Battery Thermal Management for HEV & EV – Technology overview

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Automotive Summit

Automotive Summit – Nov. 10th, 2010

Agenda

- **Introduction**
  - ➔ Hybridization level & Decision making factors
  - ➔ Battery thermal behaviour
- **Battery Thermal Management technologies**
  - ➔ Air cooling
  - ➔ Liquid cooling
  - ➔ Refrigerant cooling
  - ➔ Technology comparison
- **Trends & Next steps**

Hybridization levels

	Hybrid or EV Category							
Functions	µ	µ-Mild	Mild	Full	Plug-in (PHEV)	Series HEV (EREV)	BEV	FCEV
Stop / Start	yes	yes	yes	yes	yes	Internal Combustion Engine with electric transmission or Internal Combustion Engine Generator with electric drive	No in-board generator, just a charger and electric drive	Fuel Cell Generator with electric drive
Regenerative Braking	optional (limited perf.)	yes	yes	yes	yes			
Electrical Boost	no	optional (limited perf.)	yes	yes	yes			
Slave Electric Drive	no	no	optional (limited perf.)	yes	yes			
Electric Drive as a own mode	no	no	no	optional (limited perf.)	yes			

ICE/ZEV Mode → ICE | ZE Mode | ZE Vehicle

Battery Technologies → Ni-MH | Li-ion | Fuel cell

Battery Thermal Management

Thermal System integration
Exemple of PHEV

Hot Conditions

BTM integration into the overall thermal architecture

BTM Technologies - Decision making factors

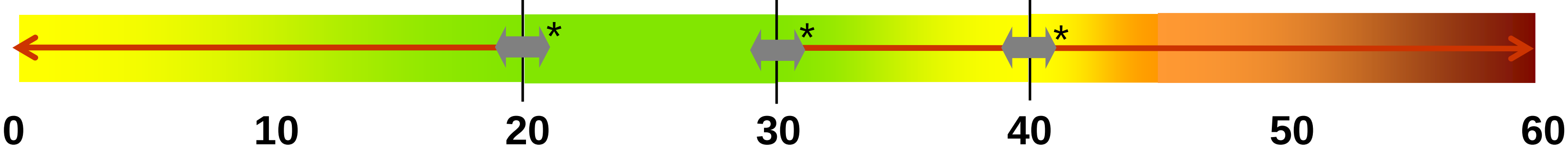
1. **Vehicle hybridization level**
   - F-HEV *vs.* PHEV, EREV *vs.* BEV *vs.* FCEV
2. **Battery technology**
   - NiMH *vs.* Li-Ion (NMC, LFP,…)
   - Cylindric cells *vs.* Prismatic cells *vs*. Pouch cells
3. **Battery capacity**
   - M-HEV: < 1kWh *vs.* F-HEV, PHEV: 1÷ 5kWh *vs.* EREV: 5÷20kWh *vs.* BEV: 15÷40kWh
4. **Power of e-motor**
   - 10 kW ÷ 70 kW
5. **Result of individual OEM - risk assessment**
   - Coolant *vs.* HV-battery
   - Refrigerant R-1234yf *vs.* HV-battery
6. **Targeted integration level**
   - Battery as stand alone sub-system
   - Battery as part of an overall energy management approach
7. **Charging speed**
   - Slow charging *vs*. Fast charging *vs.* Quick drop

The stakes : battery thermal behaviour

To avoid irreversible chemical processes during charging and discharging, which would lead to the loss of available Li ions, the cell temperature must be conditioned and monitored.

Temperature range – cells (°C)

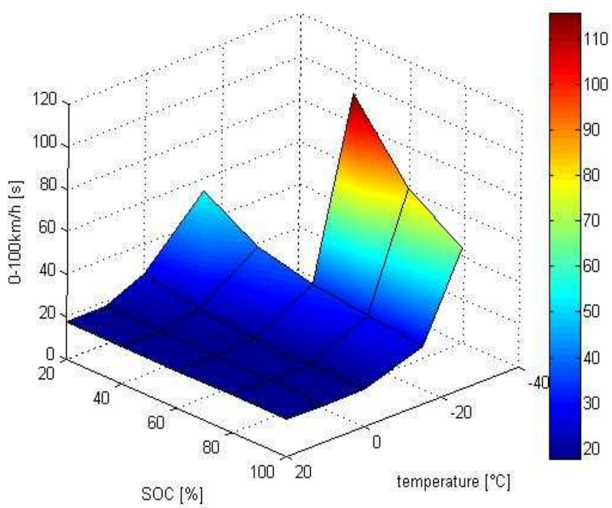
Decline of battery capacity and pulse performance	Optimal range	Faster self-discharge	Irreversible reactions e.g.: Li alleviation	Short-circuit



*According chemistries, suppliers.

Homogeneity of cell in battery pack < [3-5 K]

Low ambient temperature (winter season)



Optimum Temperature range

High ambient temperature (summer season)

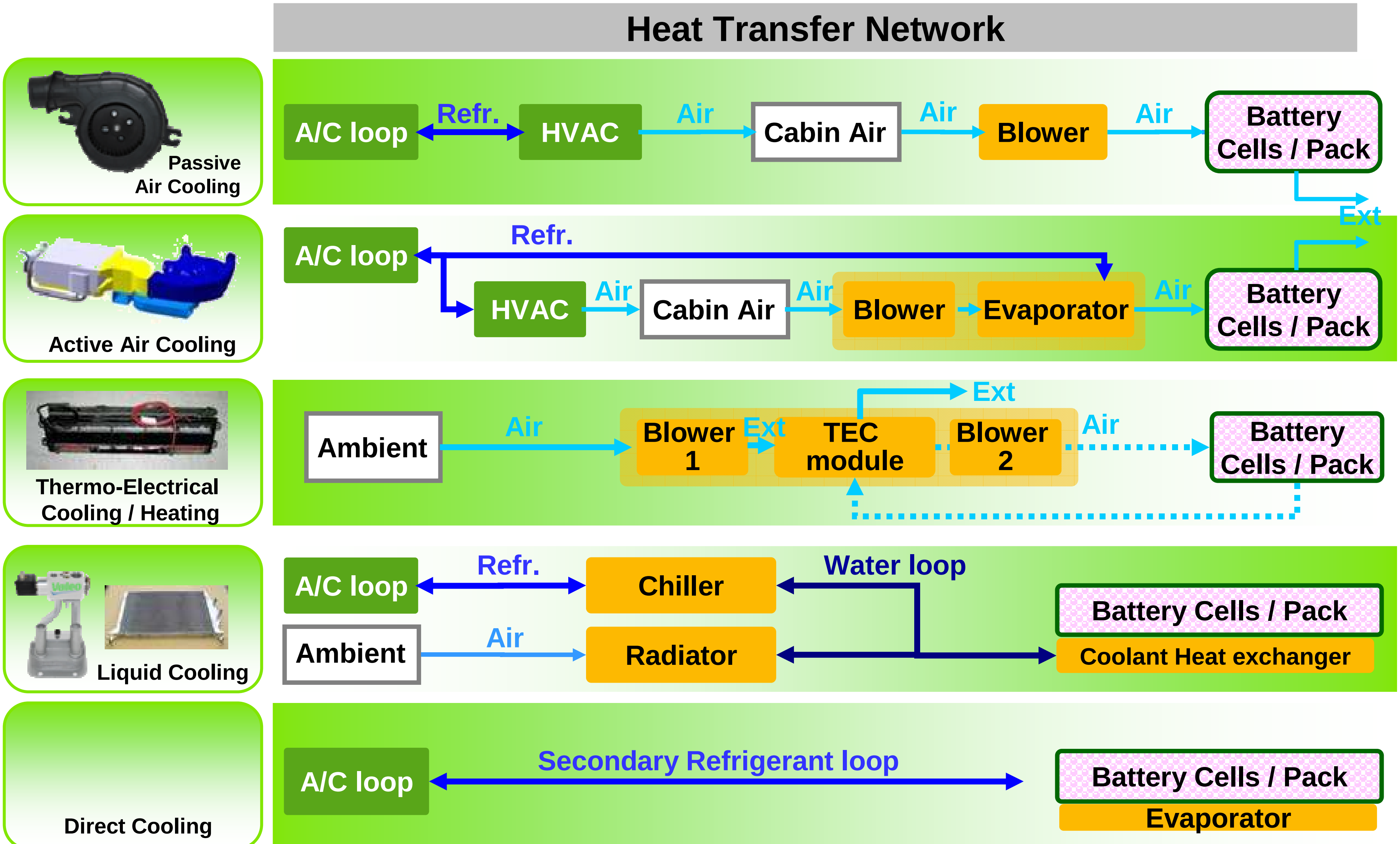
Charging : energy recovery from deceleration

Discharging: boost function in Hybrids

Fast charging in Electric vehicles

High temperature increase internal corrosion kinetics, therefore it decreases both battery life time and efficiency

Technology Portfolio



Passive air cooling

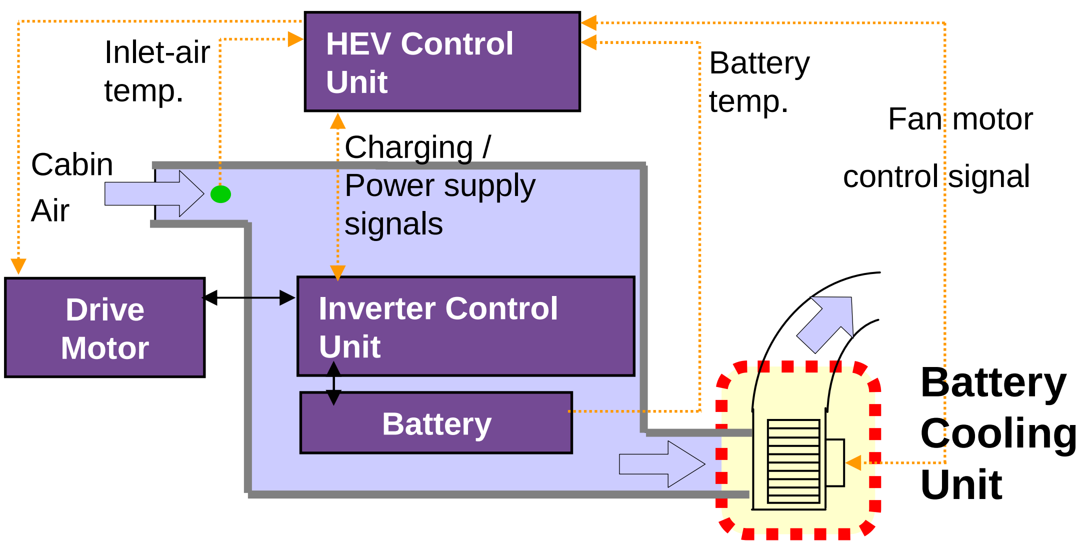
Principle

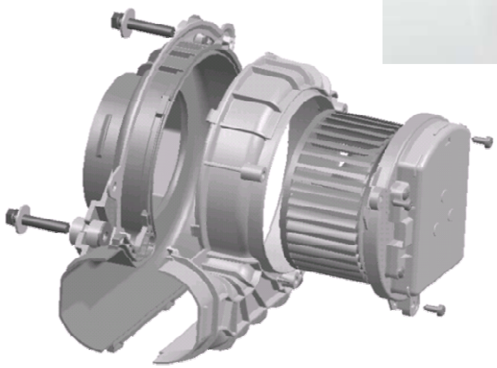
- A dedicated blower aspirate air through the battery pack from car cabin.
- Air at ambient cabin temperature exchange with battery pack.

Product & features

- Brushless motor.
- High efficiency and linear air volume control with PWM.
- Compatible with quick drop.
- Cooling power: from 0 to some 100 W

Schematic





Active air cooling

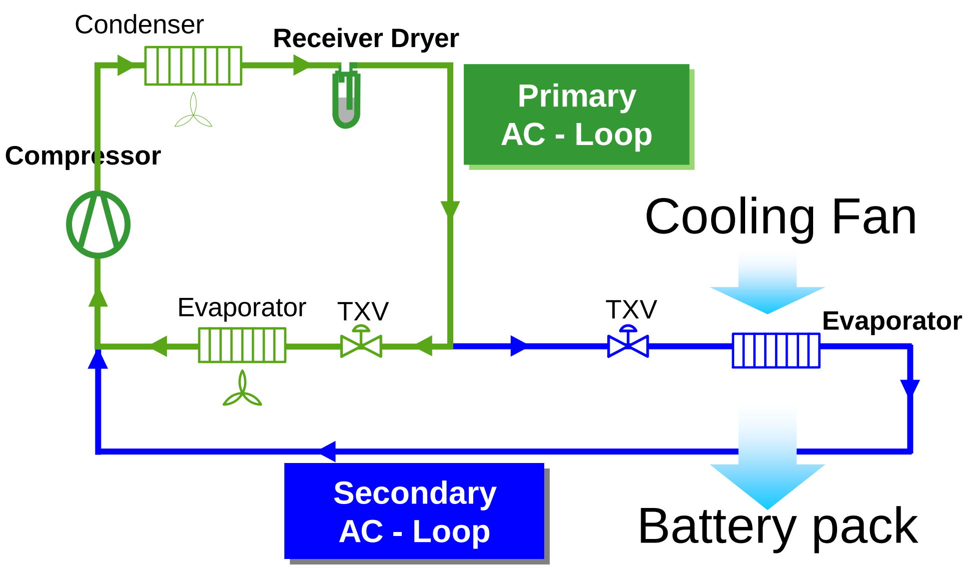
Principle

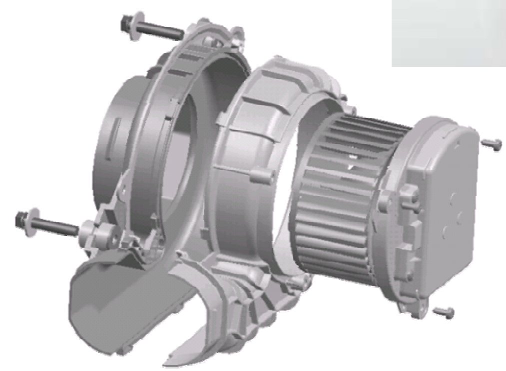
- A dedicated blower aspirate air through the battery pack from HVAC or car cabin.
- Air is cooled by a dedicated evaporator on a secondary AC loop.
- Heating is allowed by the addition of an electrical heater (air PTC).

Product & features

- Brushless motor,
- High efficiency and linear air volume control with PWM,
- Dedicated evaporator.
- Compatible with quick drop.
- Cooling power: ~1kW

Schematic





Thermo-electrical cooling-heating

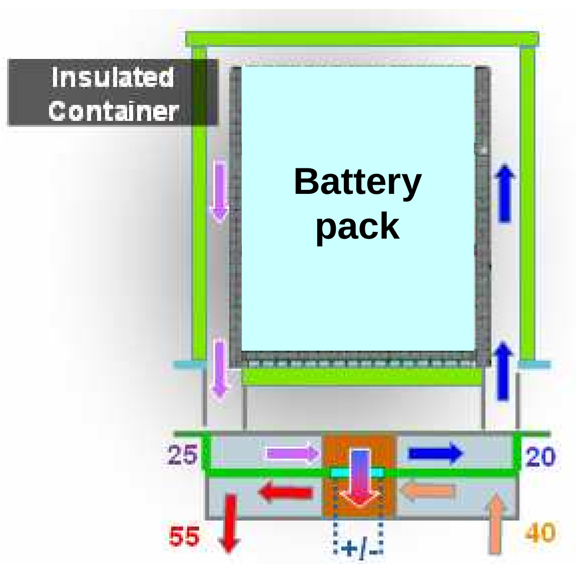
Principle

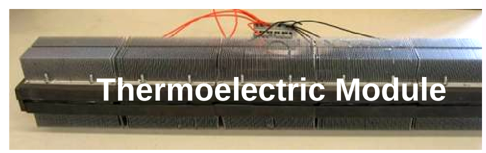
- A Peltier module produce cold (or heat) to thermally manage the battery pack.
- A dedicated blower ensure the temperature homogeneity inside the pack.
- A secondary blower evacuate heat produced by the peltier module.

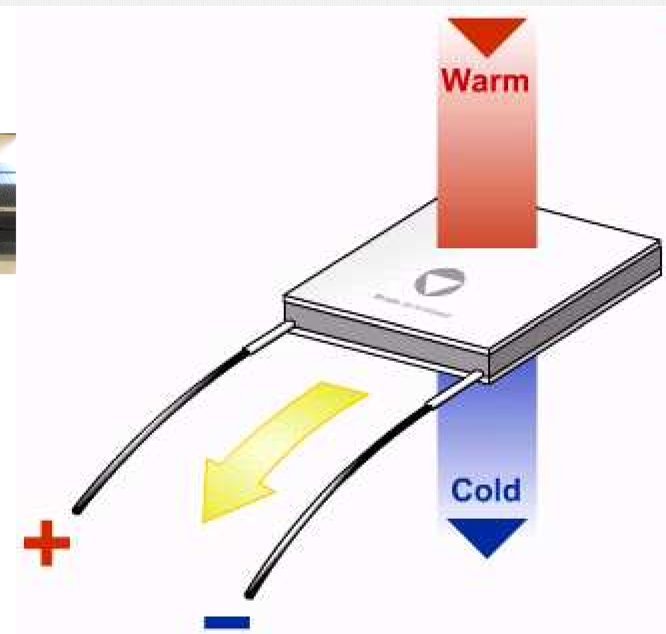
Product & features

- Peltier elements with heat sink.
- Brushless blowers
- Reversible functions (cool/heat).
- Compatible with quick drop solution.
- Cooling power: some 100W.

Schematic





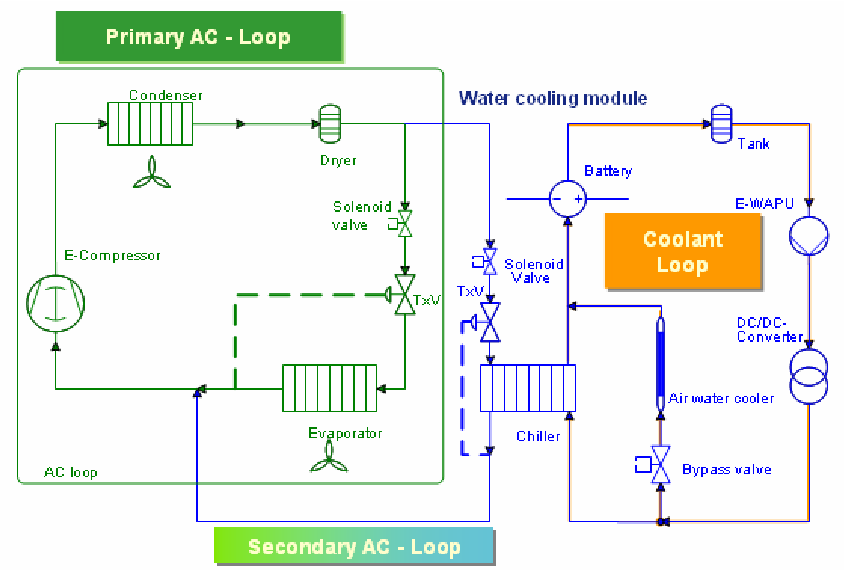


Liquid cooling

Principle

- A secondary AC loop exchange cold with a coolant loop which thermally manage battery cells.
- Direct electrical heating or indirect electrical water heating are compatible with such architecture.

Schematic



Product & features

- Dedicated heat exchanger between refrigerent & coolant (chiller).
- A second heat exchanger in contact with cells (from jacket to socket design).
- Decoupling of cabin comfort & battery temperature control.
- Compatible with fast charging.
- Optimized cell temperature homogeneity.
- Cooling power: some kW

Direct refrigerant cooling

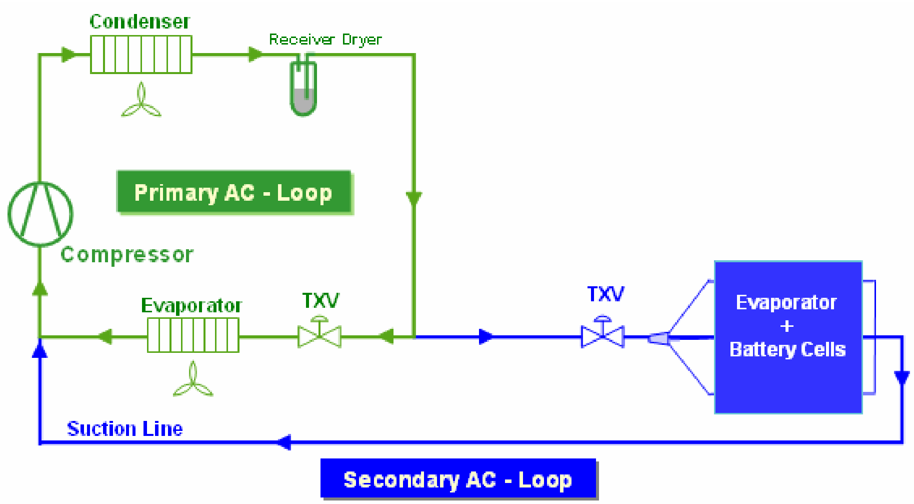
Principle

- Refrigerant expansion is done in an heat exchanger in direct contact with the battery cells (jacket or socket design).
- Direct electrical heating is compatible with such architecture.

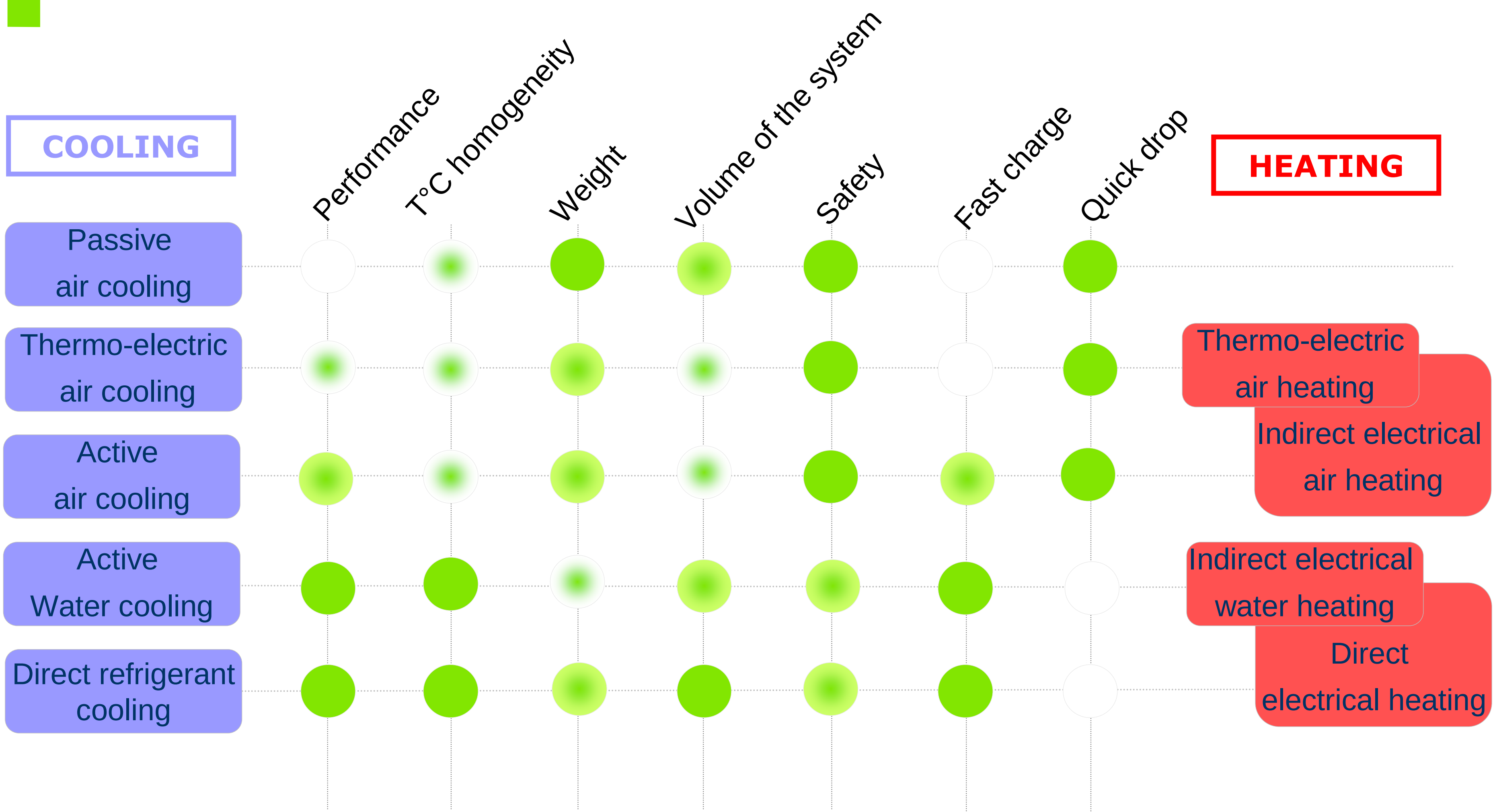
Product & features

- Dedicated heat exchanger (from jacket to socket design).
- Compatible with fast charging.
- Optimized cell temperature homogeneity.
- Low weight, small packaging.
- Cooling power: some kW.

Schematic



Technology overview

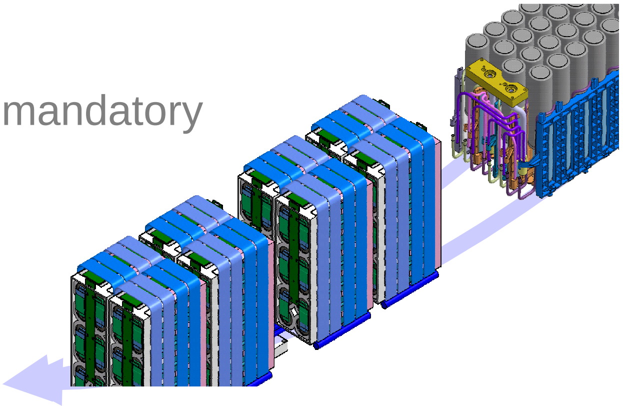


Technical choice according decision making factors

Trends & Next steps

Trends

- ➔ Li-Ion Battery: main stream for Hybrids and EVs
  - – whatever the chemistry used, thermal management is mandatory
  - – choice of solution depends on OEM strategy
- ➔ Air cooling
  - – Reduce blower package, weight.
- ➔ Direct or liquid
  - – From specific jacket cooler to socket concept



Next steps

- ➔ Focus on affordable and weight reduction solutions.
- ➔ Battery standardization through battery modules.
- ➔ Should accept fast charging constraints.

Packaging will remain car specific
➔ Modular BTM concept from extendable base definition,

High performance & affordable solutions

Thank you for your attention.

Automotive technology, naturally