# SAFE AND ENVIRONMENT FRIENDLY REFRIGERANTS FOR INDUSTRIAL ENERGY RECOVERY PROCESSES

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2014 ASHRAE Winter Conference
New York, NY
January 21st , 2014

ARKEMA
INNOVATIVE CHEMISTRY

# Learning Objectives

- **1. Design refrigeration and air-conditioning systems with respect to the thermodynamic properties of the new, low-GWP refrigerants, in comparison with the past and current refrigerants.**
- **2. Assess the overall economic aspects of the vapor-compression systems according to the performance of the refrigerant in vapor-compression cycles, accounting for the cycle efficiency, heat transfer, pressures, and material compatibility.**
- 3. Outline the design aspects of the refrigeration and AC systems with respect to the solubility of refrigerants and lubricants and their heat transfer characteristics.
- 4. Explain how the molecular formula and structure of the refrigerants determine their thermodynamic properties, thermal stability, and their relationship with lubricants and construction materials.
- 5. Describe the correlation between the chemical composition and molecular structure of the refrigerants and their environmental characteristics.
- 6. Associate the composition of the refrigerant blends with their potential flammability, environmental impact, and performance in refrigerating and air-conditioning equipment.

# Thank You

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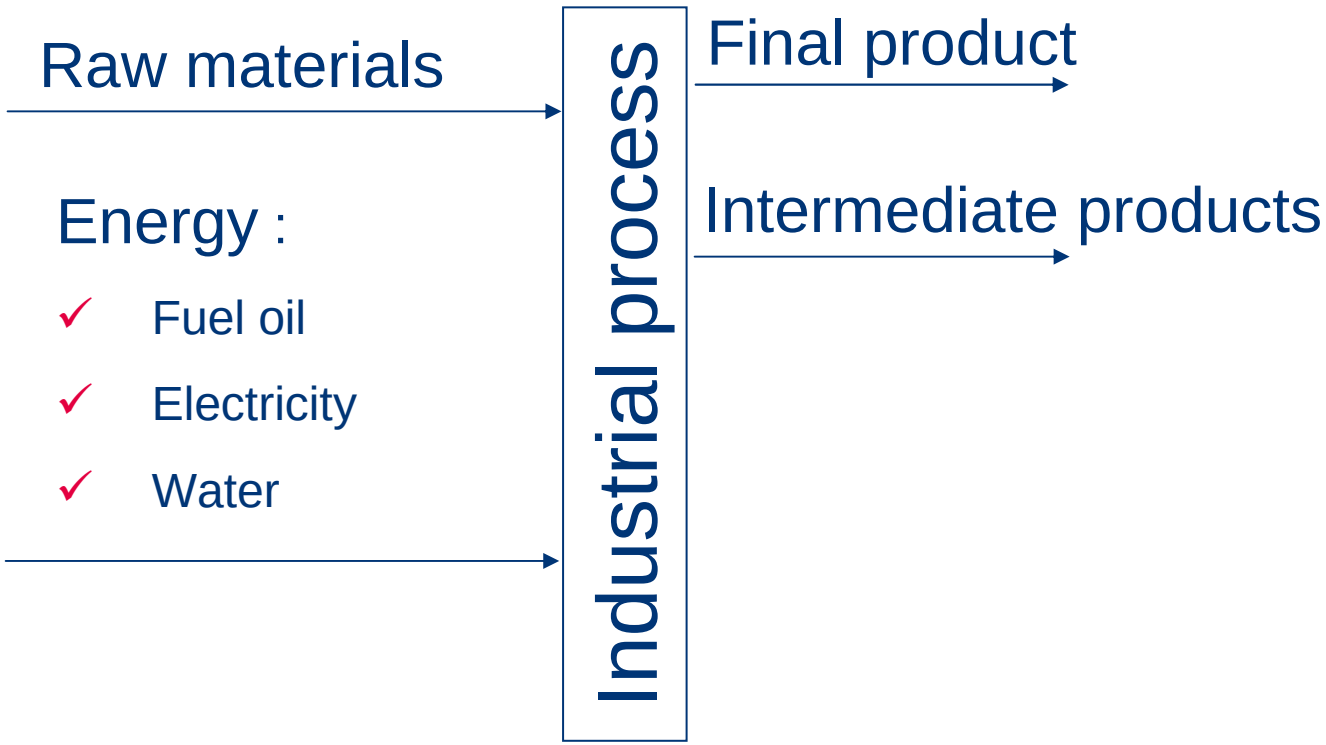
# Agenda

- High Temperature Energy – Waste Heat
- Thermodynamic Systems for Energy Recovery
- Practical experience with High Temperature Heat Pumps (HTHP)
- New low GWP fluids for HTHP
- Conclusions

# High Temperature Energy



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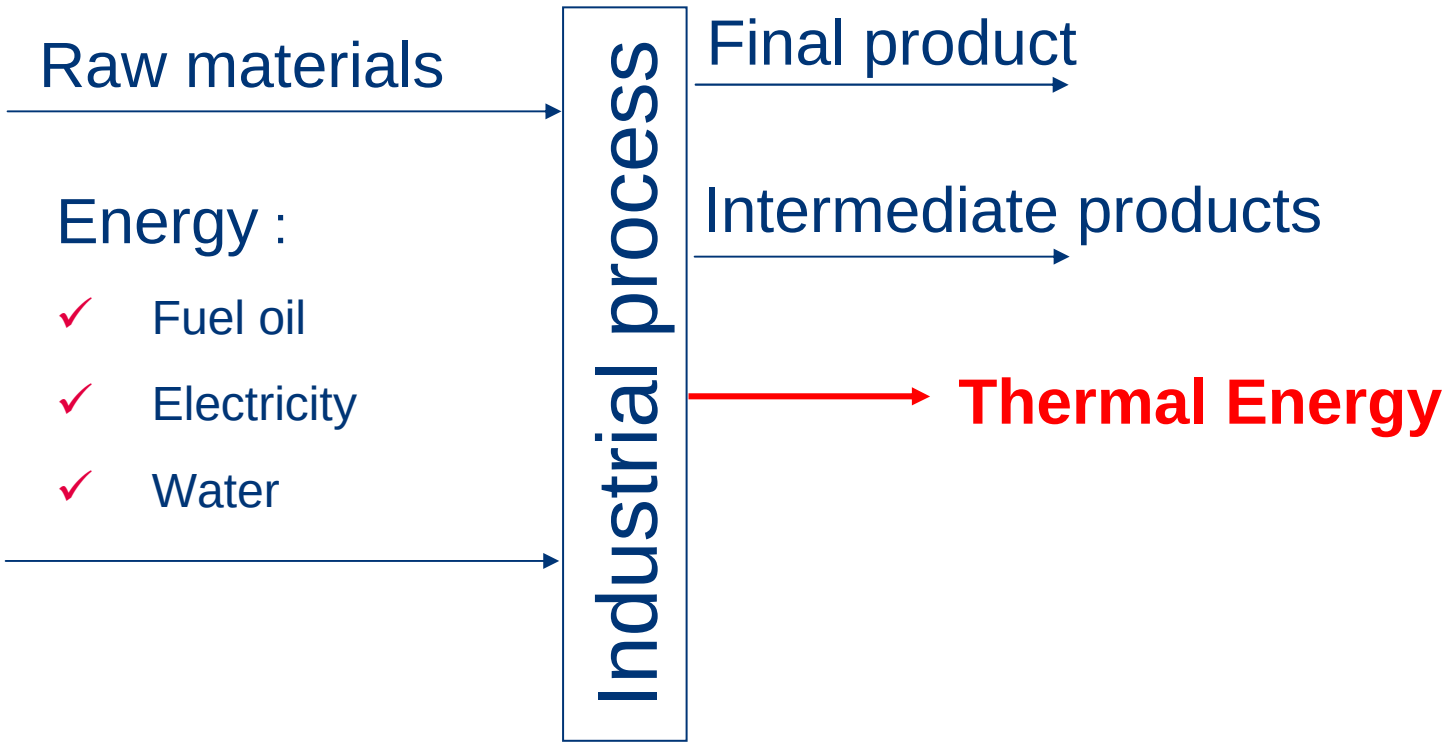

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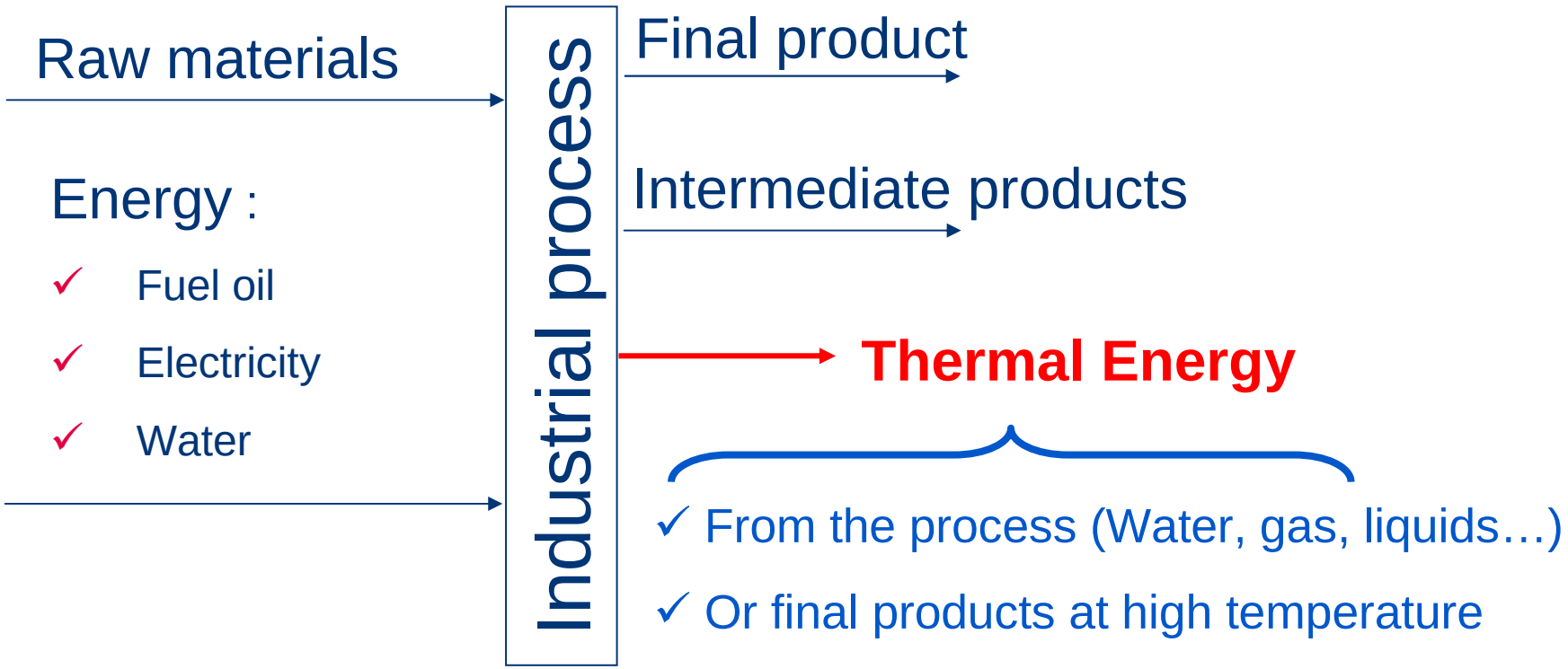
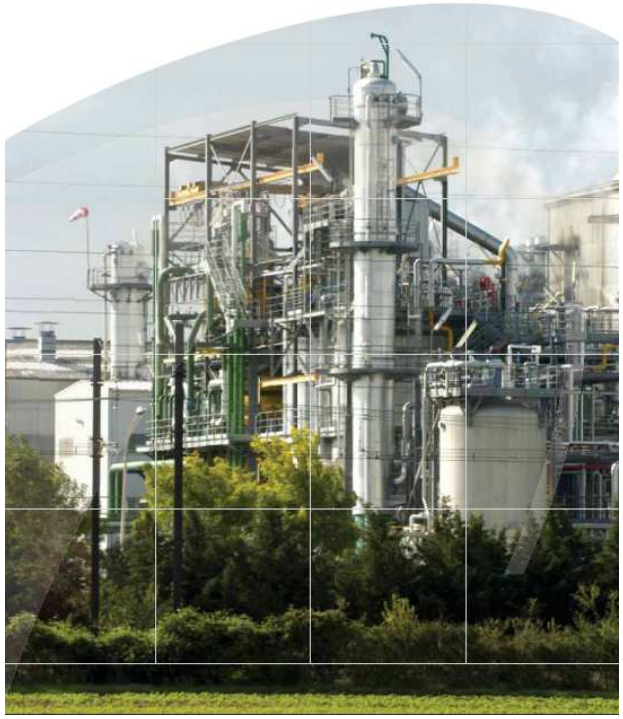


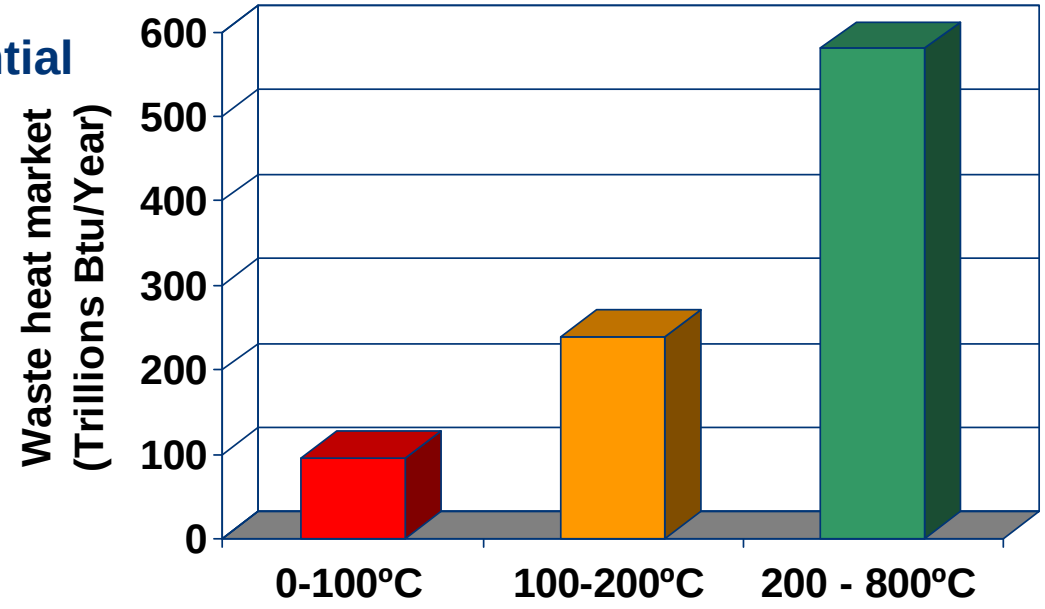
# High Temperature Energy

- ✓ All Chemical industries
  - ✓ Polymers, PVC, Plastics, Medicines…
  - ✓ Petrochemical, Oil refining industries
- ✓ Food processing
  - ✓ Milk, cheese…
  - ✓ Beer
- ✓ Water desalination industries
- ✓ Papers industries



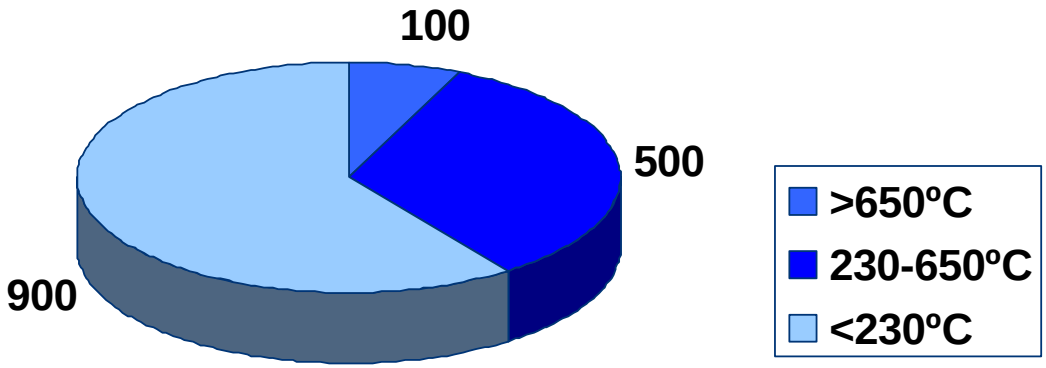
# Waste Heat Opportunities

## France Industry Waste heat potential in Trillions BTU/Year, 2008



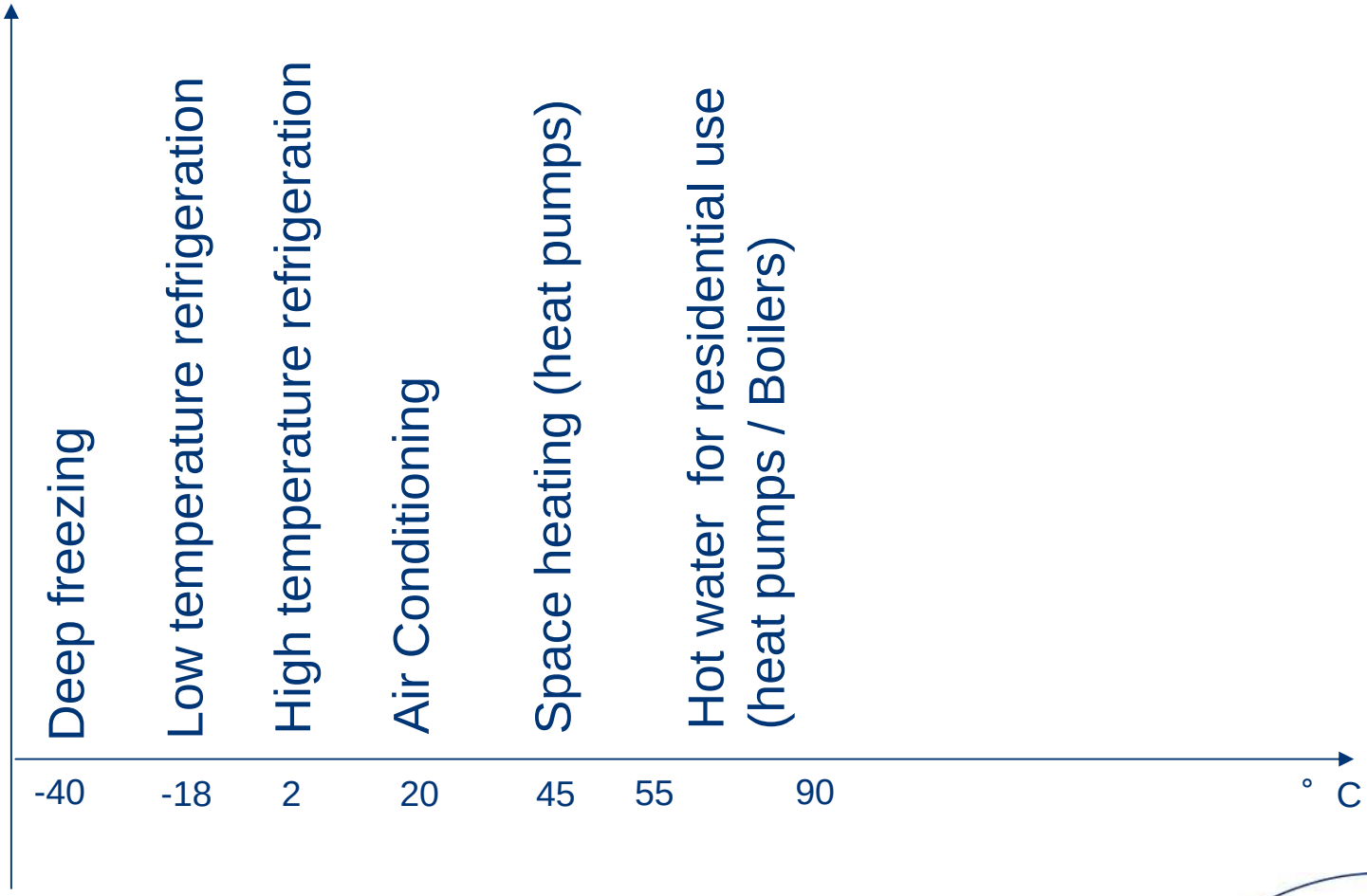

Source : EDF 2008

## US Industry Waste heat potential in Trillions BTU/Year, 2008




Source : Waste Heat Recovery, US Department of Energy, March 2008

# Thermodynamic Systems for Energy Recovery



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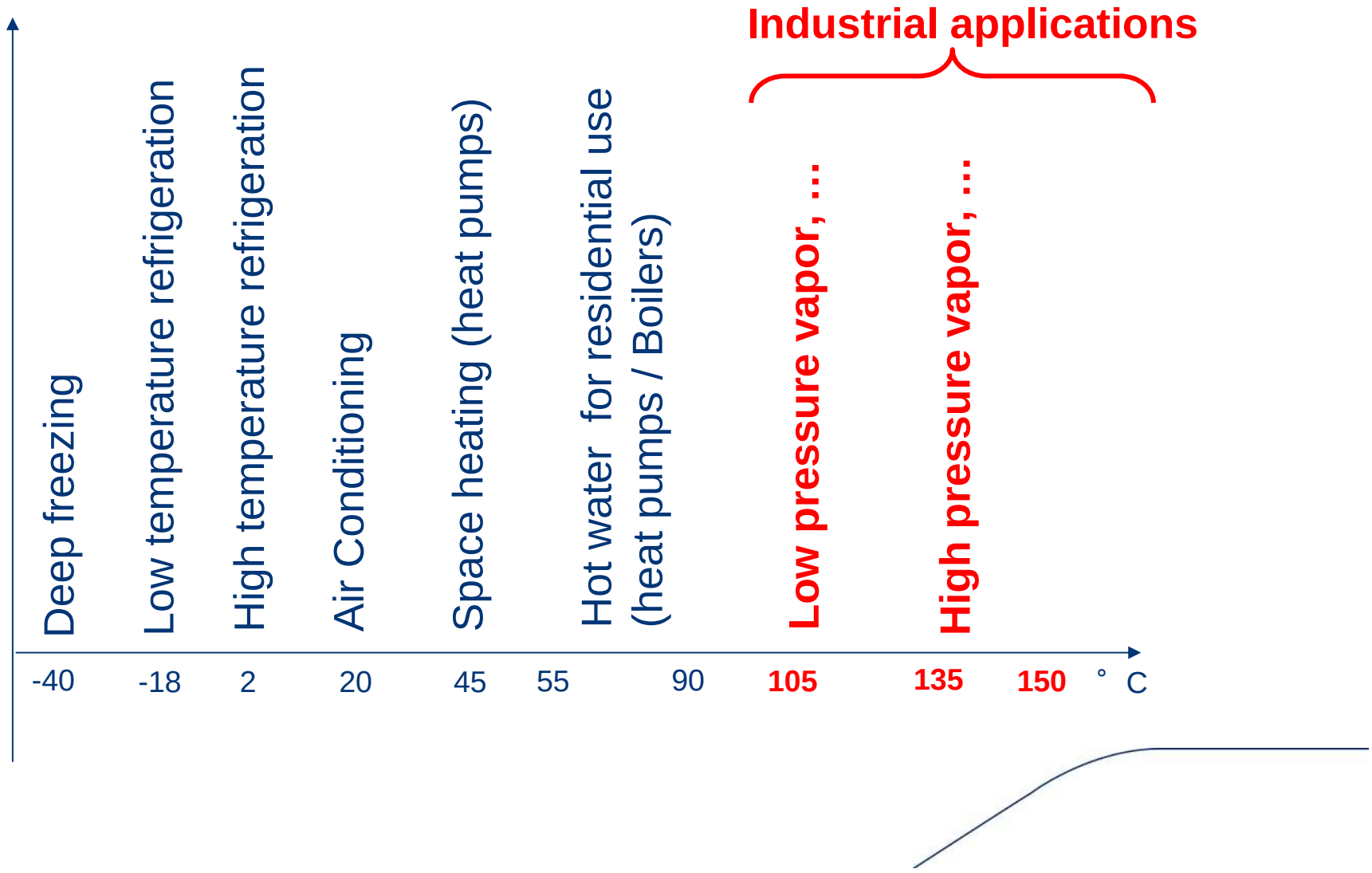

# Thermodynamic Systems for Energy Recovery

**Process needs**

High temperature energy (100…150° C)

Other energy needs outside the process

**Waste heat**

Low temperature free energy (50…70…100..° C)

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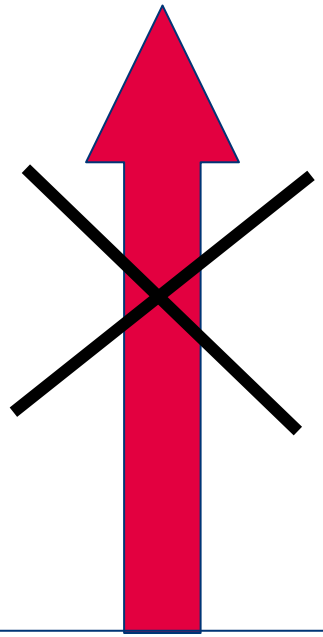

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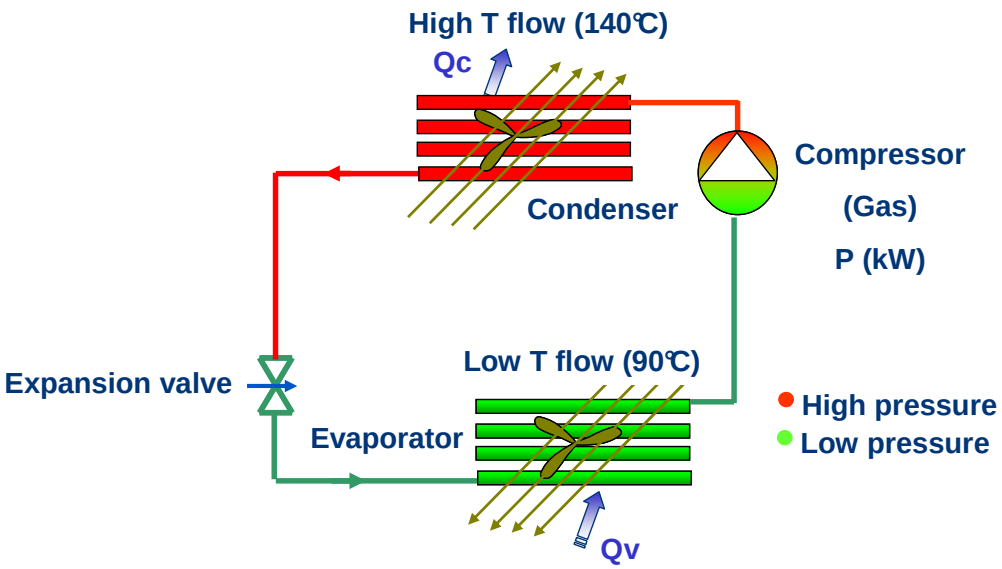



**High Temperature Heat Pump (HTHP)**

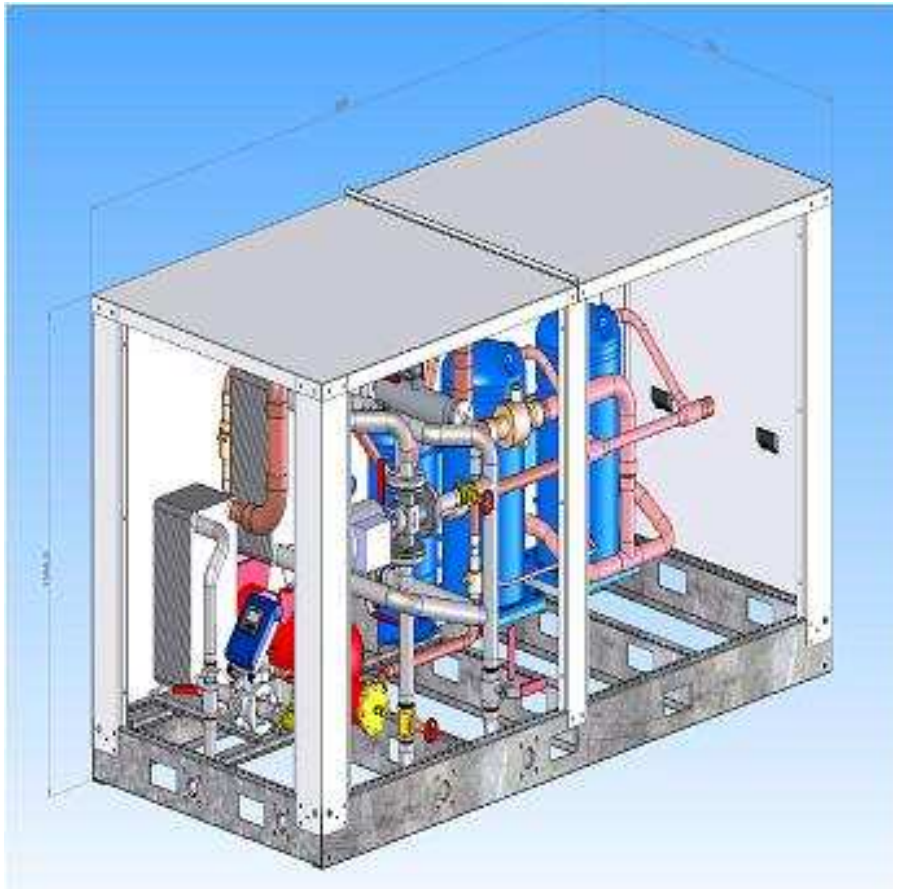
**Waste heat**

Low temperature free energy (50…70…100..° C)

# Practical experience with High Temperature Heat Pump

**A prototype was built to assess feasibility of heat recovery**

- Set of two **scroll** compressors for a 30 KW power consumption
- Pipes and tubes heat exchangers
- Installed and tested by **EDF** – France
- **Non-commercial HFC blend as working fluid**
  - $T_C$ > 155ºC



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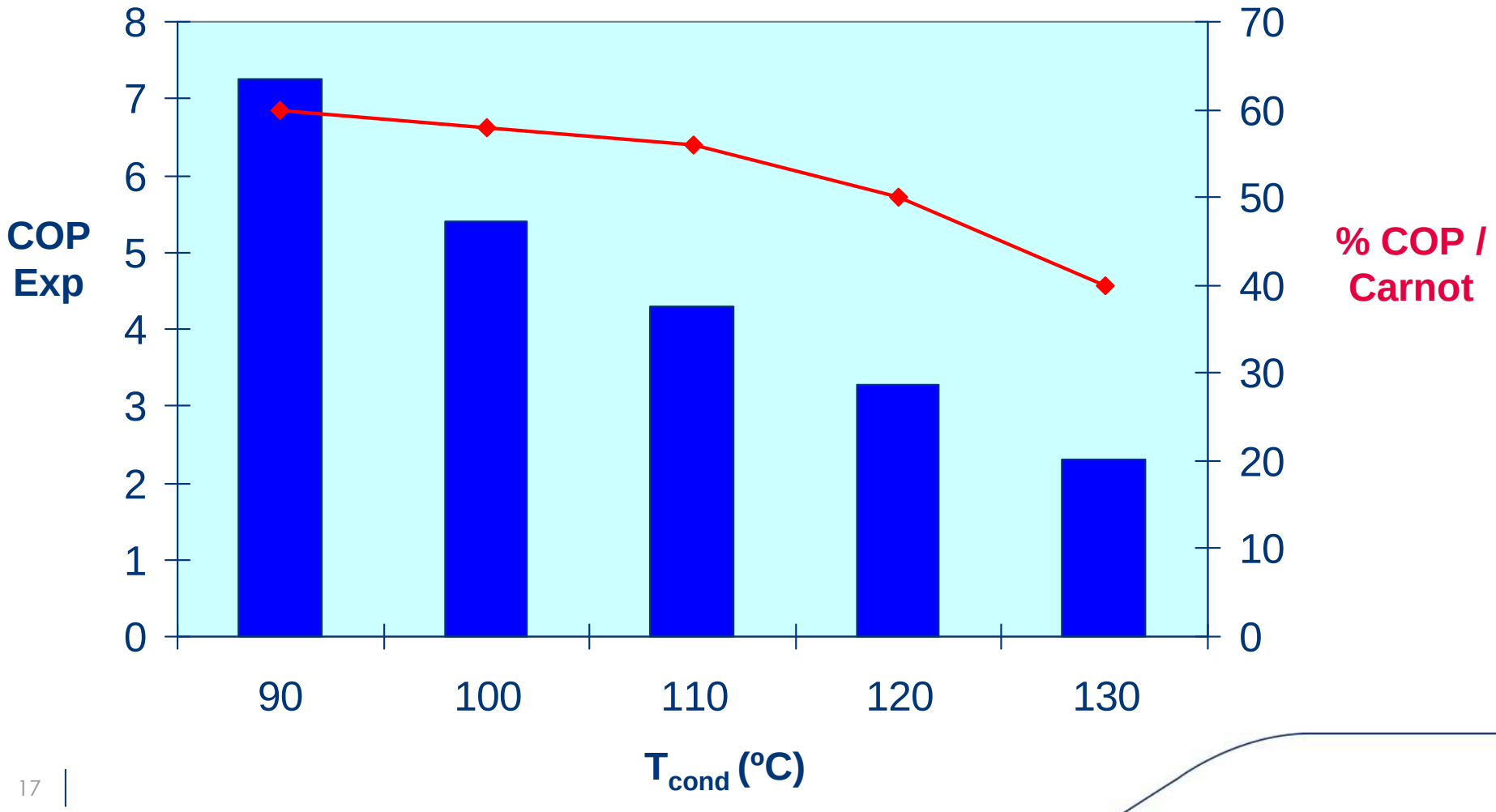
# Practical experience with High Temperature Heat Pump

## Performances at 60ºC evaporating temperature



# Working Fluids for Energy Recovery

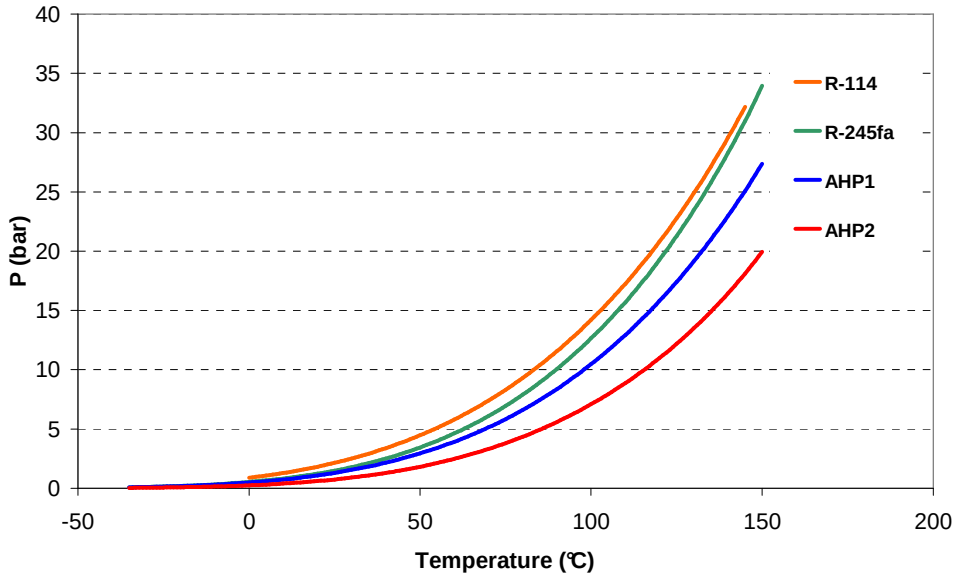
- **Benefits of the Industrial Heat Pumps depend on the :**
  - Waste heat temperature
  - Temperature lift
- **Maximum temperature lift will be determined by**
  - Type of cycle
  - Nature of working fluid
- **First working fluid identified for energy recovery was R-114**
  - Today, some hydrocarbons or HFCs can potentially be used.
  - But applications of these fluids is limited by either flammability, critical properties or GWP

**New low-GWP fluids have been identified**

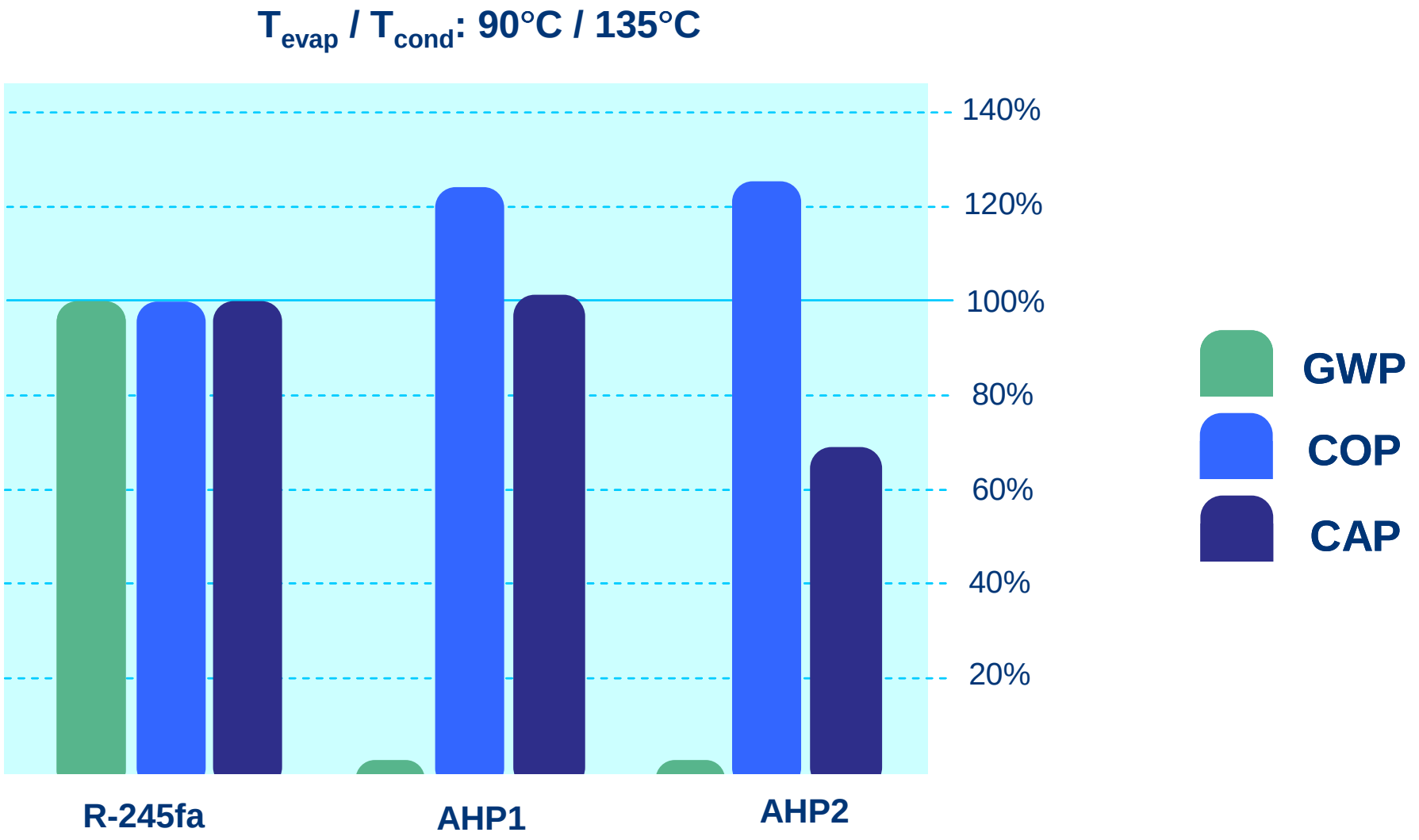
# Working Fluids for Energy Recovery

**AHP1 and AHP2** are two promising **Non Flammable and Very Low GWP** refrigerants for High Temperature Heat Pumps (HTHP)

| Substance | Tc (℃) | GWP |
|---|---|---|
| **AHP1** | **>165** | **<13** |
| **AHP2** | **>170** | **<10** |
| **HFC blend (prototype)** | **>155** | **<1000** |
| **R-245fa** | **154** | **1030** |
| **R-114** | **146** | **1040** |



# High Temperature Heat pump cycle analysis



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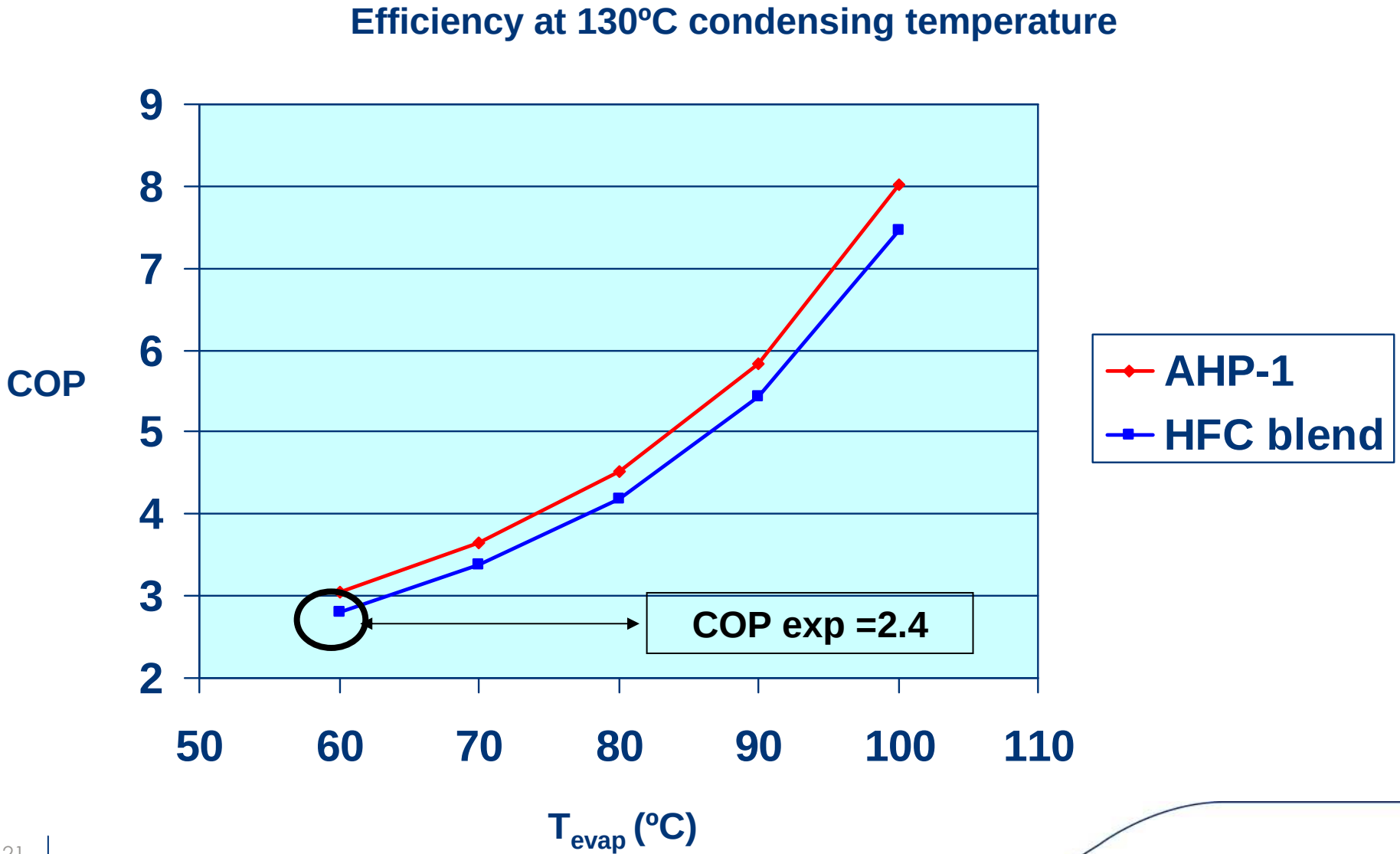

# Conclusions

- **The industrial waste heat recovery can contribute to the reduction of CO2 emission and global warming.**
- **Industrial Heat Pumps is a promising technology for energy recovery.**
- **Prototype Heat Pump confirmed potential for energy recovery and cost savings**
- **AHP1 and AHP2 are two very low GWP fluids that could enhance the use of heat pumps for heat recovery**

# Questions?

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