



XERIC

INNOVATIVE CLIMATE-CONTROL SYSTEM TO EXTEND
RANGE OF ELECTRIC VEHICLES AND IMPROVE COMFORT

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XERIC project: Hybrid climate control system able to control separately temperature and humidity

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Partners

- AIN (Spain)
- EMH (Belgium)
- Fraunhofer Institute ITWM (Germany)
- Frigomar (Italy)
- GVS (Italy)
- Ticass Genoa (Italy)
- University of Duisburg-Essen (Germany)
- University of Genoa (Italy)
- VITO (Belgium)

What is XERIC?



- **EC-funded** project
- Start: June 1, **2015**
- End: May 31, **2018**
- **8** partners + **1** third party

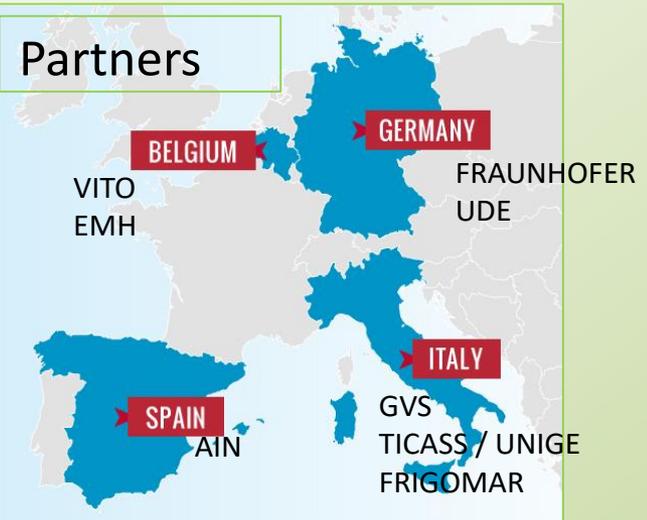


Aim

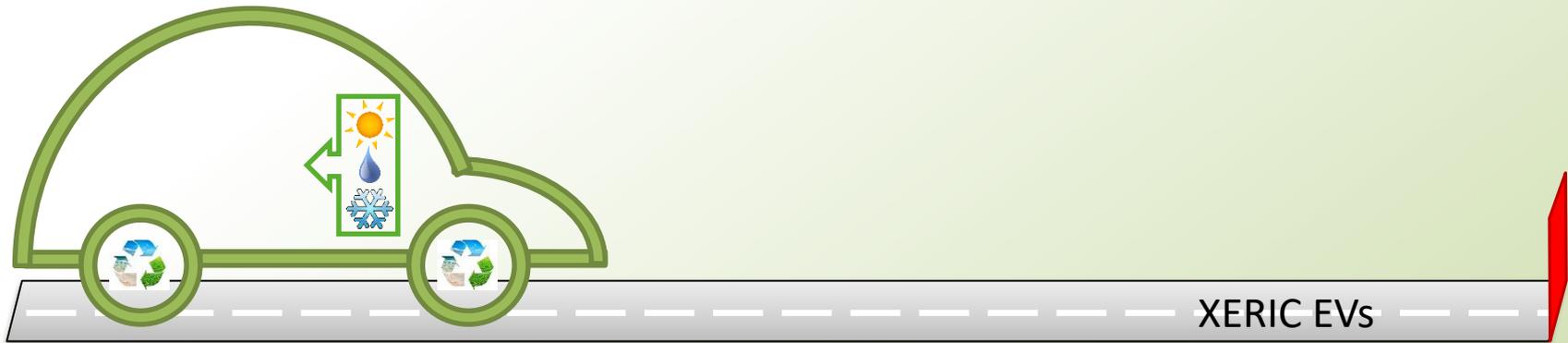
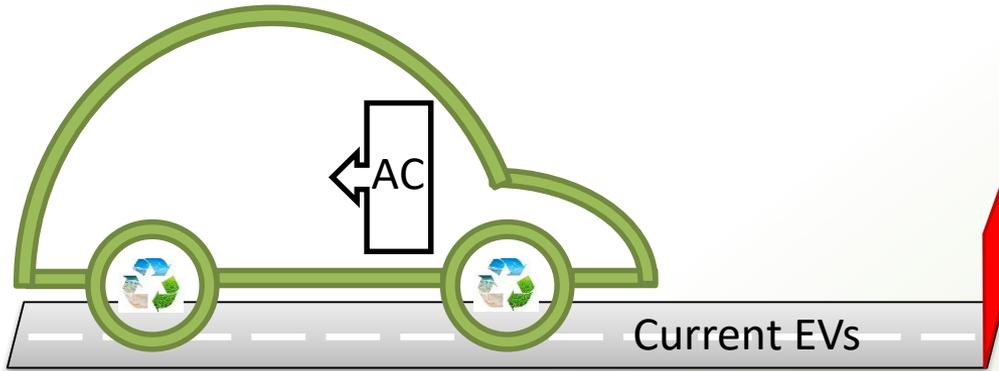
Developing an **energy-friendly climate-control system** for electric vehicles capable of reducing of at least 50% the energy used.

How?

By building a **novel 3F – CMC contactor (gas – liquid)**

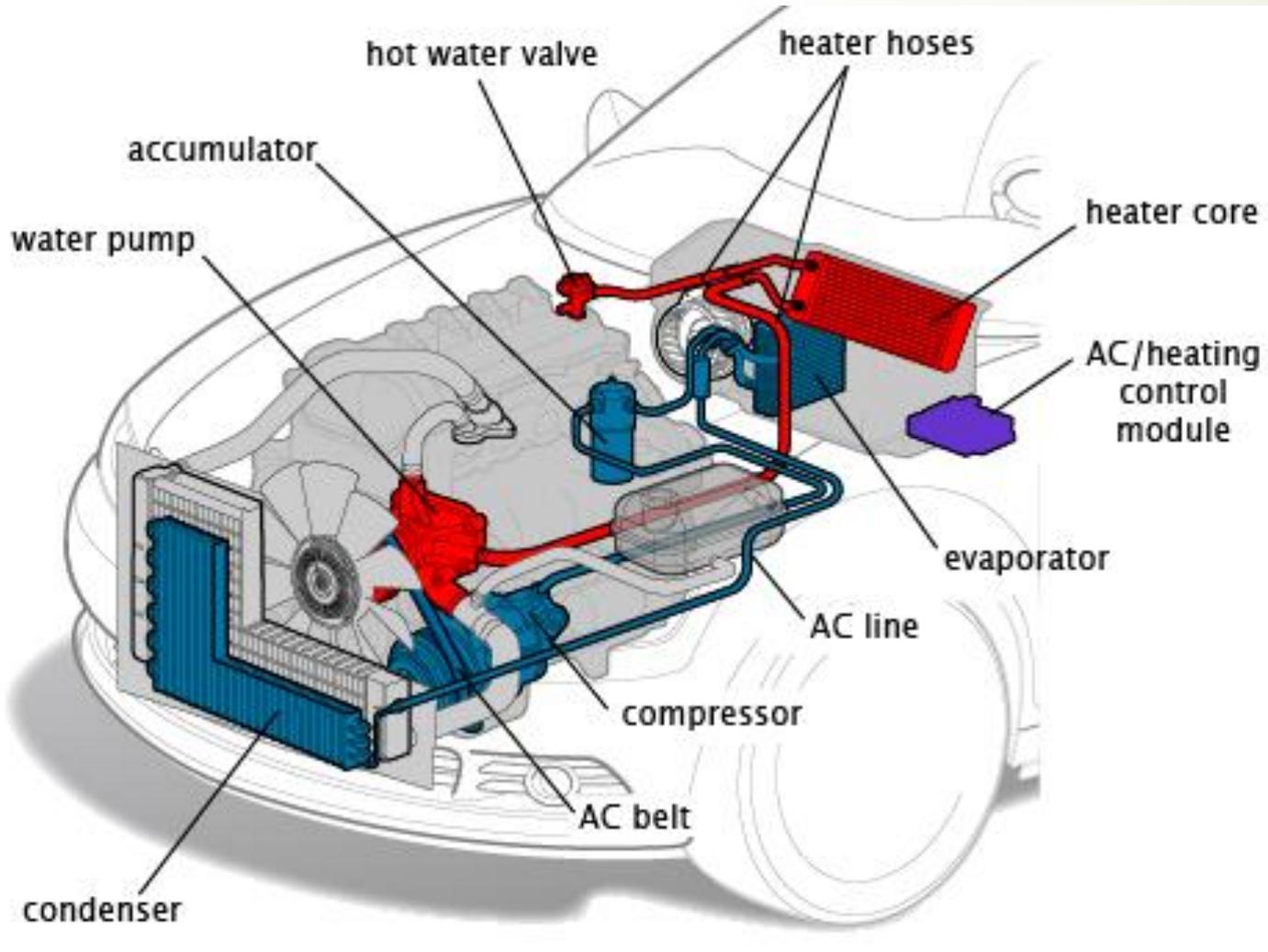


www.xeric.eu



What makes this an achievable result?

Air-Conditioning System in a car/boat: Vapour Compression Cycle (VCC)



Hybrid Air Conditioning (HAC) systems

An AC system where a VCC is coupled with a desiccant liquid cycle (Hybrid AC system) could be interesting for energy saving purpose?

Absolutely yes! Because HAC are far more energy efficient consuming 30-40% less than traditional systems.

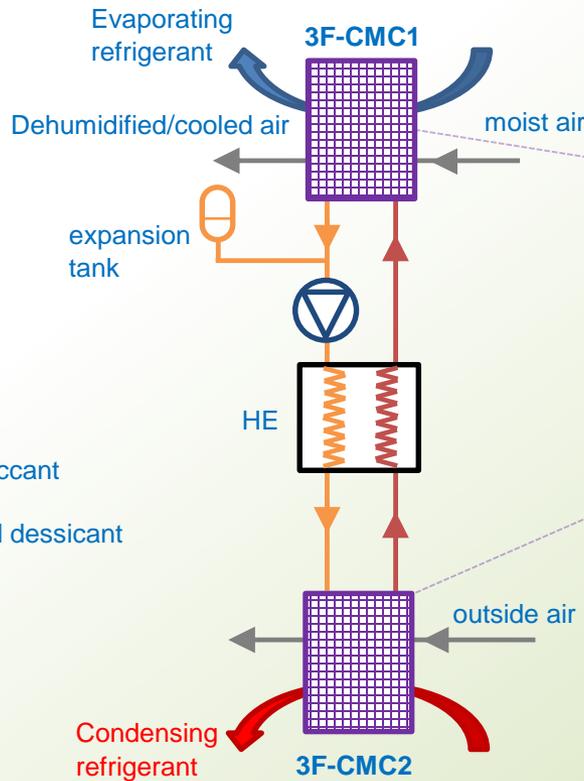
Compared to traditional AC system, they can handle separately air-dehumidification and air-cooling, thus allowing:

- ✓ higher VCC evaporation temperature;
- ✓ lower VCC condensation temperature.

XERIC in a nutshell

The XERIC system adds to the traditional VCC a liquid desiccant (LiCl aqueous solution) cycle with two innovative membrane contactors, called 3F-CMCs. The use of semi-permeable membrane allows the adoption of liquid desiccant.

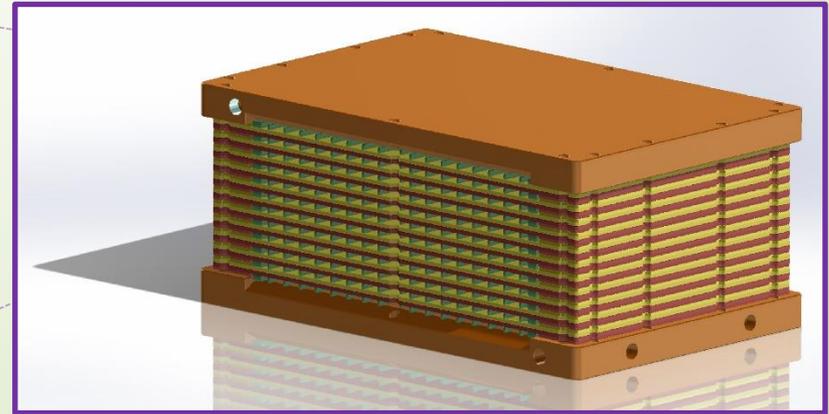
LIQUID DESSICCANT CYCLE



3F-CMC1 dehumidifies and partially cools the process air.

3F-CMC2 re-concentrates the weak solution.

The economizer HE reduces parasitic heat transfer.



Main advantages:

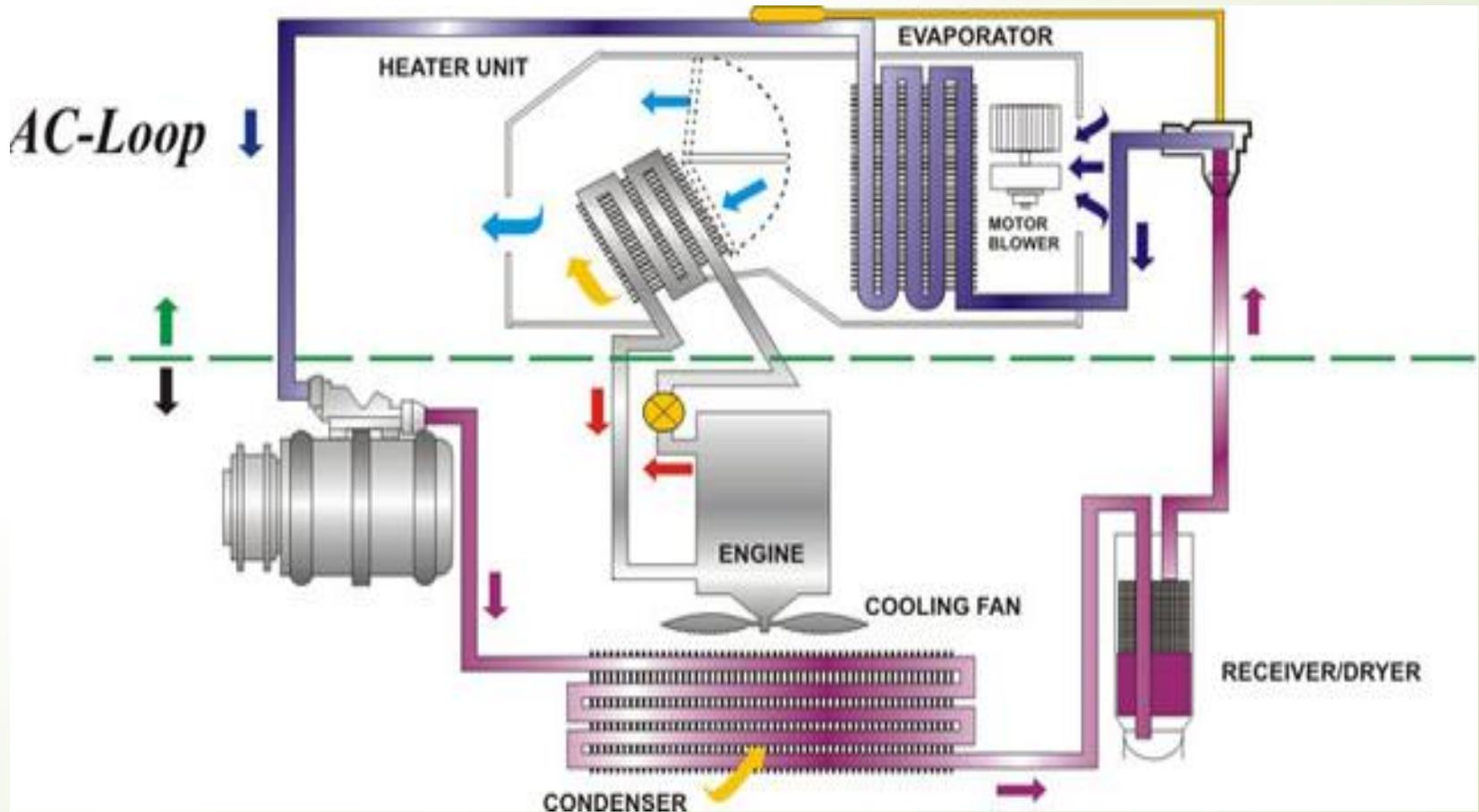
- the heat exchange between the desiccant and the refrigerant allows the desiccant temperature to be controlled throughout all the 3F-CMC;
- high efficiency and compactness (*i.e.*, increase in sensible and latent heat loads that can be faced).

Why XERIC system is so attractive ?

Since it allows:

- separate air-dehumidification and air-cooling processes (no need for under-cooling);
- development of tailored systems (thanks to the flexibility given by modularity);
- no carryover of desiccant droplets into the process air (thanks to the semi-permeable membrane).

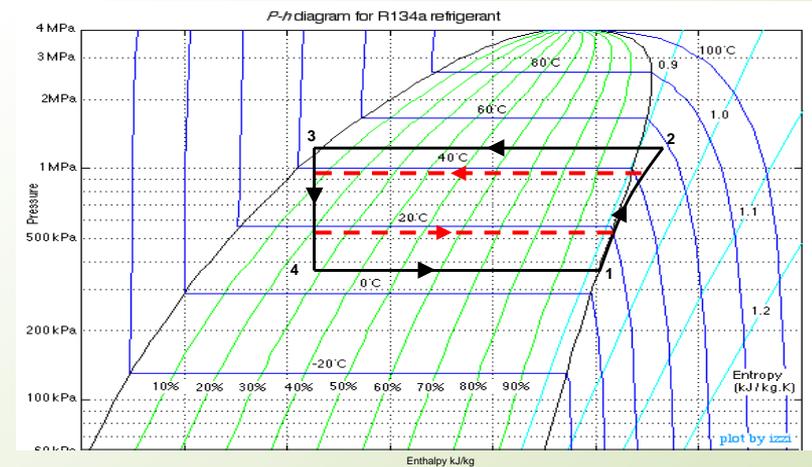
Traditional Air-Conditioning (AC) based on a Vapour Compression Cycle (VCC)



Summarizing

❑ Summer and intermediate seasons:

XERIC system allows energy savings because the VCC cycle operates at higher evaporation temperature and lower condensation temperature.



❑ Raining days:

XERIC system allows dehumidification only, with a small cooling effect.

❑ Winter:

XERIC system works as a heat pump; the heating effect is more efficient in comparison to an electrical resistance and, as a consequence, passengers comfort can be obtained with less energy requirement.

Physical and mechanical constraints

- addressing the needed heat / mass fluxes preserving a reasonable compactness;
- stresses due to pressure / temperature gradients in working conditions;
- minimum allowed thickness of the components;
 - needed mechanical stiffness;
 - proper sealing to avoid leakages;
 -

Manufacturing issues

- pressure / temperature stresses induced on the frame during membrane welding;
- pressure stresses on the components during assembling procedures;
- pressure / temperature stresses during working conditions;
-

Physical aspects: where to focus on

$$\sigma_v' = \frac{\Psi_A - \Psi_B}{z_A + z_m + z_B} \left[\frac{\text{kg}}{\text{m}^2 \text{ s}} \right]$$

Ψ_A, Ψ_B mass transfer driving potentials

z_A, z_m, z_B mass transfer resistances (air-side, membrane, liquid-side)

3F-CMC compactness is **directly** and **strongly** dependent on z_A and z_m

z_A is to be reduced by increasing the air side heat transfer coefficient

z_m is to be reduced by reducing the mass transfer resistance of the membrane

We worked in different areas which require different competences. This transdisciplinary approach of XERIC allows the results to be widen to a large number of applications.

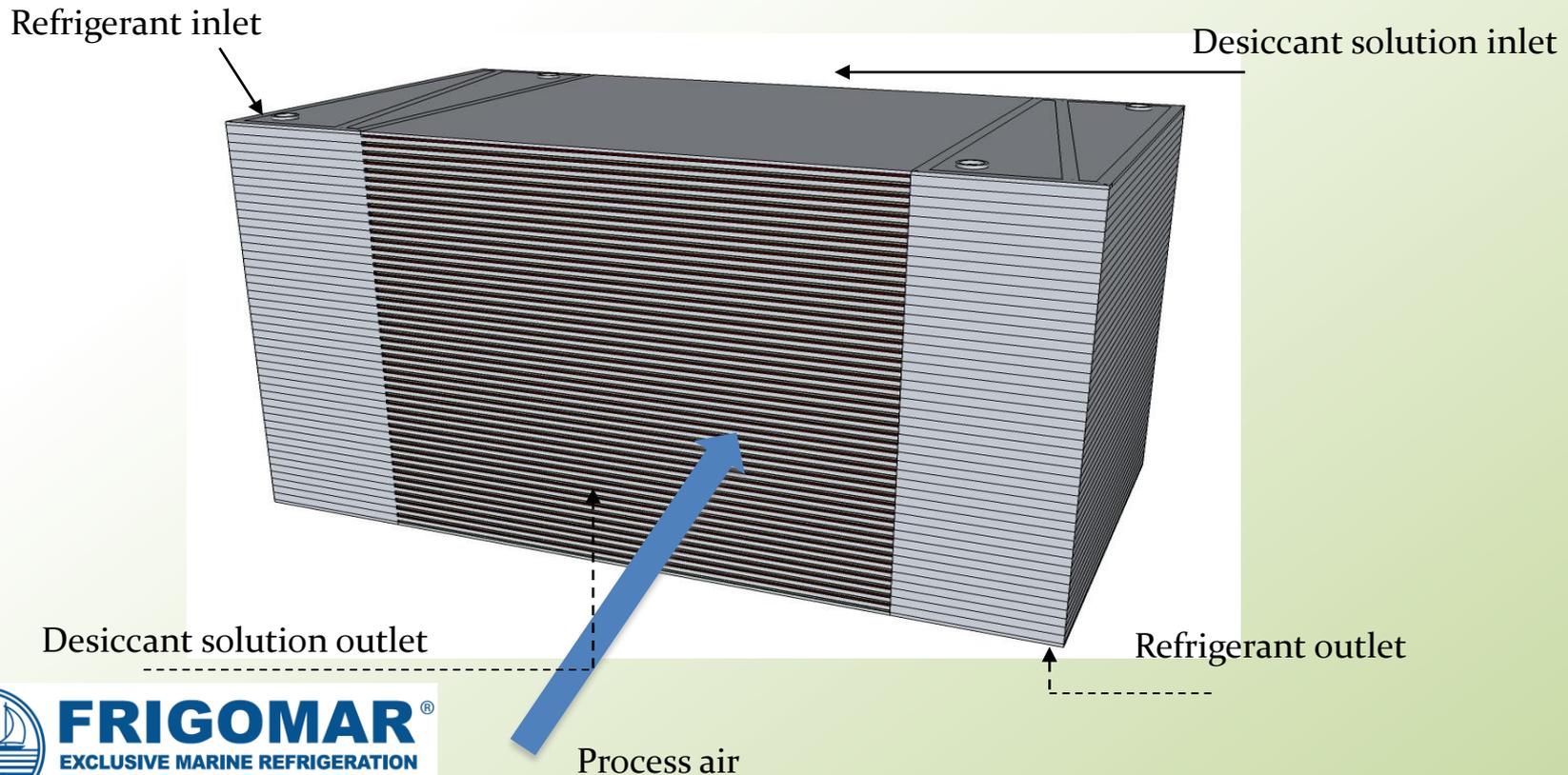
Novel membrane contactor Combined Membrane Contactor (CMC³)

A new three-fluids (air, desiccant solution, refrigerant) membrane contactor (*i.e.*, an exchanger of vapor and heat) is proposed. Advantages:

- heat exchange between the desiccant and the refrigerant allows the desiccant temperature to be controlled throughout the CMC³;
- high efficiency and compactness (*i.e.*, increase of sensible and latent heat loads that can be faced);
- noteworthy simplification of hybrid AC systems.

The new CMC³ generation

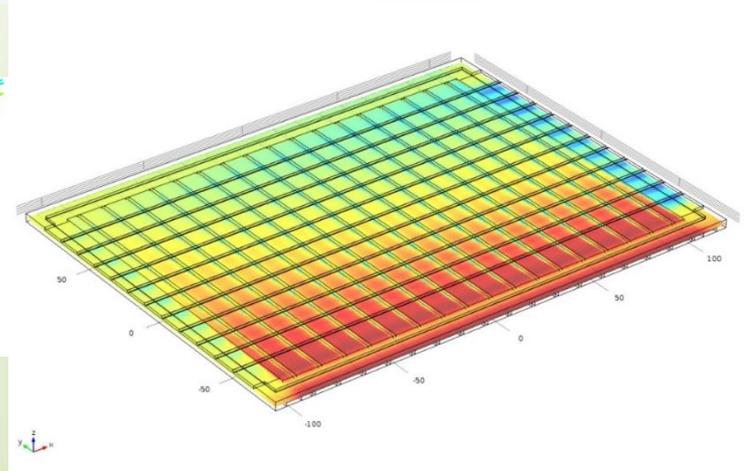
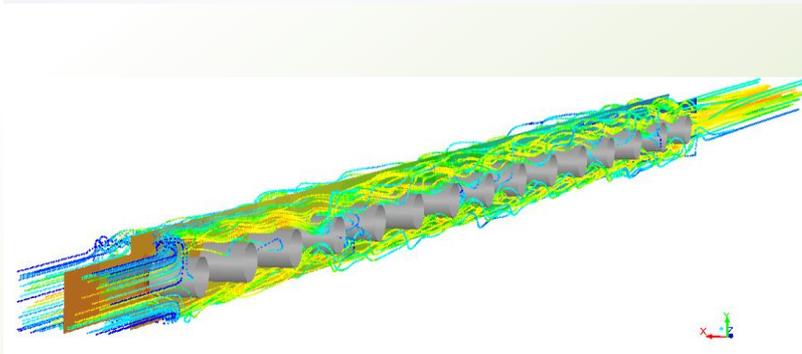
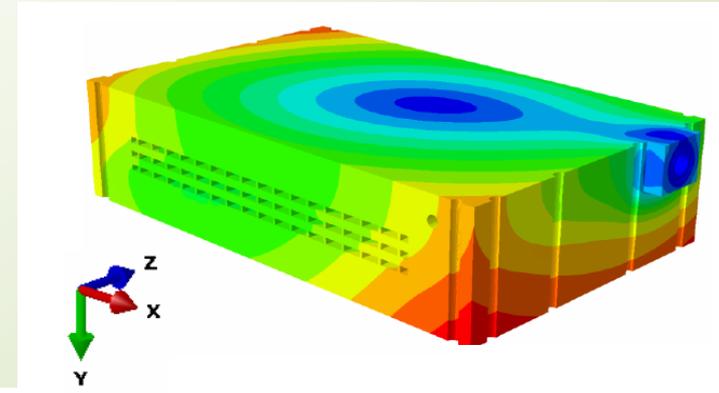
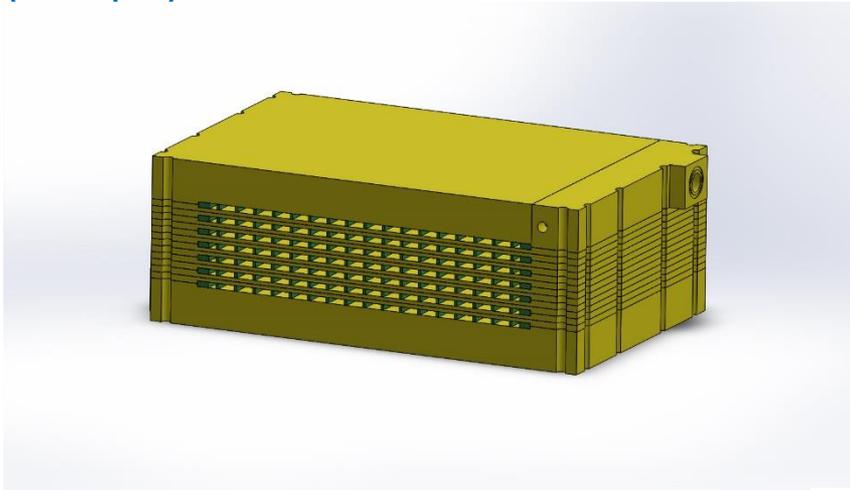
The new CMC³ is compact, light and has high energy efficiency with no corrosion problem with common desiccants (e.g., LiCl, CaCl₂).



The core of XERIC: 3F-CMC

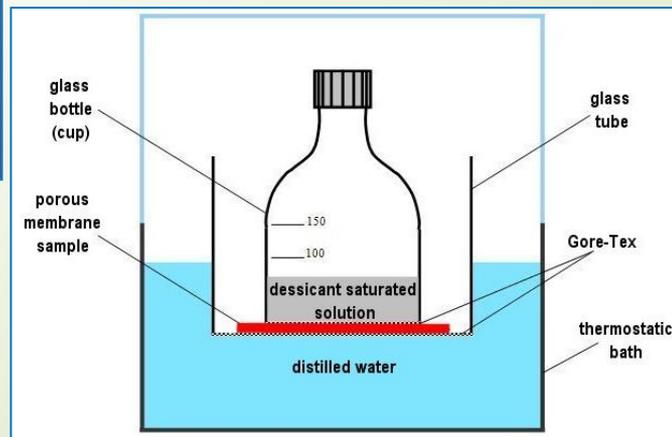
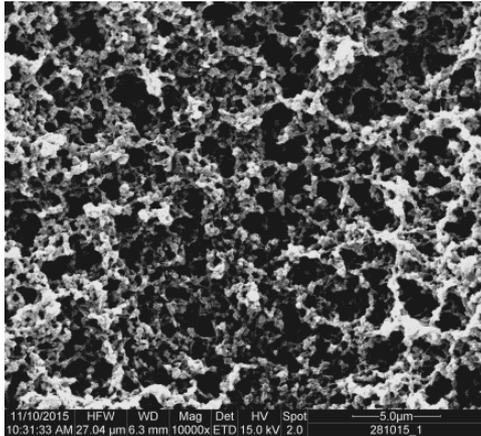
At design stage...

...supported by CFD (Fluent, COMSOL Multiphysics) and by mechanical stability simulations (Abaqus)



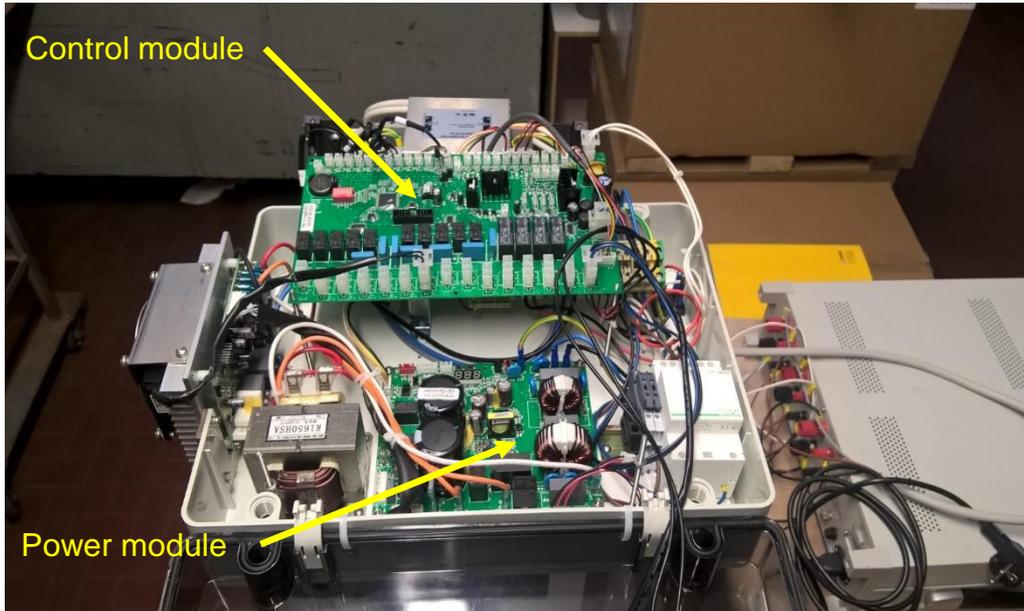
PVDF membrane development

Process development, tests, measurements



Characteristics
average pore size
pore size distribution
maximum thickness
surface tension
surface property
water vapour transmission resistance
stability in contact with desiccant
thermal resistance
chemical resistance

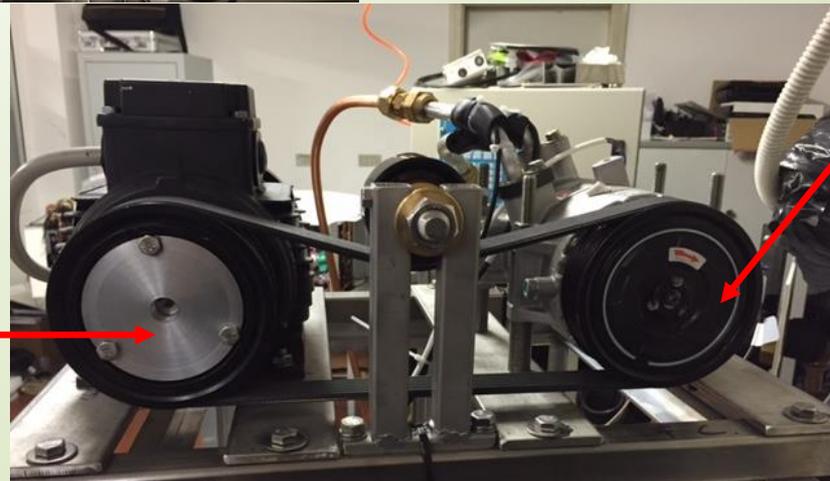
Development & preparation of electronic control system including compressor and electronic expansion valve



Equipment setup in the lab for testing purpose only

Compressor

BLDC Electric Motor

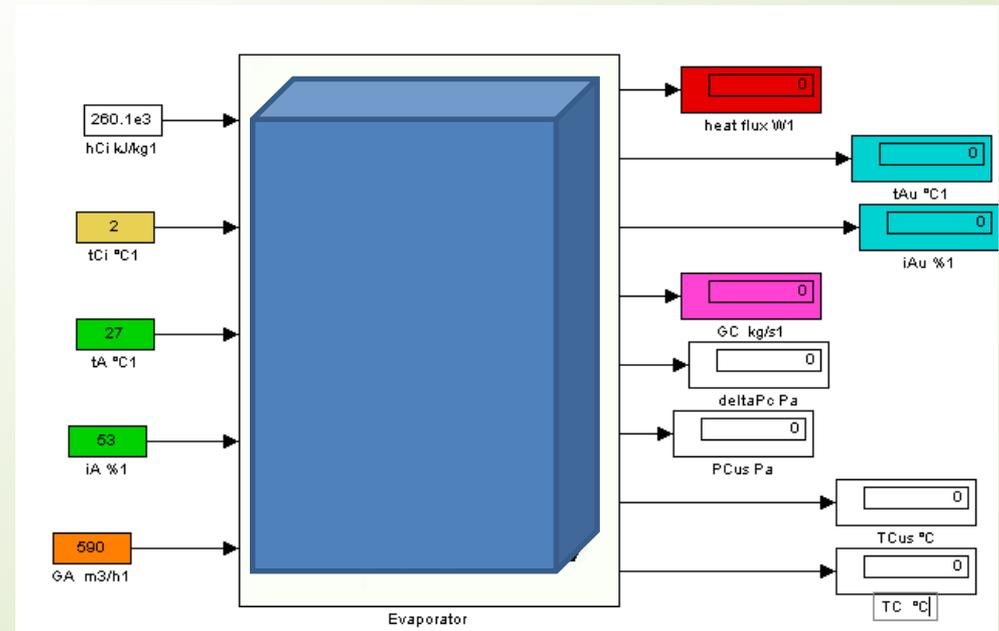


Modeling the several components of the XERIC system in Matlab/Simulink environment

AC evaporator



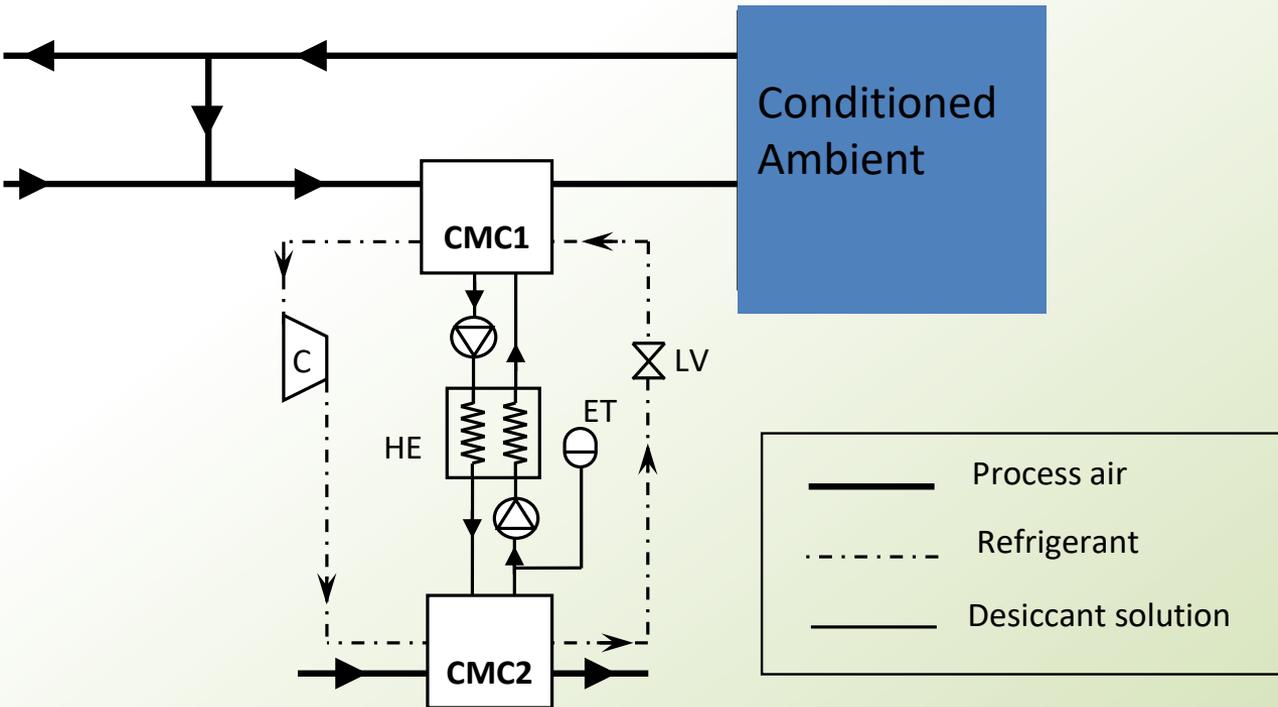
Simulink evaporator block



Then, all the Simulink blocks will be connected to evaluate the performance of the XERIC system.

Air dehumidification system with two CMCs

CMC1 dehumidifies and partially cools process air.
 CMC2 re-concentrates the weak solution.
 The economizer HE reduces parasitic heat transfer.



Summer and intermediate seasons air cooling/dehumidifying

In summer/intermediate seasons, the proposed hybrid AC system allows energy savings because in comparison to a traditional AC the VCC cycle can operate with :

- a higher evaporation temperature;
- a lower condensation temperature.

Computer simulations with outdoor air at 30°C and 60% RH indicate that such a system might **save up to 40 %** of the electric energy needed to maintain indoor comfort conditions (i.e., $25\text{-}26^{\circ}\text{C}$ and 40-50 % RH) in comparison with the energy needed by a traditional AC system.

Winter heating

In winter, wasted heat for passenger compartment is not available in EVs and the use of an electrical heater considerably increases the energy consumption.

The present system, by reversing the direction of the fluid in the VCC, allows the passenger compartment to be heated by using the heat output of the VCC condenser.

In this way, the heating effect is certainly more efficient in comparison to an electrical resistance and, as a consequence, passengers comfort can be obtained with less energy requirement.



Thank You for your kind attention

