Increasing the Electric Drive Range of EVs and PHEVs through New Concepts of Thermal Conditioning for ePT Systems and Cabin

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Summary

- BEVs Range Vs. Ambient Conditions
- OPTEMUS Project overview
- CRU and integrated Thermal Management systems
- Functionalities and control logics
- Preconditioning Function
- Eco-Routing
- Holistic and Predictive control
- Expected results
- Wrap Up

How far can you go with BEVs?

Normal (A/C OFF): + 20°C

Hot (A/C ON): + 35°C 40% rH

Cold (PTC ON): – 10°C 90% rH

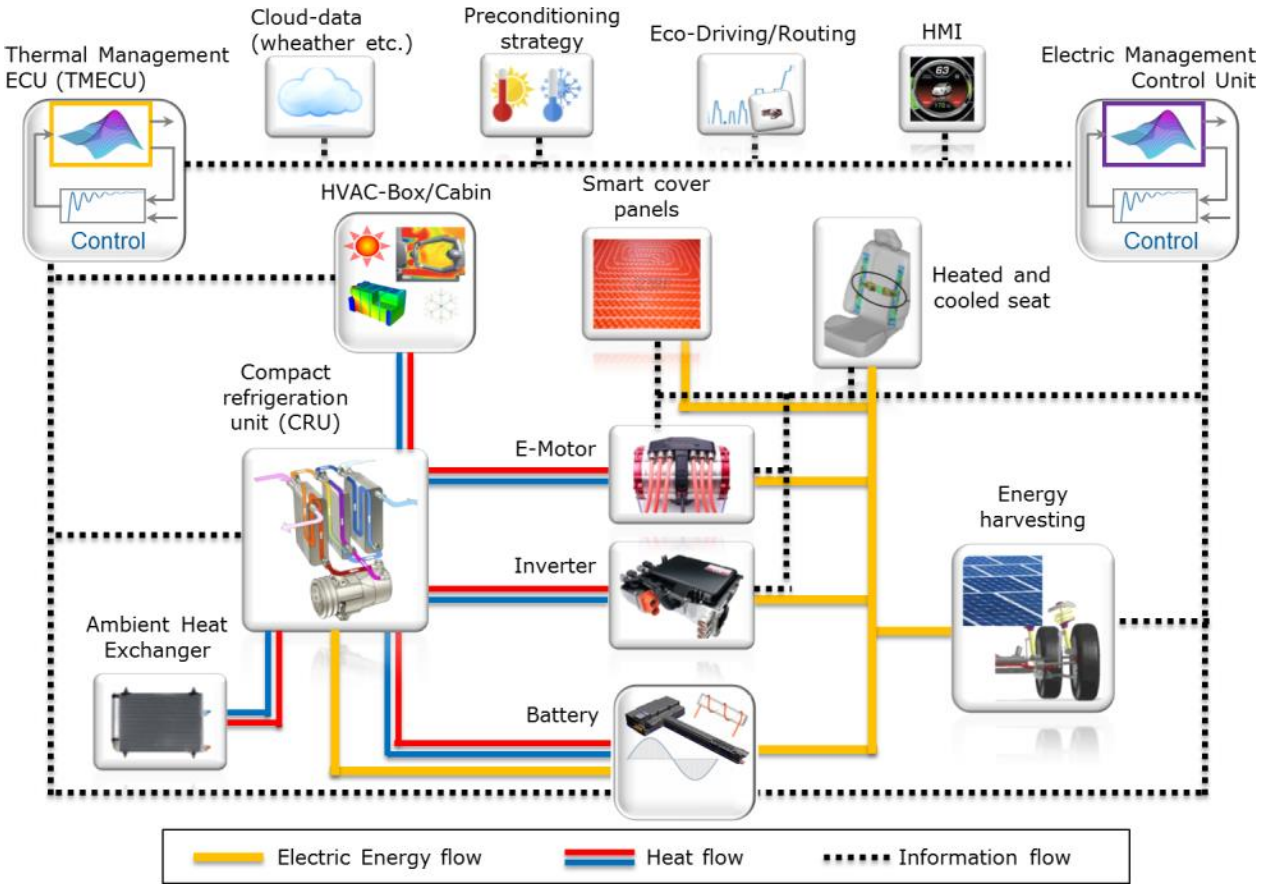
Normal — **Full Range**

Hot — **– 18%**

Cold — **– 36%**

Cabin and Batteries thermal management are main reasons to reduced EV range

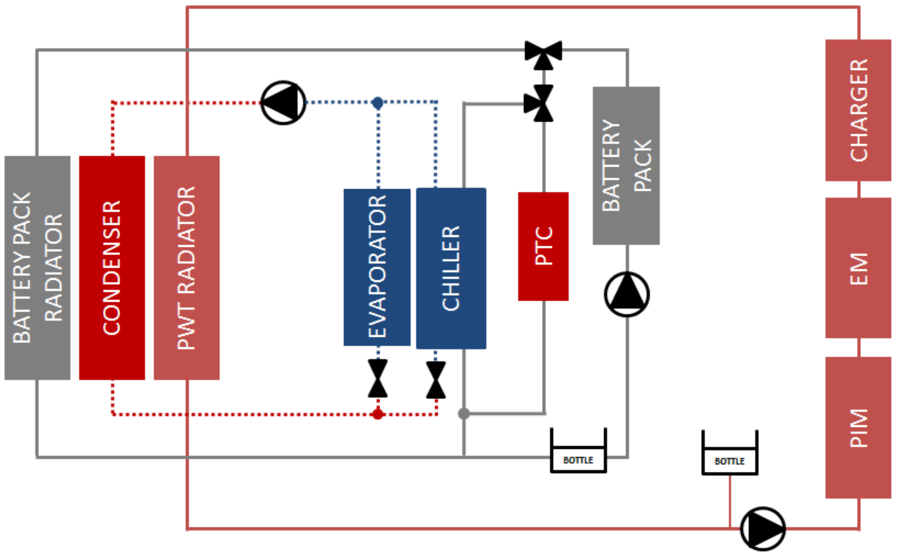
Optemus Project Overview



Holistic approach to reduce thermal management energy consumption for EVs

From Standard to Improved Thermal Management

STANDARD LAYOUT

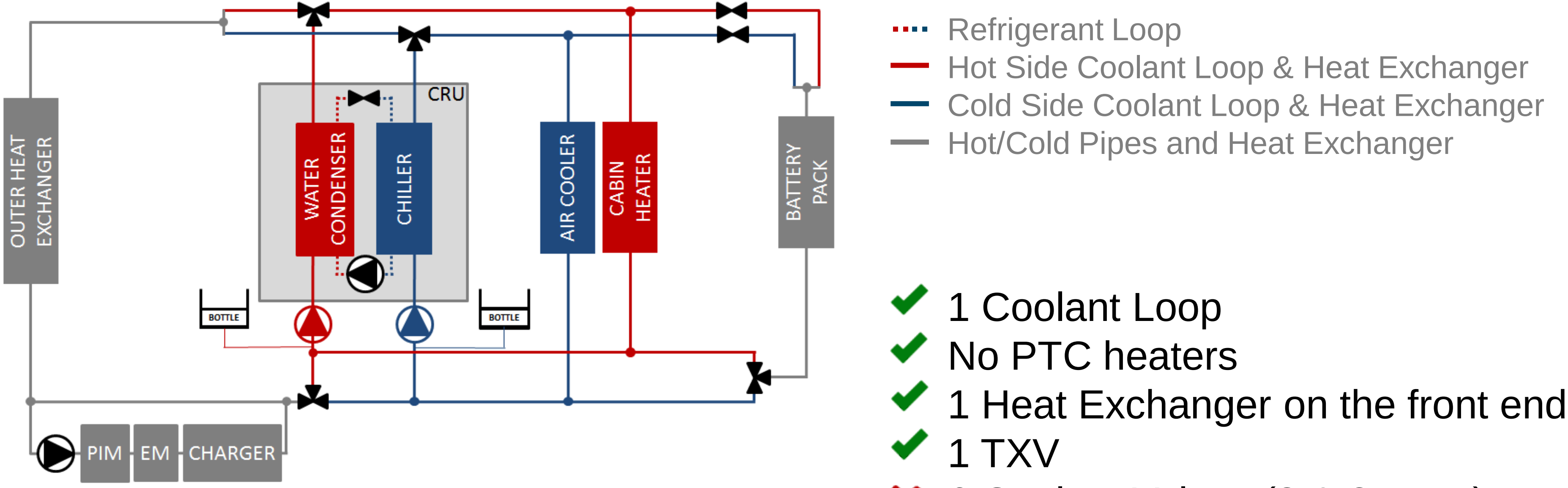


- Refrigerant Loop
- Hot Side Coolant Loop & Heat Exchanger
- Cold Side Coolant Loop & Heat Exchanger
- Hot/Cold Pipes and Heat Exchanger

- 3 Coolant loops
- 2 PTC heaters
- 3 Heat Exchanger on the front end
- 2 TXV
- 2 Coolant Valves (3 ways)

From Standard to Improved Thermal Management

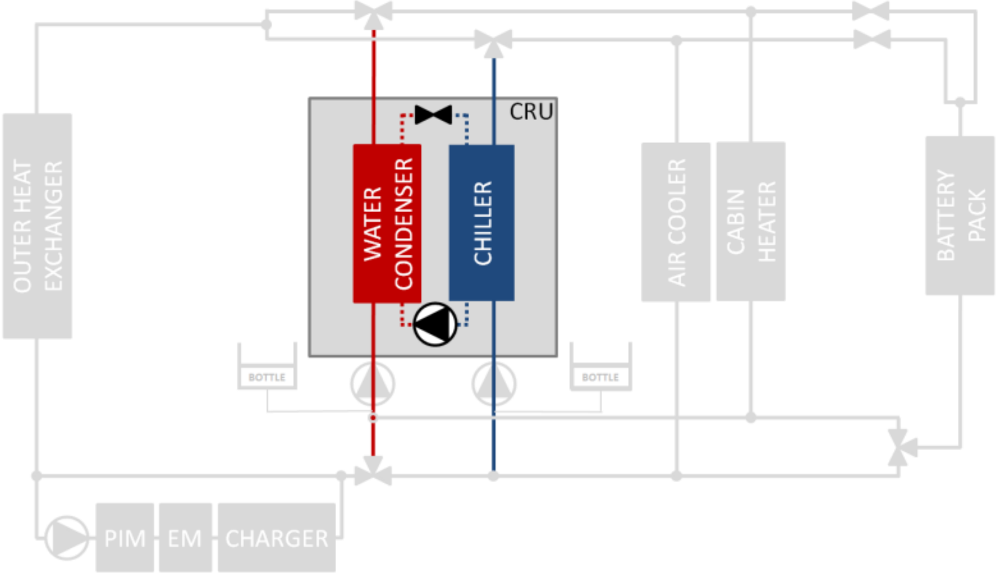
OPTEMUS LAYOUT

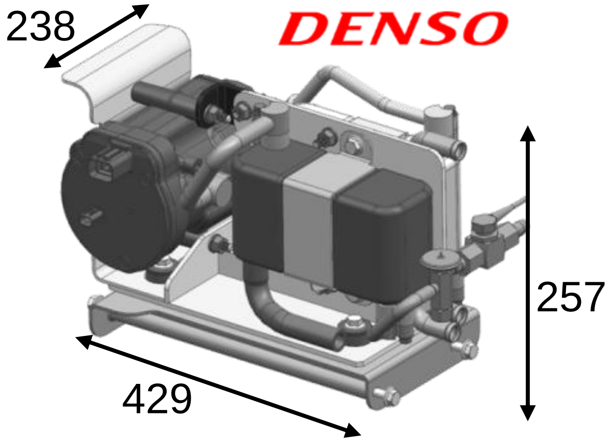


- ✔ 1 Coolant Loop
- ✔ No PTC heaters
- ✔ 1 Heat Exchanger on the front end
- ✔ 1 TXV
- ✘ 6 Coolant Valves (3 & 2 ways)

Compact Refrigeration Unit

The **CRU** unit has been designed according with the **heat exchanger and compressor CAD files.** Also the **bracket** has been realized for engine bay fitting and vibration management.

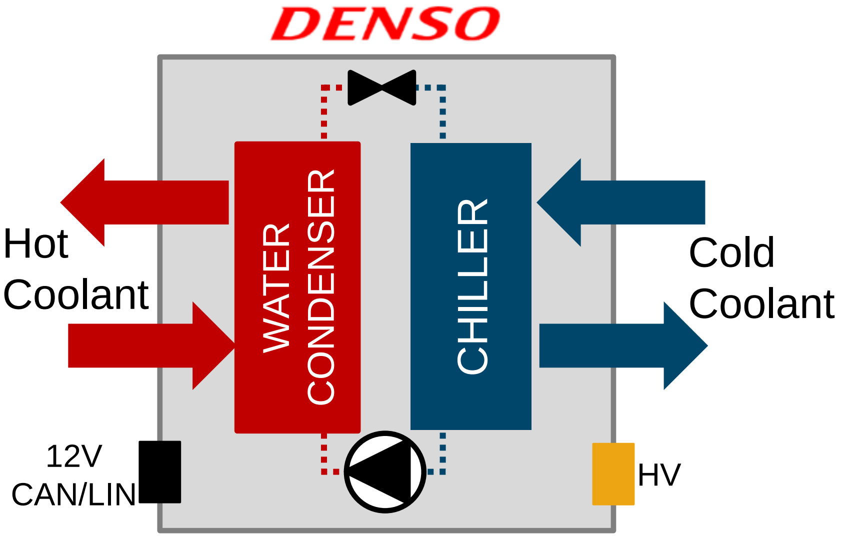


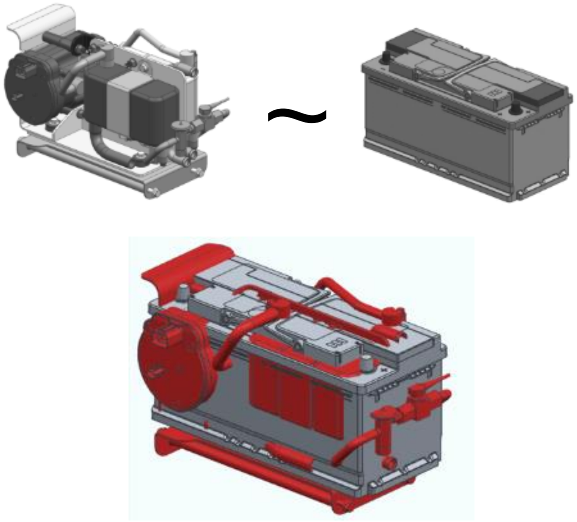


Main Characteristics:

- Short refrigerant and coolant pipes
- Damper holding solution

Compact Refrigeration Unit

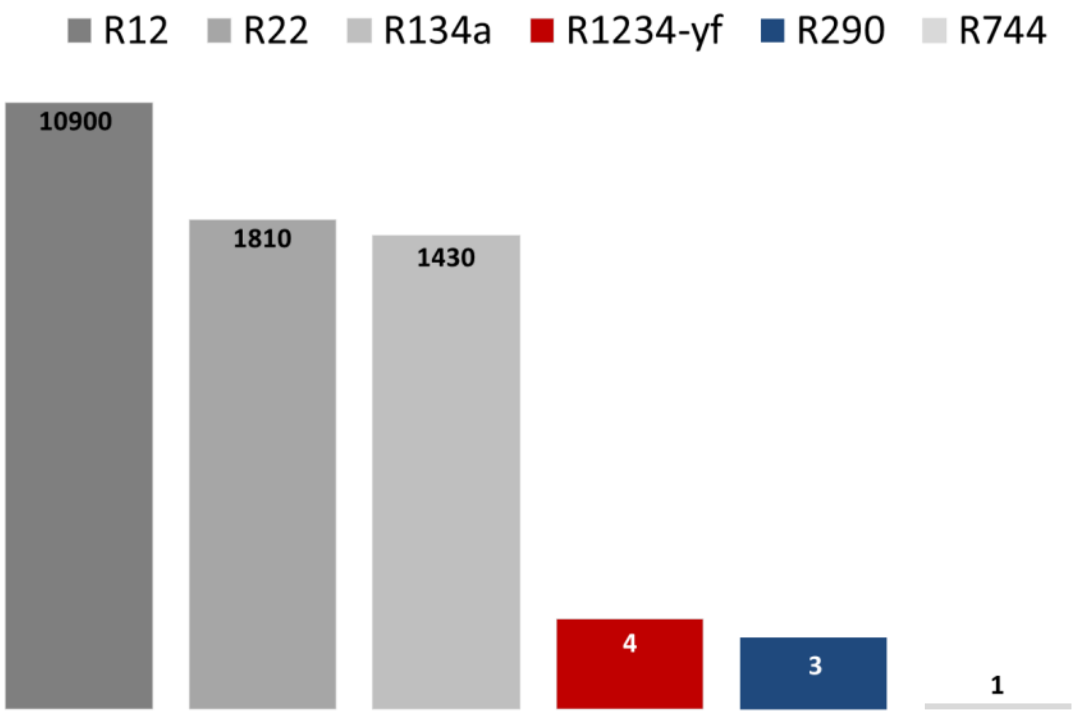




- **Compact design** with Plug and Play approach **(size comparable with 105AH Battery)**
- Oil and refrigerant **(R290) charge optimization**
- **Noise reduction** due to compressor integrated and sealed
- Well established **thermal management control** for water circuit

R290

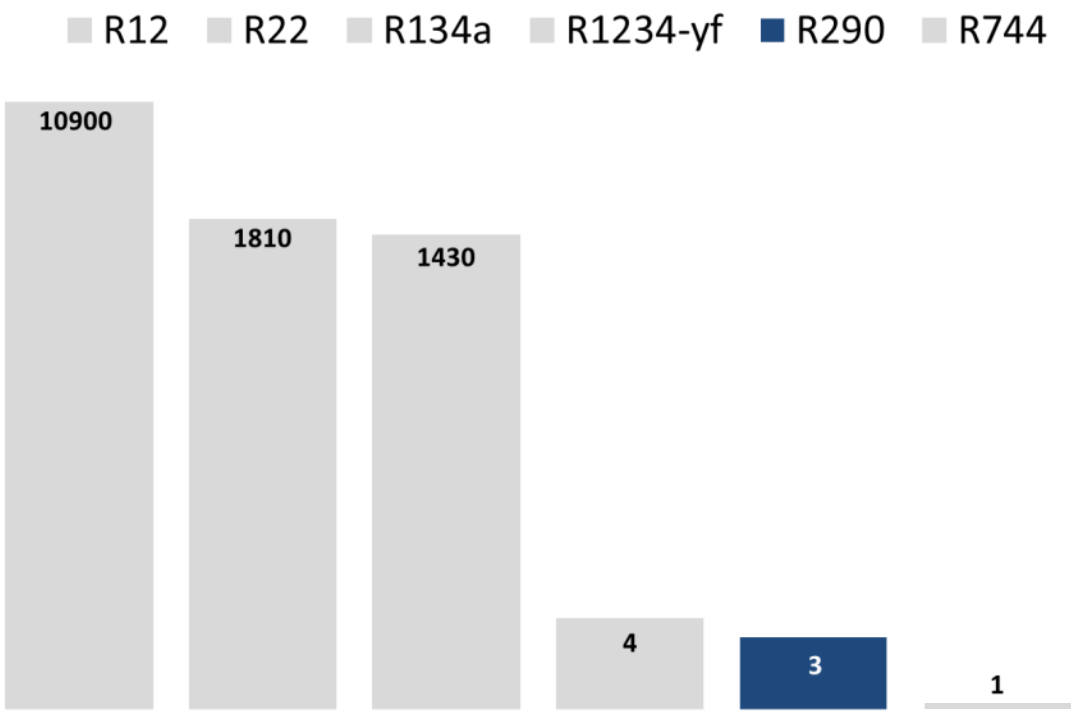
GWP

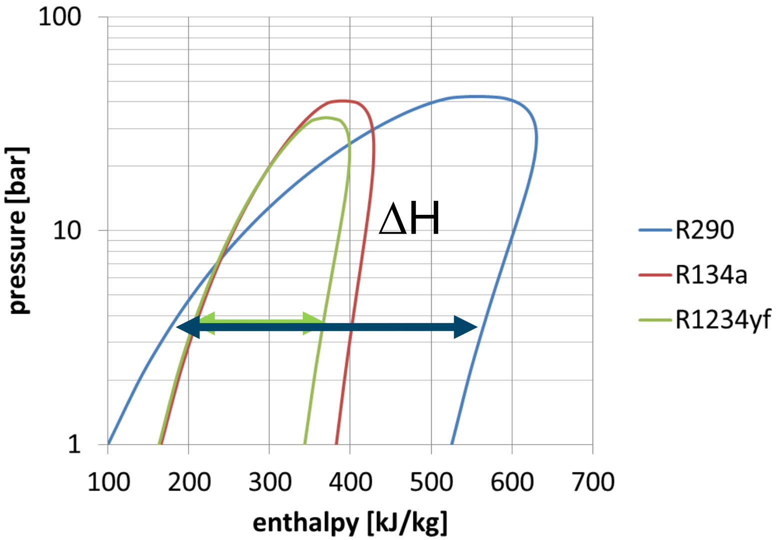


- **Natural Gas Refrigerants**
  (R-134a and R-1234yf are artificial gases)
- **Flammability**: ASHRAE A3
  (150g charge limit)
- **No Toxicity**
- **Good compatibility with components**
- Due to the **physical properties**, lower charges allow the use **of smaller heat exchangers and piping dimensions**.

R290

GWP

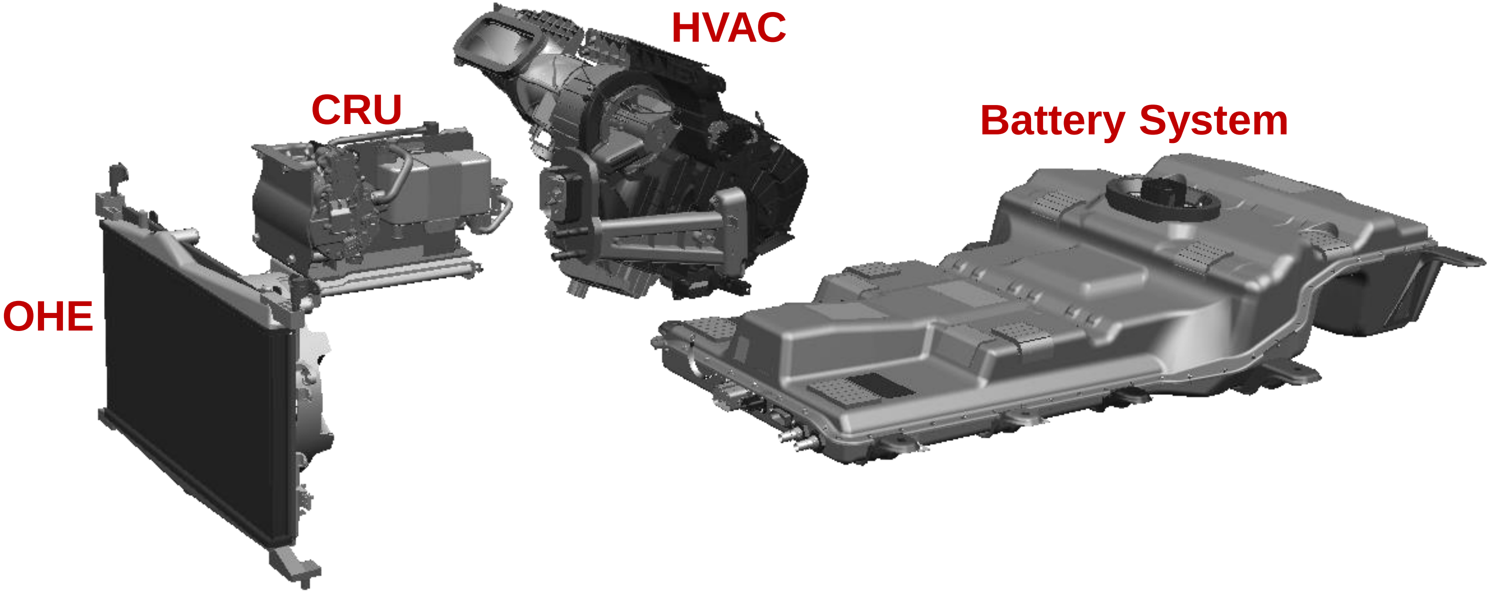




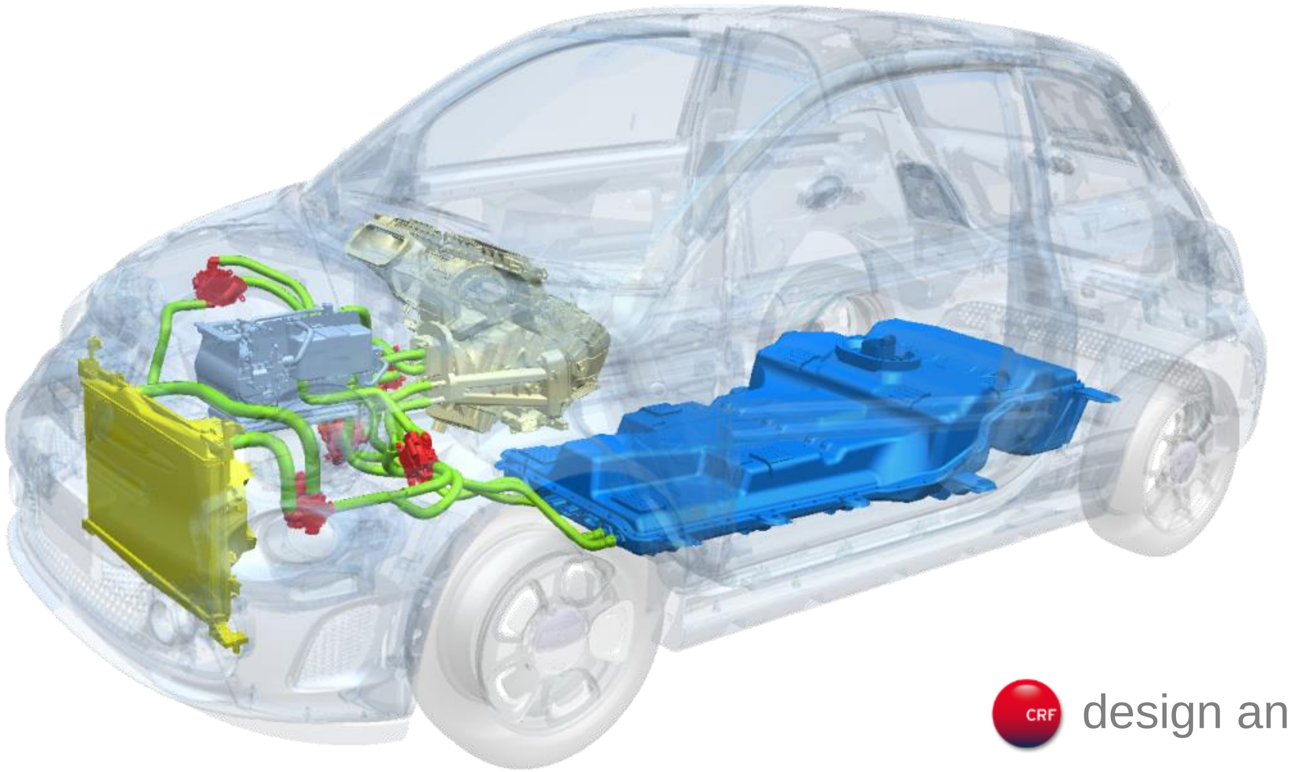
- **Excellent thermodynamic properties** leading to high energy efficiency
- **Lower mass flow rate enabled**

Thermal Management System Main Components

The **CRU** has to manage the cooling and heating function for both **HVAC** and **Battery System.**
OHE will manage the heat rejection and the heat recovery from ambient.

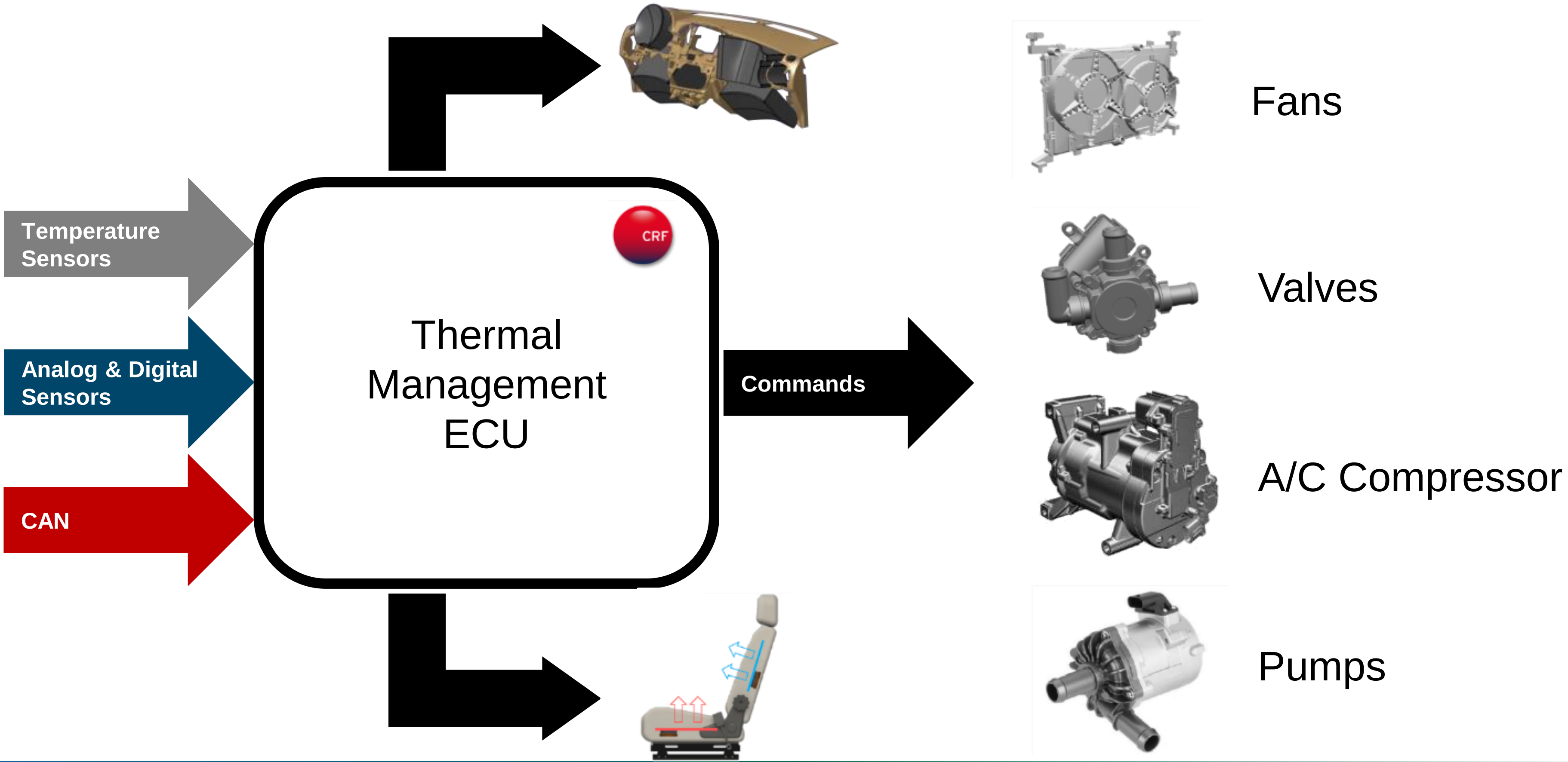


Demo Car Integration



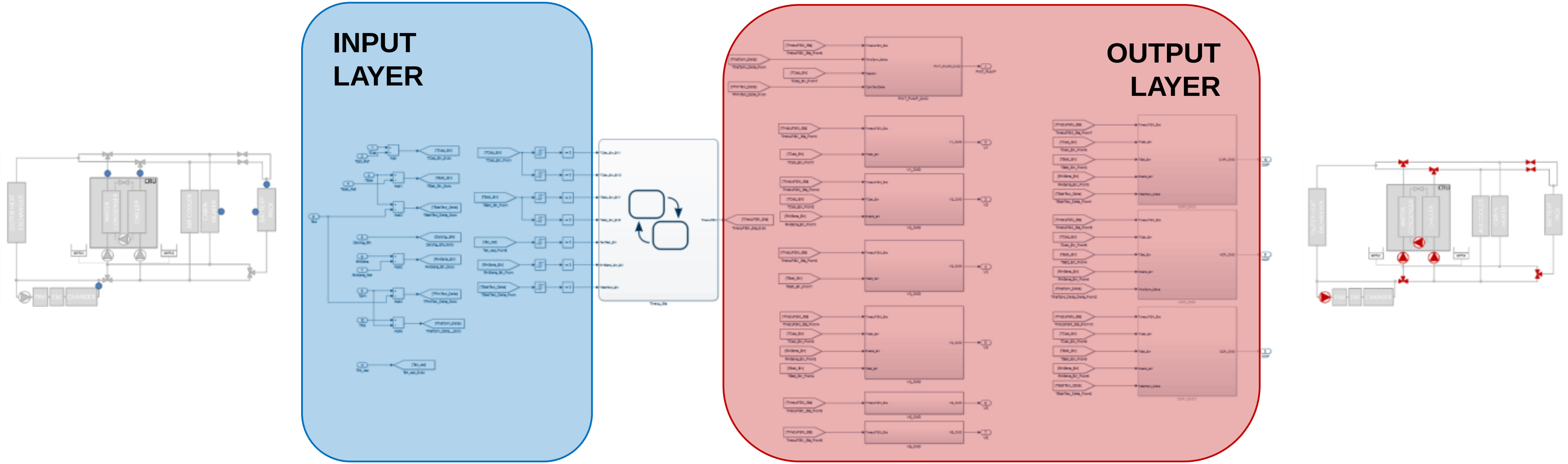
CRF design and installation

Control Strategy



Thermal Management Architecture Functionalities

Control Strategy Development



- **2 Main States** (Cooling & Heating) and **8 different functions.**
- The States and functions transitions will be managed by **PI control strategies** based on defined errors.
- The **Obj temperatures** deviations **drive the actuators** positions in order to **reach the desired temperatures**.
- The **valves** are the **main actors** to provide hot or cold coolant to the right heat exchangers.

Thermal Management Architecture Benefits

Gain Potential (Simulated by virtual vehicle)

4 fixed inputs:

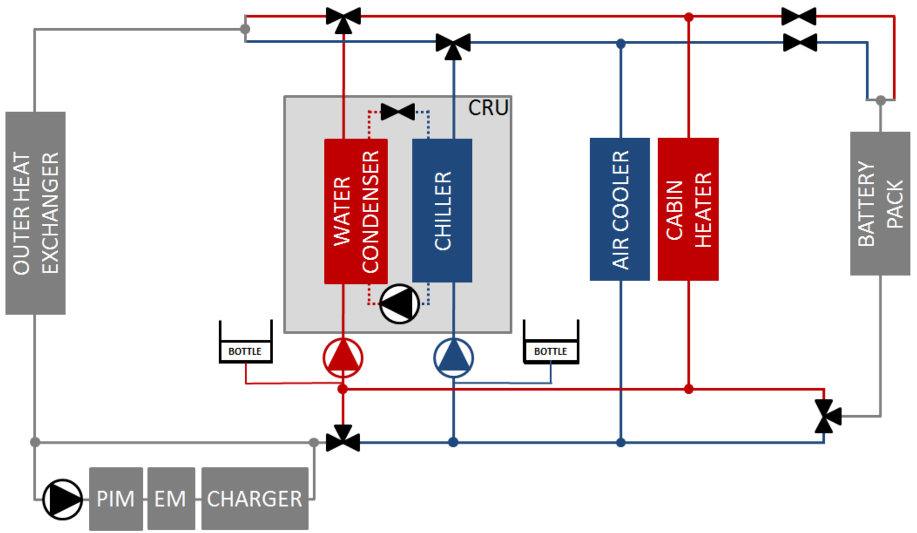
- AHX air mass flow = 2000 kg/h
- Heater air mass flow = 250 kg/h
- AHX pump speed = 100%
- Heater pump speed = 100%

1 controlled input:

- CRU compressor speed [rpm]

5 power demands:

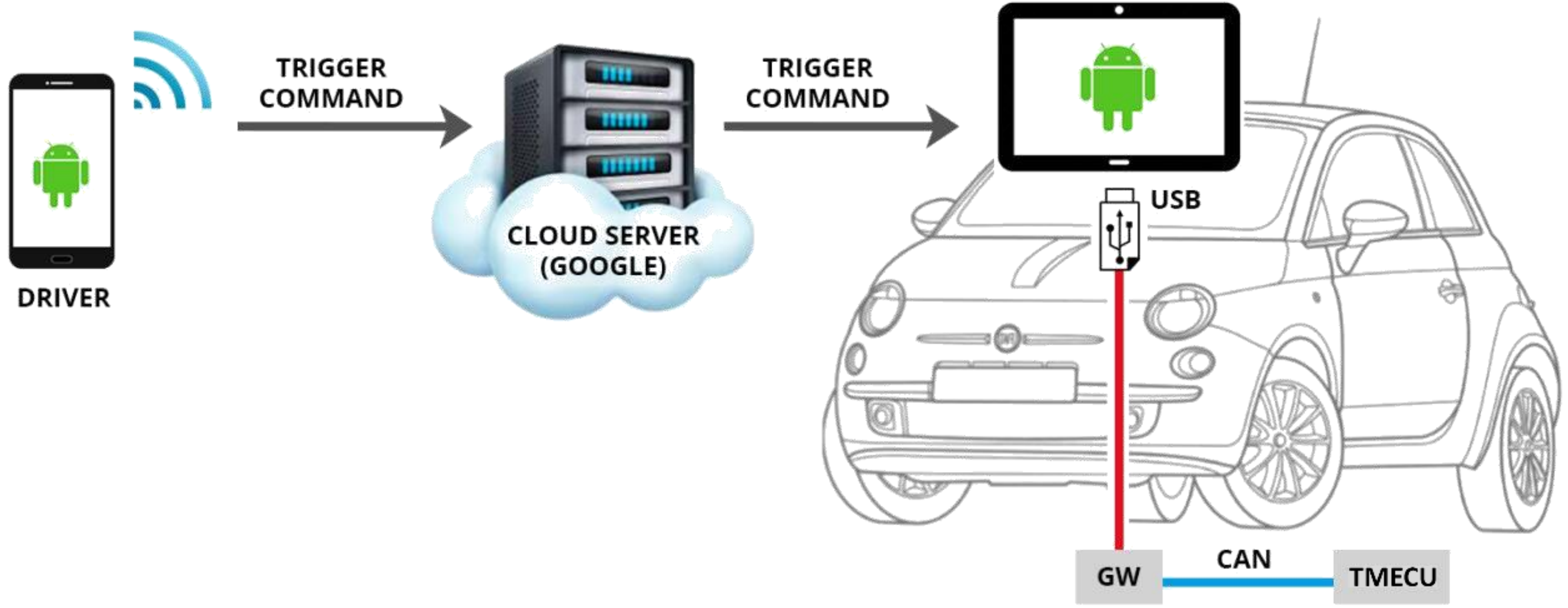
- AHX fan [W]
- Heater fan [W]
- CRU compressor[W]
- AHX pump [W]
- Heater Pump [W]



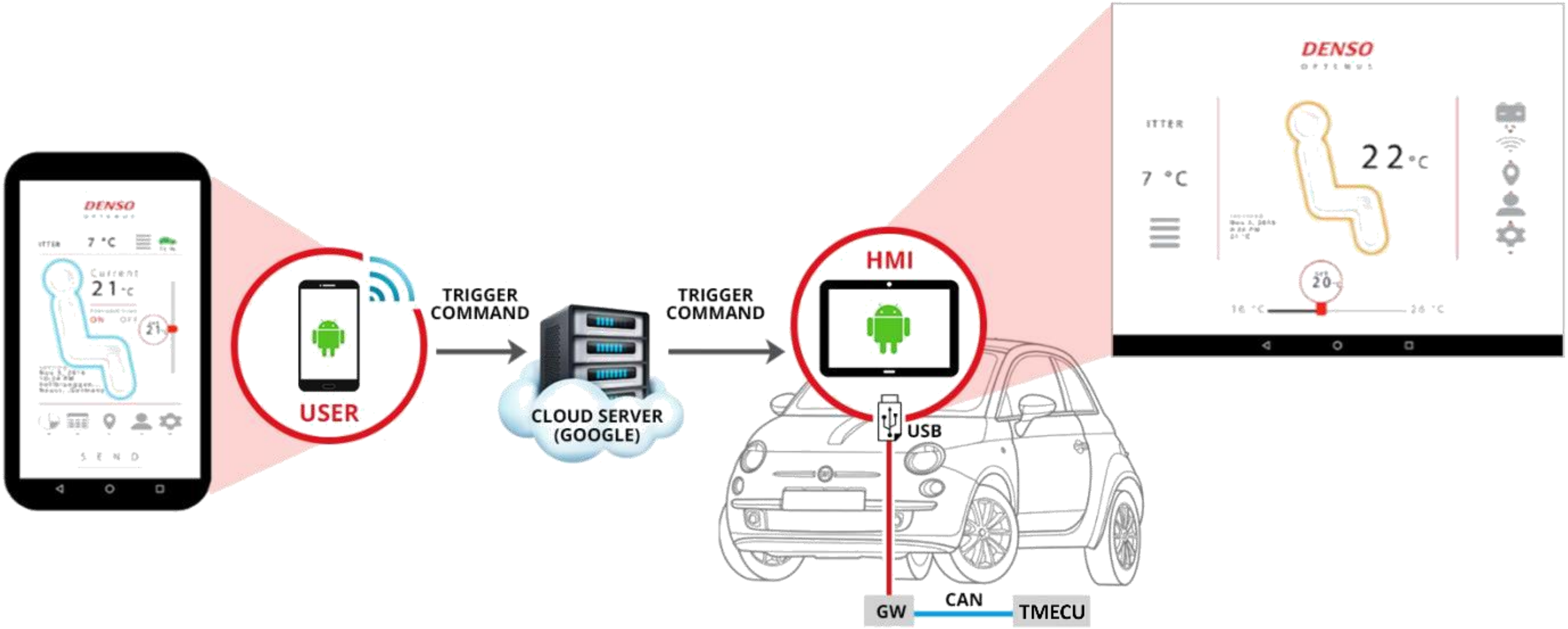
Energy Consumption: **1419 Wh**

-15% w.r.t baseline

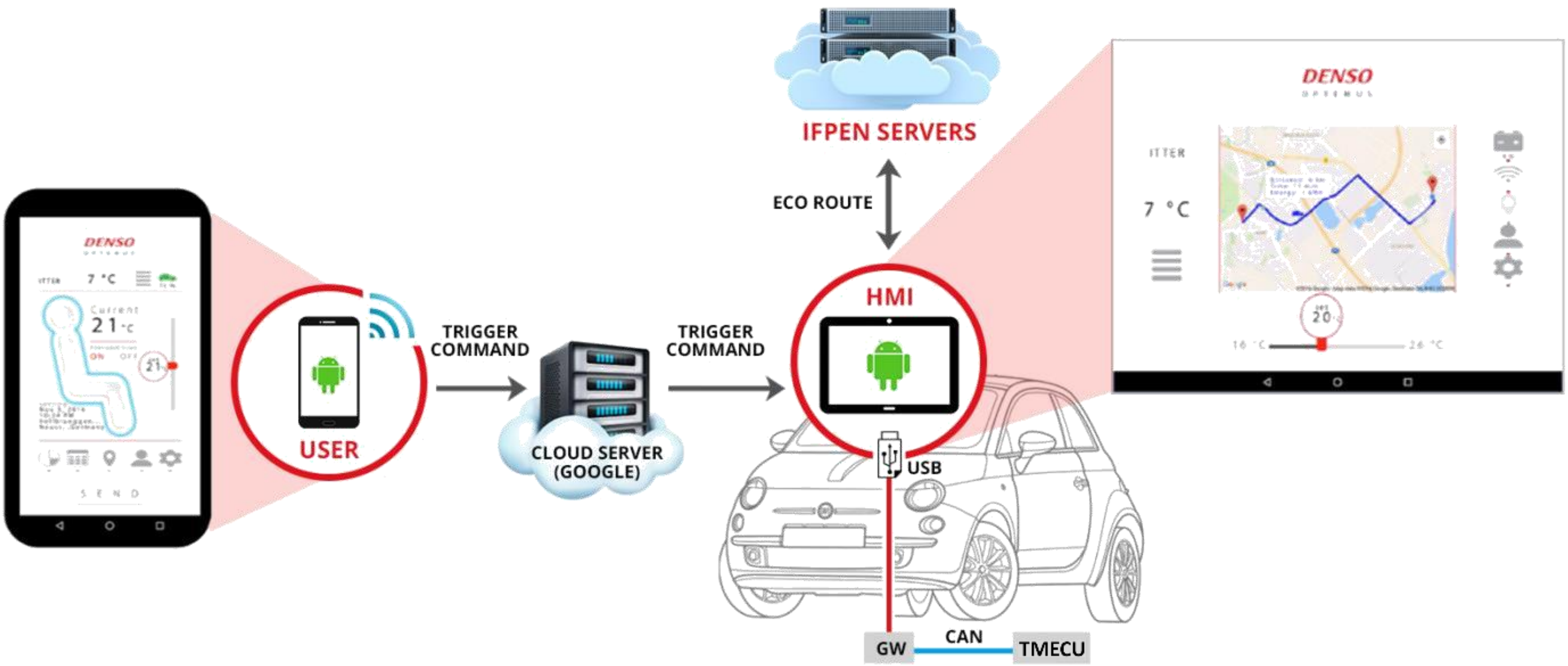
Preconditioning Strategies: User Triggered / Predictive



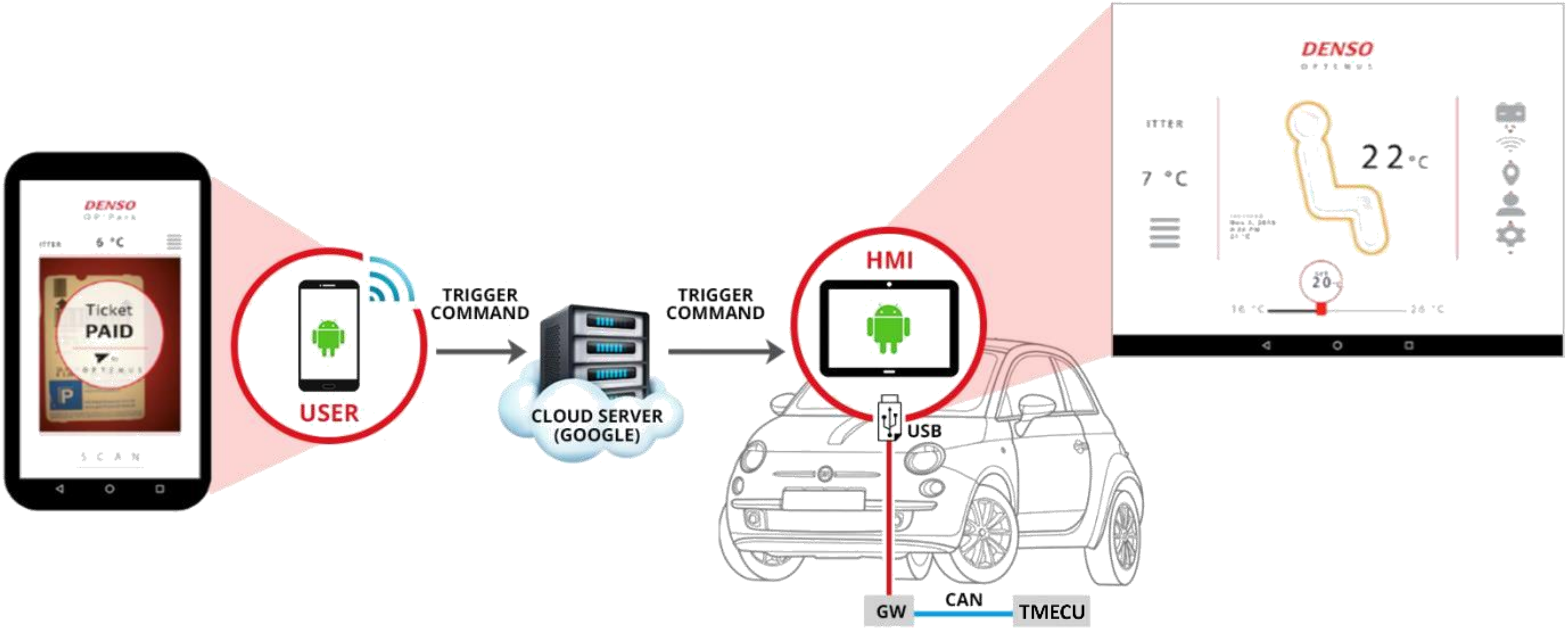
Preconditioning Strategies: HMI User



Preconditioning Strategies: HMI User & Eco Routing



Preconditioning Strategy: HMI Predictive



Eco-routing

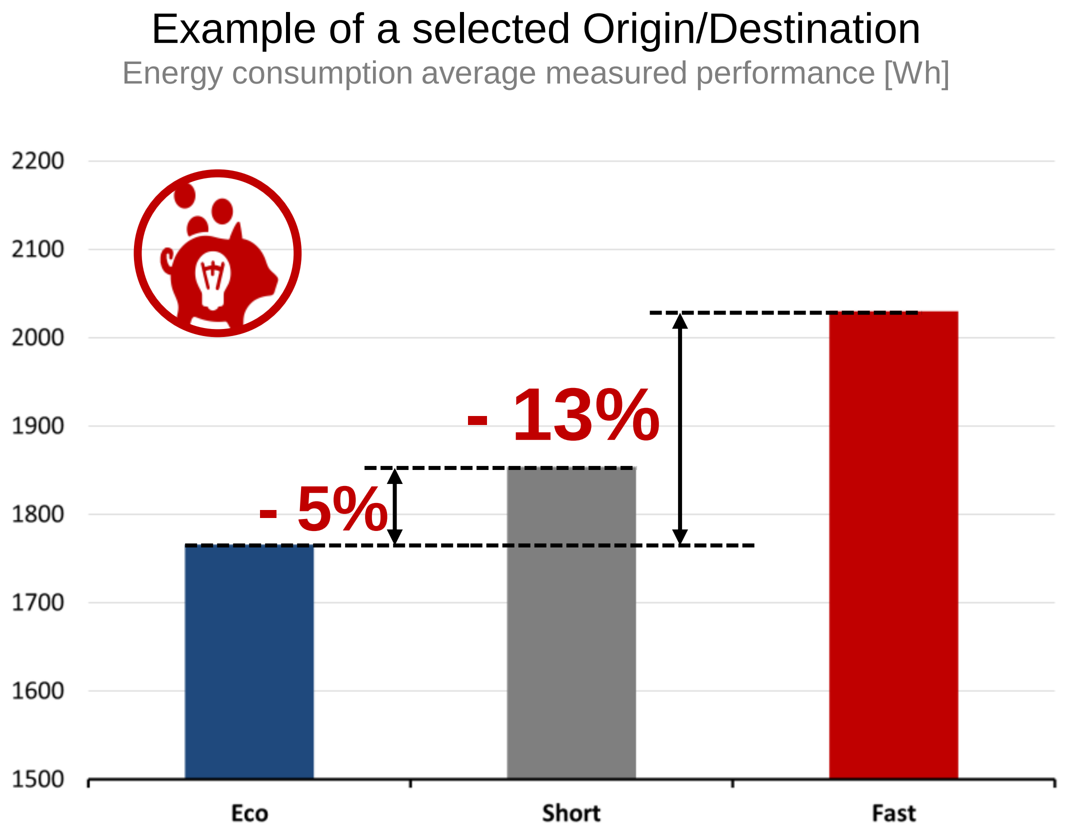
Current navigation system suggests **only** the **shortest route** and the **fastest route**.

The **"eco-routing"** navigation system suggests the **most energy efficient route**.

The Energy consumption model takes into account several parameters:

- Average traffic speed
- Acceleration
- Road grade
- Critical points infrastructure
- Vehicle parameters
- **Ambient Temperature**

Eco-routing: Experimental Validation



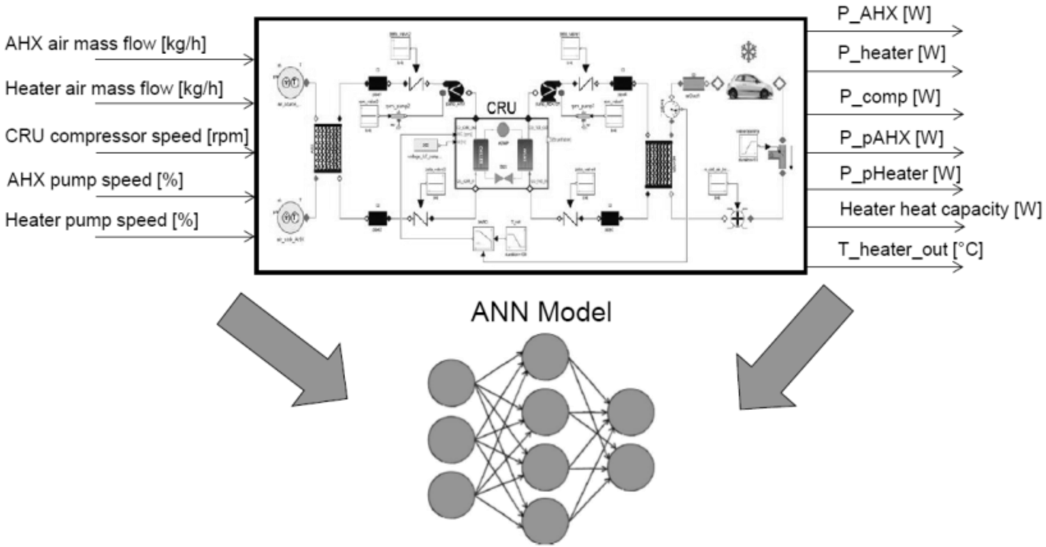
Collection of 35 driving tests with FIAT 500e

Statistical analysis: **3 repetition for each route**

Thermal Management Predictive Control

- Thermal Management Control Function will be managed with an **HOLISTIC approach**
- **Predictive functionalities** will be implemented using information from **Eco-routing** and **Eco-driving** function

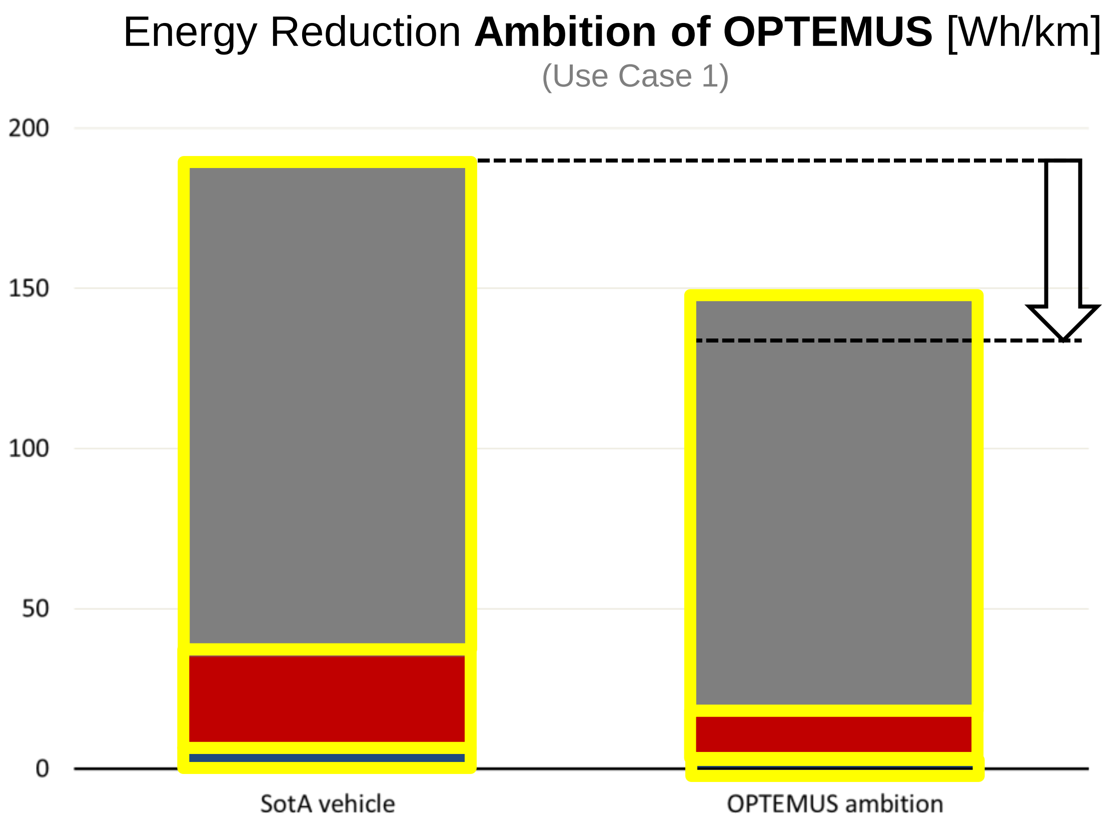
Dymola model



Expected

-25% comfort energy

OPTEMUS Prj Expected Results



- **Traction: - 15%**
- **Comfort: - 60%**
- **Component Cooling: - 32%**
- Energy Harvesting: **- 7%**
- Overall: **- 28%**

OPTEMUS Prj Expected Results

Normal (A/C OFF): + 20°C

Hot (A/C ON): + 35°C 40% rH

Cold (PTC ON): – 10°C 90% rH

Normal (Full Range) → +14% → **OPTEMUS Full Range**

Hot (-18%) → +38% → -1%

Cold (-36%) → +70% → -5%

Wrap up

Range extension is one of the most challenging goals for BEV vehicles

Thermal Management Issues have a big impact and a large room for improvements

Integrated design approach allows to save components and optimize the lay-out

Holistic control is the key factor for range extension benefits achievement

Preconditioning and predictive control functions can help the energy efficiency, reducing the cabin and batteries thermal management impact on the vehicle autonomy

Contacts

Thank you!

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