New generation of ecological refrigerant: how do they affect the building design and management?
The global forecast
The refrigerants

- **Safety**
  - toxicity (acute and chronic)
  - flammability

- **Environment**
  - Ozone depletion potential (ODP)
  - greenhouse warming potential (GWP)
  - atmospheric lifetime

- **Materials**
  - compatibility with metals, plastics...

- **Plant performance**
  - suitable thermodynamic and transport properties

- **Miscellaneous**
  - low cost, availability, easiness to detect leakages, ...
The refrigerants evolution

FIRST GENERATION (1830 – 1930)
Whatever substance (obviously natural) could grant a result.

SECOND GENERATION (1931 – 1990)
Early-synthesized compounds with some natural substances
CFC, HCFC, HFC, NH₃, H₂O, ....

THIRD GENERATION (1990 – 2010)
Montreal Protocol
Safeguard of the Ozone Layer.
Additional synthesized compounds & reconsideration of some natural fluids
(HCFC), HFC, NH₃, H₂O, HC, CO₂,

FOURTH GENERATION (2010 – ?)
Kyoto Protocol, EU F-gas Regulation
...HFO, HFA, HCFO, HFC, NH3, H2O, HC, CO2, Kyoto Protocol, EU F-gas Regulation
GWP is an index assigned to a chemical compound. It is based on radiative properties of greenhouse gases, measuring the relative greenhouse effect (radiative forcing) following an emission of a mass of a given greenhouse gas in the present day atmosphere integrated over a specific time horizon (for example 100 years), as compared to that expected from the same gas emission of Carbon Dioxide.

Consequently for CO₂ GWP = 1.
According to the UNEP document ‘The Importance of Energy Efficiency in the Refrigeration, Air –Conditioning and Heat Pump (RACHP) Sector:

- RACHP equipment at present represents between 25% and 30% of the global consumption of electricity.
- Increasing average global temperatures due to climate change, economic growth and urbanization are widely expected to lead to a greater demand for cooling. Additional factors driving this growth are: i- wider use of air-conditioning in homes, in the workplace and in cars; ii- the strengthening of the cold chain to reduce food waste; iii- increased use of heat pumps to reduce GHG emissions from heating systems.
- The lion’s share of this growth will be in emerging economies / developing countries.

- the number of air conditioners in use globally will increase from 1.5 billion to 5.5 billion units between 2015 and 2050 (IEA)
TEWI – Total Equivalent Warming Impact

- from the production of the electric energy used by the system in its life-time.
- The **DIRECT** and **INDIRECT** effects must be added together to compute the TEWI index.

\[
 TEWI = m \cdot GWP + \alpha_{CO2} \cdot T \cdot e
\]

- \( m \): total mass of refrigerant leaked into the atmosphere during system’s lifetime
- \( GWP \): global warming potential of the refrigerant with respect to \( CO_2 \);
- \( \alpha_{CO2} \): mass of \( CO_2 \) emitted into the atmosphere per unit electric energy reaching the final user;
- \( T \): useful life-time of system;
- \( e \): mean electric energy used in unit of time.

<table>
<thead>
<tr>
<th>CO(<em>2) EMISSION FROM ELECTRICITY PRODUCTION [kg(</em>{CO2})/kWh(_{el})]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 DATA *</td>
</tr>
<tr>
<td>Argentina 0.394 kg(<em>{CO2})/kWh(</em>{el})</td>
</tr>
<tr>
<td>Austria 0.151</td>
</tr>
<tr>
<td>Brasil 0.160</td>
</tr>
<tr>
<td>France 0.041</td>
</tr>
<tr>
<td>Germany 0.474</td>
</tr>
<tr>
<td>Italy 0.331</td>
</tr>
<tr>
<td>Slovenia 0.226</td>
</tr>
<tr>
<td>Spain 0.255</td>
</tr>
<tr>
<td>Sweden 0.011</td>
</tr>
<tr>
<td>United Kingdom 0.413</td>
</tr>
<tr>
<td>OECD Europe 0.311</td>
</tr>
<tr>
<td>Australia 0.735</td>
</tr>
<tr>
<td>Botswana 1.587</td>
</tr>
<tr>
<td>China (PRoC) 0.680</td>
</tr>
<tr>
<td>Cuba 0.770</td>
</tr>
<tr>
<td>Japan 0.556</td>
</tr>
<tr>
<td>New Zealand 0.131</td>
</tr>
<tr>
<td>South Africa 1.009</td>
</tr>
<tr>
<td>USA 0.486</td>
</tr>
<tr>
<td>WORLD 0.519</td>
</tr>
</tbody>
</table>

*Source: IEA Statistics 2017*
VRF vs CHILLED WATER SYSTEM

VRF

VS

CHILLED WATER
VRF vs CHILLED WATER SYSTEM

SIMPLIFIED SCHEME
VRF vs CHILLED WATER SYSTEM

La pompa di calore ANKI con gruppo di pompaggio integrato per riscaldamento e raffrescamento con impianto a cattuconvettori - Produzione di ACS mediante pompa di calore dedicata SWP

VRF E6
Pannello di controllo centralizzato

VRF E19
Termostato (slave)

VRF E19
Termostato (master)

VRF E4X
Interfaccia a parete
VRF vs CHILLED WATER SYSTEM

**VRF**
- High nominal efficiency
- Installation cost
- Easy designing
- Huge refrigerant amount
- No compatibility among different brand

**CHILLED WATER**
- Flexibility
- Minimal refrigerant amount
- Lower nominal efficiency
- Installation cost
- Design is required
VRF vs CHILLED WATER SYSTEM

EFFICIENCY = \( F(DISTANCE) \)

WITH VRF +2.5\% of the power input of the compressor every 10 m of pipe

Piping for hydronic and VRF
Ducting for VAV and VVT
VRF vs CHILLED WATER SYSTEM

**56 kW VRF vs 56 kW CHILLED WATER**

- **NOMINAL**
  - EER 3,5
- **TOT Refrigerant charge**
  - 44,3 kg

VS

- **NOMINAL**
  - EER 2,9
- **TOT Refrigerant charge**
  - 8,3 kg

+21%

+20%
# VRF vs CHILLED WATER SYSTEM

<table>
<thead>
<tr>
<th></th>
<th>VRF</th>
<th>Chiller</th>
<th>DELTA VRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q gas system [kg]</td>
<td>44,3</td>
<td>8,3</td>
<td></td>
</tr>
<tr>
<td>GWP R410a (100 a)</td>
<td>2088</td>
<td>2088</td>
<td></td>
</tr>
<tr>
<td>CO2 equivalent (Tons)</td>
<td>92</td>
<td>17</td>
<td>+534%</td>
</tr>
<tr>
<td>EER (Catalogue)</td>
<td>3,5</td>
<td>2,9</td>
<td>+21%</td>
</tr>
<tr>
<td>Input [kW]</td>
<td>16</td>
<td>19,3</td>
<td></td>
</tr>
<tr>
<td>Energy losses [for 10m]</td>
<td>2,5%</td>
<td>N.A</td>
<td></td>
</tr>
<tr>
<td>DISTANCE [m]</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Pump [kW]</td>
<td>N.A</td>
<td>1,1</td>
<td></td>
</tr>
<tr>
<td>TOTAL INPUT</td>
<td>18,8</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>OVERALL EER</td>
<td>2,84</td>
<td>2,74</td>
<td>+3%</td>
</tr>
</tbody>
</table>

Does the slight energy efficiency justify such a large amount of refrigerant and its potential damages?

The most frequent damage in an air conditioning unit is the leakage of refrigerant!
...new refrigerants?

... often trade-off solutions are now required!
Conclusions
QUESTIONS?

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