High temperature residential heat pump for refurbishing – What preferred refrigerant for the next future ?

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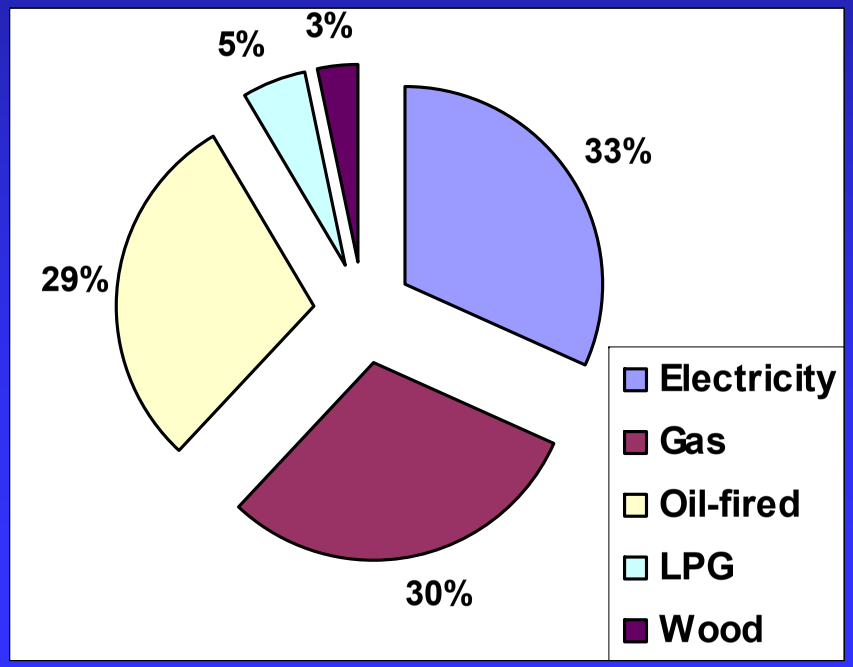
Heat pump specifications for the refurbishing market

- **100 % of the heating needs at the lowest outdoor temperature are to be provided by a heat pump in replacement of a boiler.**
- **Radiators and the hot water circuit have not to be changed in order to limit the replacement cost.**
- **Domestic hot water has to be provided all along the year and the storage temperature has to be maintained above 60°C (for legionella destruction).**

The possible market for replacement of domestic boilers

- **The French market is split equally between electricity, gas and oil, representing each about 30 %. The complementary energy is shared between LPG and wood.**



The possible market for replacement of domestic boilers

- **Structure of the replacement « parc »**
- **Average replacement age of boilers :**
  - **15 years for wall boilers.**
  - **17 to 16 years for other boiler types.**
- **In France, the part of the aged parc is significant**
  - **22 % of boilers, i.e. about 2.5 million, were 20 years old or more in 1999**
  - **12. 6 % had between 15 and 20 years, i.e. about 1.4 million.**

TEWI analysis of HFC refrigerants compared to CO_2

- **CO_2 content of the kWh of the different energies**

Oil gCO_2/kWh	Natural gas gCO_2/kWh	Electricity gCO_2/kWh
310	280	223

- **The old gas boilers represent**
  - **34.71 TWh/yr, equivalent to 9,72 Mt CO_2/yr.**
- **The oil-fired boilers represent**
  - **33.57 TWh/yr, equivalent to 10.41 Mt CO_2/yr.**

Refrigerant emissions of current R-407C heat pumps

- **Annual emission rate : 10 % integrating**
  - **Fugitive emissions, emissions during maintenance and at end of life**

Refrigerant charge (kg / $kW_{heating}$)	**Annual emission rate (%)**	**GWP of R-407C** (kg eq. CO_2)
0,3	10	1 653

- **If all aged gas and oil-fired boilers are replaced by electric heat pumps, the necessary heating capacity is equivalent to approximately 38 million kW (heating).**

Refrigerant emissions of current R-407C heat pumps

- **The residential heat pumps corresponding to those 38 million kW (heating) are charged with approximately**
  - **11 500 t of R-407C**
  - **Meaning**
  - **1 150 t of R-407C annual emissions**
  - **And 1,9 Million t of CO_2 eq. emissions**

CO_2 emissions due to electrical consumption of R-407C heat pumps

- **Depending on the heat pump efficiency and on climatic conditions, the seasonal efficiency may vary from 2.8 to 3.6 (with current HP technology)**

Seasonal energy efficiency	2.8	3.0	3.2	3.4	3.6
TWh elect /yr	24.38	22.76	21.33	20.08	18.97
Emissions (Mt CO_2/yr)	5.44	5.07	4.76	4.48	4.23

TEWI comparison of old boilers and heat pumps

Seasonal energy efficiency of heat pump	2,8	3	3,2	3,4	3,6
Heat pump indirect emissions (Mt CO_2/yr)	5,44	5,07	4,76	4,48	4,23
Heat pump direct emissions (Mt CO_2/yr)	1,9	1,9	1,9	1,9	1,9
Annual TEWI of heat pumps (Mt CO_2/ yr)	7,34	6,97	6,66	6,65	6,13
Avoided emissions (MT CO_2 /yr)	12,79	13,16	13,47	13,5	14
Boiler emissions/ Heat pump emissions	2,75	2,89	3,03	3,16	3,29

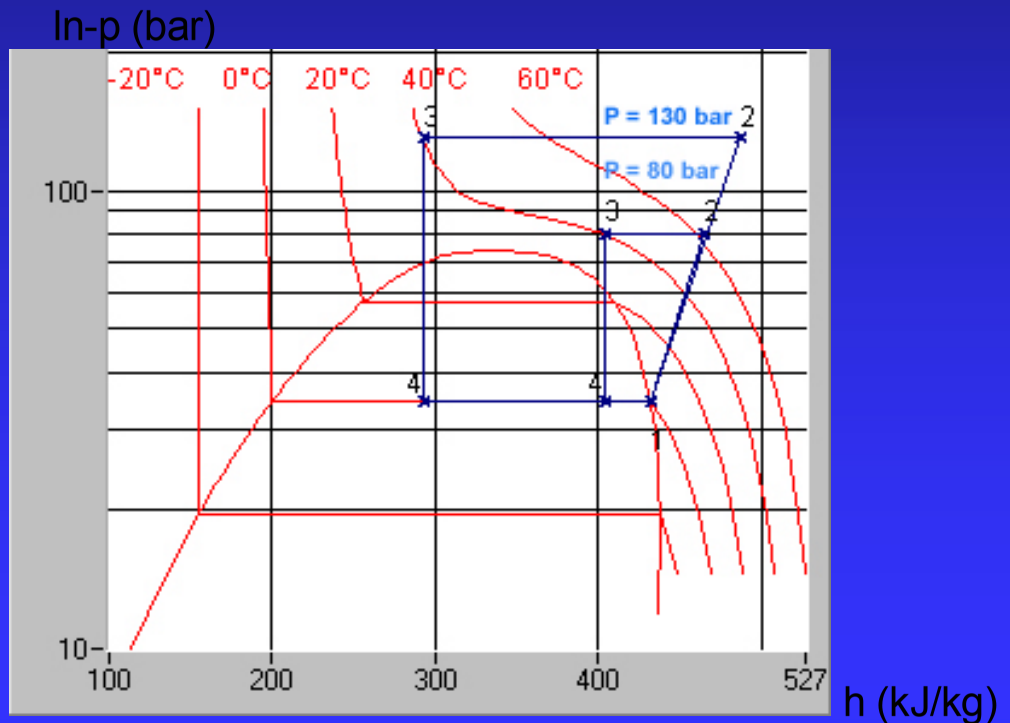
- **The replacement of the aging parc of boilers could lead to avoiding in the range of 13 to 14 MtCO_2/yr.**
- **Globally the TEWI of heat pumps is lower of a factor 3 compared to boilers.**

The refrigerants of the future

- **Is the efficiency of Residential HP running with CO_2 as a refrigerant the new reference line for TEWI?**
- **Is the cost of CO_2 heat pump possibly competitive?**
- **Are HCs acceptable as a widespread solution?**
- **How leak tight a HP system using HFCs could be along its life time ?**

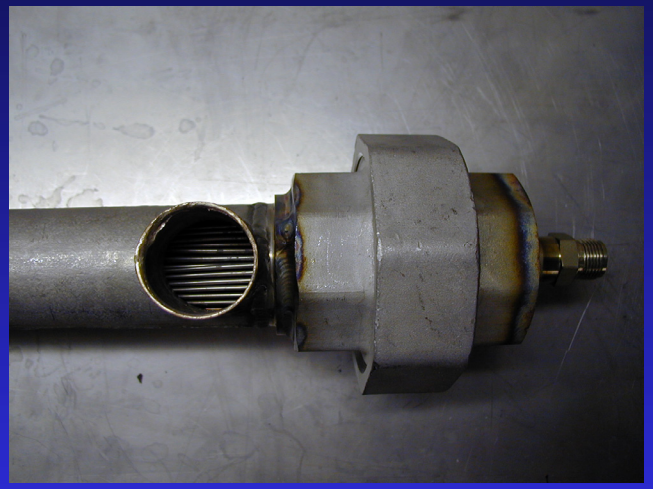
CO_2 Heat Pump main characteritics

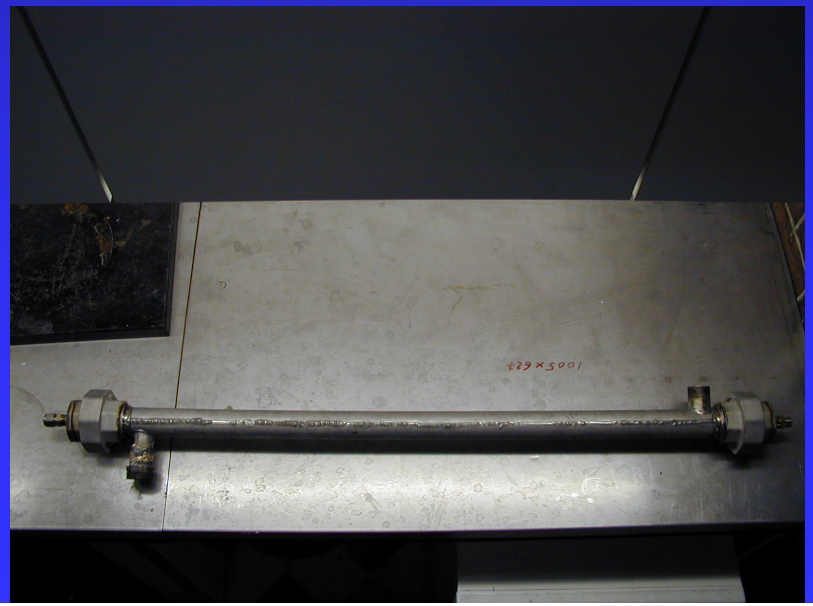
- **The GWP is 1**
- **Welcomed by many EU policy makers**
- **The transcritical cycle is inherently less efficient than a classical phase change cycle due to large difference of temperature during the refrigerant cooling process at high pressure**



CO_2 Heat Pump main characteritics

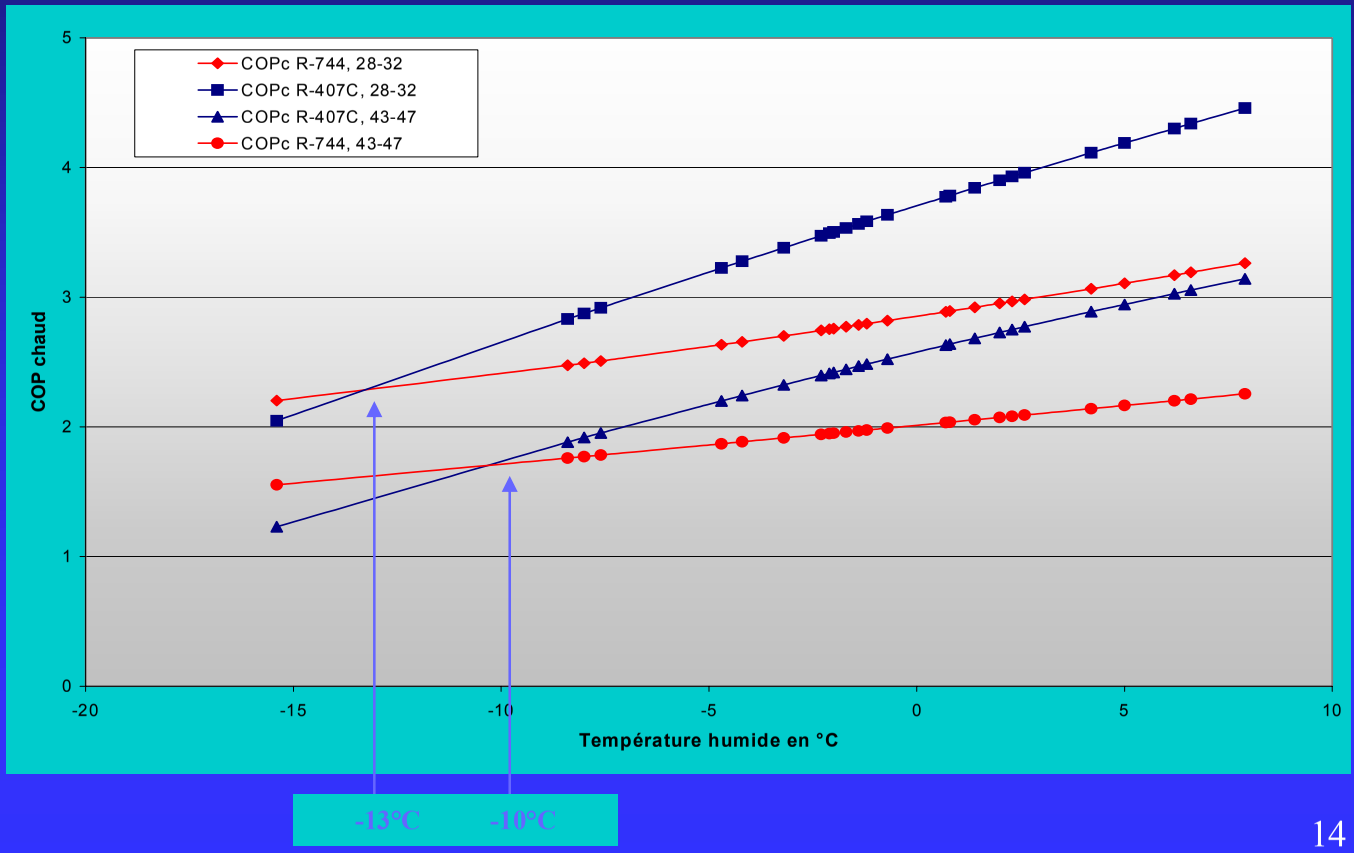
- The pressures are higher of a factor 8 to 10
- Dense gas at high pressure requires small tubes
- New designs, new opportunities ?
- High compactness
- Higher costs





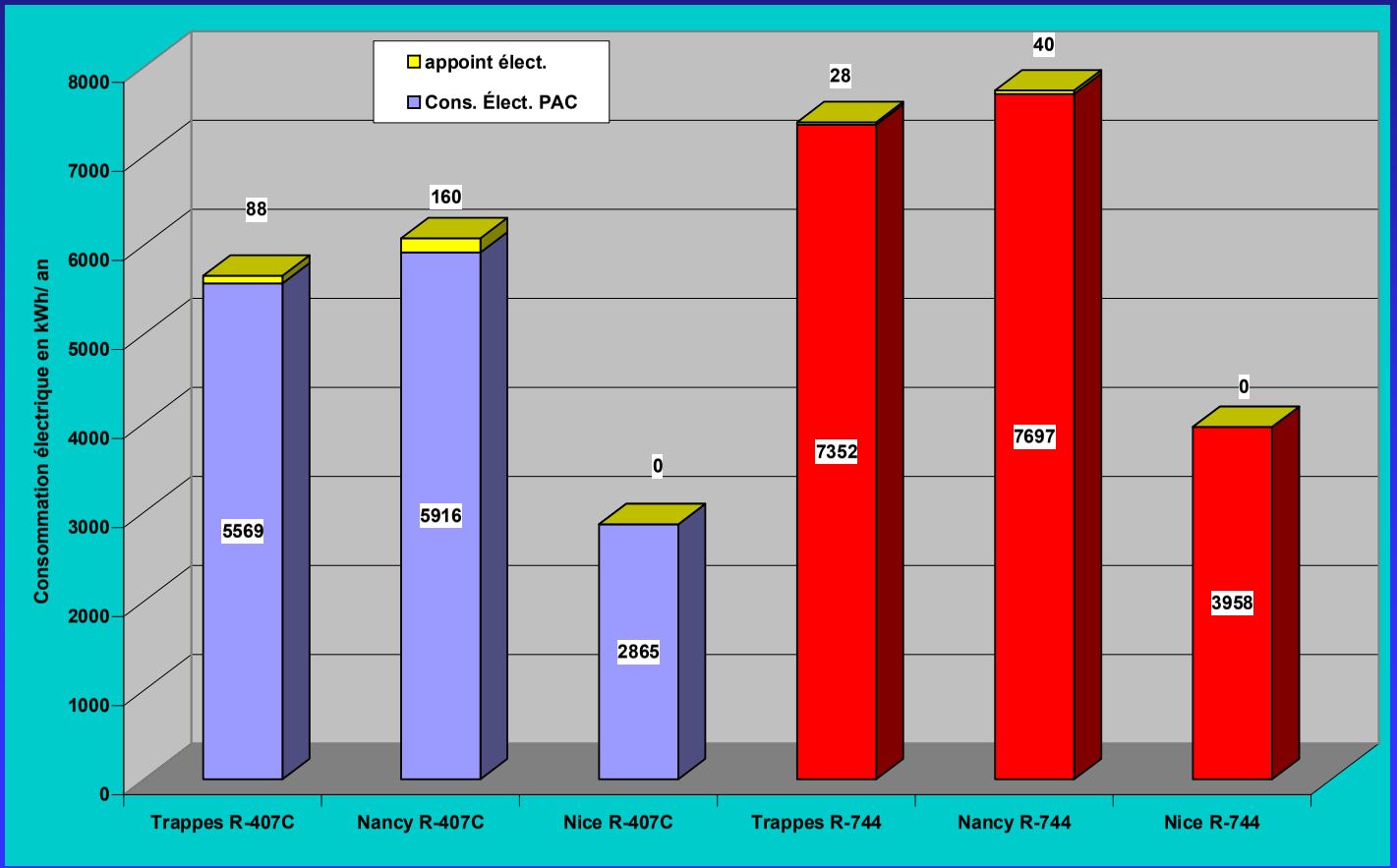
CO_2 Heat Pump main characteristics

- **The lower the outdoor temperature, the better the relative efficiency of CO_2**
- **The higher the heat delivery temperature, the lower the relative penalty for CO_2 for single stage system**



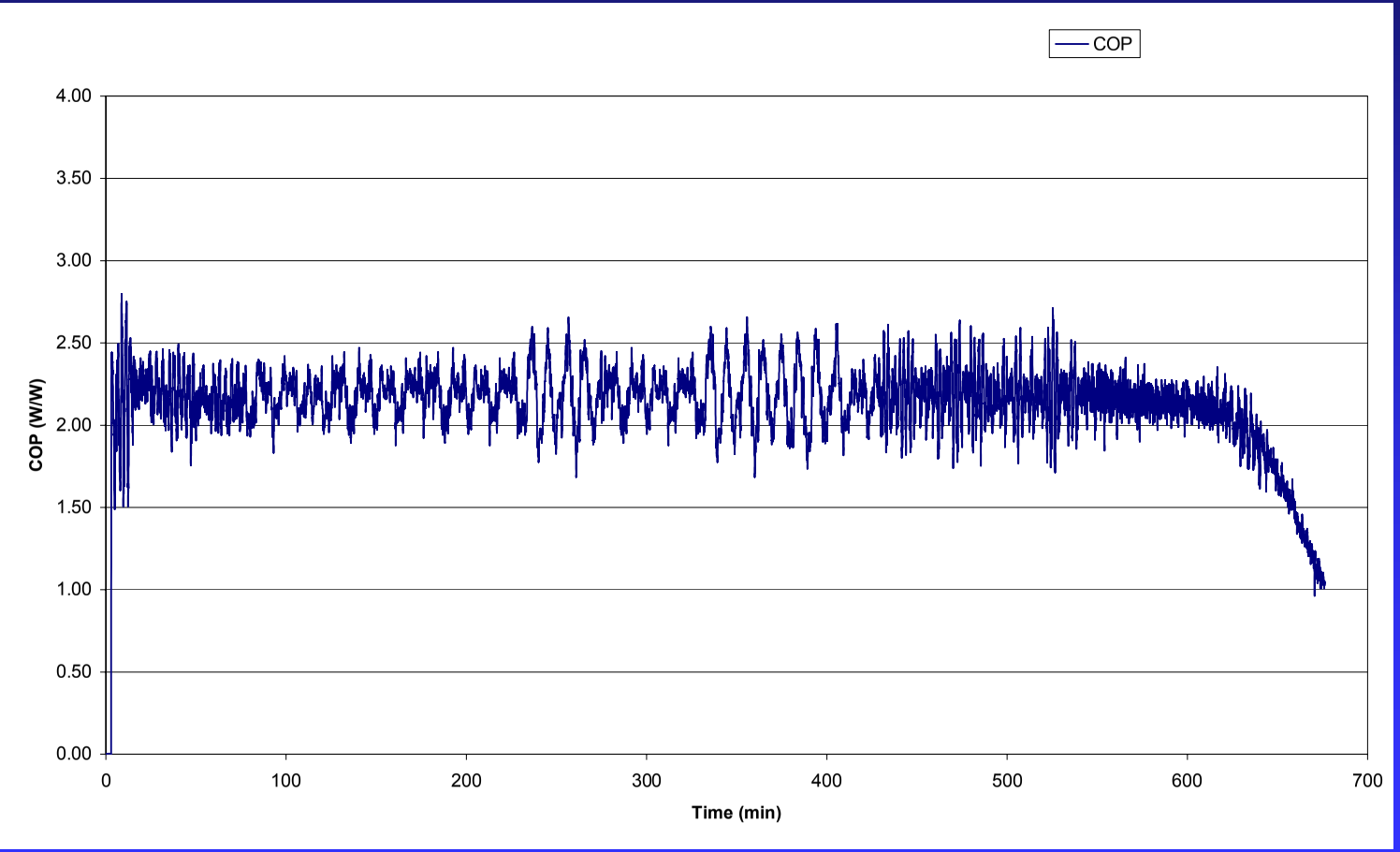
CO_2 Heat Pump main characteritics

- For a Heating delivery temperature @ 50°C
- R-407C has a higher seasonal efficiency in the range of 30% with current EU technology compared to CO_2



CO_2 Heat Pump main characteristics

- **For heating domestic hot water from 20 to 85°C for an outdoor temperature of 6°C the COP of Japanese High Effiicient CO_2 water heater is abour 2.3.**



How to reach a seasonal efficiency in between 3.5 to 4.5 for a 60°C condensing temperature?

- **Single-stage or 2-stage strategy?**
- **Both?**
- **Heat pump only or reversible HP?**
- **R-410A or R-407C?**

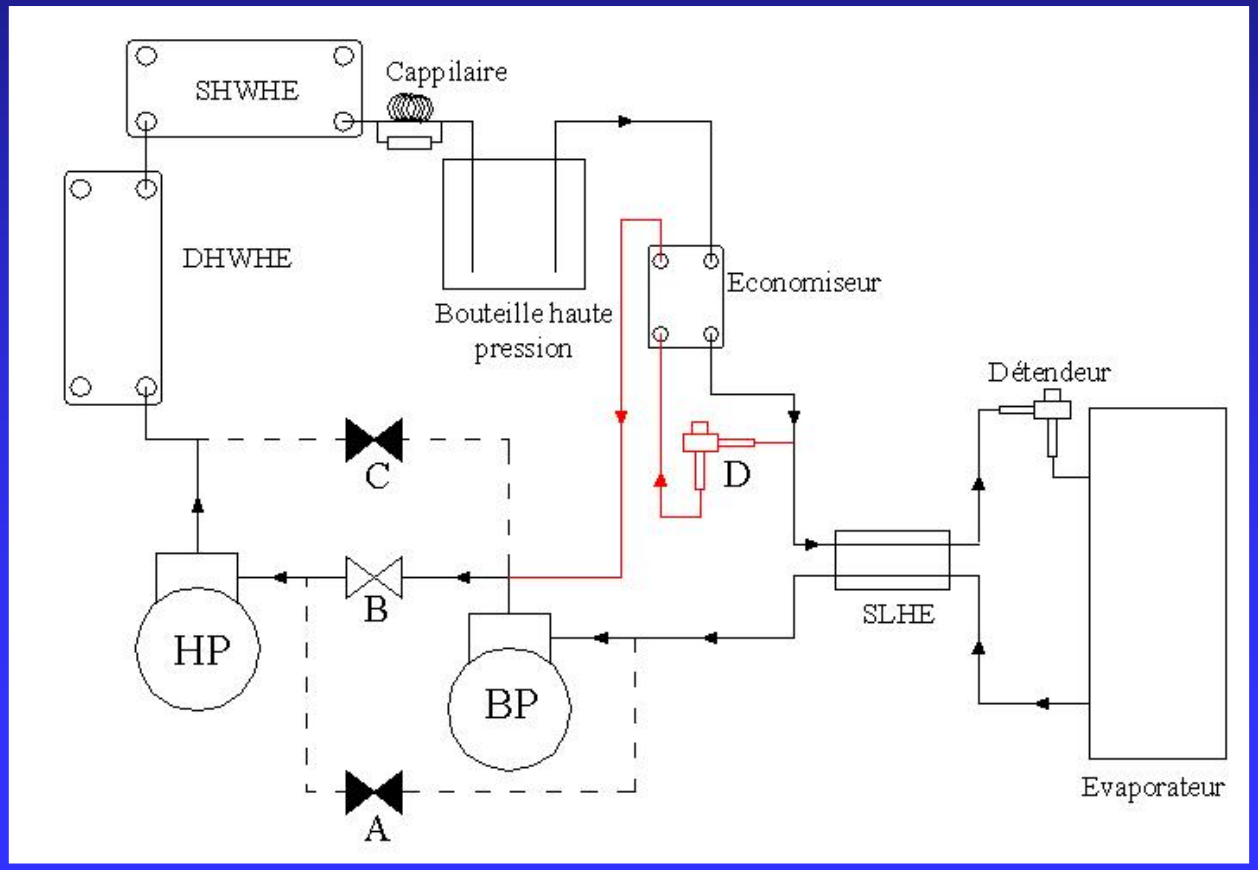
How to reach a seasonal efficiency in between 3.5 to 4.5 for a 60°C condensing temperature?

- **Depending on the condensing temperature R-407C may have advantages compared to R-410A**
- **R-407C Tc = 86.2°C**
- **R-410A Tc = 72.5°C**

- **R-407 composition can be controlled by appropriate devices and strategies so that capacity and efficiency can be adapted according to outdoor temperatures.**

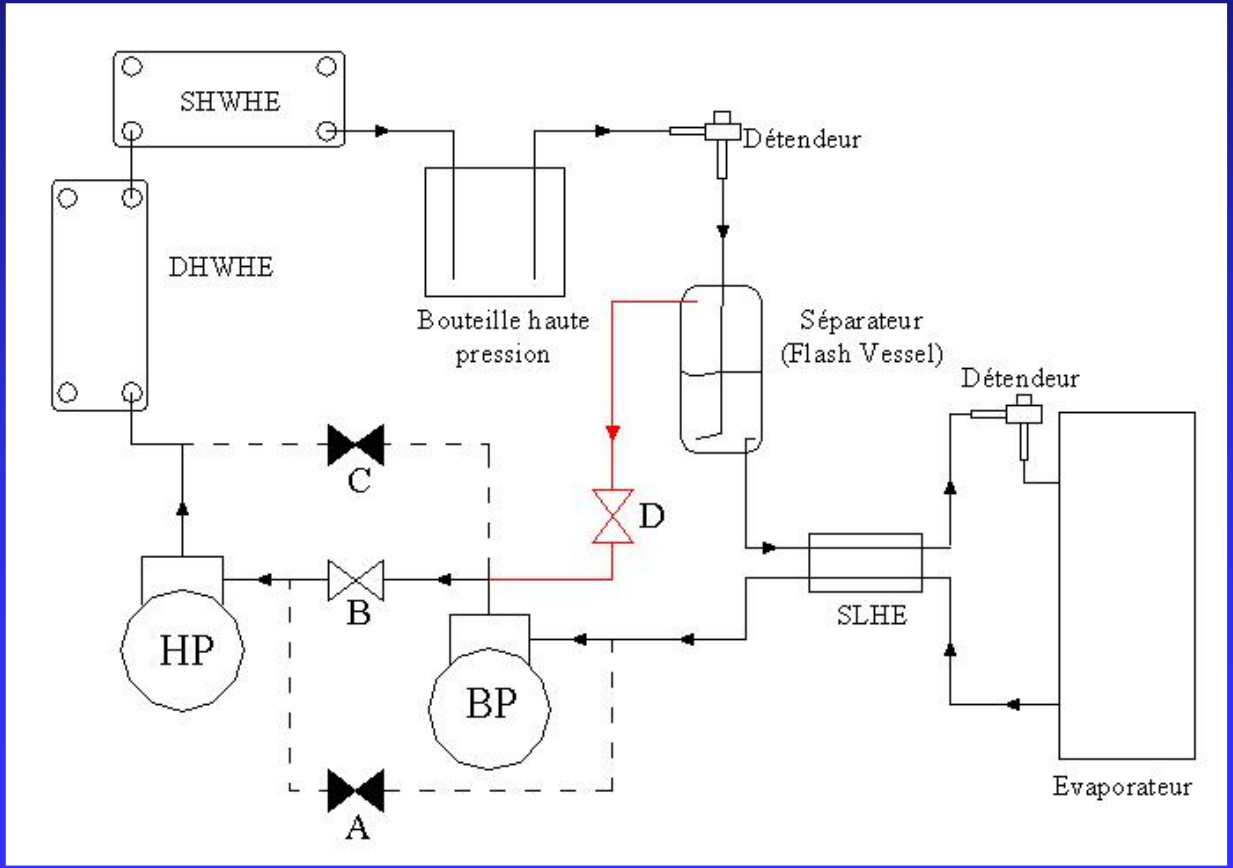
How to reach a seasonal efficiency in between 3.5 to 4.5 for a 60°C condensing temperature?

- **2-stage strategy with economizer and possibly injection at a medium pressure of a single compressor**



How to reach a seasonal efficiency in between 3.5 to 4.5 for a 60°C condensing temperature?

- **2-stage strategy with 2 compressors**



GWP only oriented policy or Environment performance oriented policy?

- **How low is a low GWP refrigerant ?**
- **Decisions on moving Energy and Environment performance targets**
- **Or**
- **Ban of HFCs?**