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

European Commission

3rd XERIC WORKSHOP

PS4-Application of Xeric technology to other potential fields

Carlo Isetti, TICASS - Innovative Technologies for Environmental Control and Sustainable Development

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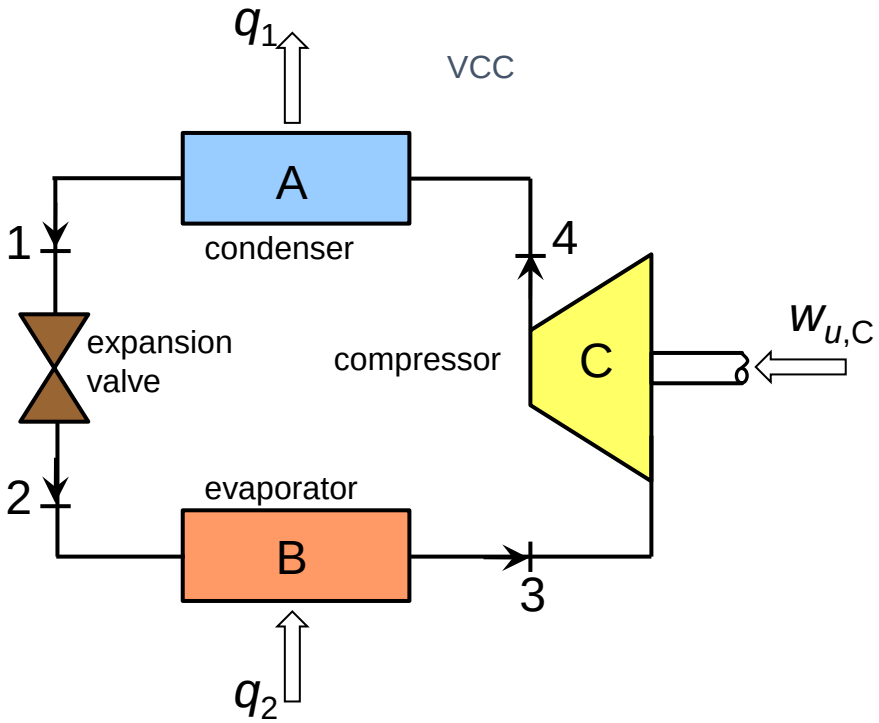
Xeric Project (Horizon 2020 Call)

The Xeric project aims to increase the autonomy of Battery Electric Vehicles (BEV) by reducing more than 30 % the energy used for air conditioning in summer conditions and more than 50 % for the climate control all over the year maintaining indoor comfort conditions in all weather conditions. The normal AC cycle and direct electric heating are considered for comparison.

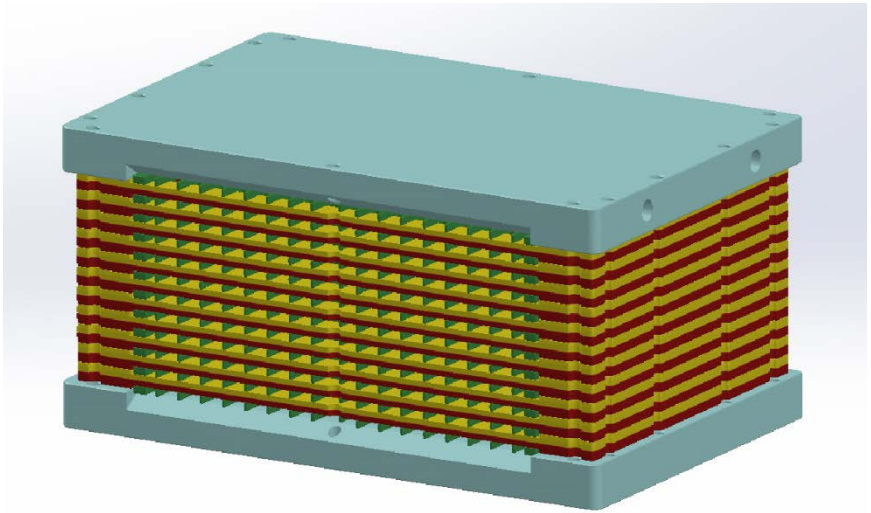


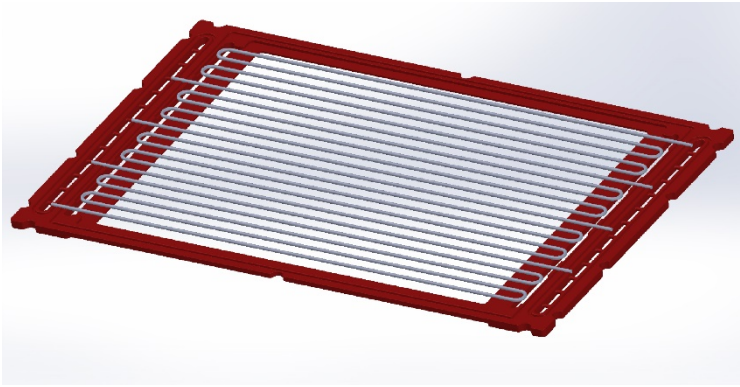
XERIC upgrades the traditional Vapour Compression Cycle (VCC) with a liquid desiccant cycle to get an hybrid air handling system provided with innovative membrane contactors (3F-CMCs) components. The desiccant is a salt aqueous solution ($LiCl/CaCl_2$).

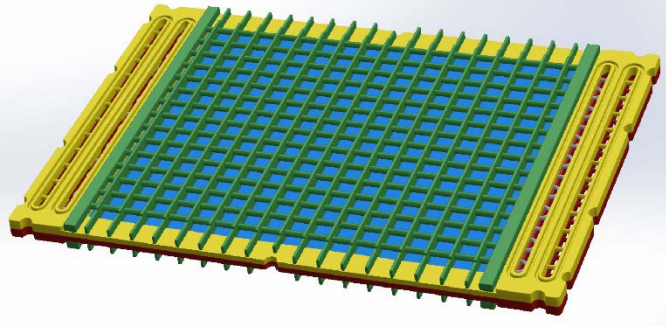
The 3F-CMC component

The innovative 3F-CMC component which is the core of the XERIC system is simultaneously crossed by the air, by the liquid desiccant and by the refrigerant to control the desiccant temperature. The internal cooling/heating action of the VCC refrigerant maintains through on the whole 3F-CMC an higher gradient of the mass transfer potential improving its efficiency.

Sensible/latent heat transfers take place through a hydrophobic membrane which is permeable only to the vapour phase, while the refrigerant undergoes phase changes.

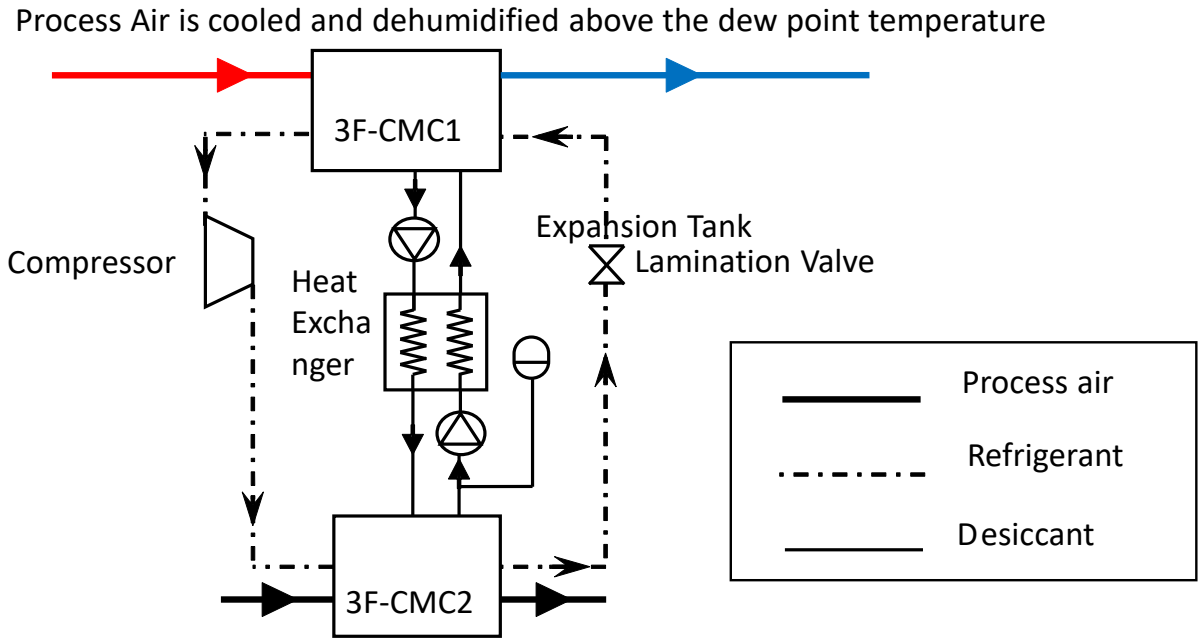


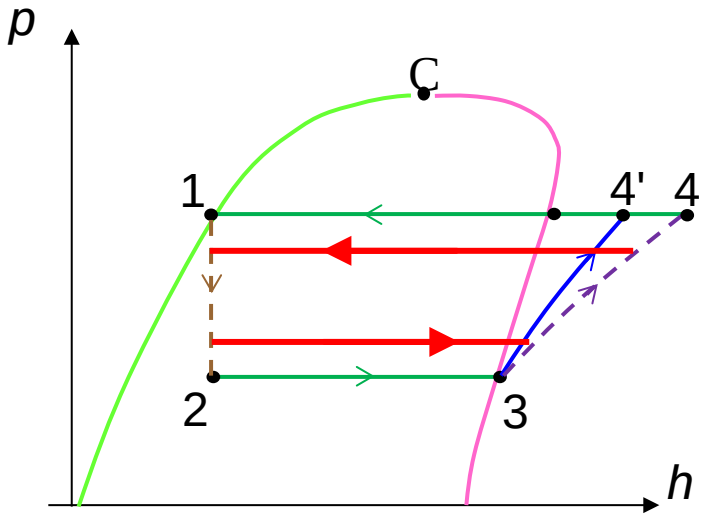




Hybrid cycle with 3F-CMCs

Working principle: 3F-CMC1 dehumidifies and partially cools processed air while the 3F-CMC2 re-concentrates the weak solution. The economizer Heat Exchanger reduces parasitic heat transfer.

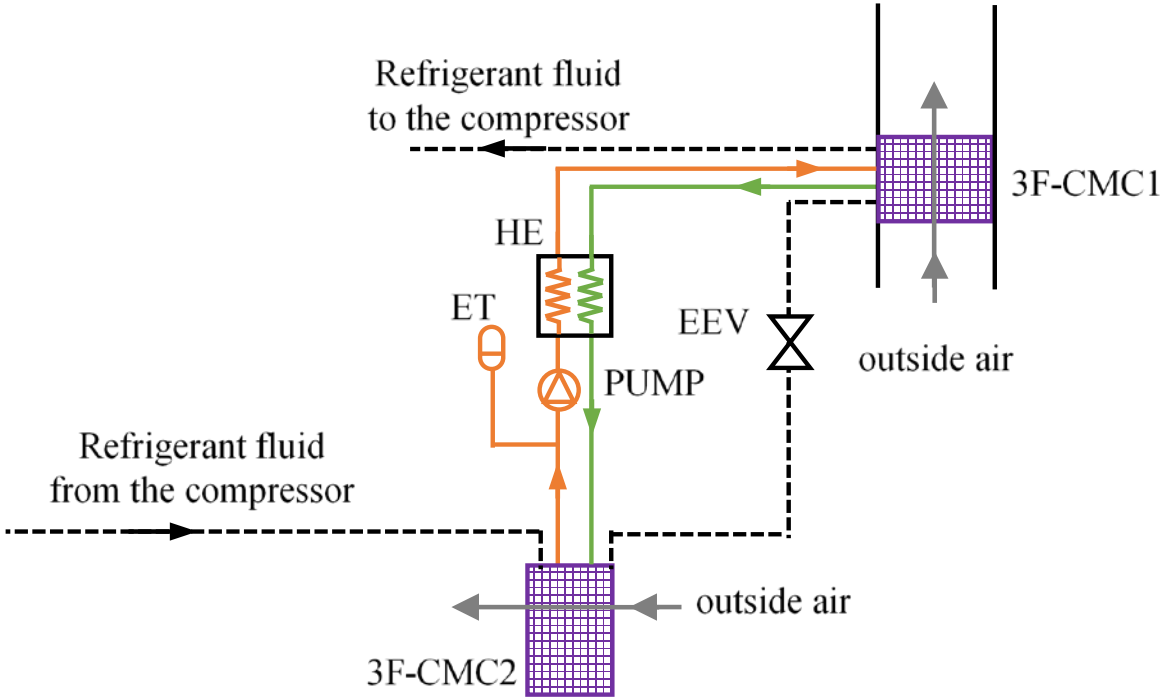


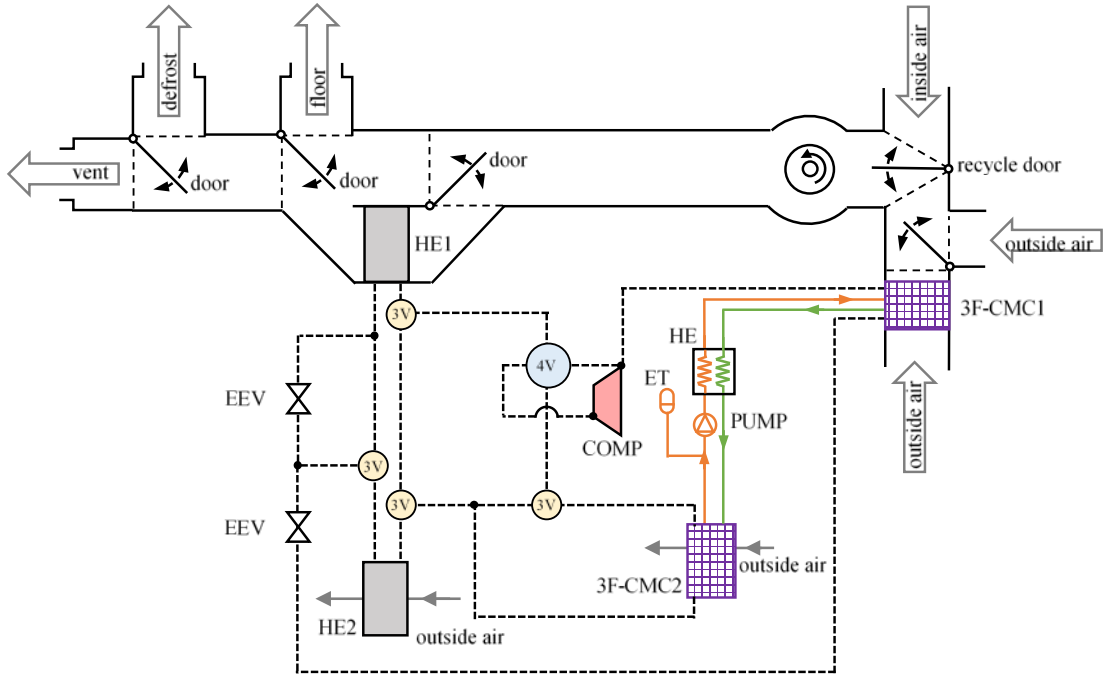


It is not more necessary to cool the air below the dew-point temperature to get dehumidification so the VCC operates with a higher evaporation and a lower condensation temperature than a traditional Air Conditioning (AC) system.

Xeric system architecture for the BEV application

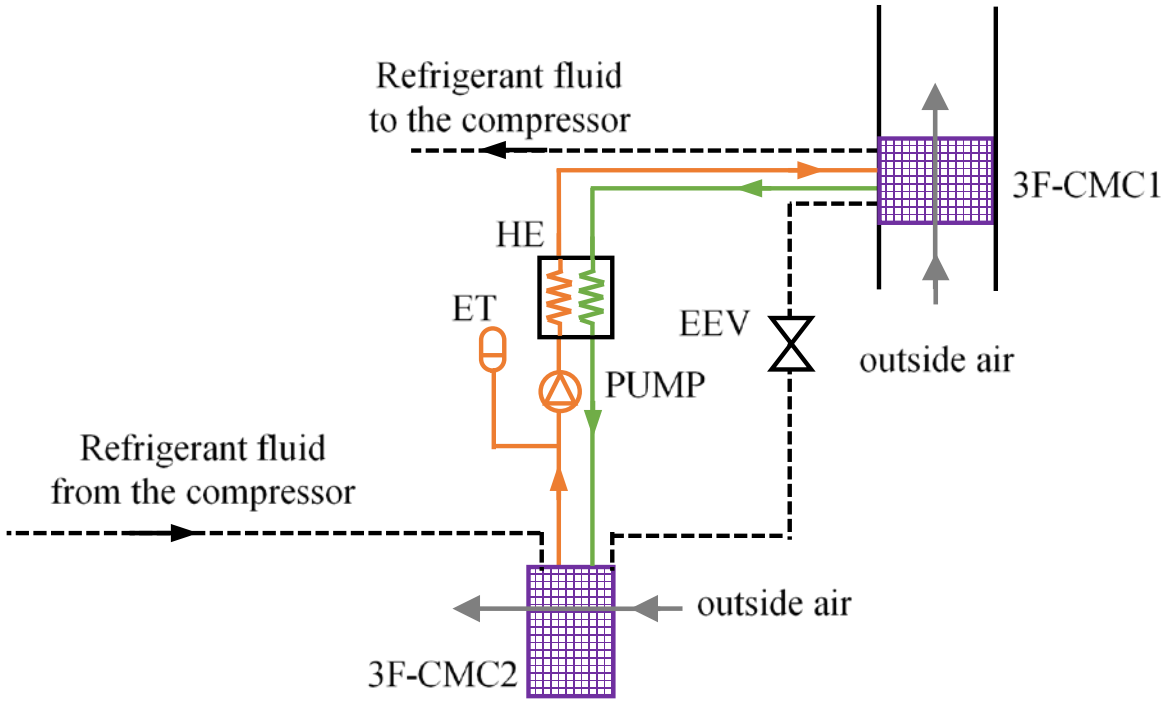
The Scheme shows as the liquid desiccant cycle is combined with the Vapour Compression Cycle (VCC). When heating is required the desiccant cycle is stopped and the VCC cycle is reversed by the Four-way valve to work as heat pump.





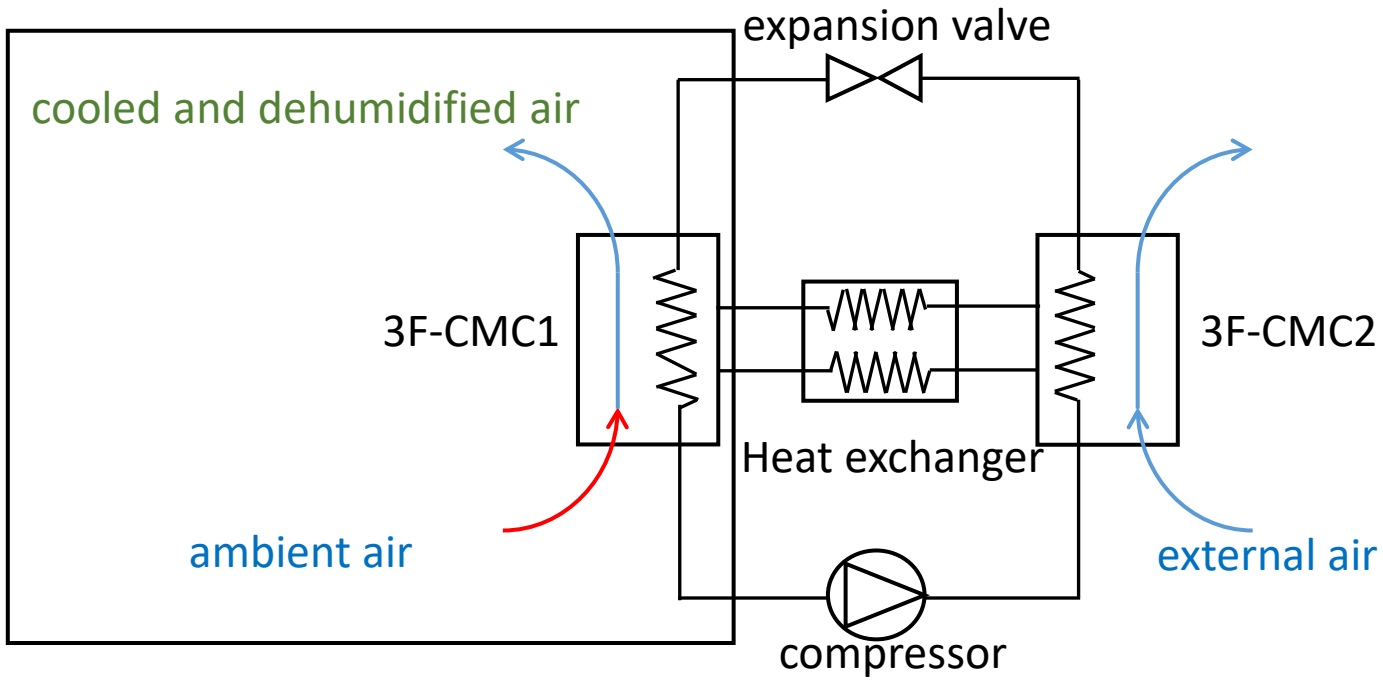
XERIC technology for traditional cars

The adoption of an Hybrid cycle with 3F-CMCs is also profitable for improving AC in traditional vehicles equipped with a combustion engine: it allows to reduce fuel consumption and related air pollution. For heating purpose, instead of reversing the VCC, wasted heat from the engine is advantageously used.



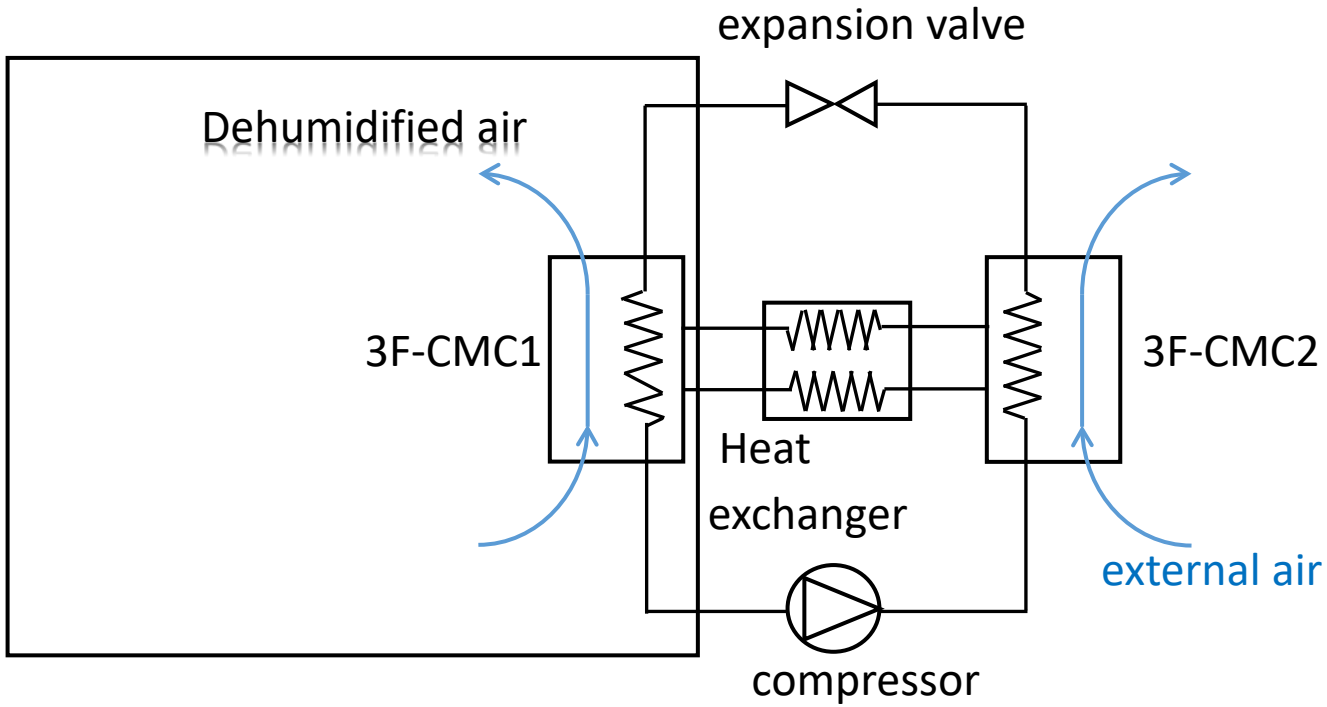
Civil air-conditioning

Besides automotive applications the technology can be adopted in many other Air Conditioning (AC) applications, particularly, when compactness and energy saving are important concerns. Climate control in rooms, cabinets, in transport sector trains, trams, buses, caravans, etc. when the air cooling requirement is moderate the following more simple system can be considered.



Industrial air-dehumidification

In many industrial applications often only air dehumidification is required. The traditional process by cooling is a very energy intensive process, particularly in warm and humid climates. The hybrid system with 3F-CMCs can be applied in several industrial sectors (pharmaceutical, agricultural, food processes etc.) particularly when a moderate air dehumidification is required.



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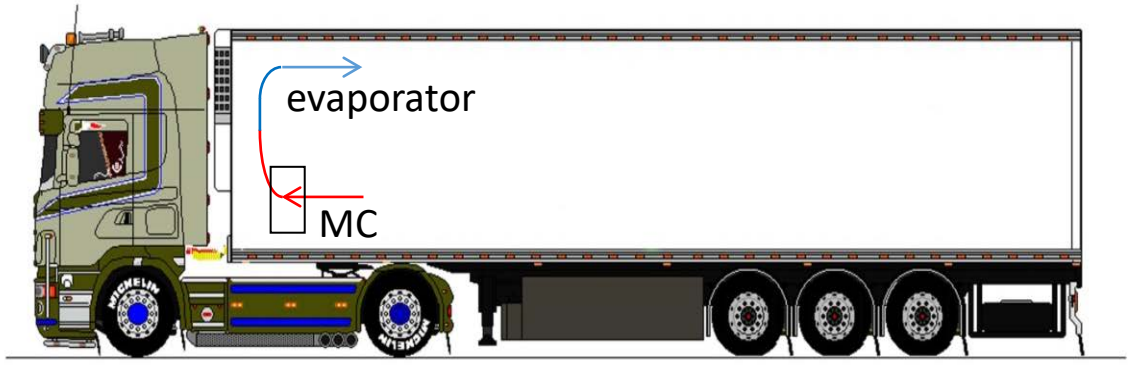
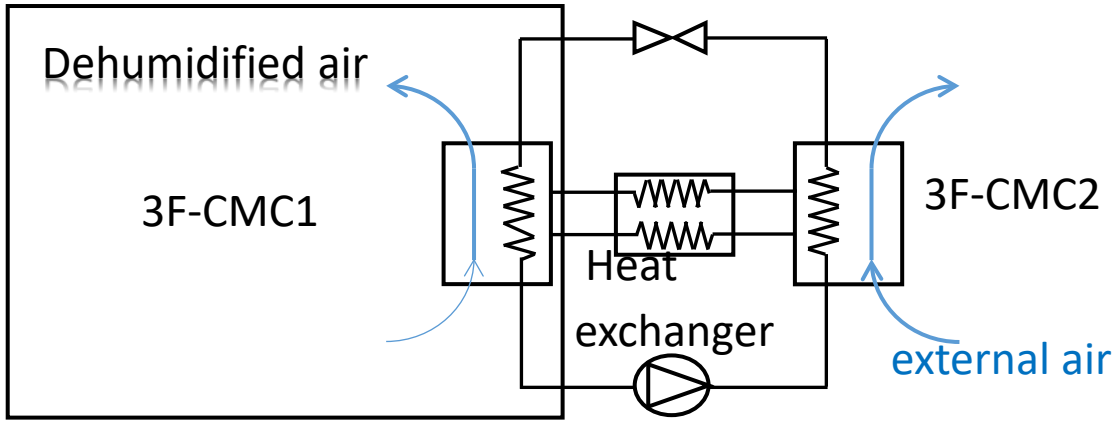
Application to chilled transport

In chilled environments (refrigerated trucks/warehouses, containers for fresh cuts) by dehumidifying air upstream the evaporator's inlet to prevent frost and related periodic defrosting cycles with an increased energy consumption thought, in this case, the main concern is product quality and not energy saving.

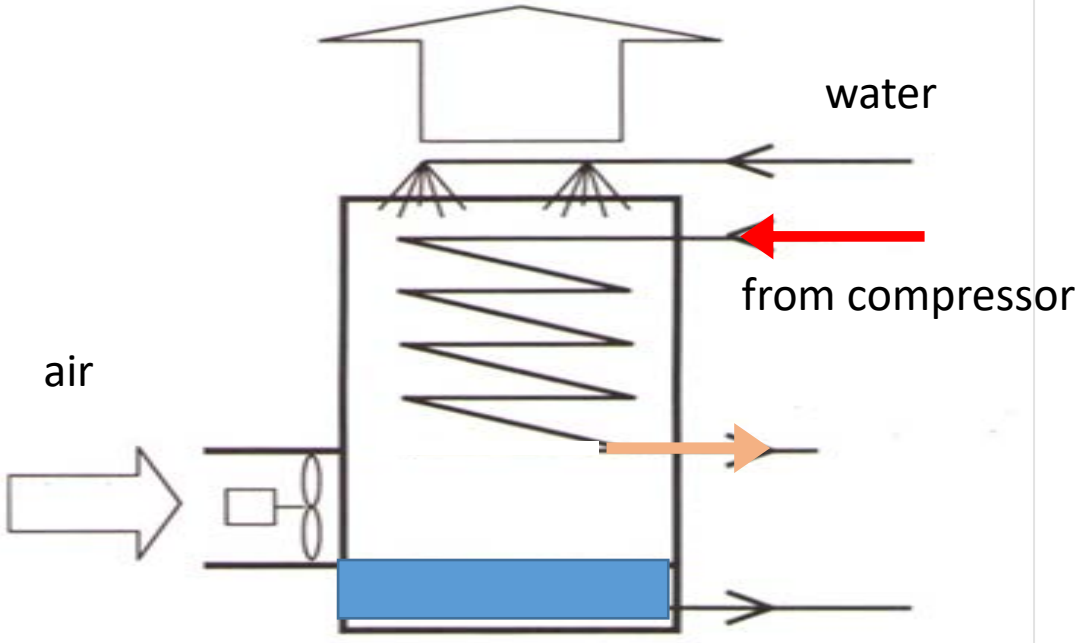
Thanks to a small, independent hybrid cycle with 3F-CMCs the regeneration process of the desiccant (3F-CMC2) can be carried out contemporaneously to the absorption process (3F-CMC1).

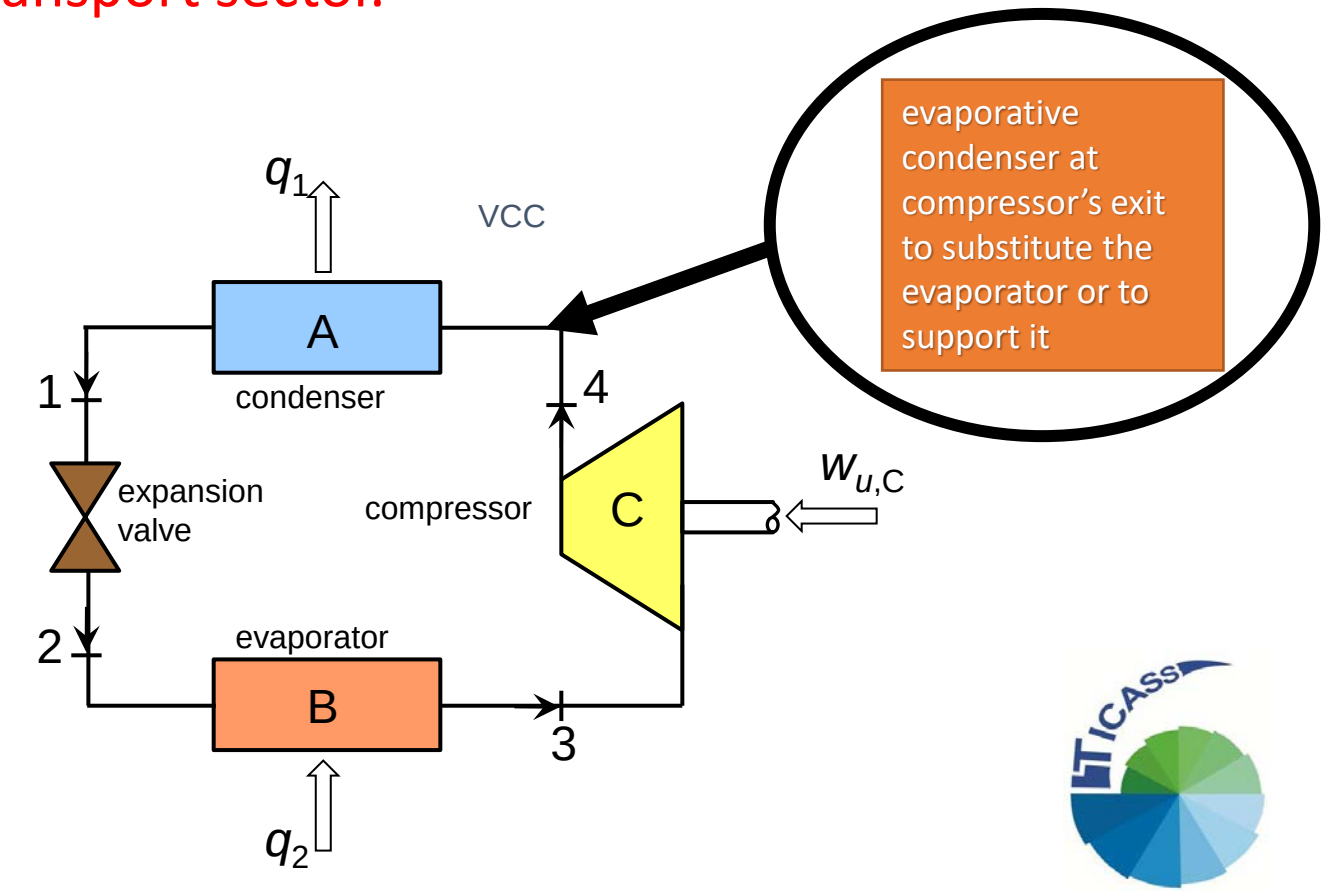




Evaporative condensers applications

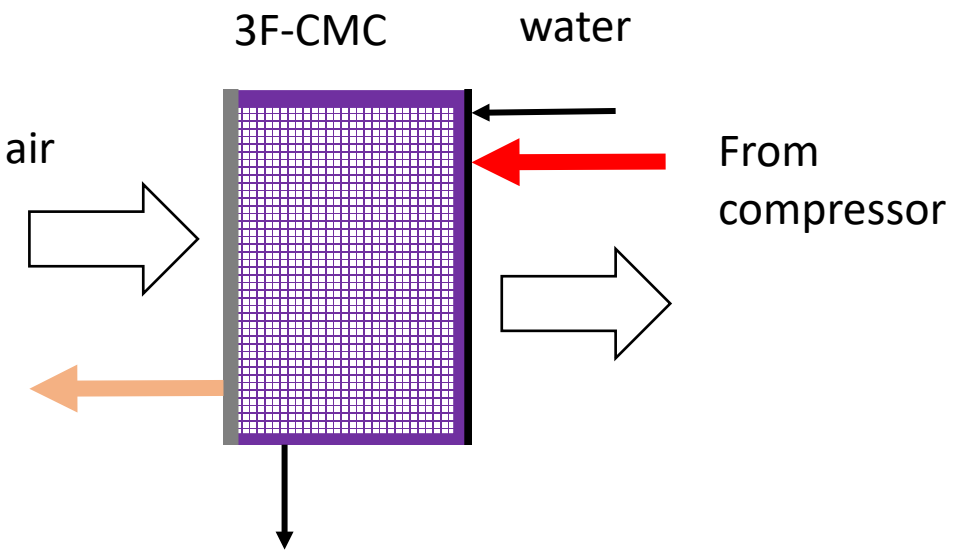
Direct contact air-water components are used to get lower condensation temperature increasing the energy efficiency of the VCC used in the refrigeration and AC sector. Such components lack in compactness; not suitable to be used in the transport sector.

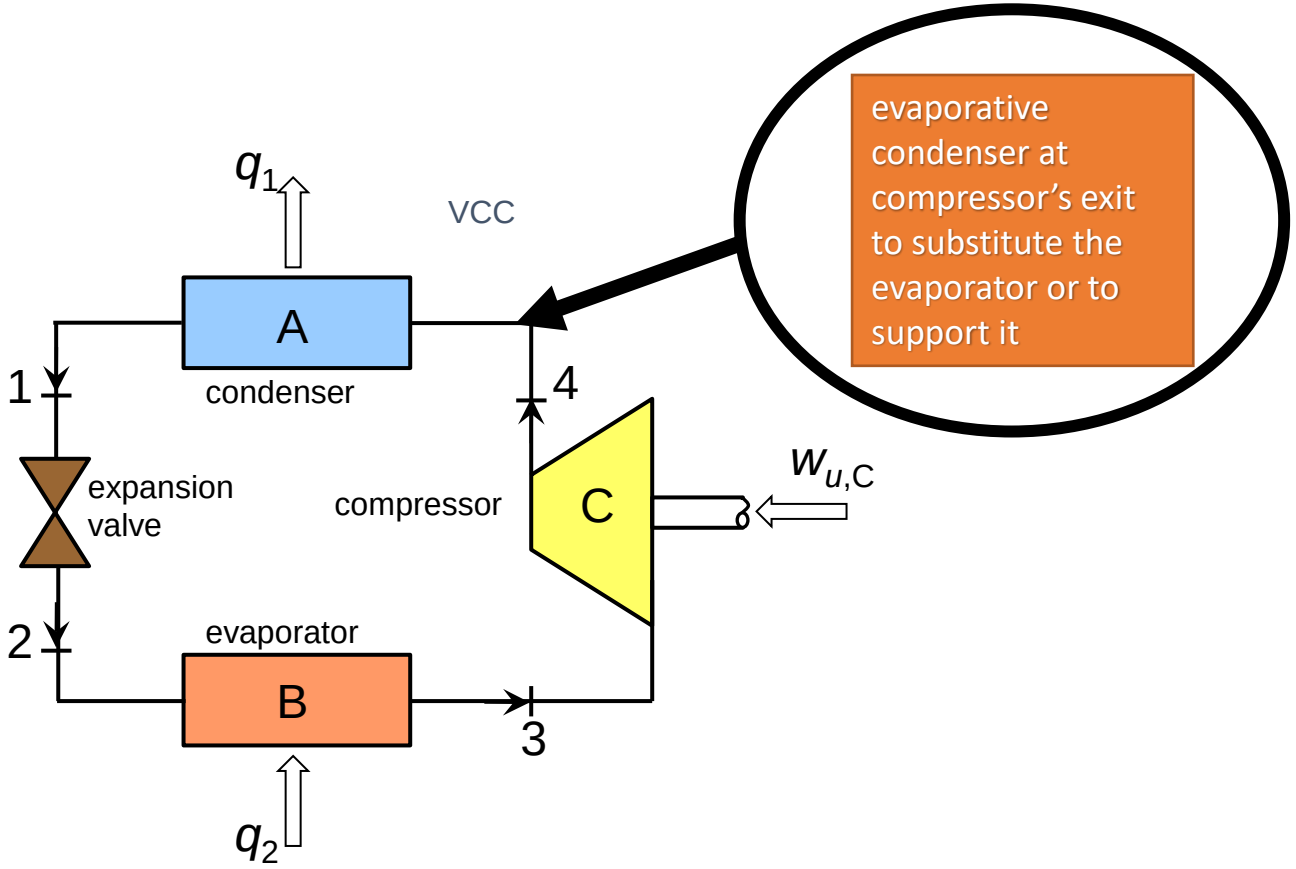




Evaporative condensers with a 3F-CMC

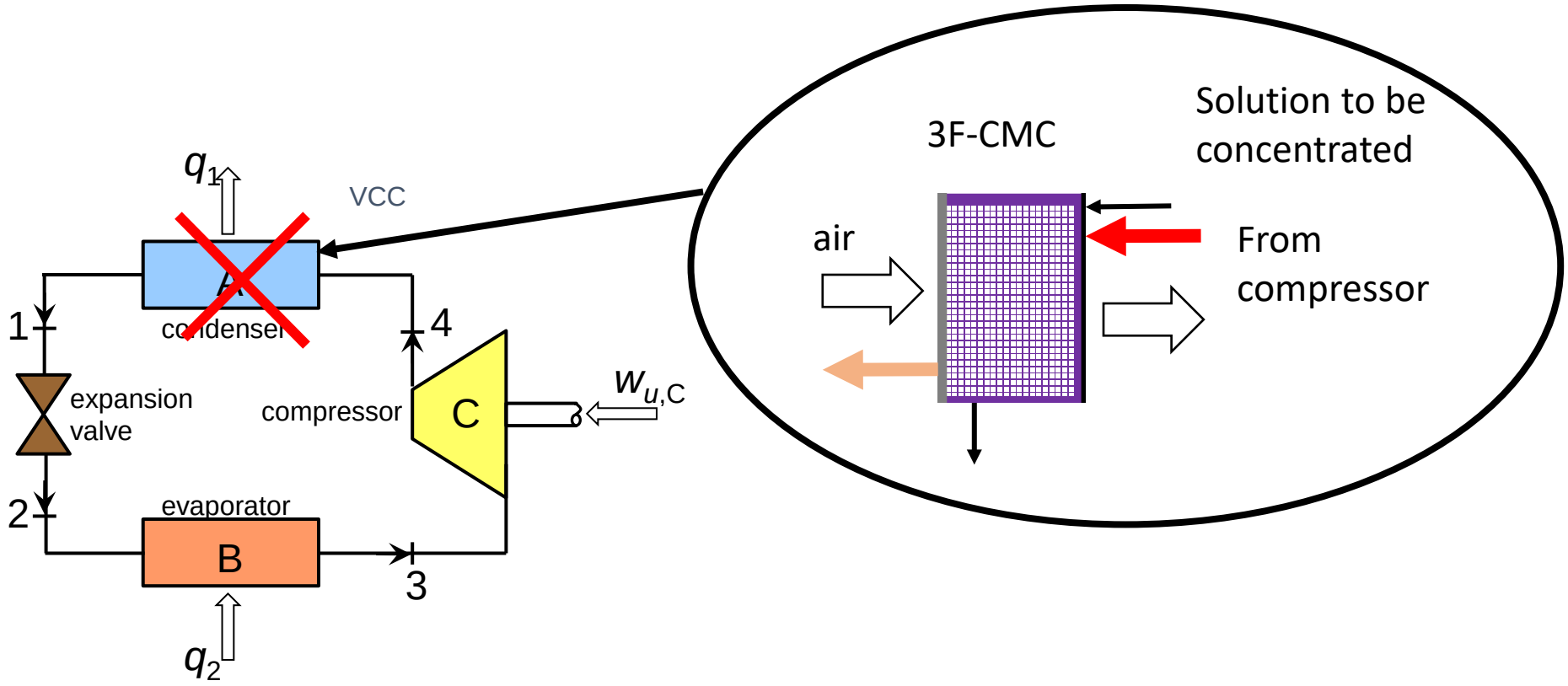
For this application a 3F-CMC component can be used as well by setting it at the compressor's exit to get lower condensation temperature of the VCC. Great gain in compactness and possibility to use in the transport sector.





Salt solution concentration in food industries

For this application a 3F-CMC can be used in substitution of the condenser of a VCC. Instead of using a refrigeration cycle it is possible to fed the 3F—CMC with warm water.



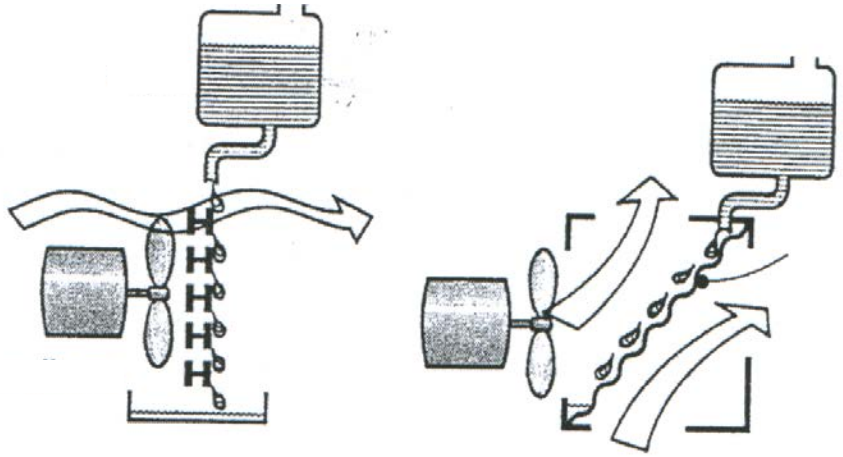
Summer refreshing applications (free cooling)

Evaporative effects are used to produce refreshed air and/or water in summer with temperatures that are few degrees below the outside air temperature.

In the sketch:

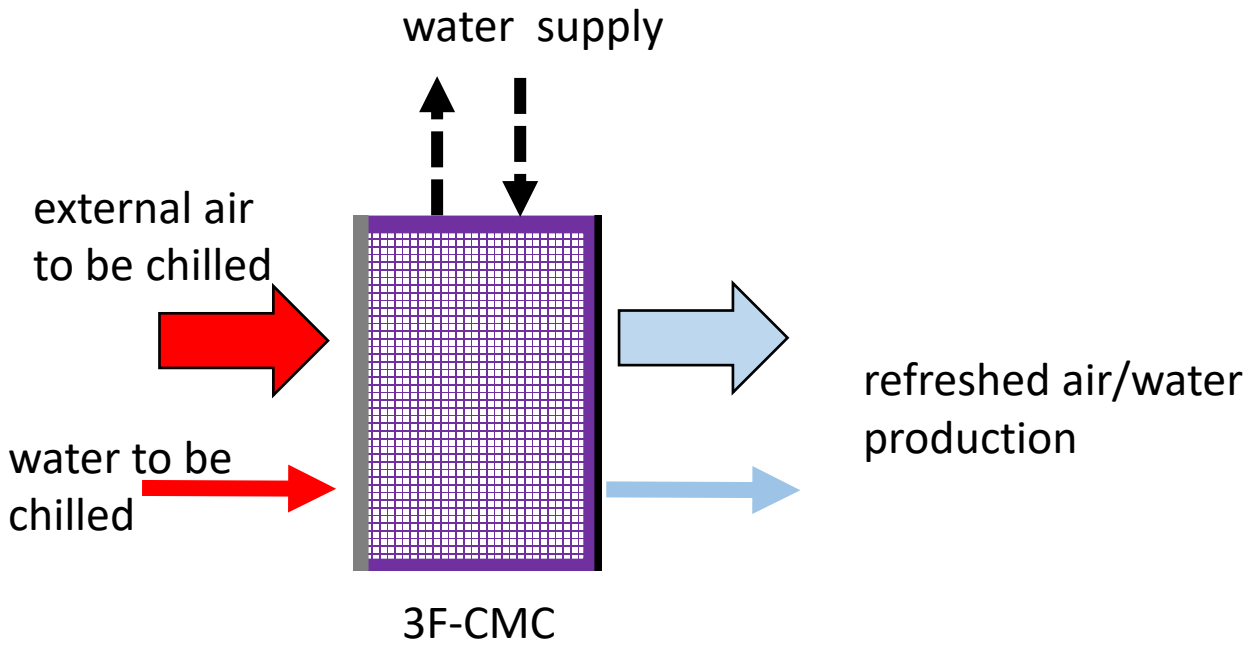
- direct approach: i.e. the processed air is refreshed but also humidified
- indirect approach: i.e. the processed air is only refreshed thanks to an air to air heat exchanger.

Such effects allow to reduce the power need by the heat pumps or up to get passive climate control systems.



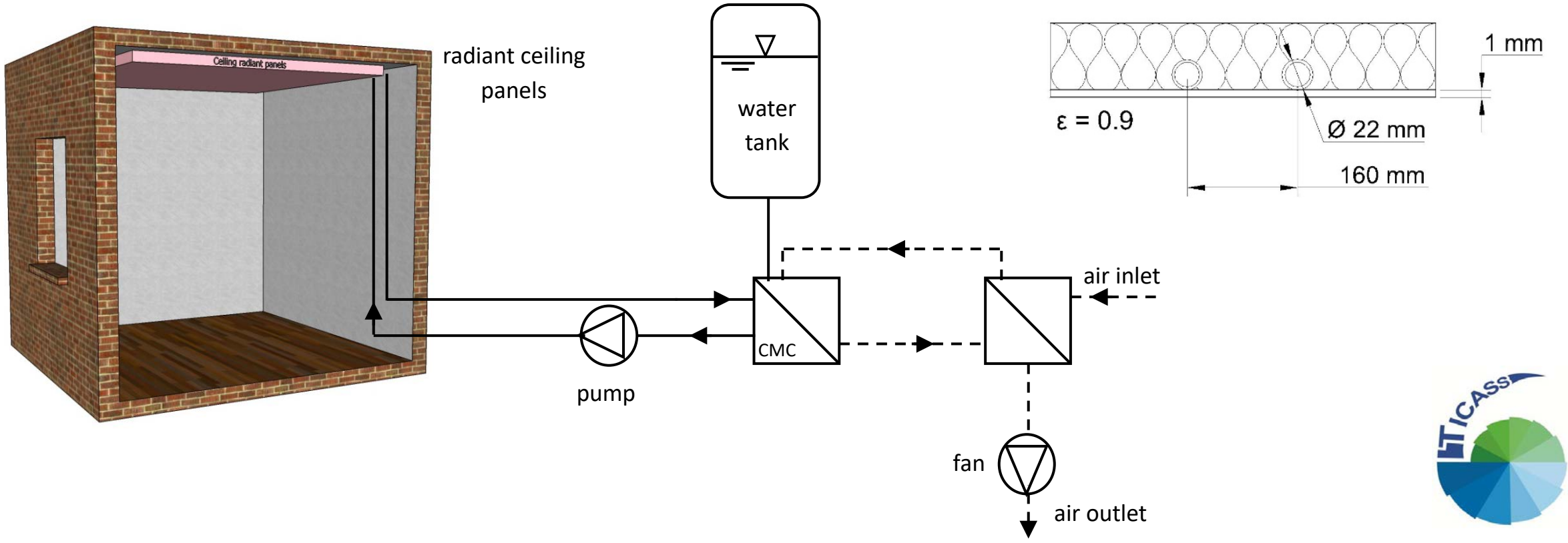
Summer refreshing with 3F-CMCs

Evaporative actions are easily obtained with 3F-CMCs: for instance, in summer, to get refreshed air and/or water. The water to be evaporated comes from a reservoir tank.
Air/water flow, refreshed up to few degrees below the outside air temperature (4 ÷ 6°C), can be used for the climate control in residential environments, boats etc.. to reduce the power need by the heat pumps or up to get fully passive systems.



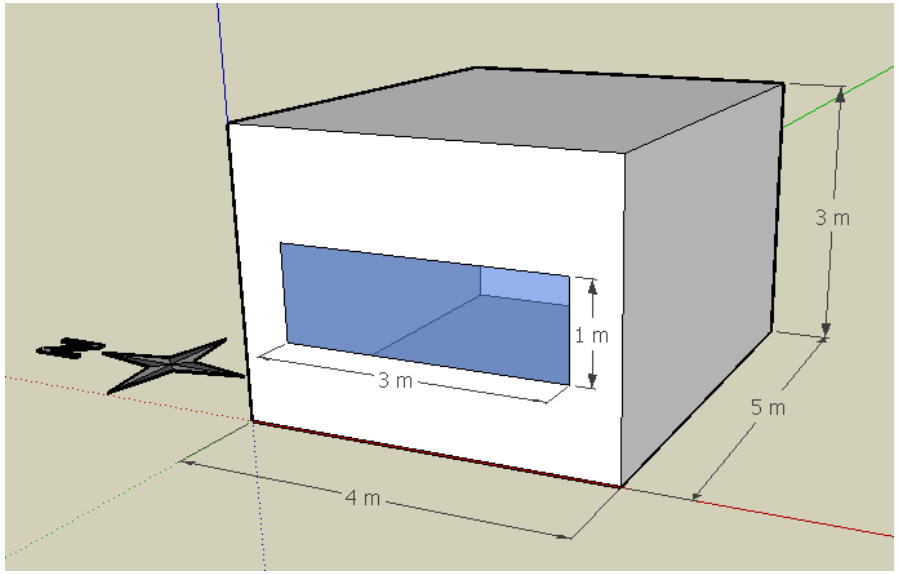
An indirect summer refreshing system

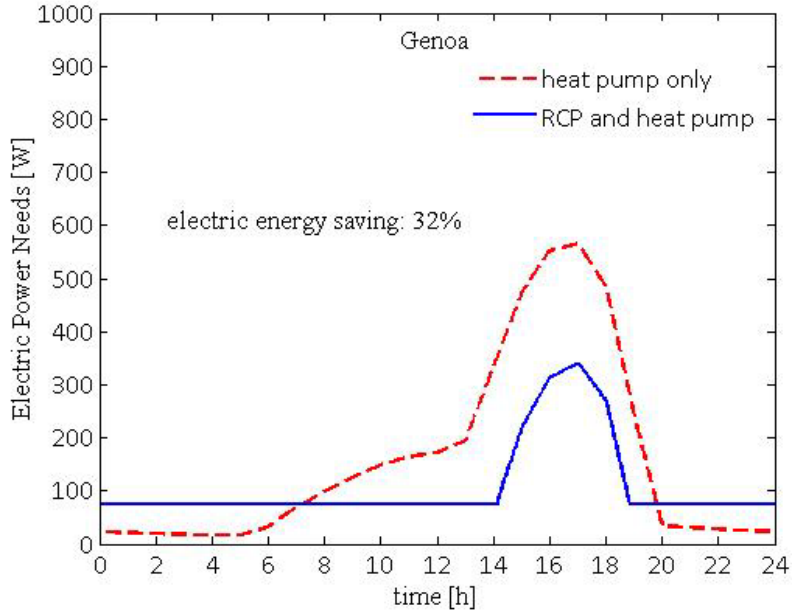
An original approach can obtained with a simple air-water **Combined Membrane Contactor (CMC).** The water refreshed by this component is sent to a **Radiant Ceiling Panel (RCP)** set in the ambient. The **CMC+RCP** system aims to reduce the power need by the heat pumps or up to get the a passive climate control with a negligible electric power consumption.



CMC + RCP system to support the heat pump

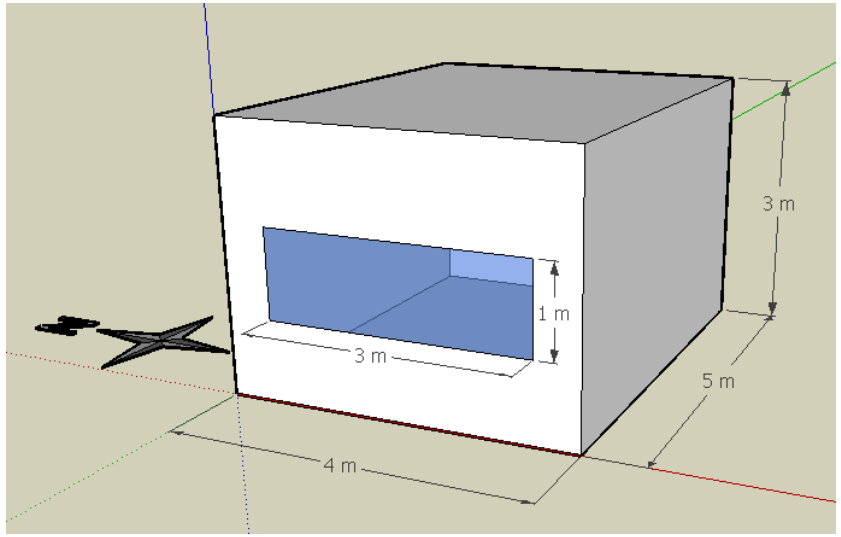
Reducing the electric power required by the heat pump. The CMC+RCP system mitigates the heat pump action to maintain in summer indoor comfort conditions in a residential room for the occupants. A simulated case for Genoa (44° 25' Lat. N) 21th July, 2 m^2 membrane surface.

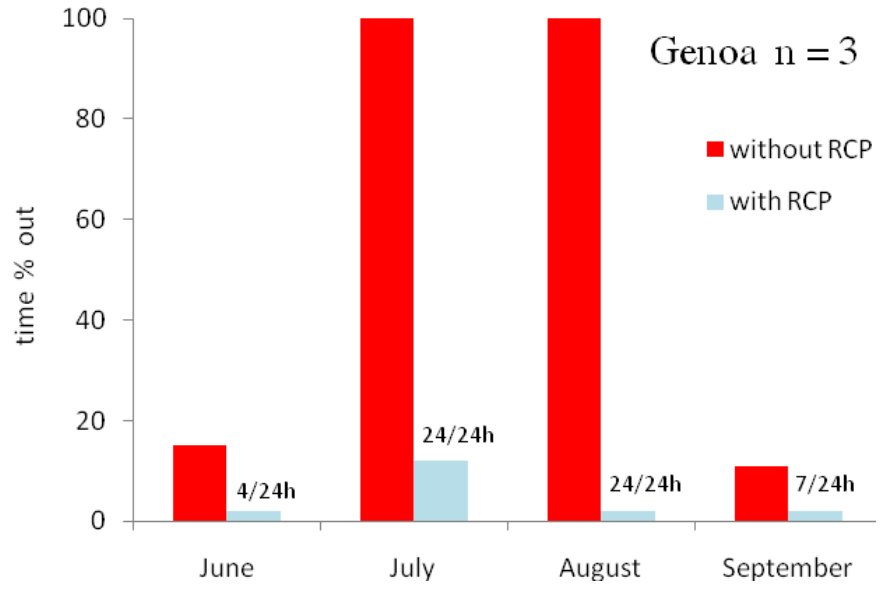




CMC+RCP : passive control of a residential environment

Passive climate control (no heat pump) with the CMC+RCP system to get in summer season comfort indoor conditions. A simulated case for a residential room in Genoa, contactor with 2 m^2 membrane surface.





CMC+RCP passive refreshing: caravans and trailers

The CMC+RCP, in summer, maintains indoor comfort conditions for the occupants with a negligible energy consumption (very important to preserve battery charge during long parking).

Summer refreshing in marine applications

The CMC+RCP system can be applied:

a) To support the heat pump action for great units

b) To get a fully passive climate control with a negligible energy consumption (very important to preserve battery charge during long sailing).

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Conclusions

- Innovative 3F-CMC components can be applied for air handling purpose in many sector particularly when energy saving and compactness are important concerns
- Hybrid cycle with 3F-CMCs can be applied to get air dehumidification in the refrigeration sector as well for other industrial applications
- 3F-CMCs coupled with radiant panels can lead to several free cooling approaches: from auxiliaries to heat pumps to a fully passive climate control in residential rooms, boats, caravan, etc.
- 3F-CMC component can be used both for salt solution concentration in food industries and for capturing atmospheric humidity to produce potable water

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Thanks for the attention