

Design Issues for Heat Pumping MAC Systems in Cars, Using R-1234yf

Automotive summit November 10th, 2010

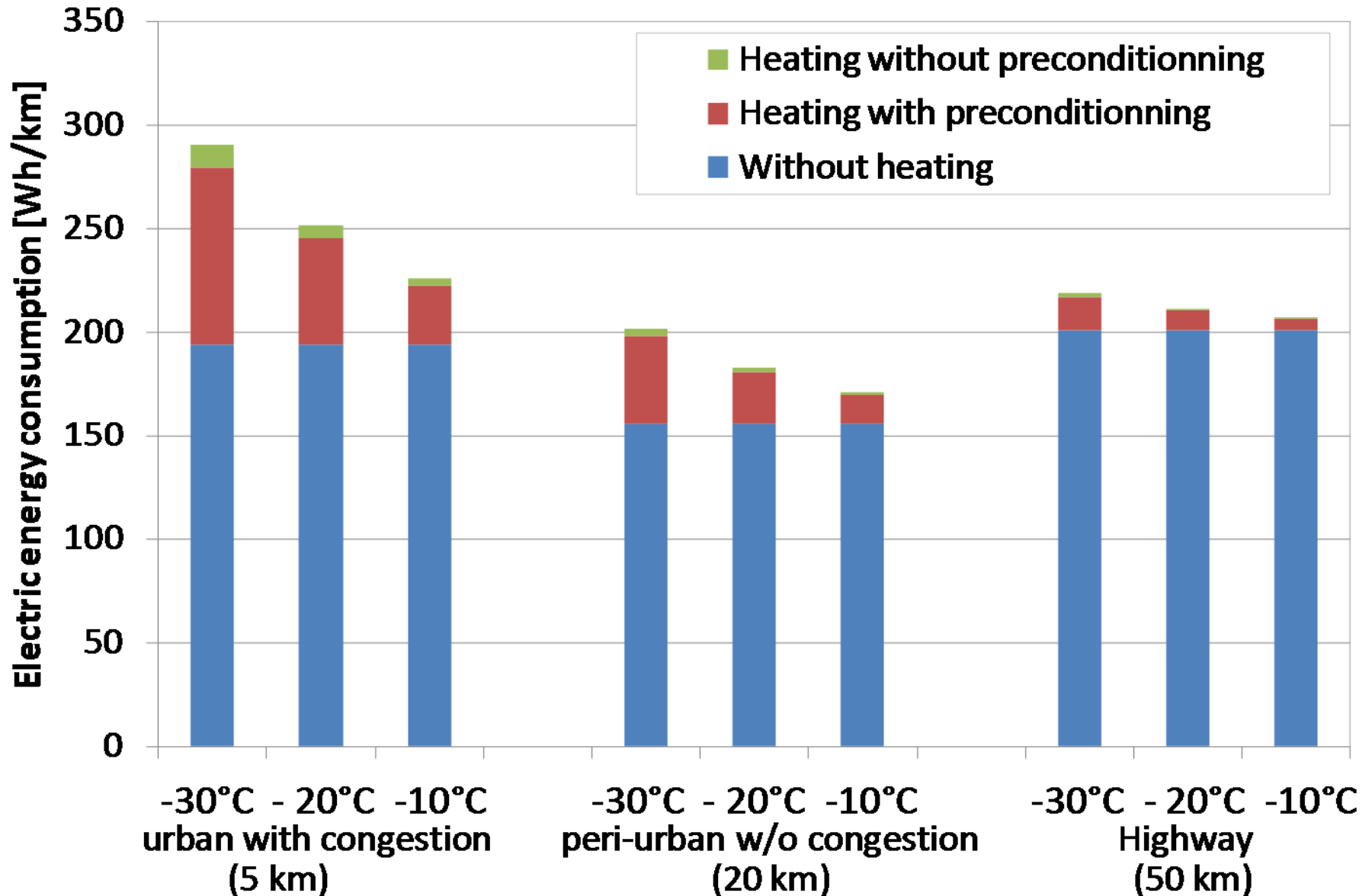


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- Heating: how to be energy efficient and at low CO₂ emissions ?
- Heat-up : sizing issues
- Heat pumping : how to be efficient ? R-1234yf and CO₂
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- Conclusions and perspectives

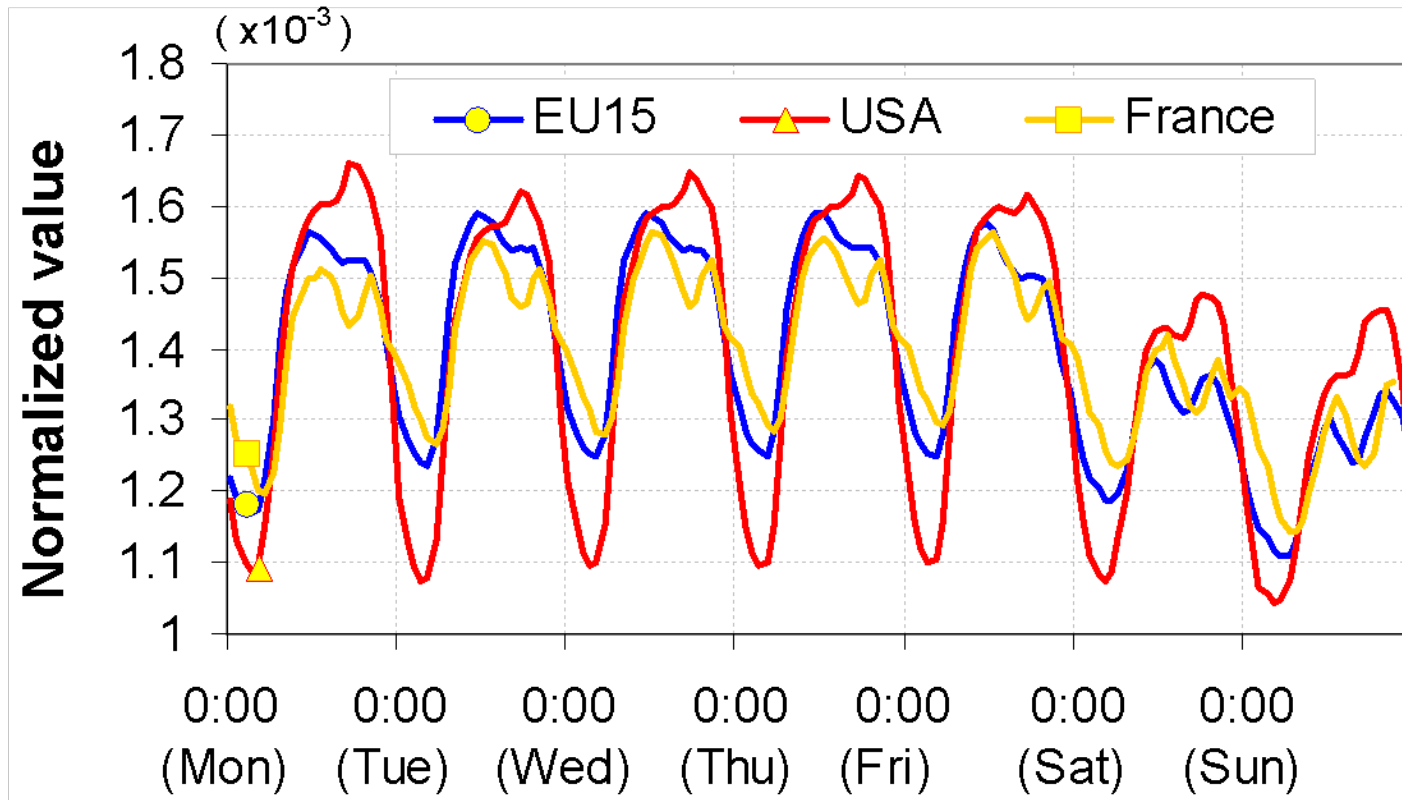
First evaluations on heating impact on EV



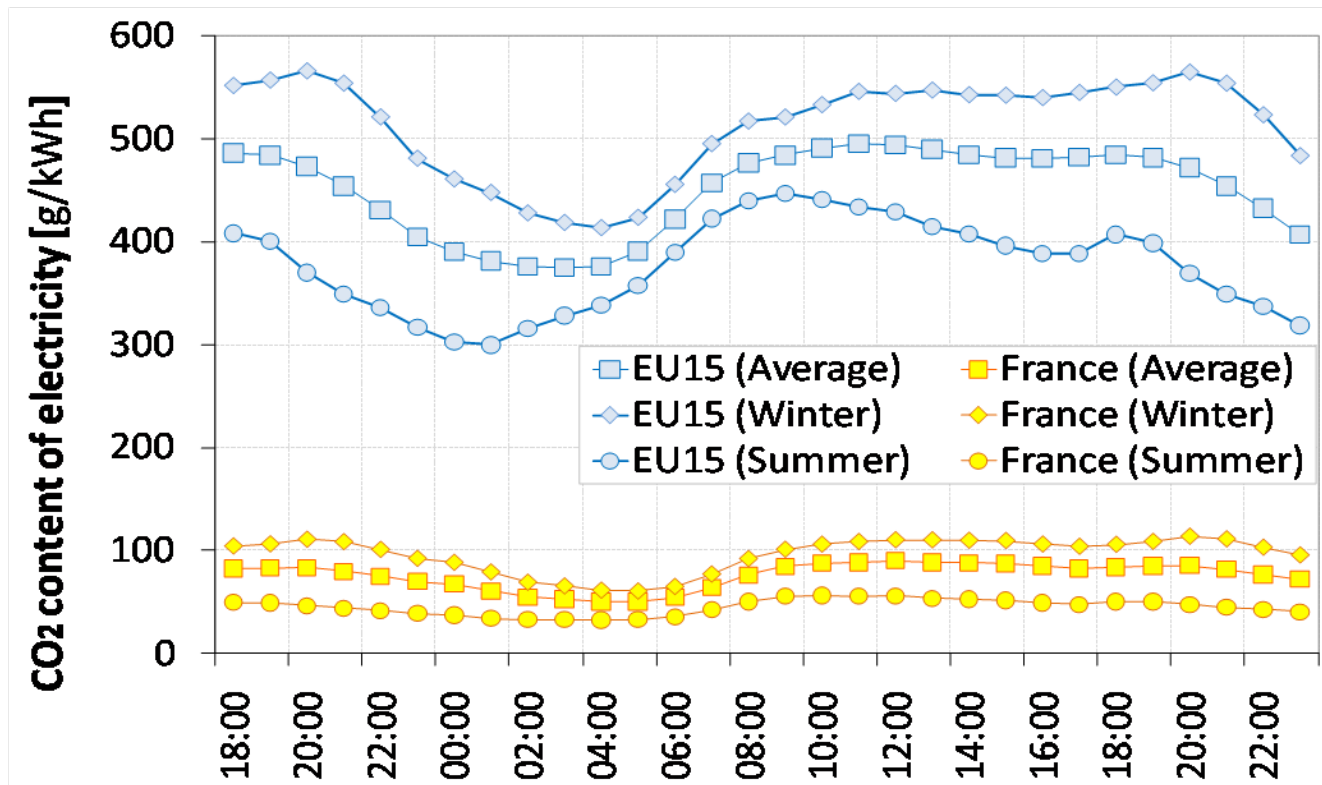
Normalized load cycle

Dimensionless load profile normalized by the electric energy produced during the month

Average week in 2007



CO₂ value of heating

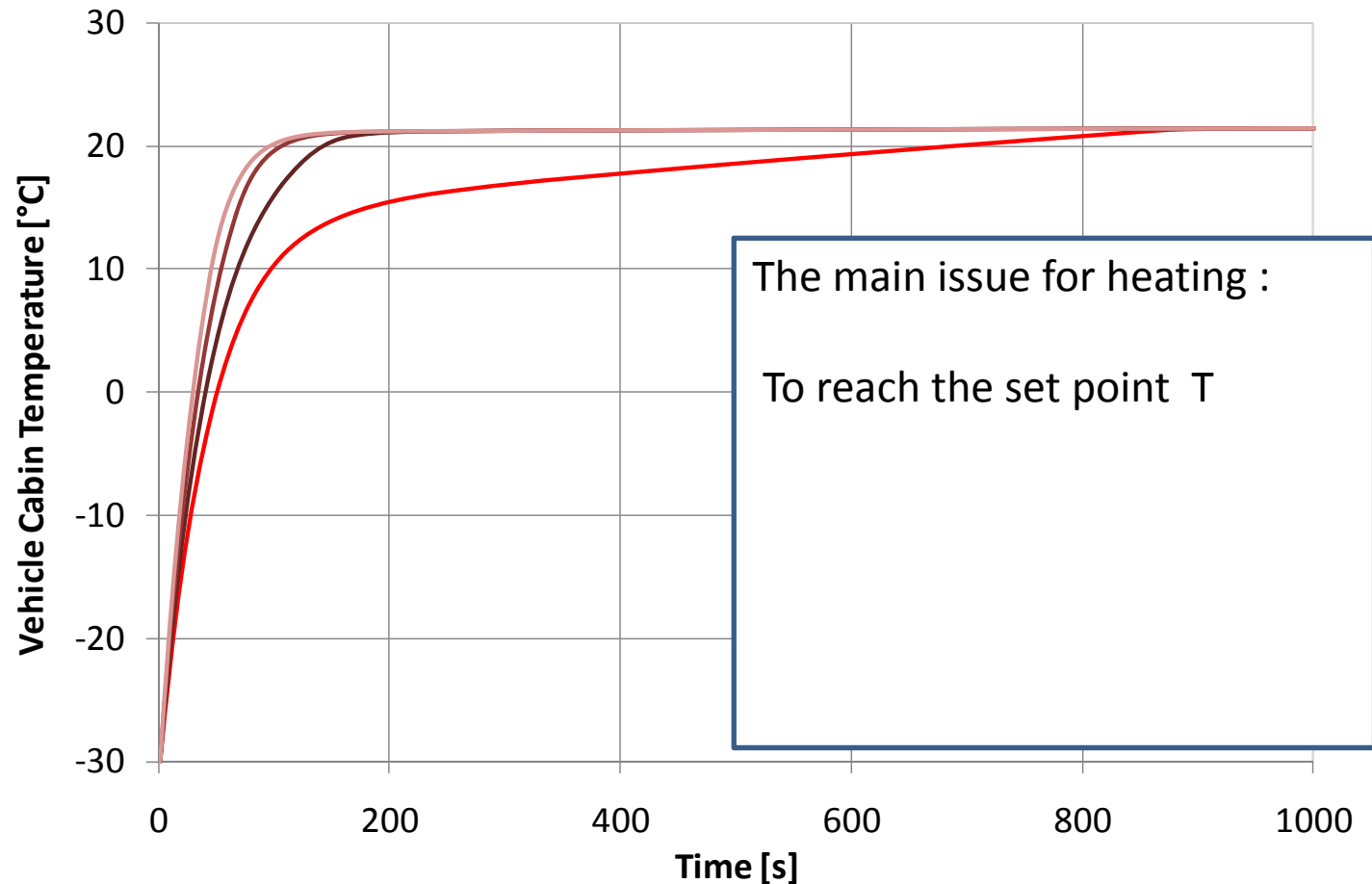


- CO₂ value for burning gasoline is 300 g/ kWh
- Electrical resistance heat generation has a higher impact than a burner except in France and Norway

**Initial heating :
how to reach the set point ?**

EV Heating how to be efficient ?

For electrical vehicle : the current PTC with 1.7 KW is not able to reach temperature difference of more than 10 K in 10 minutes



The main issue for heating :
To reach the set point T

Electric vehicle and on board heating

The initial energy necessary for heating is higher than the energy for driving when the outdoor temperature is lower than -5°C and the car at the same temperature

Electricity stored has an exergy value which is meaning less for heating

Fuel burner is :

- a well known solution used in trucks and buses
- has been used for electric vehicles
- is simple
- and thermodynamically can only be challenged by heat pumping

Heat pumping : a generic issue for all vehicles ?

Usual heating for conventional vehicle :
PTC and water to air heat exchanger

- Heating of Plug-in vehicle : The Prius PHV experiments a Heat pump to save autonomy for initial heating
- Electric vehicles :
 - some old one fuel burners
 - New ones : PTC

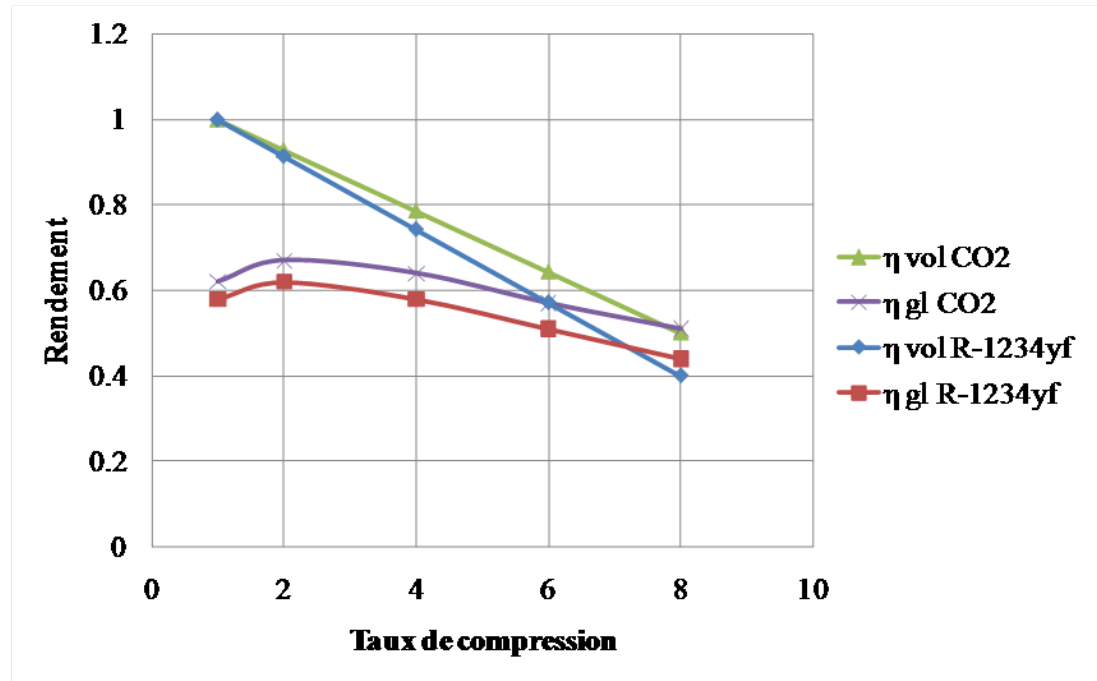


By courtesy of Webasto

Heat pumping : How to be efficient ?

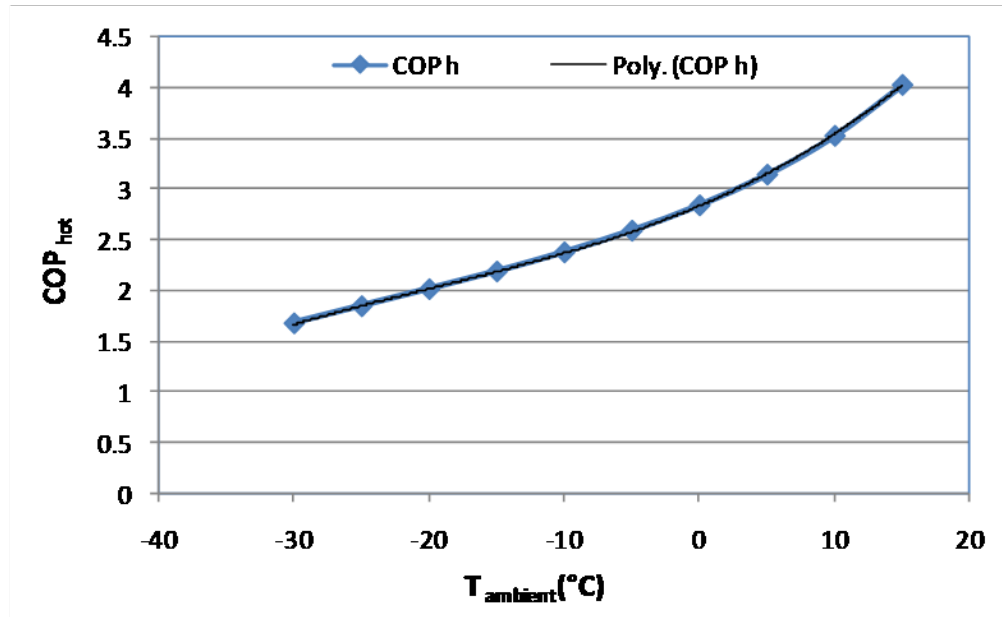
R-1234yf and CO₂

What is the most adapted refrigerant for cooling ?



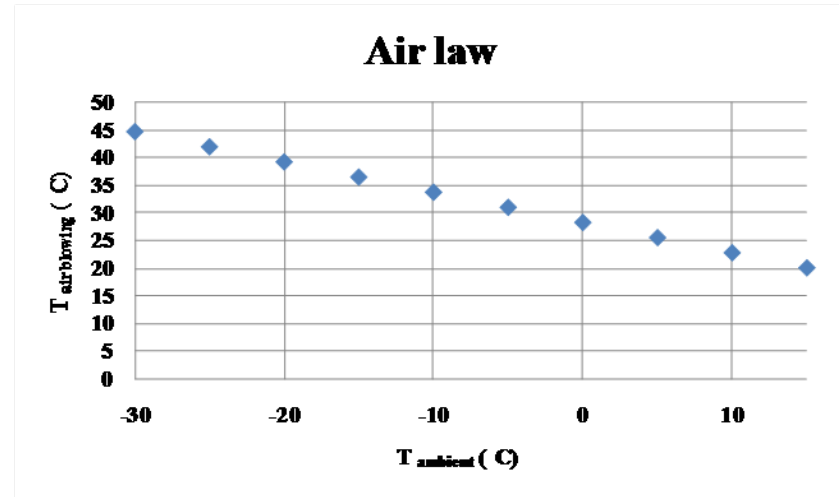
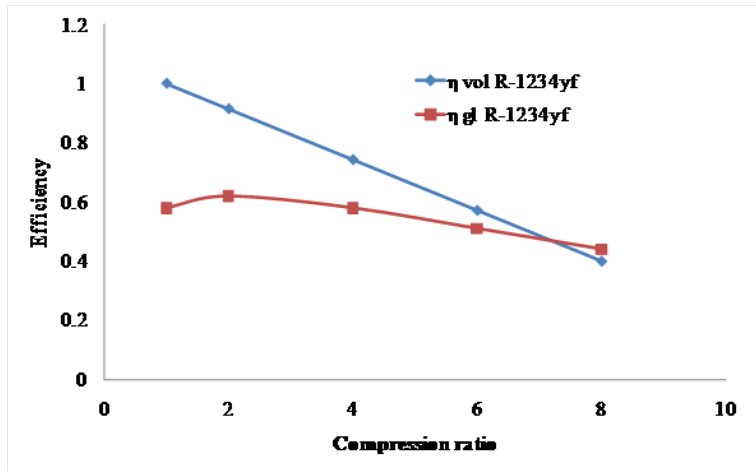
- For low temperature operation $-30\text{ }^{\circ}\text{C} < T < 0\text{ }^{\circ}\text{C}$: the higher the evaporation pressure the higher the capacity
- For heat pumping CO2 has a significant advantage compared to R-1234yf based on pressure ratios and heating capacity

CO2 Heat pumping



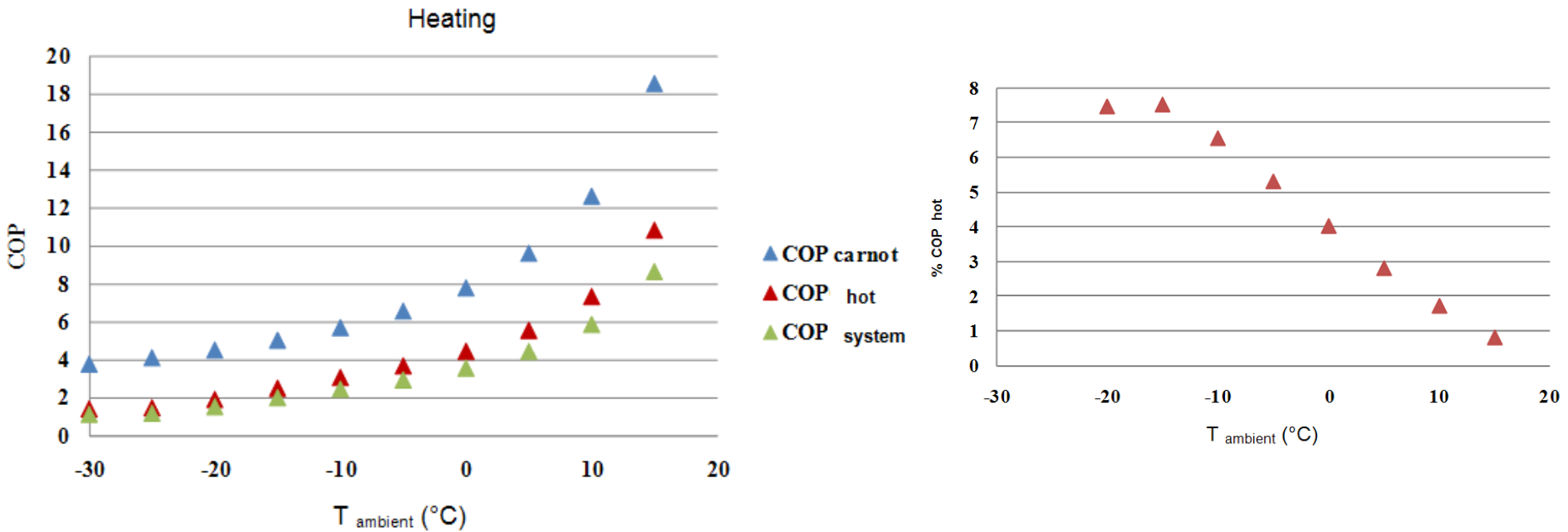
- The so called « triangle cycle » is at the best as efficient as a PTC
- The CO₂ Triangle cycle is not adapted for saving energy
- HP Performances are better than a burner only for reverse cycle

How to use R-1234yf for heat pumping ?



- Limiting Source / Sink temperature
- « Air law » meaning adaptation of air blown temperature to outdoor temperature

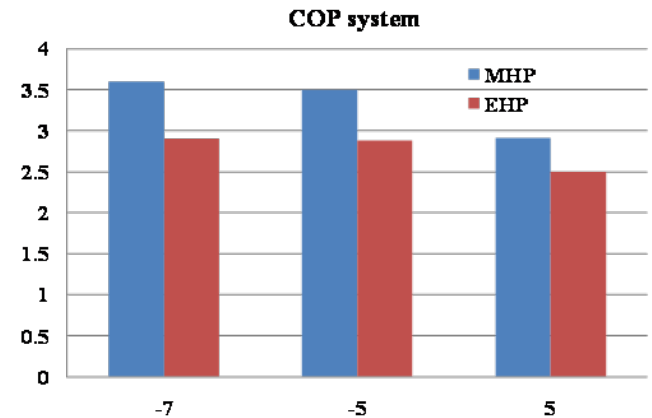
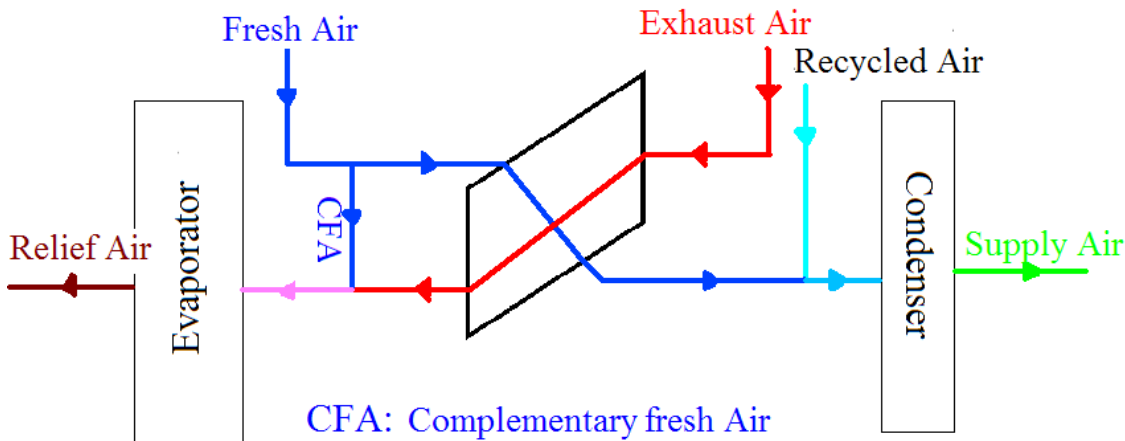
How to use R-1234yf for heat pumping ?



- For a single stage « medium pressure » refrigerant as R-1234yf
- At -30°C outdoor temperature and $+45^{\circ}\text{C}$ air blown temperature the COP is around 1
- The liquid vapor Hex improves the COP at -30°C of about 7%

How to improve all HP systems ?

Air recirculation and Heat recovery on air



- air recirculation in the cabin with CO₂ control
- Recovery of exhaust air to improve efficiency and to limit frosting

Overall energy management

Overall energy management for EV and PHV

Heating the human body and not the car

- seat heating
 - still electric resistance
 - To be improve in terms of comfort
- Air diffusion
 - Number of passenger identification
 - Air diffusion on the body
- Miscellaneous
 - Wheel heating
 - Adapted garments

Overall energy management for EV and PHV

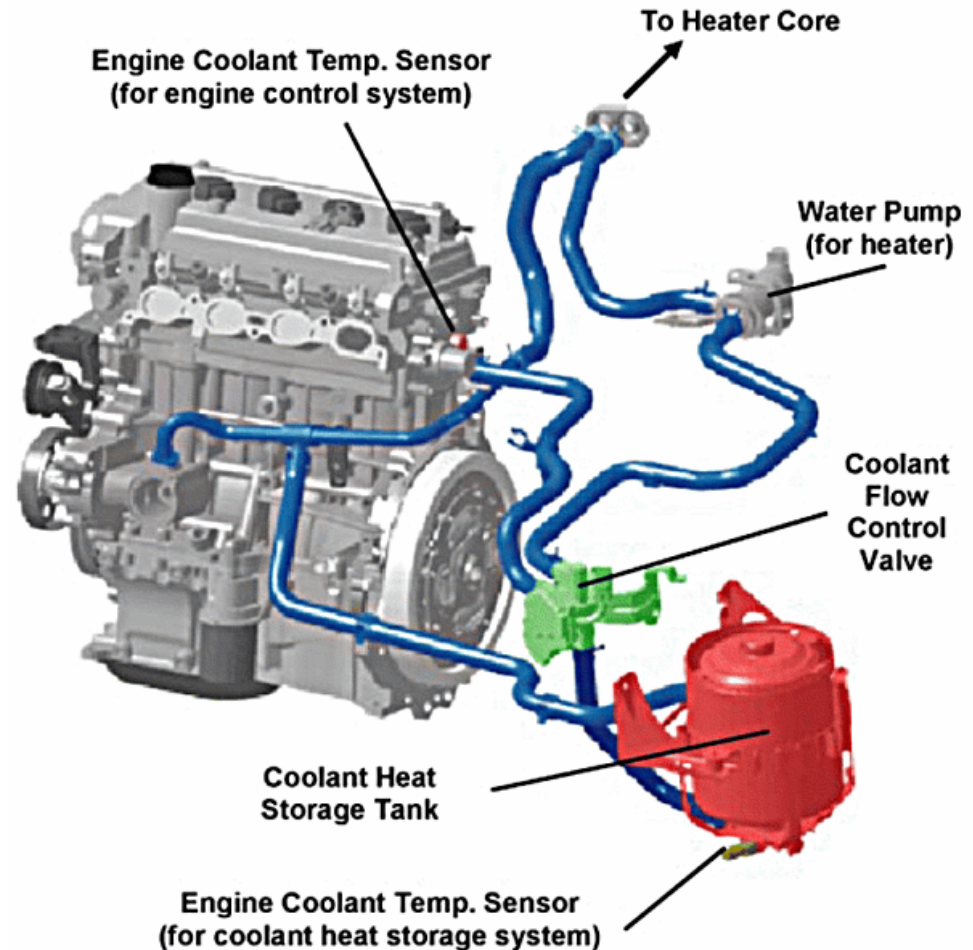
Pre-heating

- Car parking (the easy solution)
- **Vehicle insulation**
 - insulation of the car body is a gain for hot and cold transient
 - curtains or double glazing are essential to limit heat transmission
 - the experience gain in buildings has to be revisited
- **Preconditioning**
 - for EV and PHV : preheating is essential for the electrical mobility and comfort
 - Preconditioning can be done either electrically or by a burner

Overall energy management for EV and PHV

Heat storage

- Prius II integrates a hot water heat storage
- For PHV is a smart concept to recover heat from the engine operation
- For EV it could be also a smart concept to operate mainly on storage while driving



Conclusions and perspectives

- Heating is an underestimated constraint for electrified vehicles
- Heating hampers electric mobility
- Electric heating by PTC is undersized for heat up
- Heating a car should be analyzed in terms of:
 - CO2 content
 - Capability to rapid heat-up
 - Costs

Heat pumping is challenging because it is still operating on electricity

Conclusions and perspectives

- Heating during the stand still period is a possible efficient solution
- New efficient burners are a part of the possible solutions
- New design of the cabin is necessary to limit heating demand
- Heat storage is an adapted solution for PHVs but also for Evs
- The best use of electricity is driving the car!