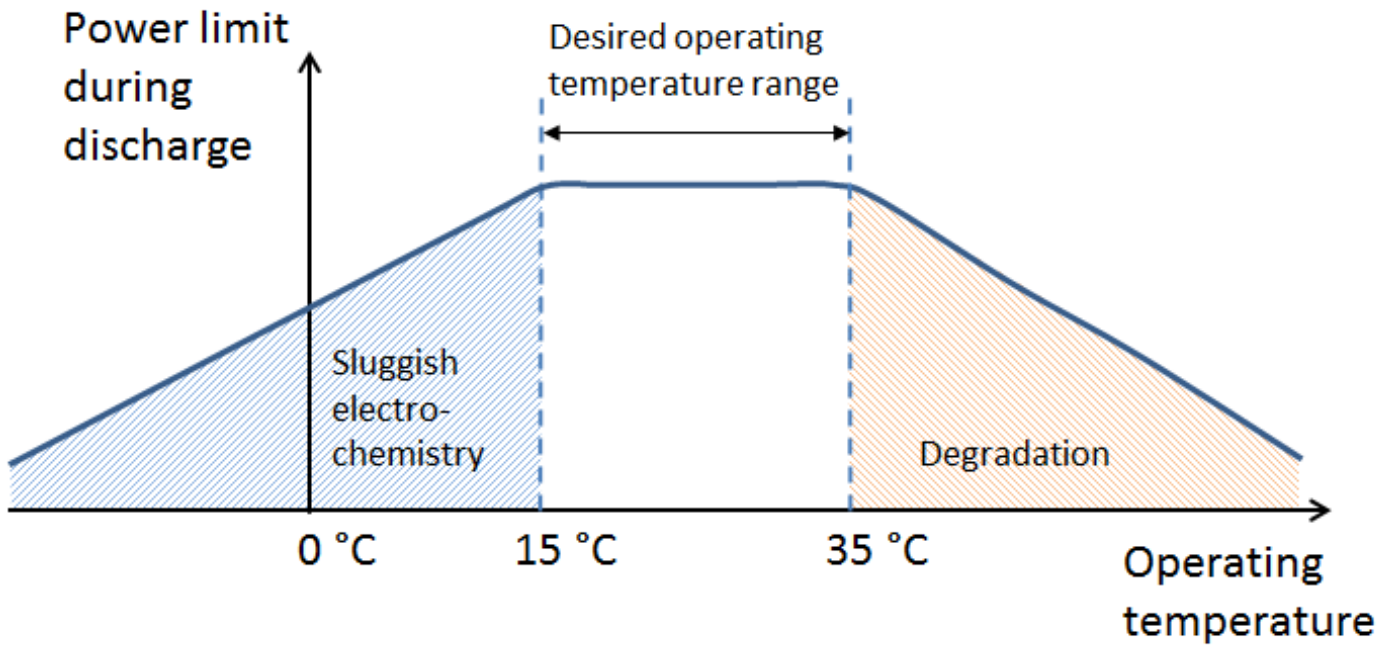
2. Entropic reactions within the cell (exothermic reactions within the cell due to the transfer of ions and electrons)



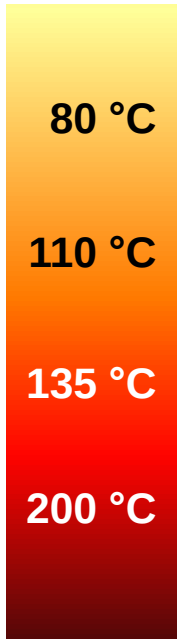
Battery Thermal Management

Temperature is one of the most critical factors in designing and operating batteries for HEVs

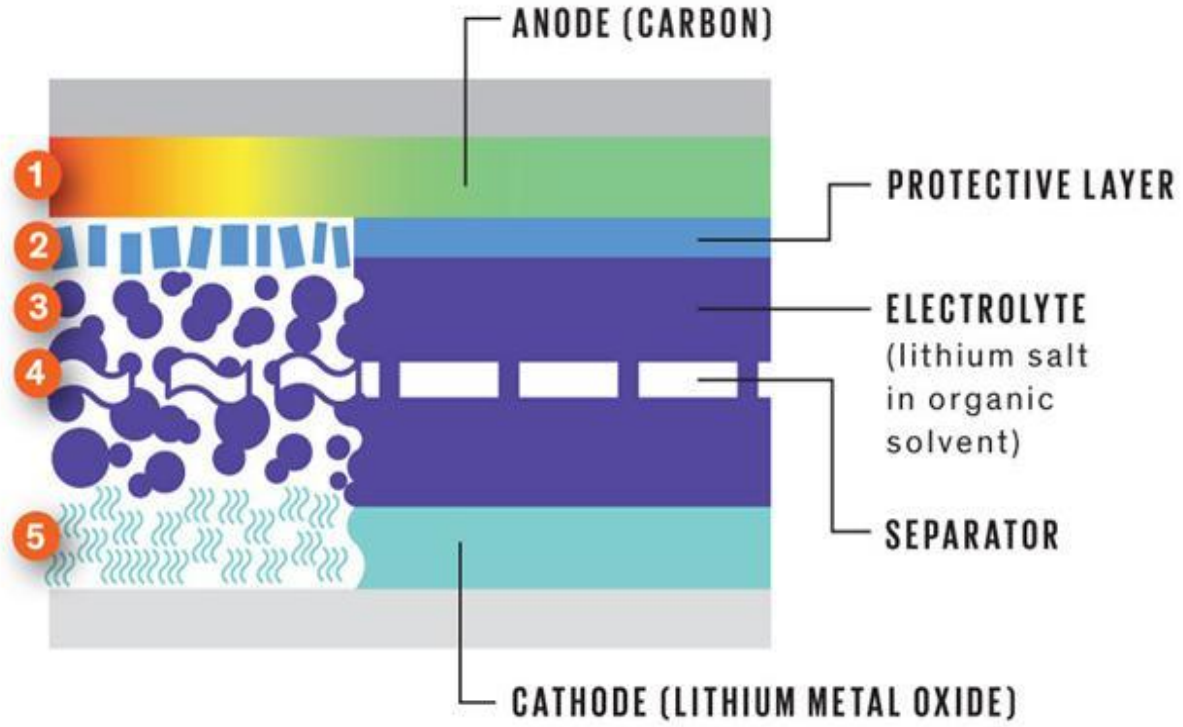
Li-ions battery power vs. operating temperature



Thermal Runaway
in a Lithium-Ion Battery



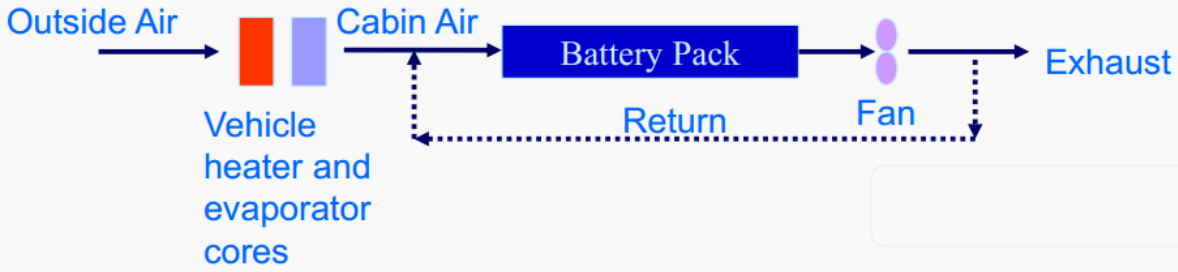
1. Heating starts.
2. Protective layer breaks down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down, generating oxygen.



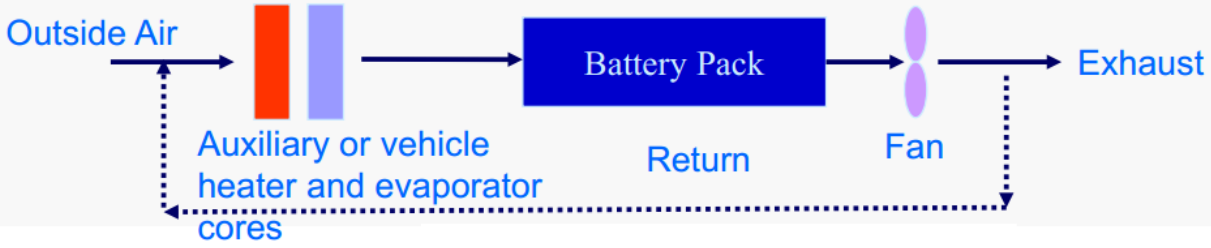
Thermal Management - Air cooling

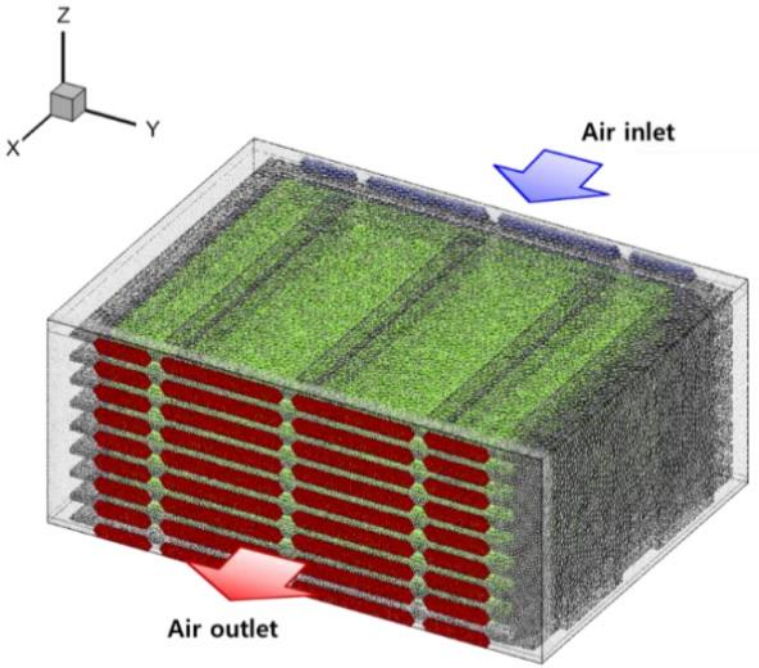
Outside Air Ventilation

Cabin Air Ventilation



Heating/cooling of Air to Battery – Outside or Cabin Air





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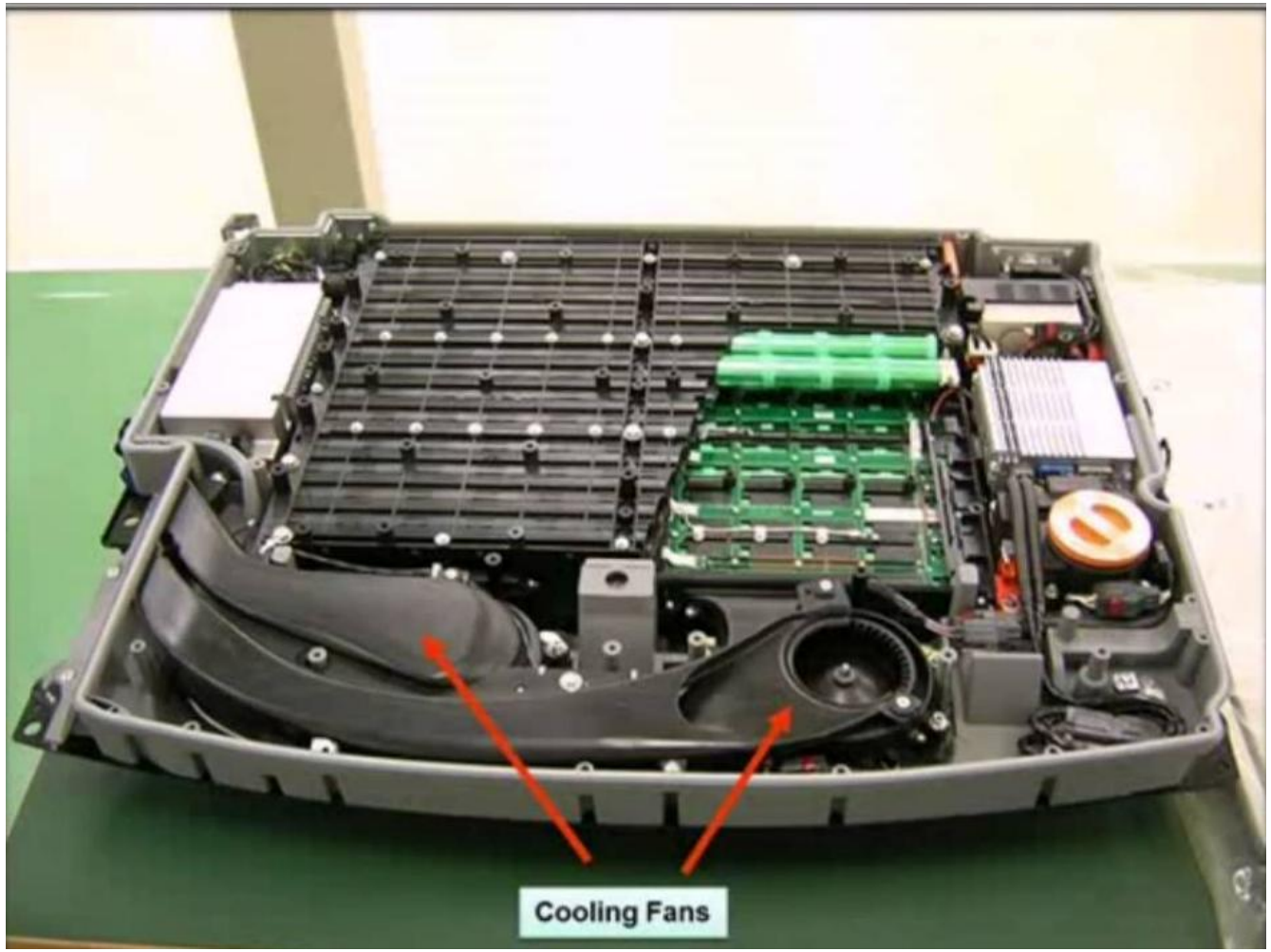
Active Air cooling – Ford Escape Hybrid 2012

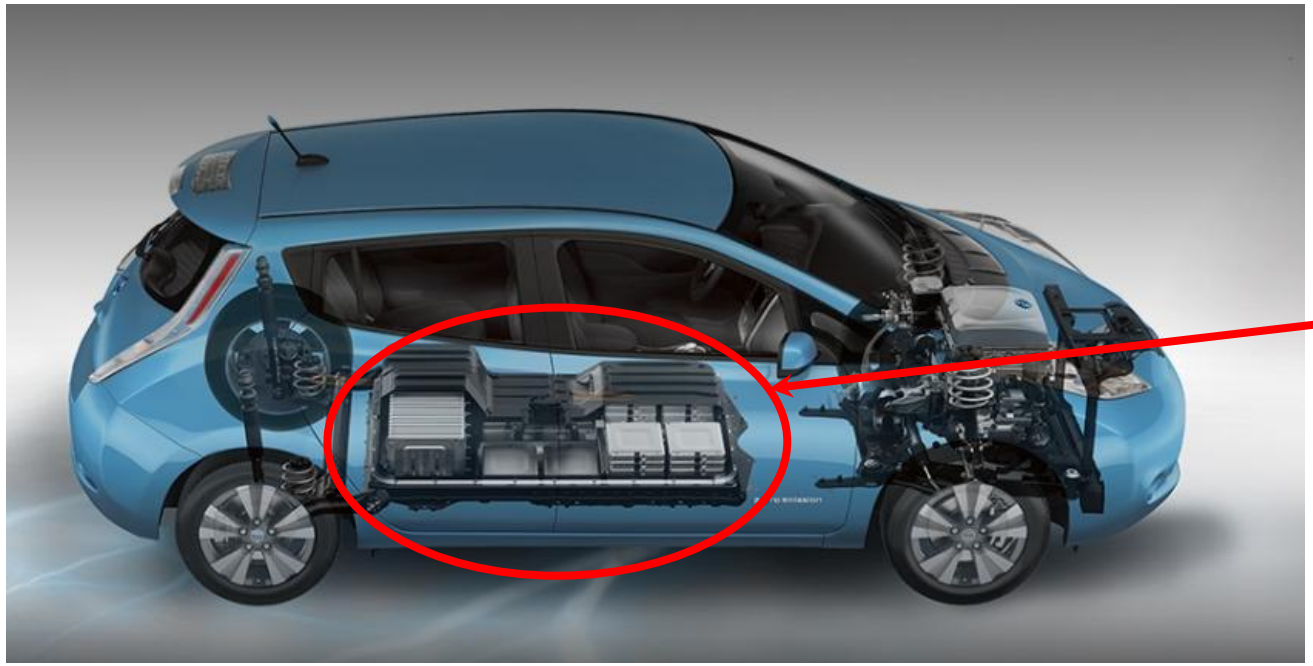
FORD Escape (Plug-in Hybrid)
• 10 kWh Nickel-Metal-Hydride (NiMH) battery pack

• Air cooled

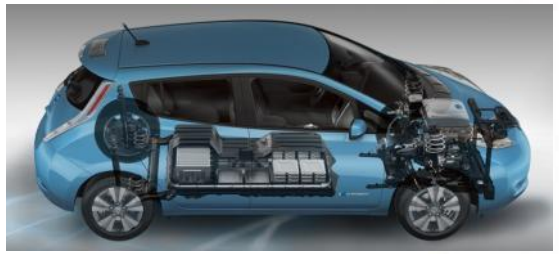


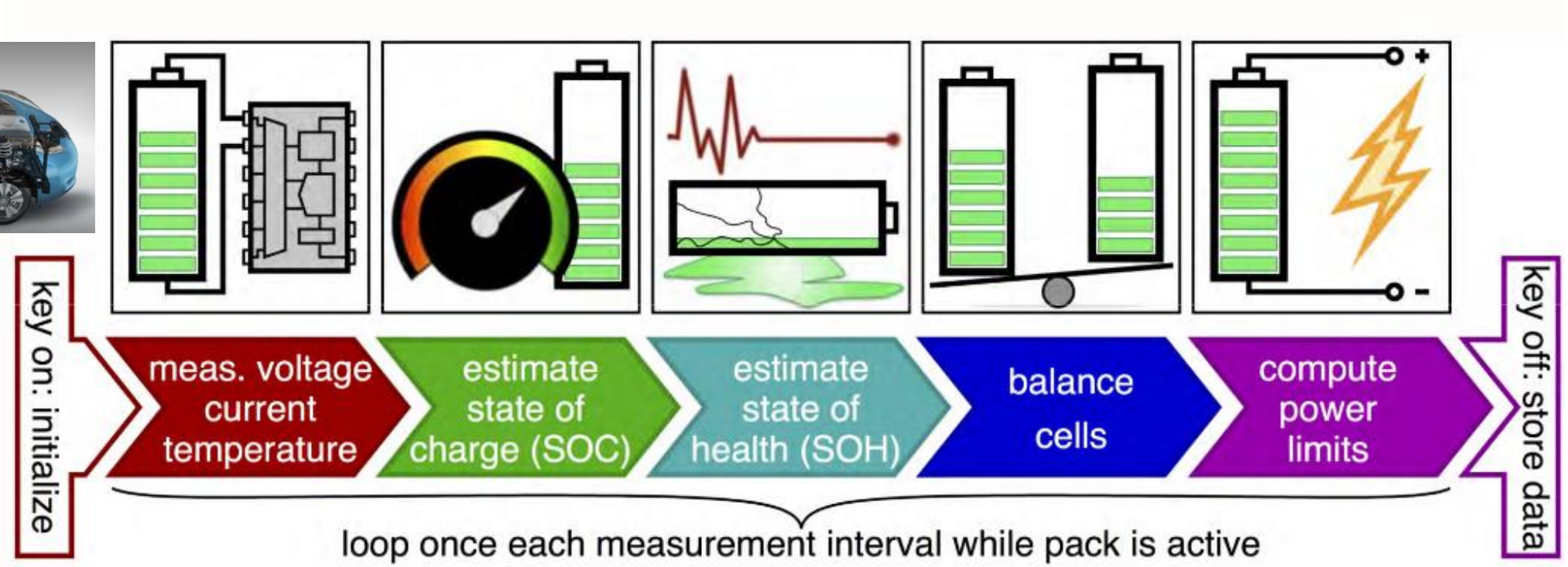
Passive Air cooling – Nissan Leaf

NISSAN Leaf (Full electric)
- 40 kWh Lithium-ion battery pack.
- 192 Lithium ion cells (48 modules)
- 303 kg total weight



Passive Air cooling – Nissan Leaf BMS (Battery Management System)





Air cooling

Pro	Con
All waste heat eventually has to go to air	Low heat transport capacity
Separate cooling loop not required	More temperature variation in pack
Low mass of air and distribution system	Connected to cabin temperature control
No leakage concern	Potential of venting battery gas into cabin
No electrical short due to fluid concern	High blower power
Simple design	Blower noise
Lower cost	
Easier maintenance	

Air cooling, at least without an advanced BMS like Nissan Leaf, is not suitable for most recent high performance applications due to the power density required and the inability to cope with a wide range of ambient temperatures.

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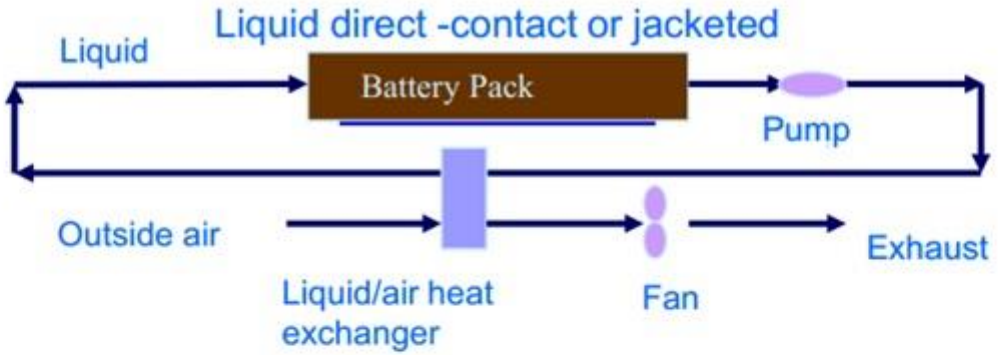
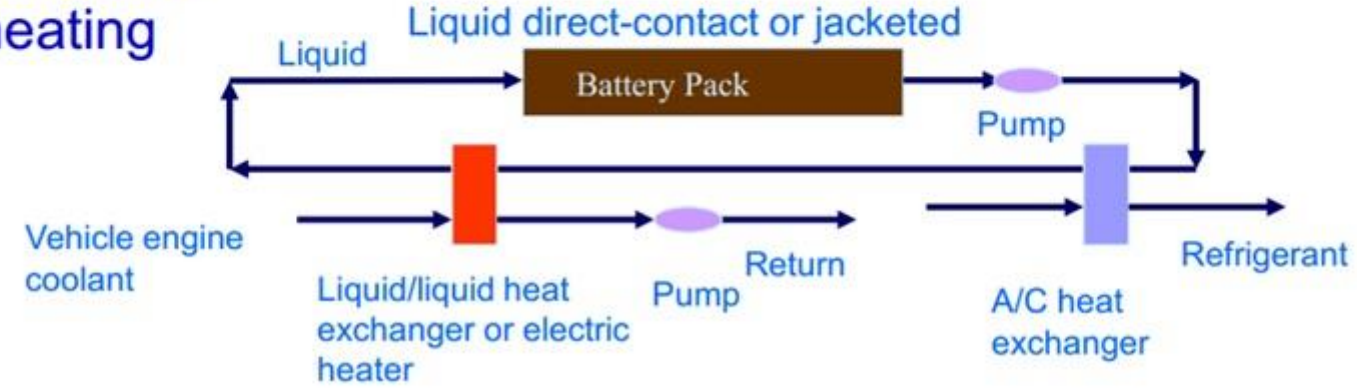
Thermal Management – Liquid cooling

Ambient cooling



Active dedicated cooling/heating



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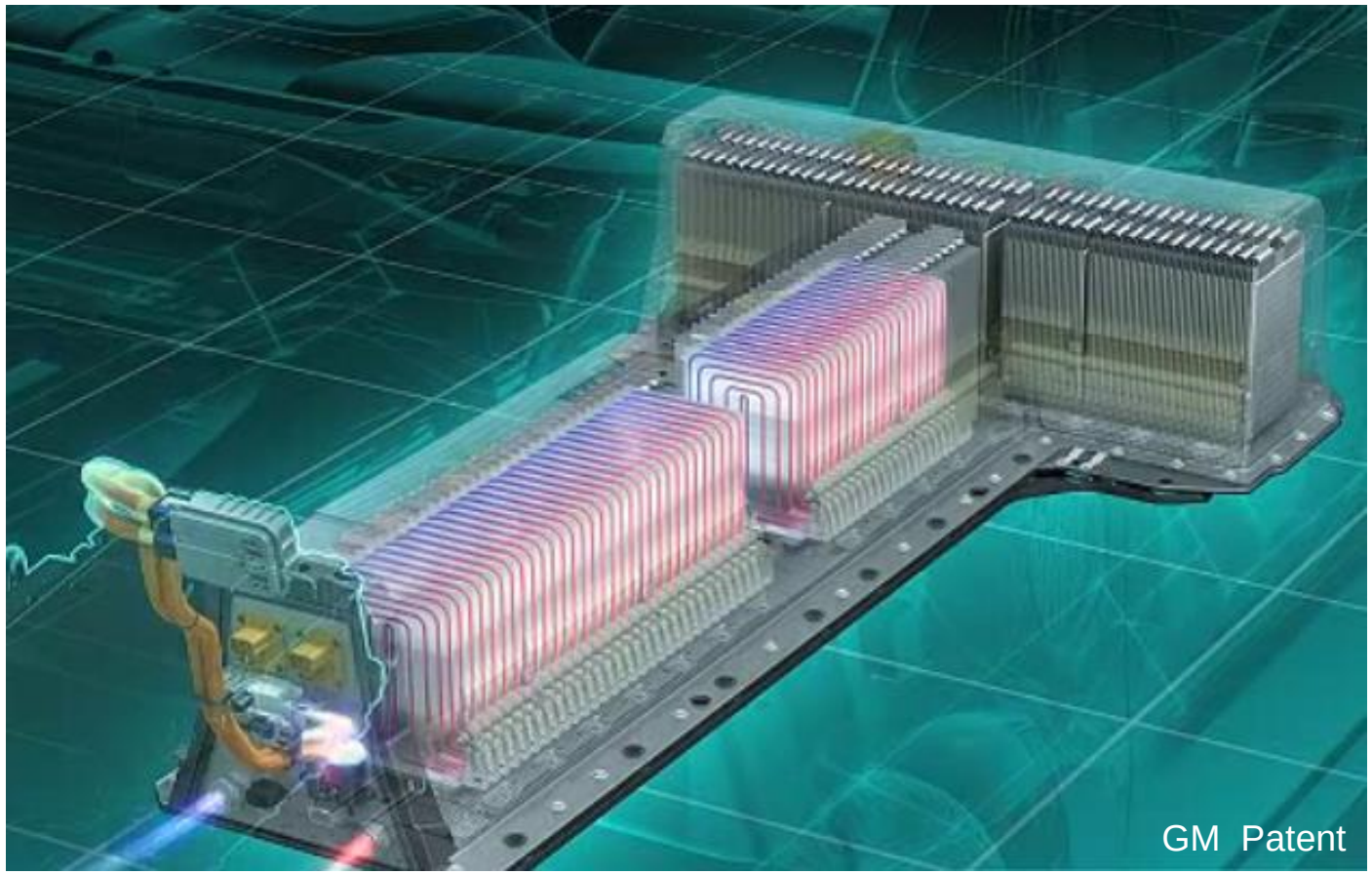
Liquid cooling – GM Thermal Fin ®

Chevrolet Bolt EV

- 60 kWh Lithium-ion battery pack.
- 288 Lithium-ion “POUCH” cells
- 435 kg total weight

- Coolant: Water + Ethylene Glycol Mixture

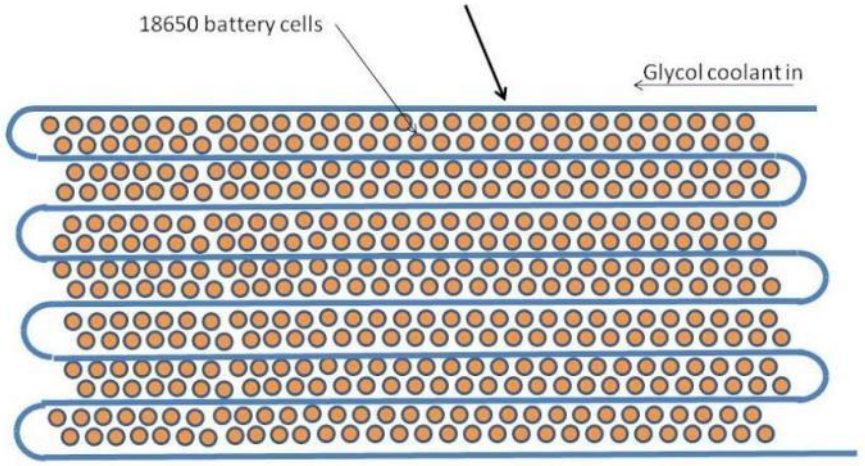


Liquid cooling – Tesla Model-S

TESLA Model S
- 85 kWh Lithium-ion battery pack.
- 7104 CYLINDRICAL Lithium ion cells (16 modules wired in series)
- 504 kg total weight

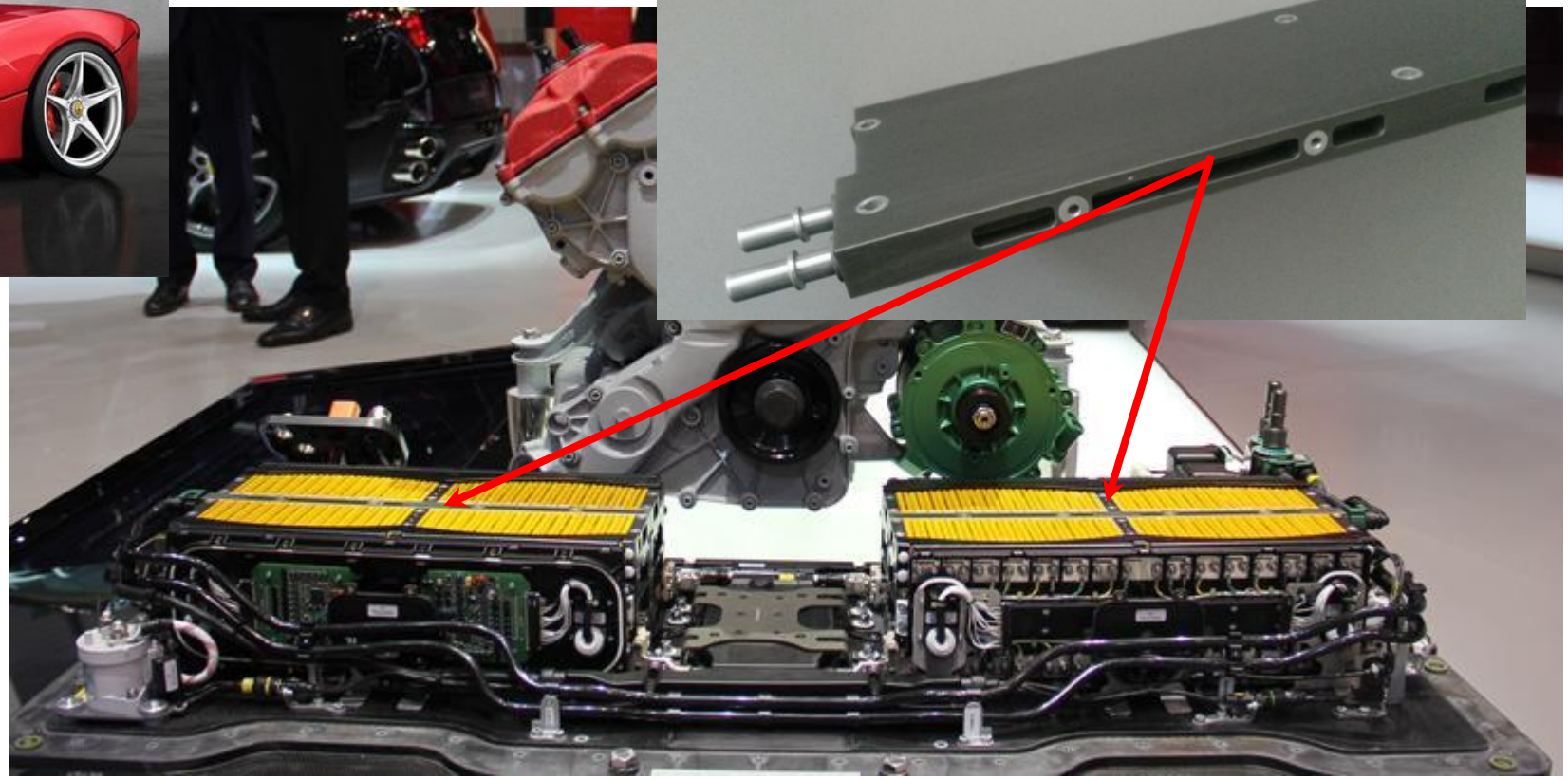
- Coolant: Water + Ethylene Glycol Mixture

Tesla patent cooling tube



1 Model S battery module (16 total)

Liquid cooling – F150 “La Ferrari”



Ferrari F150
- 120 kWh Lithium-ion battery pack
- 120 Lithium ion cells in 8 modules
- 140 kg total weight

- Coolant: Water + Ethylene Glycol Mixture

Liquid cooling

Pro	Con
Pack temperature is more uniform - thermally stable	Additional components
Good heat transport capacity	Weight
Better thermal control	Liquid conductivity – electrical isolation
Lower pumping power	Leakage potential
Lower volume, compact design	Higher maintenance
	Higher viscosity at cold temperatures
	Higher cost

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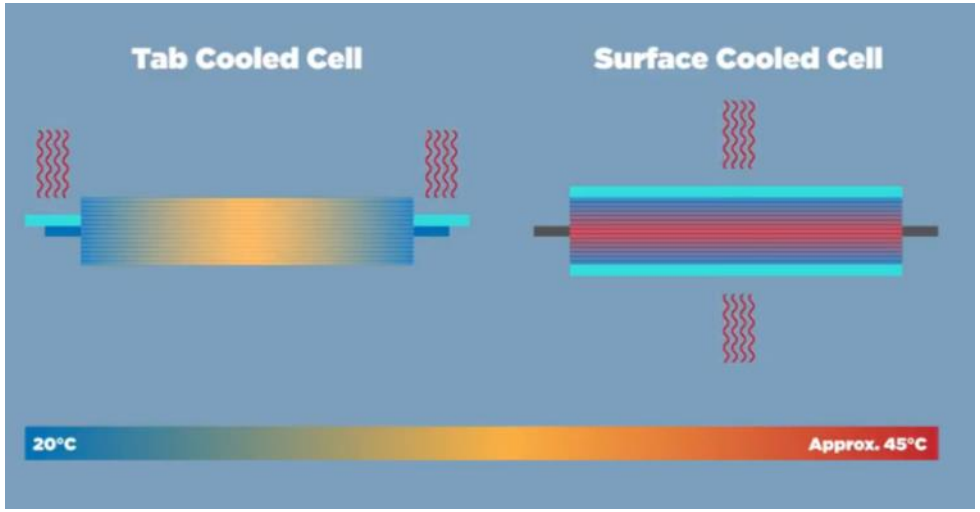
Design guidelines: input data

- Cells shape (+ modules geometrical configuration)
  Prismatic; Pouch; Cylindrical
- Weight constraints and battery location
- Cooling media available on board
  Water (+ antifreeze, anticorrosion…); Oil, Bi-phase fluids…
- Inlet Fluid Temperature
- Thermal Interface Materials
  Graphite, Phase Change Materials…
- Surface vs. Tab cooling



Conclusions

From 2020 onwards the utilization of conventional gasoline engines is expected to be decreased and it will have been disappeared by 2050. Lithium-ion batteries represent the most prevalent storage device in EVs and HEVs and their study is attracting more and more interest.

A well-designed temperature regulation of Lithium-ion batteries is a basic requirement to get optimized efficiency from electrical engines.

Keeping the temperature within the desired range and low temperature gradients can guarantee furthermore a longer battery life time and better energy efficiency.

Thermal management topics have to be investigated by a team of experts involving batteries manufacturers, electrical engineers and thermal management specialists, since from the earlier stages of the design process.

Question?

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Bent u er ook bij? Meldt u zich nu aan en we ontmoeten u graag 6 september!

Locatie
Stolwijkstraat 33
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Aanmelden kan via onze website:
batenburg-mechatronica.nl/open-huis

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