Thermally Operated Mobile Air Conditioning Systems

R. de Boer

Presented at the 3rd European Workshop – Mobile Air Conditioning, Vehicle Thermal Systems and Auxiliaries, Torino, Italy, November 26-27, 2009

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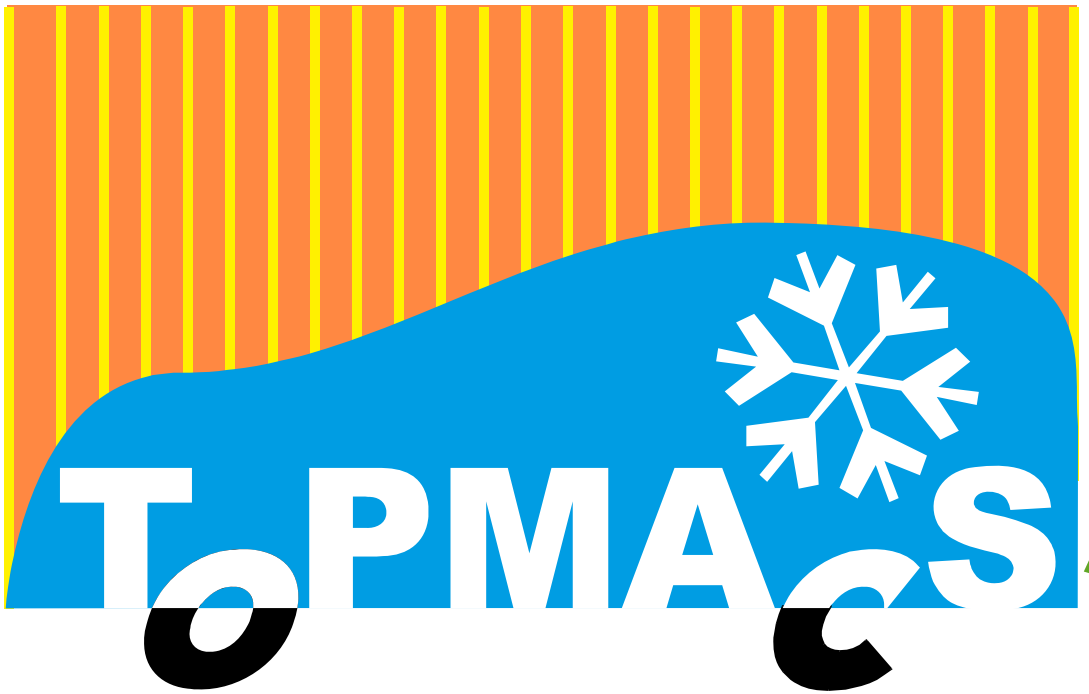


Thermally OPerated Mobile Air Conditioning Systems

TOPMACS was part of the EU 6th framework program (STREP) research

Timeline: March 2005 – March 2009

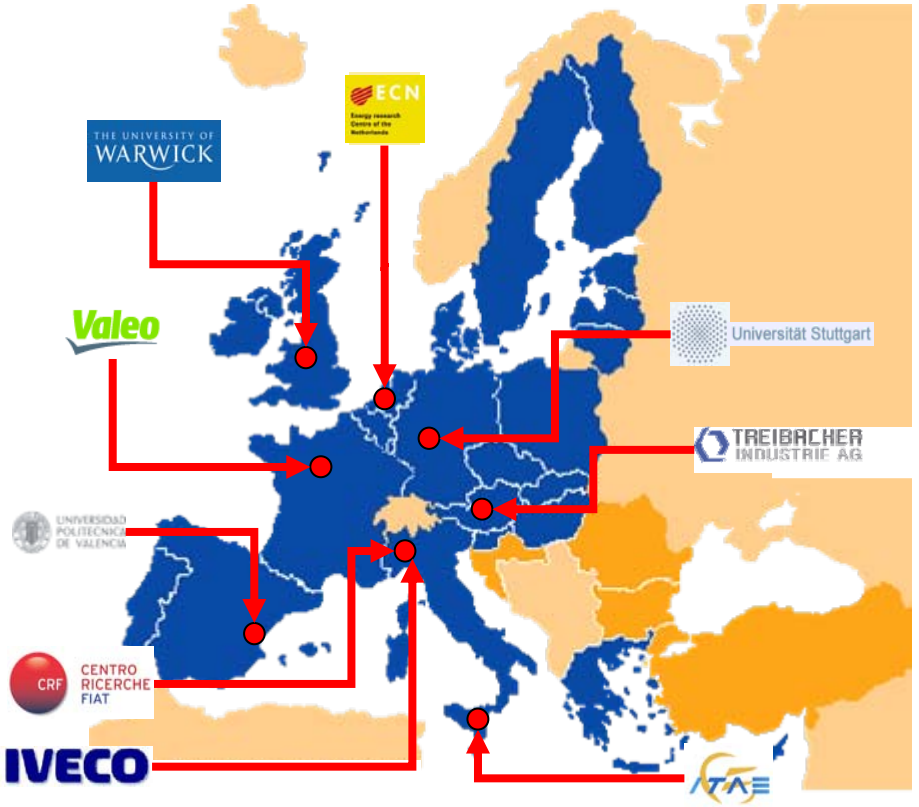
The TOPMACS Initiative

Object : to develop innovative **Mobile Air Conditioning Systems** with a low to zero impact on the environment.

The Consortium:

- 1 Car Manufacturer
- 1 Truck Manufacturer
- 1 major A/C supplier
- 1 advanced material supplier
- 5 of the most acknowledged excellence Centres in the EU

The TOPMACS people



The TOPMACS Focus

The innovative A/C System main Features

- Powered by the engine waste heat
- Use refrigerant with no GWP (compliant with the new EC regulation)
- The core of the system is a sorption heat pump

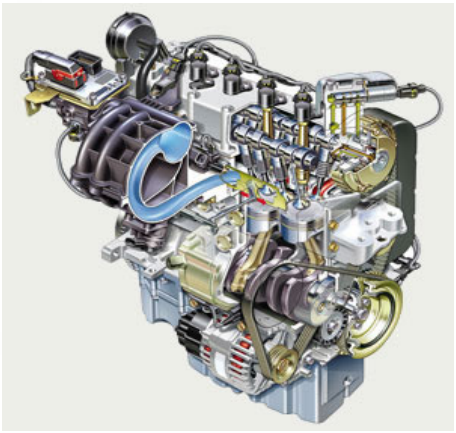
Project Motivations

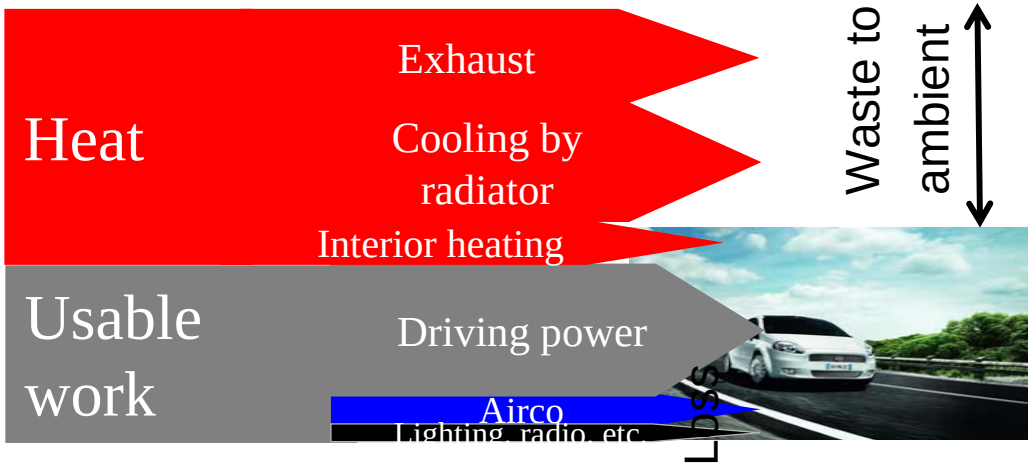
- To meet the new EC regulation on refrigerant
- To meet the EC new regulation on CO2 emissions target
- To significantly reduce the fuel consumption due to the A/C usage
- To lower the A/C impact on the engine

The TOPMACS A/C & Engine System Concept

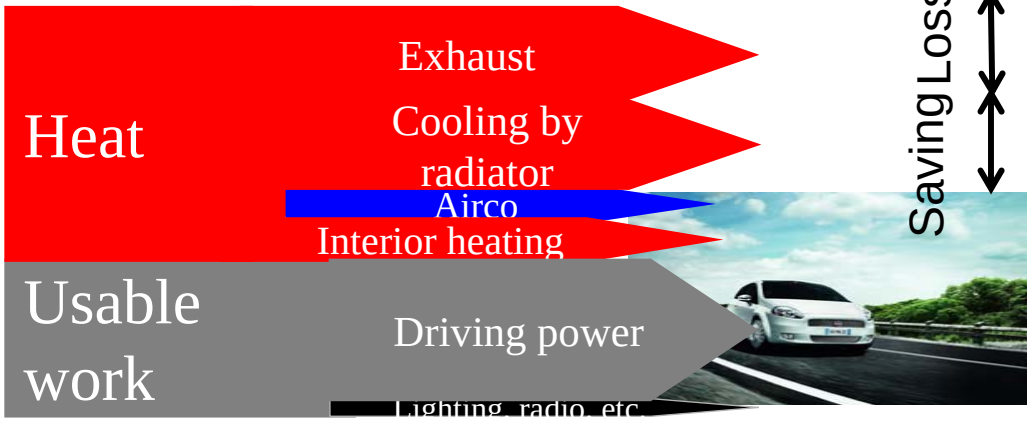
The use of waste heat to power the airconditioning has energy saving potential

Current





TOPMACS



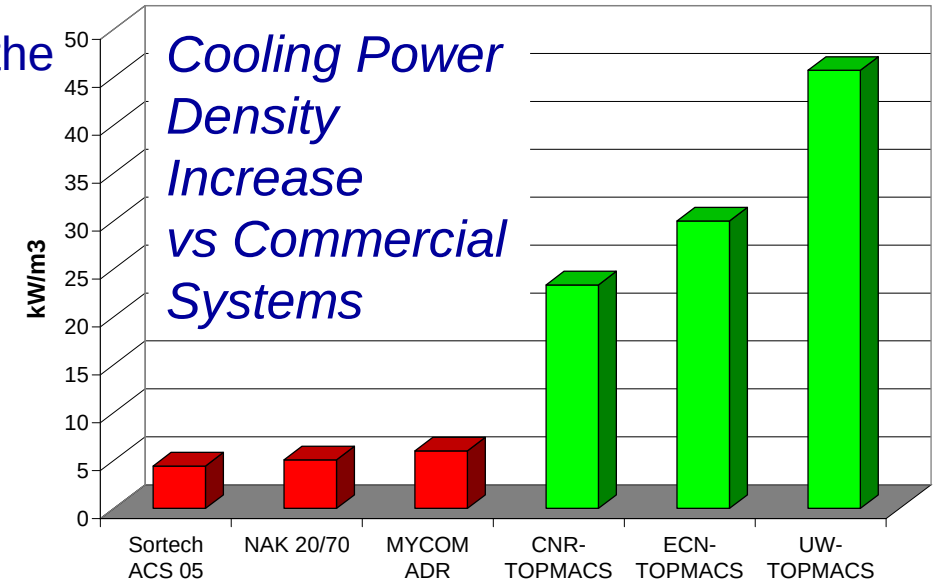
The TOPMACS Project major Outputs

- 4 First Generation Prototype Units with 4 different technologies
- 1 Demontrator Car equipped with a silicagel-water cooling system
- 1 Demonstrator Truck equipped with a zeolite-water cooling system
- 1 Upgraded Activated Carbon-Ammonia cooling system bench prototype
- 1 MeH Mechanical Compression based cooling system bench prototype
- 1 Advanced Simulation Tool able to reproduce the overall system and all technologies
- 33 Papers and participations to international events
- 27 Students participated to the project, 3 Post-Dot Scholarship

The TOPMACS Sorption Cooling Systems main results

Key Results

- No GHG emission due to refrigerant
- Small CO2 emission due to A/C operation
- Low to zero fuel consumption due to A/C usage
- No impact on vehicle handling (no mechanical compressor attached to the engine)
- Coupled with a small fuel burner can provide the cabin preconditioning.



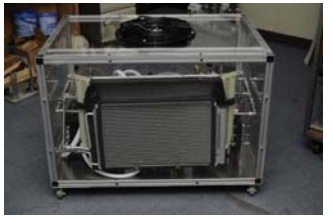
Compared to the state of the art TOPMACS Sorption Systems improve the Cooling Power Density up to 9 times!

3rd European Workshop - Mobile Air Conditioning, Vehicle Thermal Systems and Auxiliaries Presentations

A passenger Car with an air conditioning system working on the engine waste heat

A passenger Truck with a thermally operated air conditioning system

Adsorption cycle MAC powered by vehicle cooling loop



A passenger car with an air conditioning system working on the engine waste heat

Robert de Boer[a], Simon Smeding[a], Daniela Magnetto[b], Stefano Mola, Walter Ferraris[b], Abdelmajid Taklanti[c]

[a] ECN, Energy research Centre of the Netherlands
[b] CRF, Centro Ricerche Fiat, Italy
[c] Valeo Thermal Systems, France

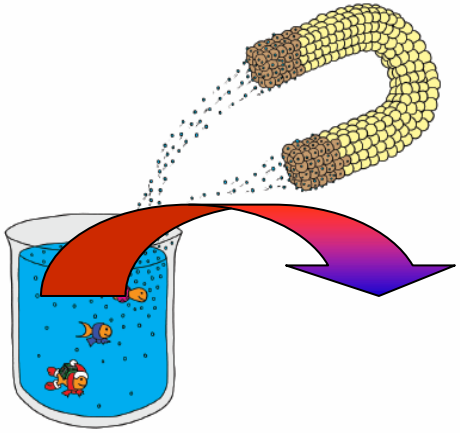
Content

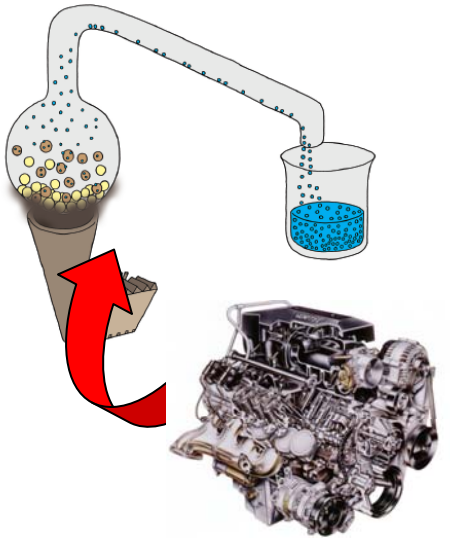
- The Thermally driven AC system concept
- Prototype sorption cooler development and laboratory tests
- On board installation and test
- Redesign and system integration study
- Conclusions and discussion

Sorption Cooling basic principle

A dry sorbent material (silica-gel) adsorb fluid (water) which evaporates generating the cooling effect.

Heat is needed to “dry” the sorbent material making it ready for a new cycle

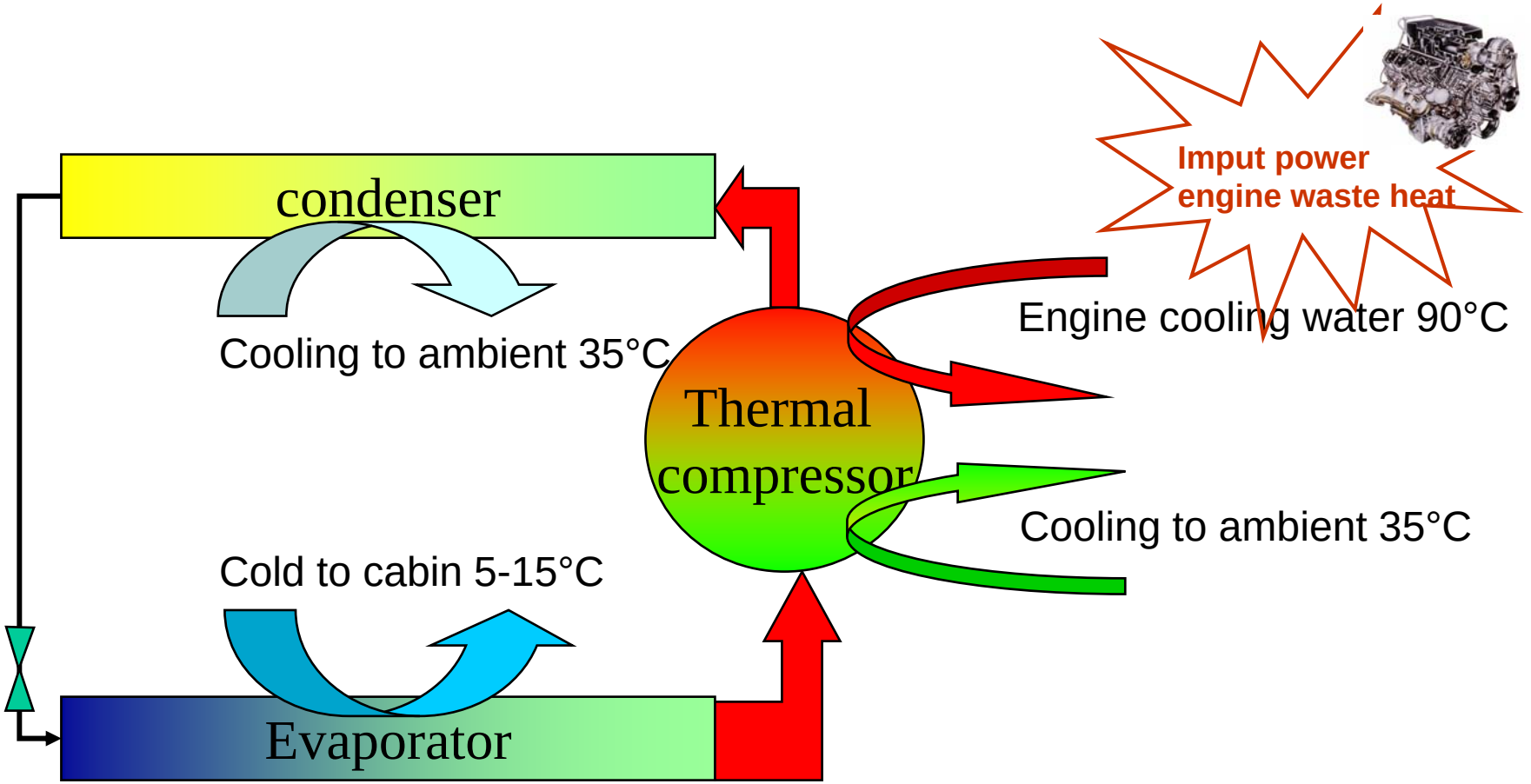




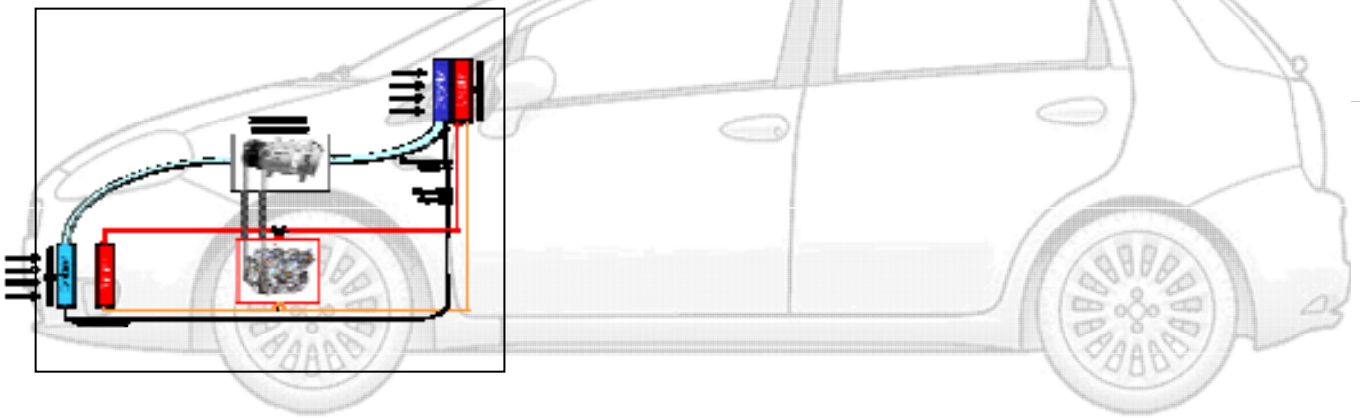
With 2 reaction bed a continuous cooling process can be realized

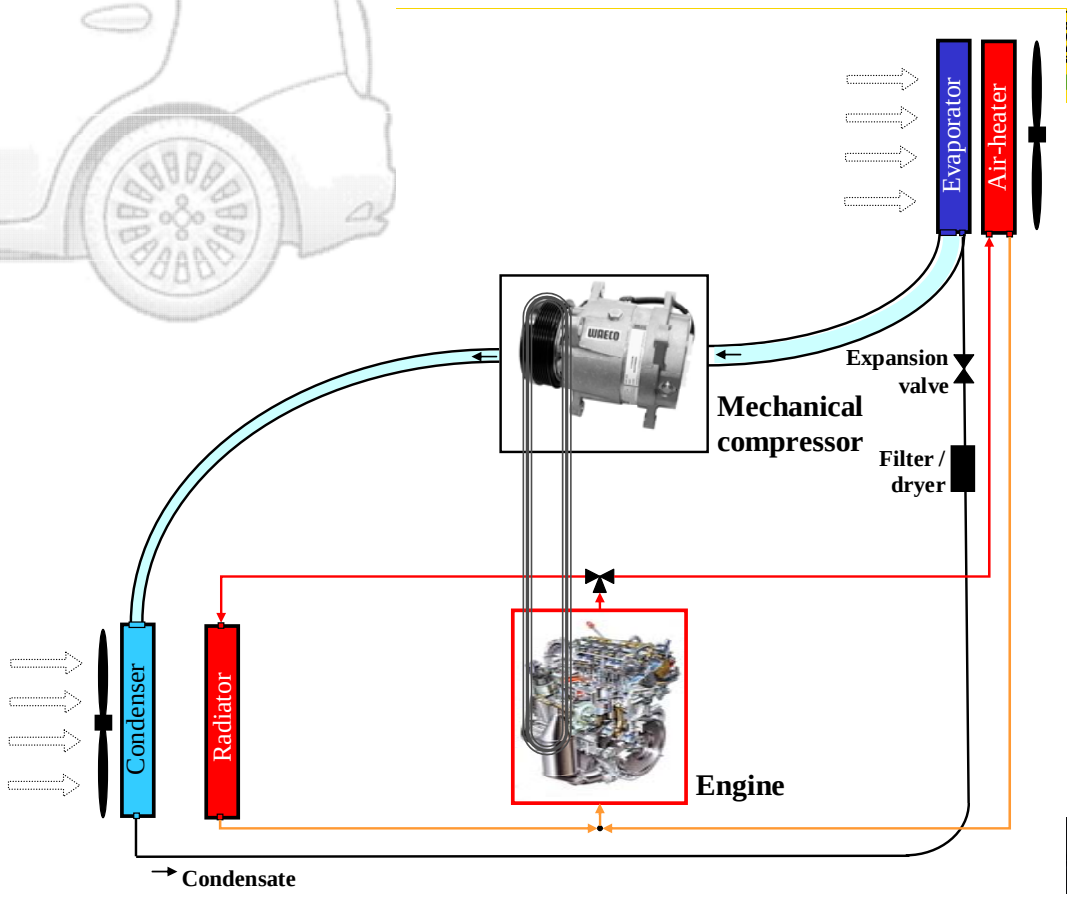
Sorption Cooling System process scheme

Basically an heat pump working on 3 temperature levels



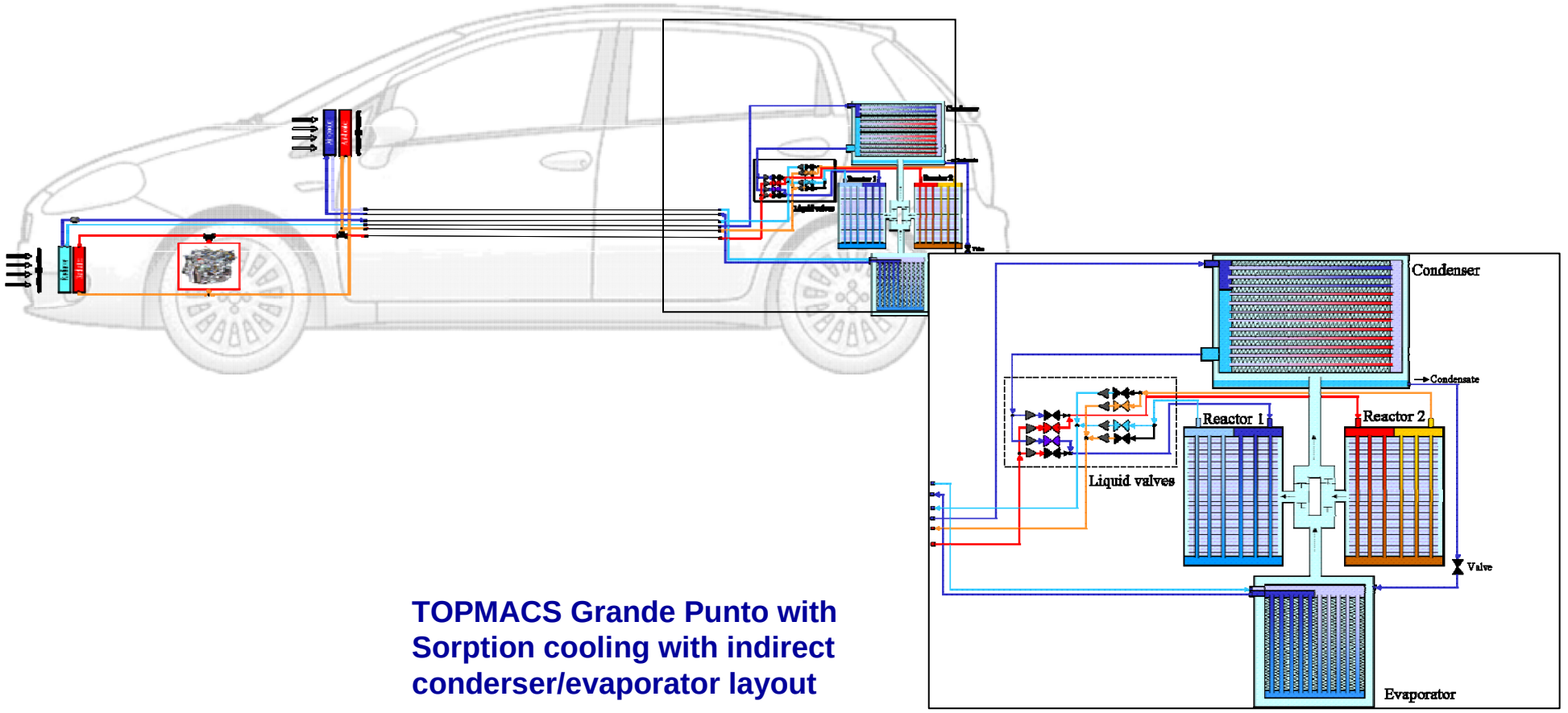
Conventional mechanical compression A/C





Topmacs Thermal compression A/C System

The Thermal compression A/C System is based on the sorption cooling technology



TOPMACS Grande Punto with Sorption cooling with indirect conderser/evaporator layout

The Sorption Cooling System design

The Sorption cooler operation requires three process circuits:

Heating circuit for the sorbent material regeneration **(Input power)**

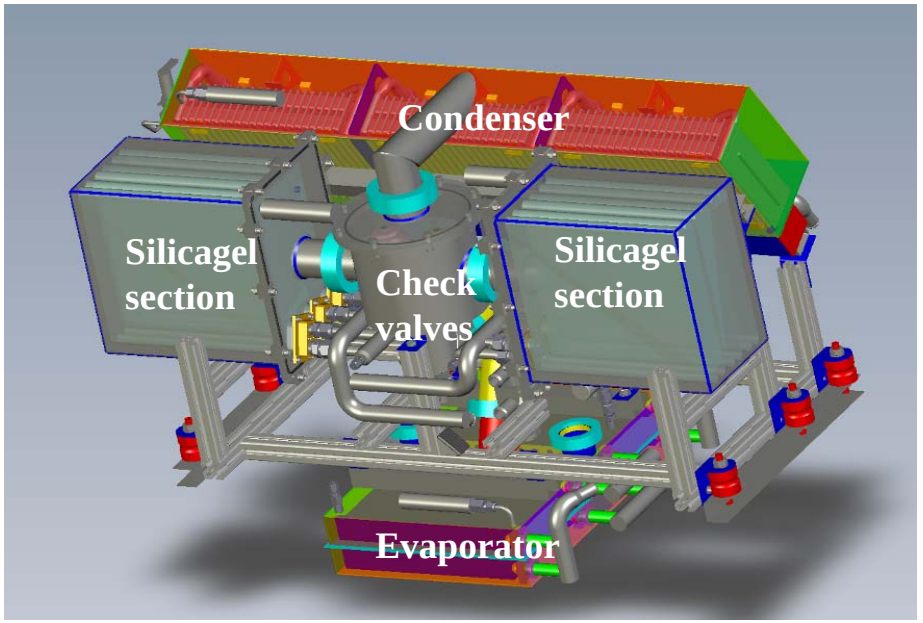
Cooling circuit for the reaction beds and SC heat rejection

Chilling to provide the cabin cooling usefull effect **(Useful effect)**

Target operating conditions of the adsorption chiller

	Temperature [°C]			Flow setpoint		Power
	min	setpoint	max	m^3/h	l/min	kW
Heating - supply - return	 5 5	 90 85	 95 90	0.72	12	4,0
Cooling (condenser incl.) - supply - return	 5 5	 33 40	 45 60	0.72	12	6,0
Chilling (evaporator) - supply - return	 5 5	 15 11.4	 45 45	0.48	8	2,0

The SCS Prototype development and laboratory tests@ECN



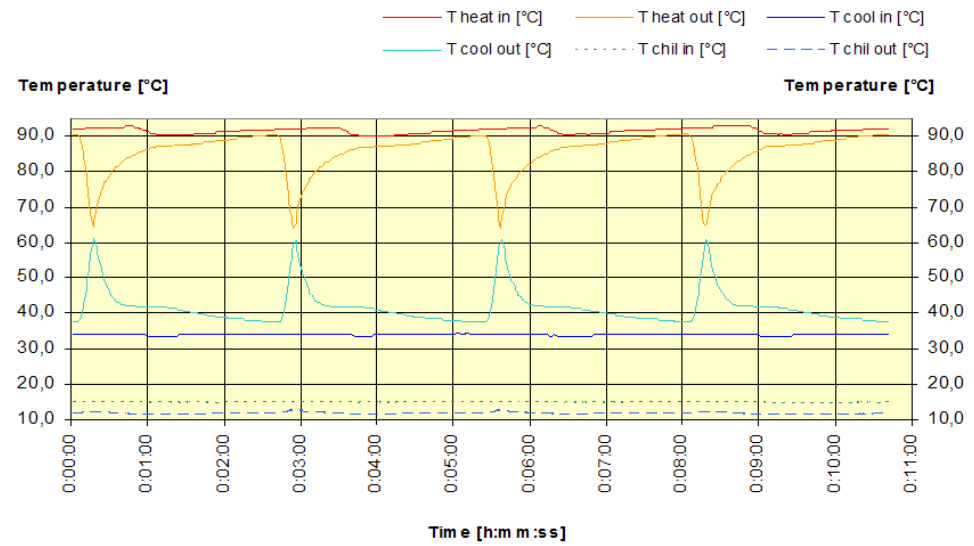
ECN team: R. de Boer, S. Smeding….

Characteristics

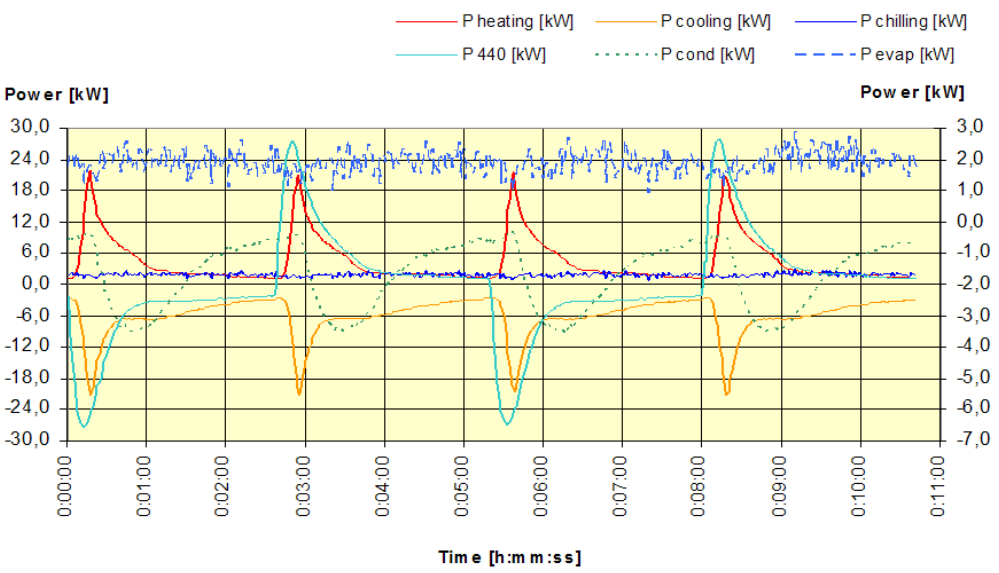
- Refrigerant: water
- Sorbent material: silica-gel
- HEXs+ pipes+valves: stainless steel + aluminum
- Silicagel Weight 9 kg
- Total Weight 85 kg

The SCS Laboratory tests results

Operating temperatures:



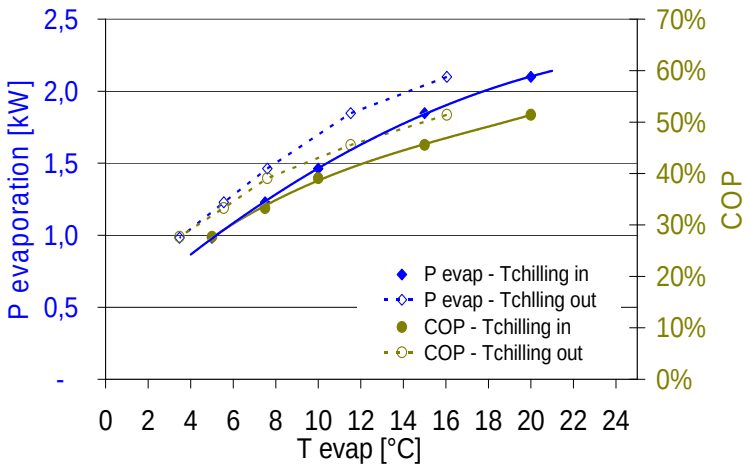
Thermal powers



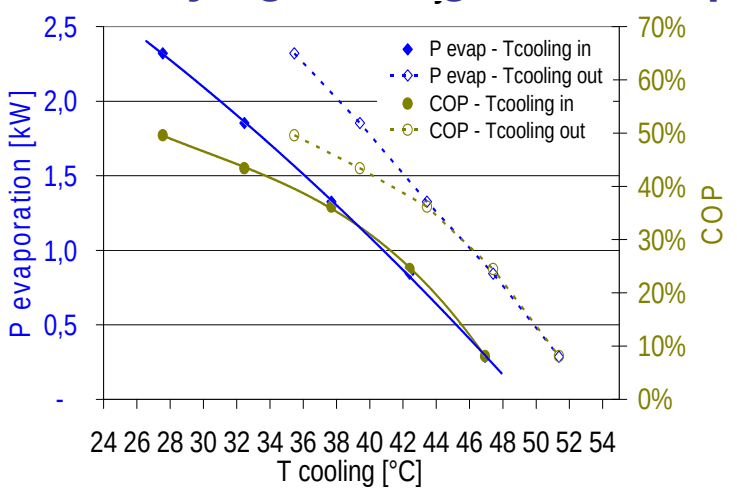
Depending on the varying operating temperatures, the system can deliver
2.5kW cooling power
COP 0.3 ÷0.5.

SCS Laboratoty tests results

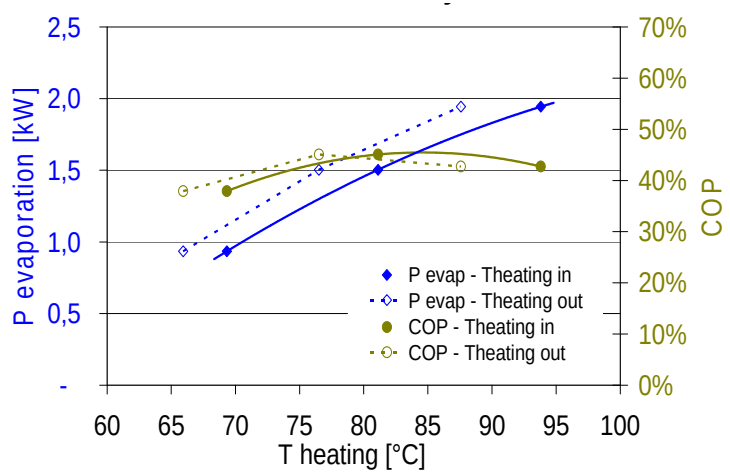
Varying chilled water temp.



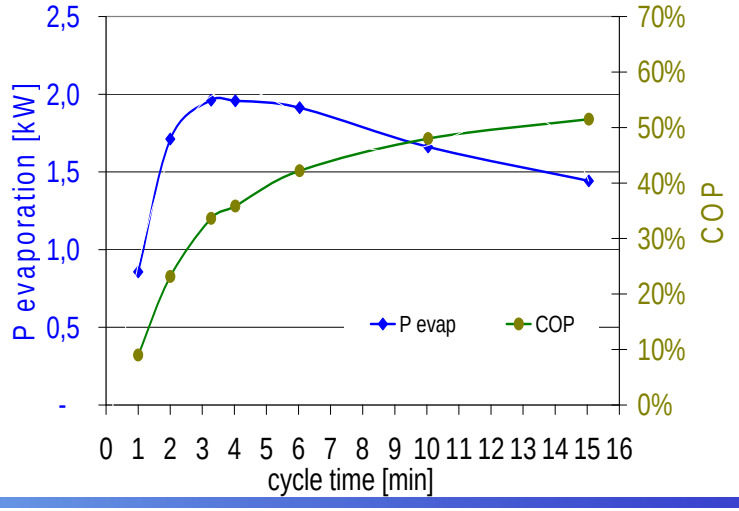
Varying cooling water temp.



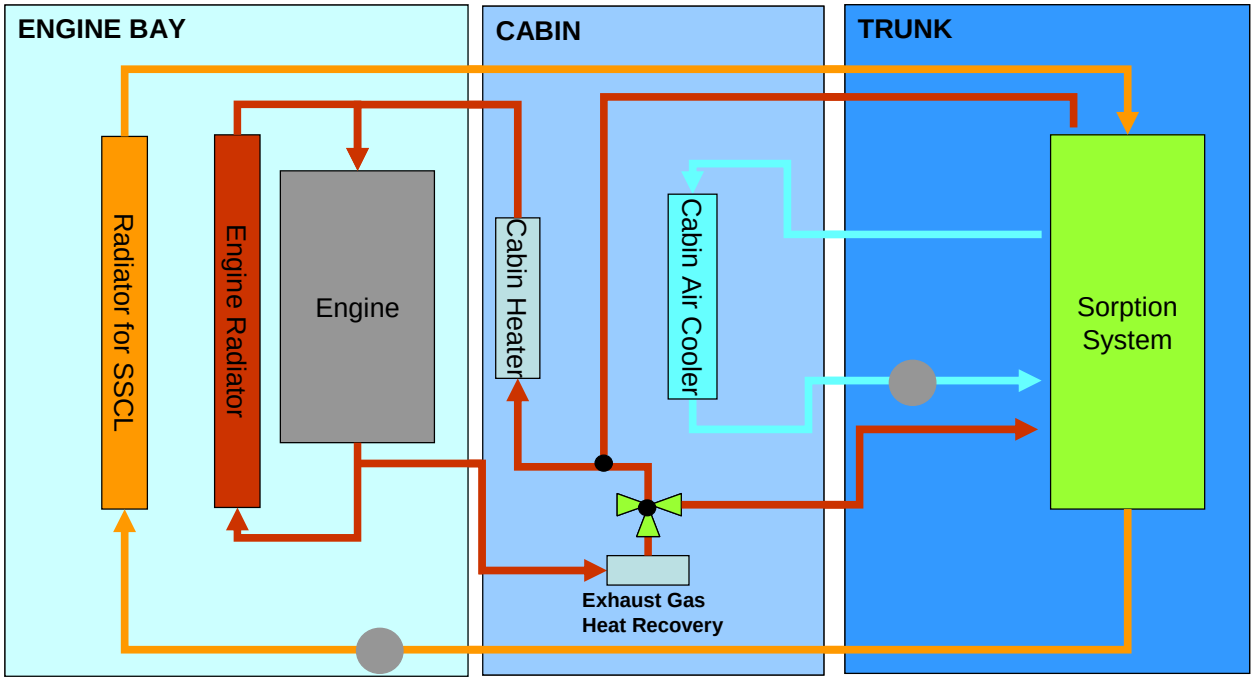
Varying heating water temp.



Varying cycle time.



Grande Punto A/C Overall System layout



On board system overall characterisitcs:

- ECN Sorption Cooling System
- Heating loop connected with the engine coolant + heat recovery from the exhaust gas
- Cooling loop connected with an additional radiator
- Chilling loop connected with the air cooler placed into the standard HVAC module

The Grande Punto installation

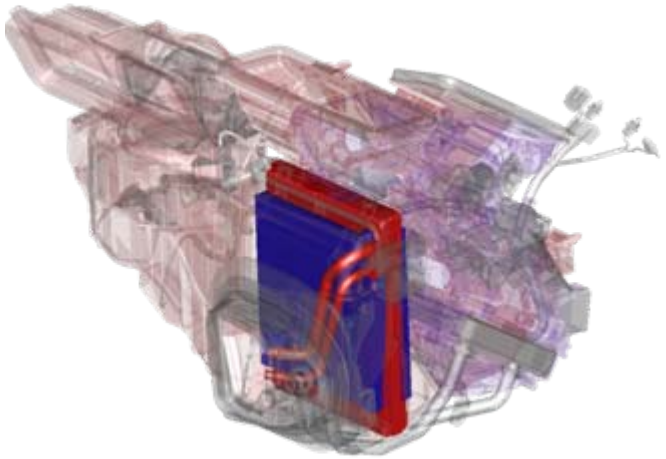
Sorption cooler

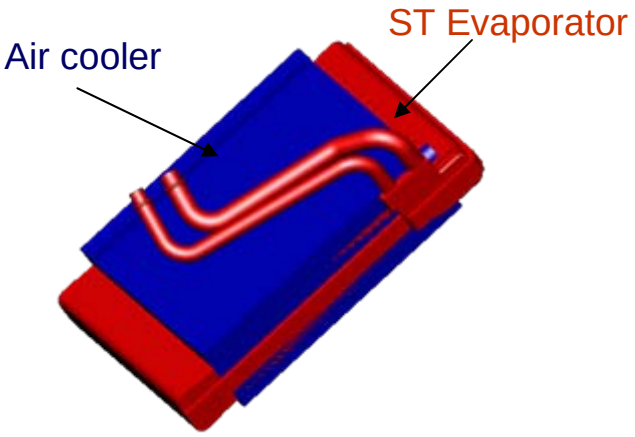
Air Cooler

Additional radiator

CRF Team: S.Mola, D.Magnetto, W.Ferraris,
L.Cancedda, A.Secondi, S.Sandri, F.Cavallaro

The Grande Punto installation

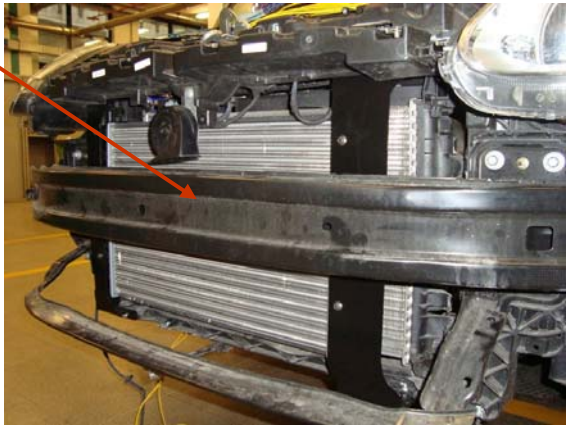




Air cooler installation in the HVAC module

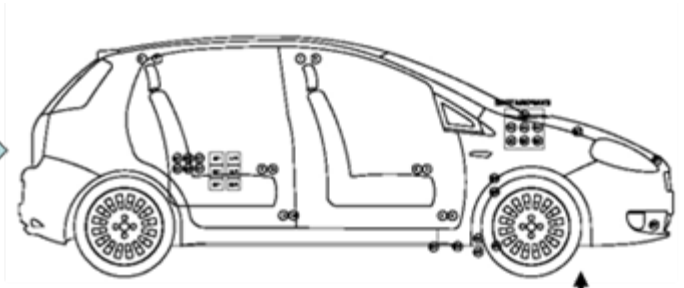
Sorption Cooling System

Heat rejection module



Control and acquisition system

ECN PLC
Sorption System control BOX



CAN C
(Sorption System information)

CAN B
(vehicle information)

NI Compact Field Point

CAN TRANSCIEVER

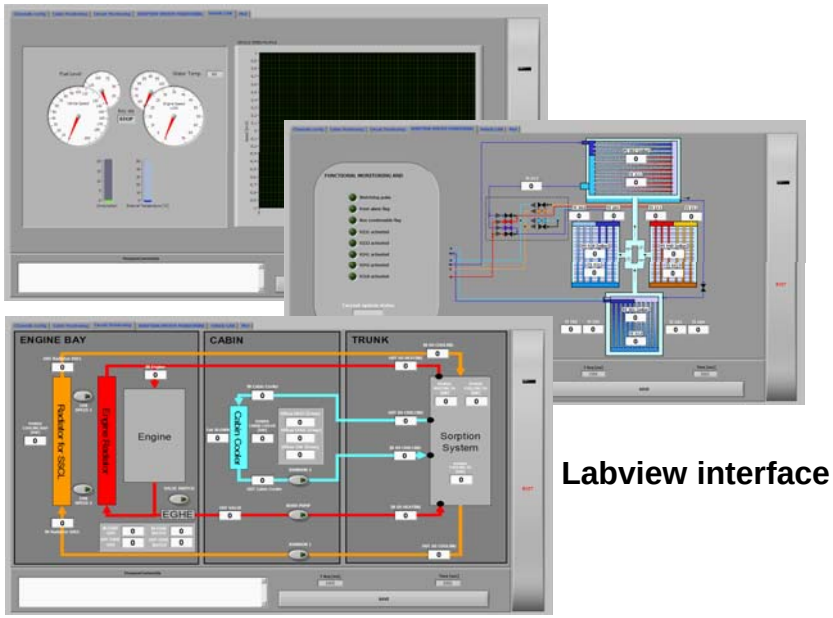
LabVIEW Software

LAN

To the sensors and actuators:

- Thermocouples
- Mass Flow Sensors
- Pumps ON/OFF
- Fan ON/OFF

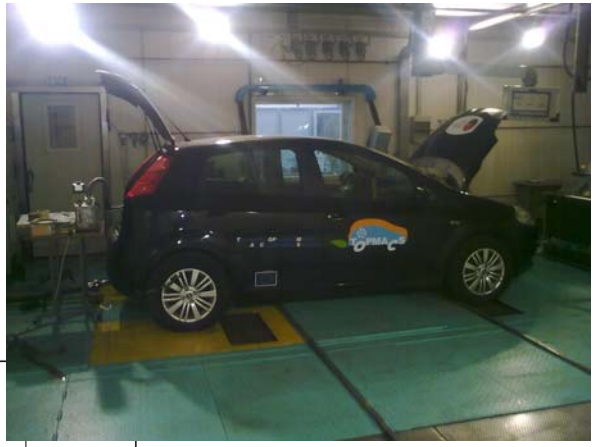
PCMCIA CAN Card

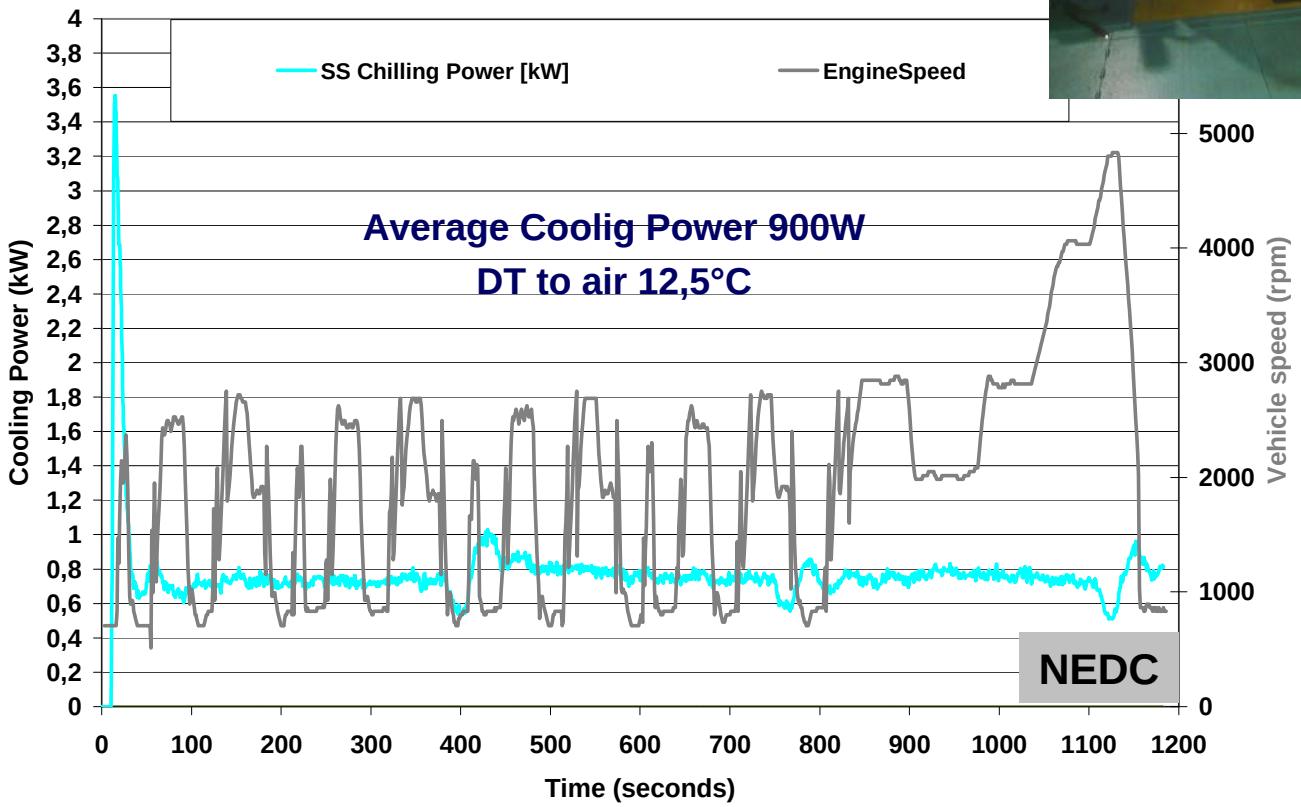


Labview interface

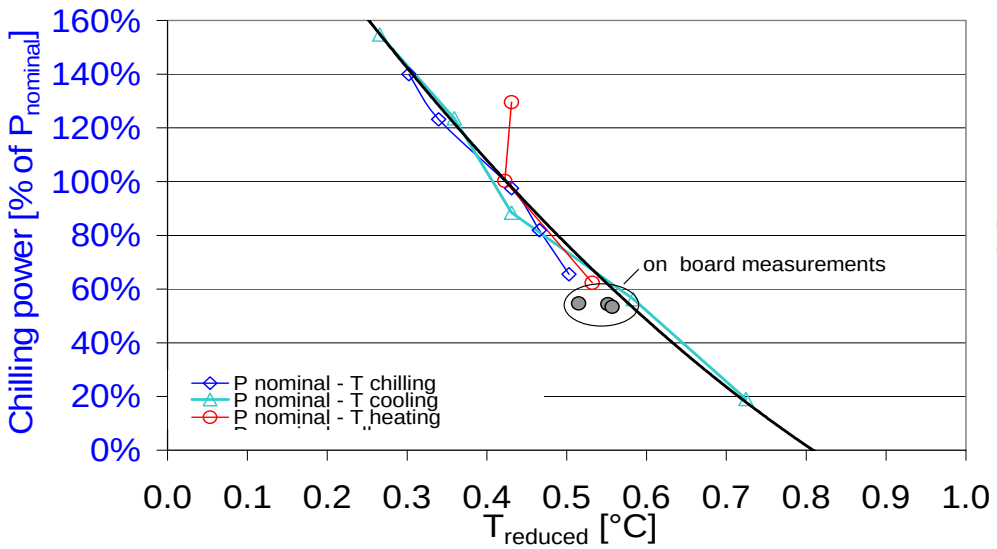
On board tests

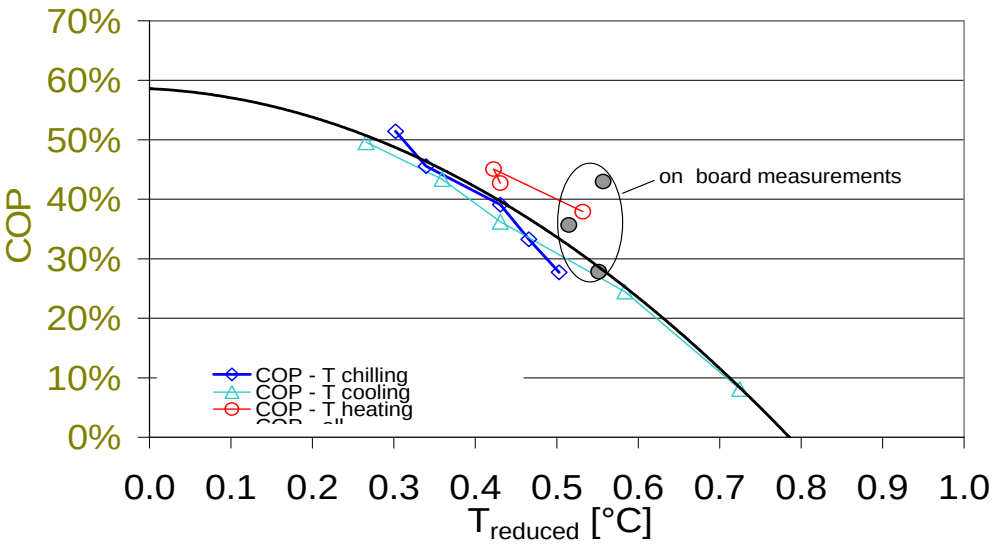
Test conditions
Ambient temperature 20°C & 28°C
Vehicle speed constant & NEDC





On board performance overview





On board performance comparable to bench scale tests

Conclusions

- World first passengers car with sorption cooler working on waste heat of engine is installed and working

- The present prototype peak cooling power is unable to provide the Standard Cool-Down Performance, but it is suitable to mantain the steady state conditions

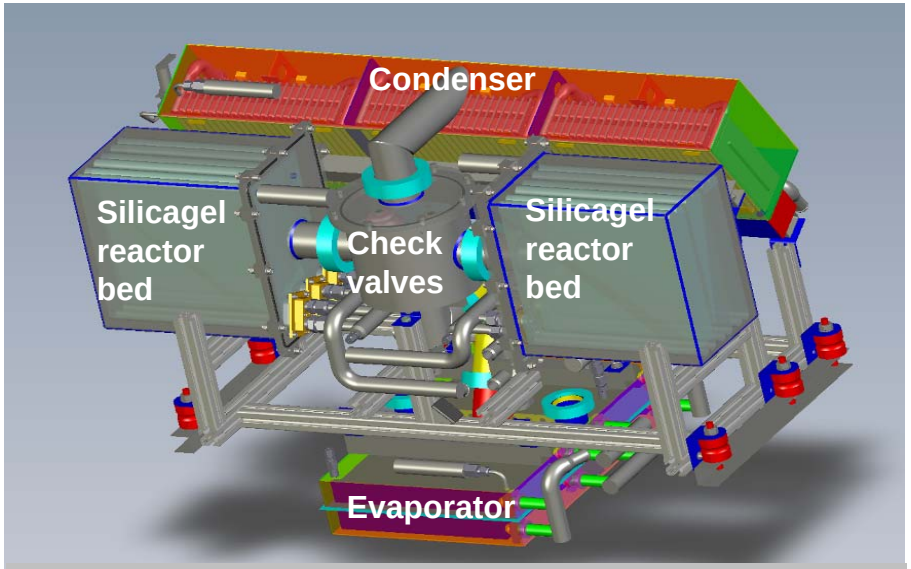
- Powering heat to the System with a small fuel burner could provide the car cabin preconditiong and allow the cooling system downsizing

- The system is able to mantain the cooling power for the time of the cycle (good option for stop&start powertrain)

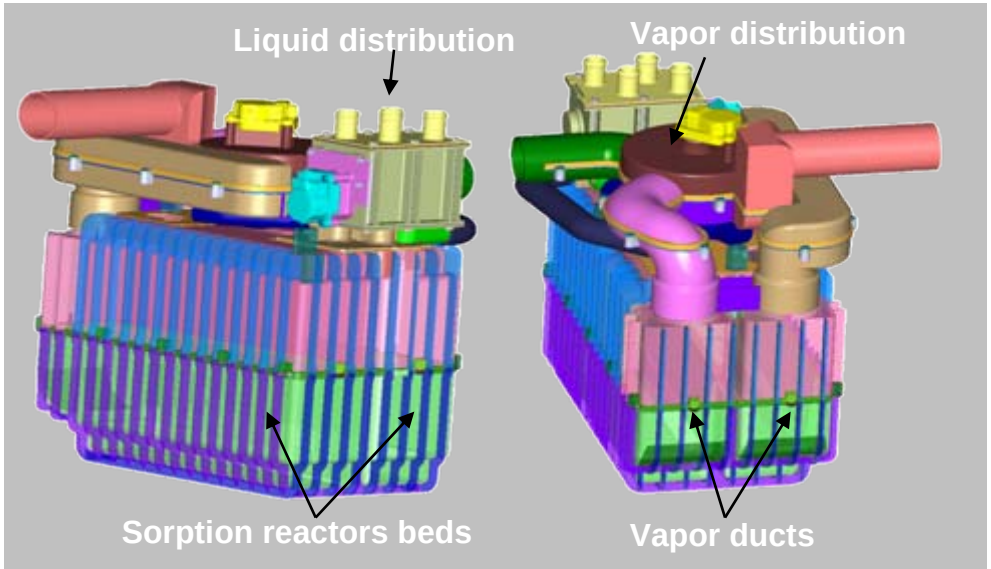
Conclusions

- The chosen switching control works properly in fluctuating flow and temperature conditions
- During dynamic driving conditions the system provide constant cooling power
- The additional radiator to reject the heat of the Sorption System has limited performance
- The cabin heat exchanger could perform better
- Design study indicates the possibility for location in the engine bay

Sorption cooling system reactors redesign



Current cooling system reactors design

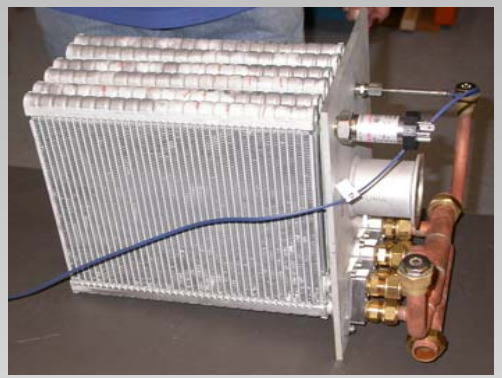


New cooling system reactors design

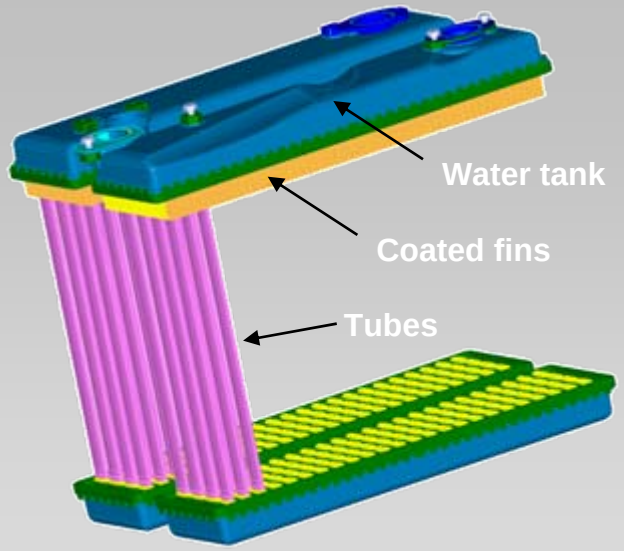
- Two reactors + Check valves
- Indirect condensation & evaporation
- Use of serial exchangers
- Stainless steel + aluminum
- Dimensions: 900 x 400 x 500
- Weight : 85 kg
- Silicagel : 9 kg

- Integrated sorption reactors, Vapor and liquid distribution valves
- Direct condensation & evaporation
- Molded plastic + aluminum
- Dimensions: 460 x 220 x 420
- Estimated weight : 15 kg
- Silicagel : 4 kg

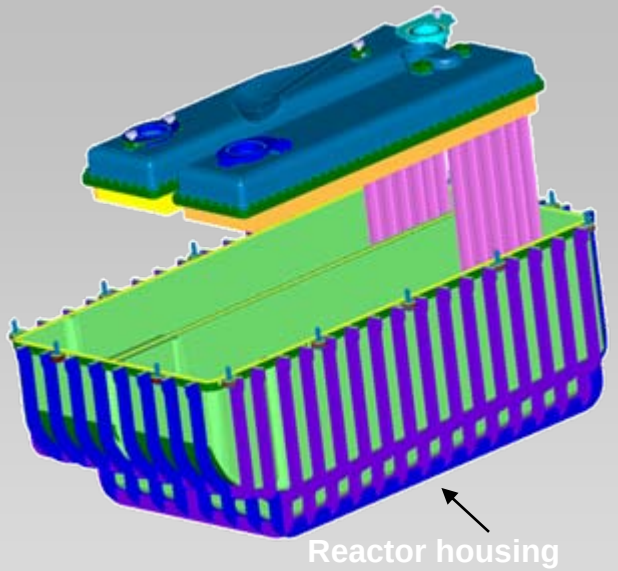
Sorption cooling system reactors redesign



Current design: 3 exchangers by sorption reactor bed



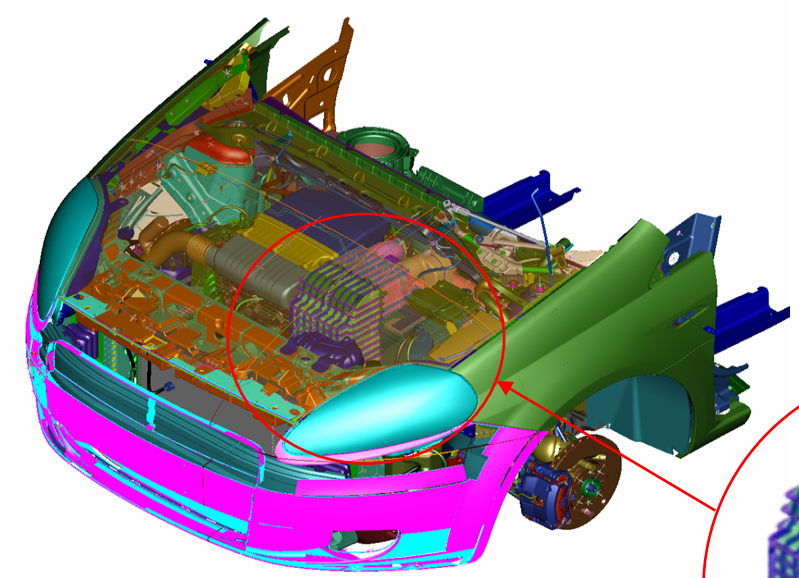
Mechanical tubes and fins exchangers

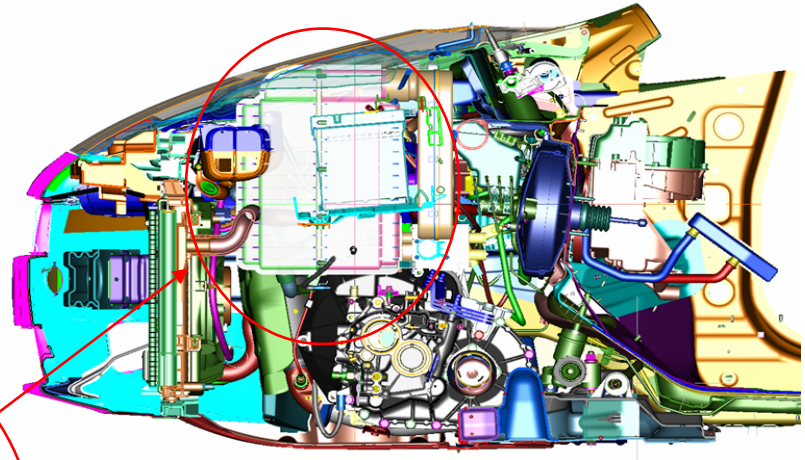


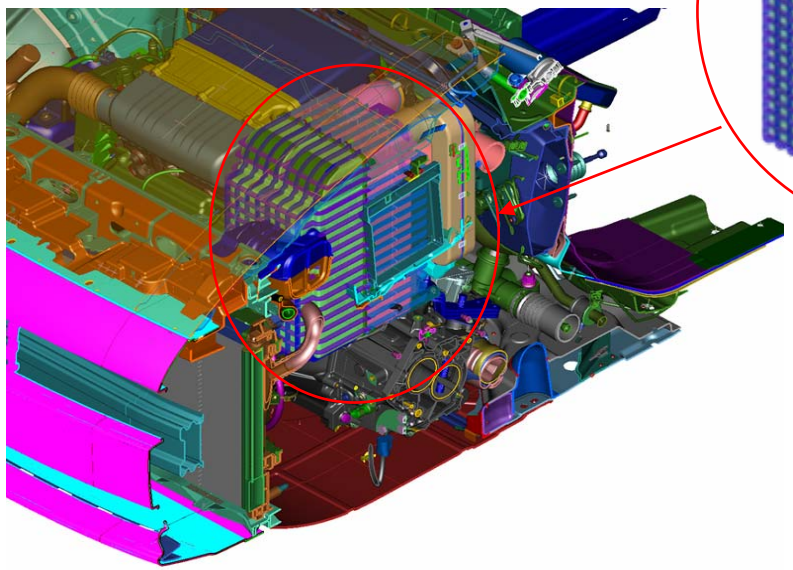
Assembly of exchangers and reactor bottom housing

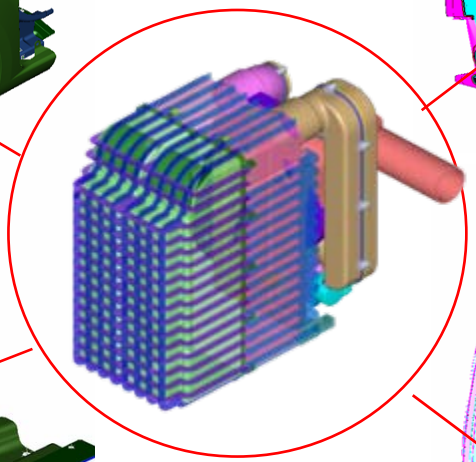
- **Sorption Reactor Design**
  - One mechanical tubes and fins exchanger by reactor bed
  - 4 rows tubes by exchanger
  - Fins coated with sorbent sheet material
  - Common molded plastic housing for the two reactor beds

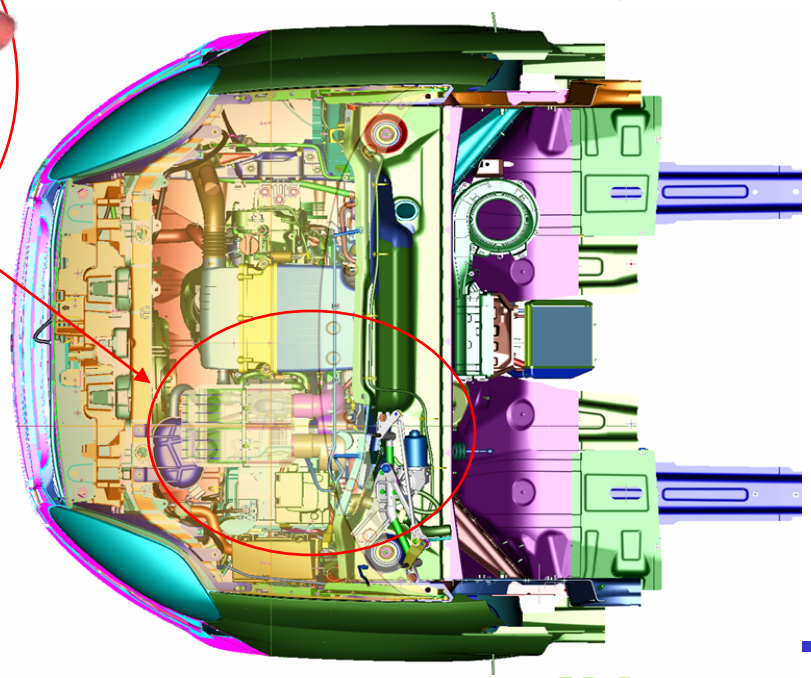
Fiat Punto vehicle integration



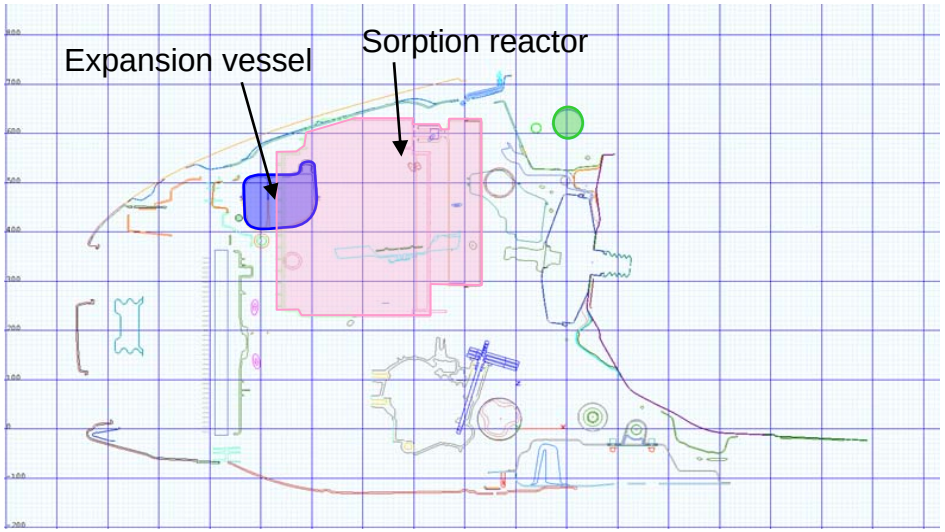


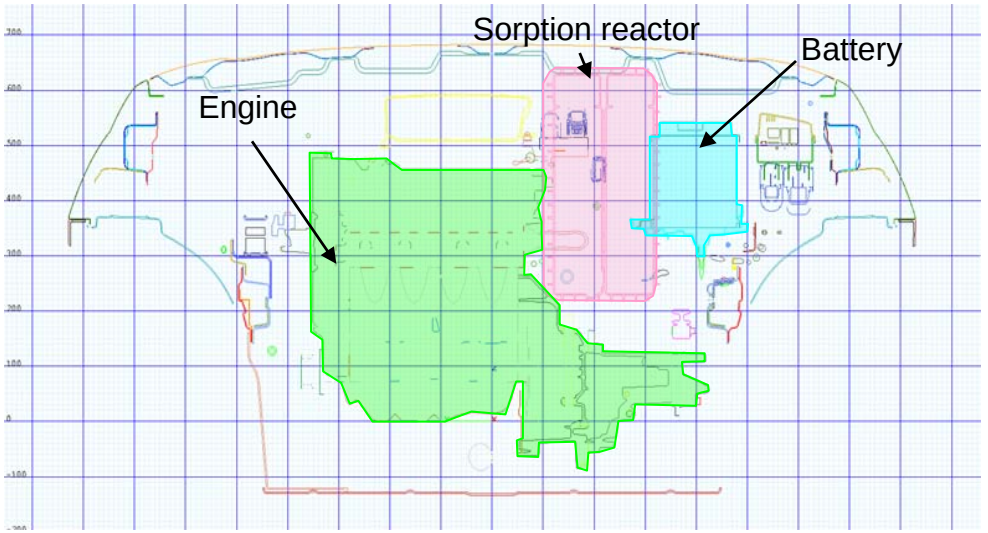






Fiat Punto vehicle integration summary





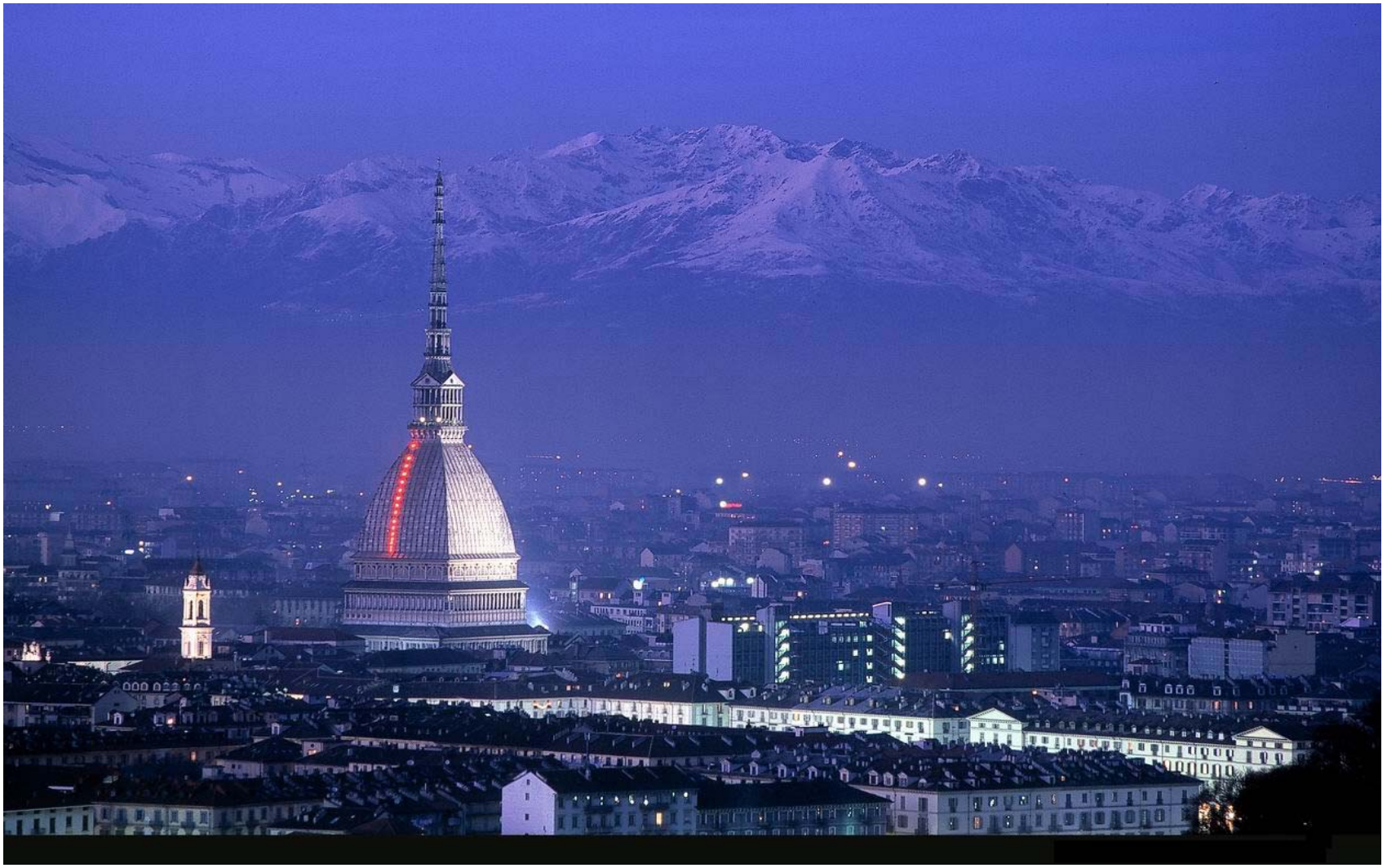
- Use of sorption cooling system with direct condensation and evaporation
- Implementation close to engine and dashboard
- No major interferences with vehicle structure and with engine
- Minor interferences with some components of the engines compartment (tubes, ducts…)
- Expansion vessel & battery need to be repositioned

Next steps

The development of adsorption cooling technology for MAC application requires further research and development effort.
These efforts should include:

- purposely developed heat exchanger
- further reduction of system volume and weight
- application of an air cooled condenser and a direct driven evaporator
- increased integration in the car/engine system is an important issue to improve performance, volume weight

Thanks for your attention



CENTRO RICERCHE FIAT

ECN Energy research Centre of the Netherlands

Valeo