



Development of Ground-Source Heat Pumps with natural refrigerant for the reduction of the impact in historical buildings

Ing. Fabio Poletto

HiRef S.p.a. – Galletti Group

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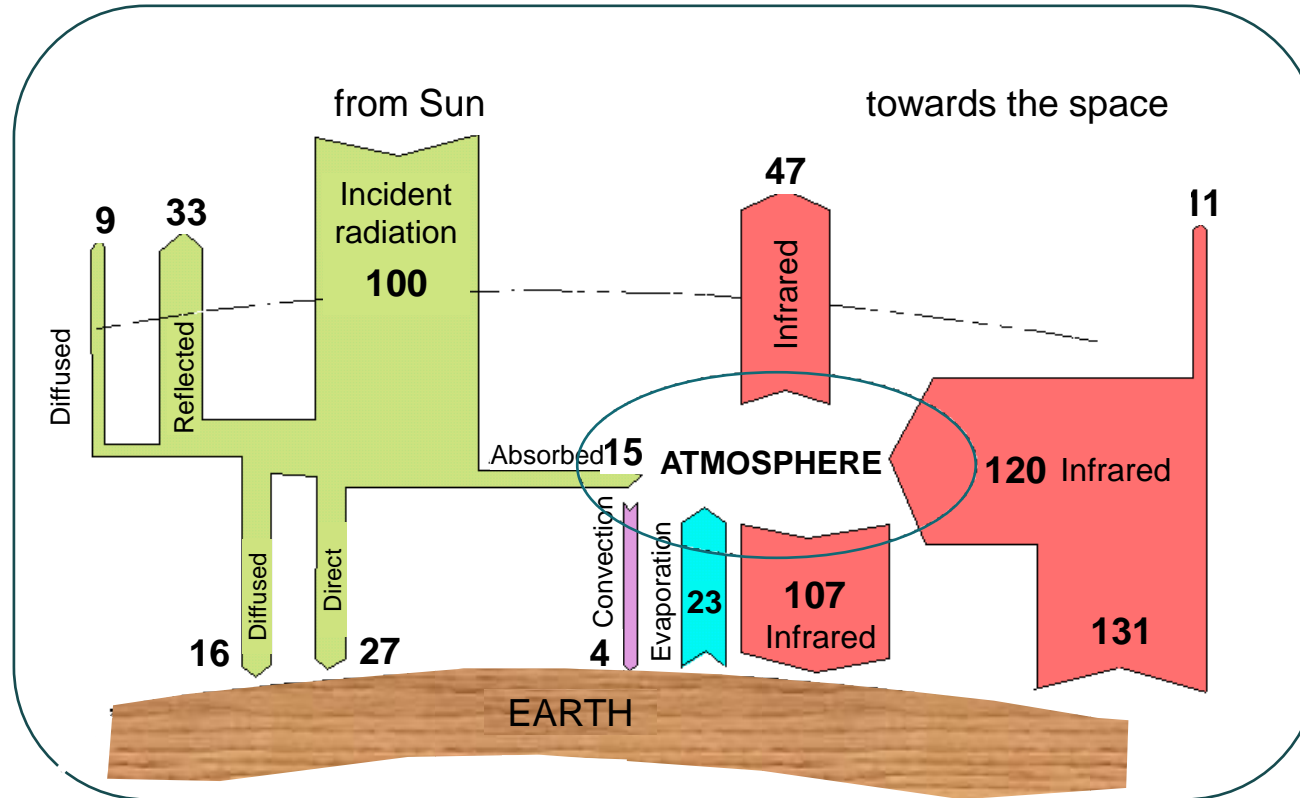
Technical Challenges for the development of Ground-Source Heat Pumps

- Suitable for the refurbishment of existing building:
 - Reduction of impact in the installation:
 - **No interference** with surround
 - **Little space available** for technical room
- Environmental friendly substances:
 - **Refrigerant with Low Impact**
 - **Reduced charge**
- Optimization of **CAPEX** and **OPEX**



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THE GLOBAL WARMING ISSUE

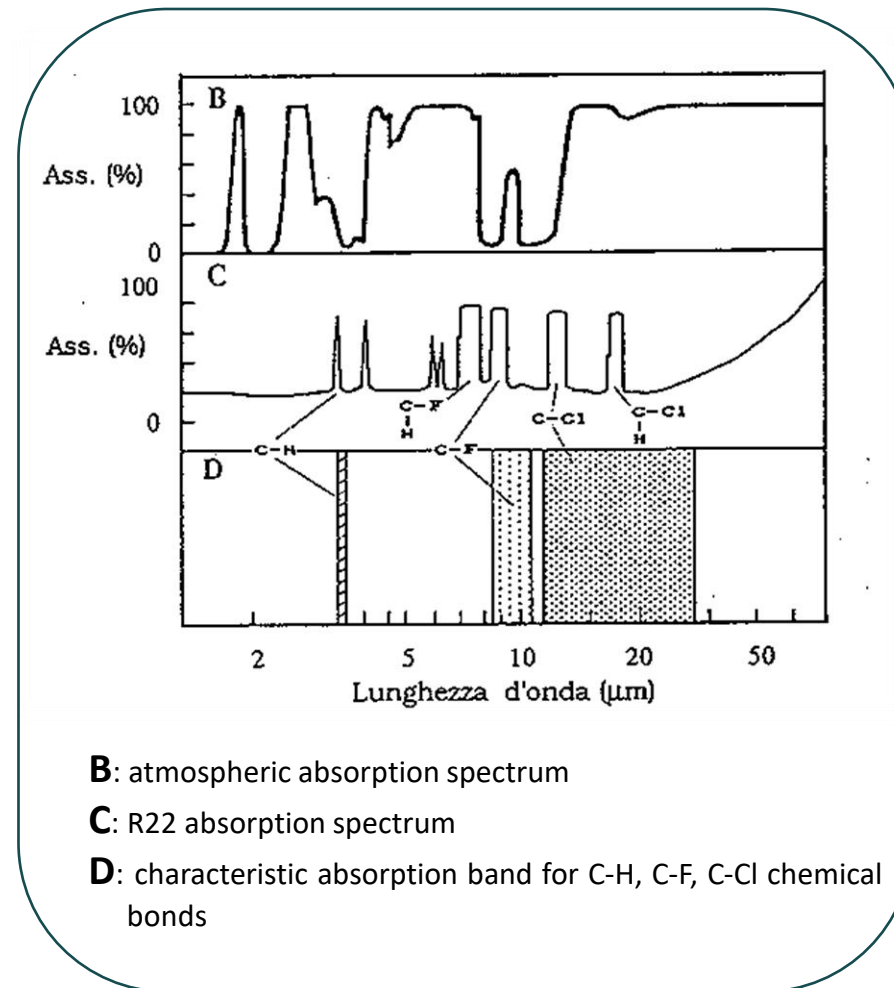


ANTROPOGENIC EMISSIONS OF GREENHOUSE GASES ARE ALTERING THE ENERGETIC EQUILIBRIUM OF ATMOSPHERE

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FACTORS INFLUENCING THE GLOBAL WARMING

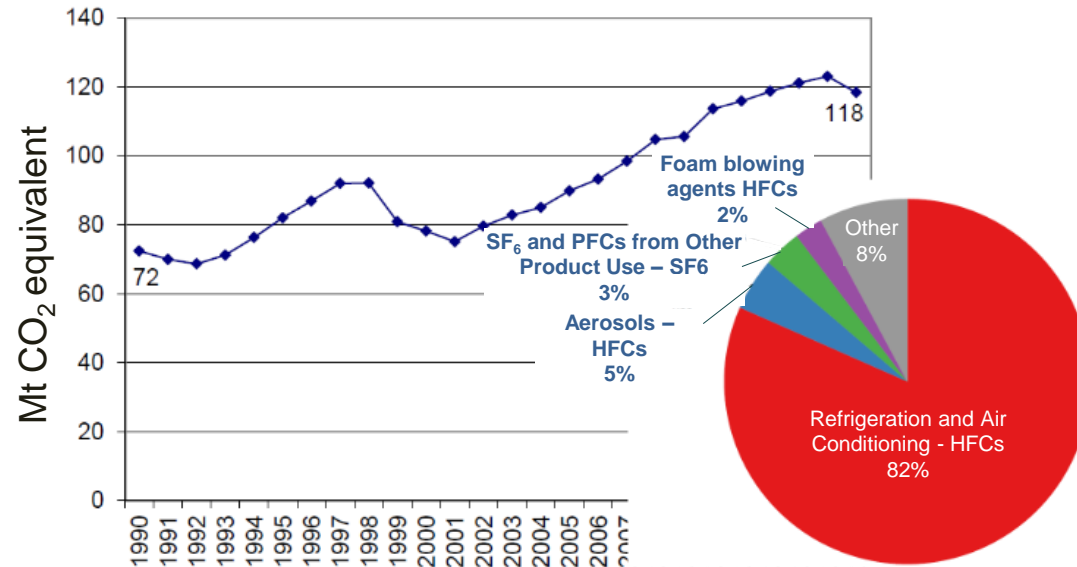
- Infrared radiation **ABSORPTION PROPERTIES** of the gas
- **AMOUNT OF GAS** emitted in the atmosphere
- **LIFETIME OF GAS** in atmosphere



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European Scenario

EU Fgas Emissions 1990-2015



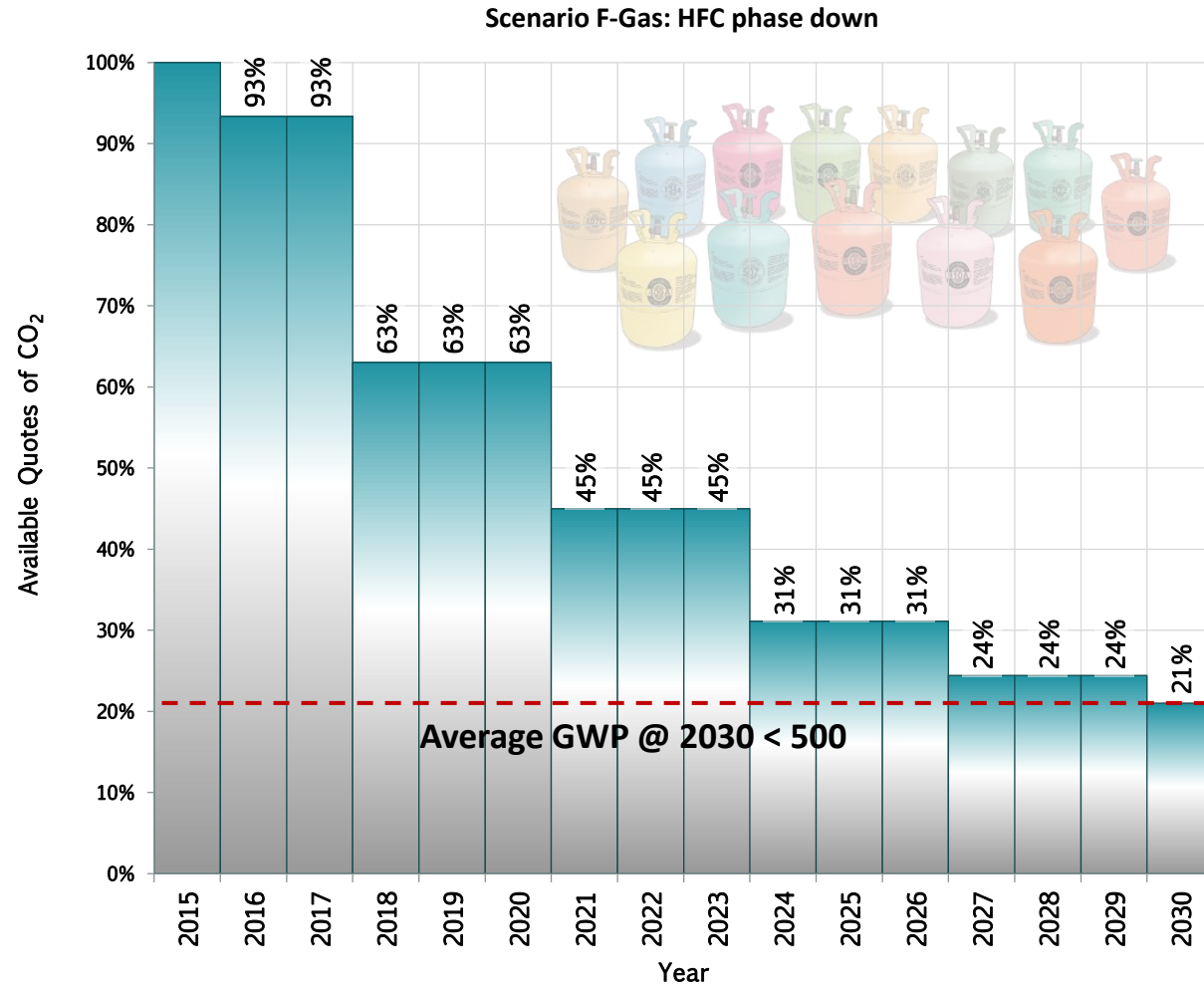
Source: EU submission to UNFCCC (EEA Report No 6/2017)

F-Gas Regulation (2015)

Phase-down of bulk HFCs (79% by 2030)

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F-Gas: HVRAC Market impact



GWP (Global Warming Potential) represents the contribution of a refrigerant to the greenhouse effect compared to the effect of CO₂ whose reference potential is equal to 1

=> Instability on the market of refrigerant:

- Uncertainty on **availability**
- Uncertainty on **prices**
- Uncertainty on **local taxes**

MEDIUM TERM SOLUTION: new synthetic refrigerants



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- HIGH PRESSURE refrigerants - reference fluid R410A

Fluid	GWP	ASHRAE Safety Class [27]	Composition (wt %)	T _{crit} (K)	P _{crit} (MPa)	T Glide (K)	NPB (K)
R410A	2088	A1	R32/R125 (50/50)	343.32	4.770	0.05	212.15
R32	675	A2L	R32 (100)	351.55	5.816	-	221.15
R454B	466	A2L	R32/R1234yf (68.9/31.1)	350.15	5.041	1	222.15
R452B	698	A2L	R32/R125/R1234yf (67/7/26)	350.25	5.200	0.9	222.15

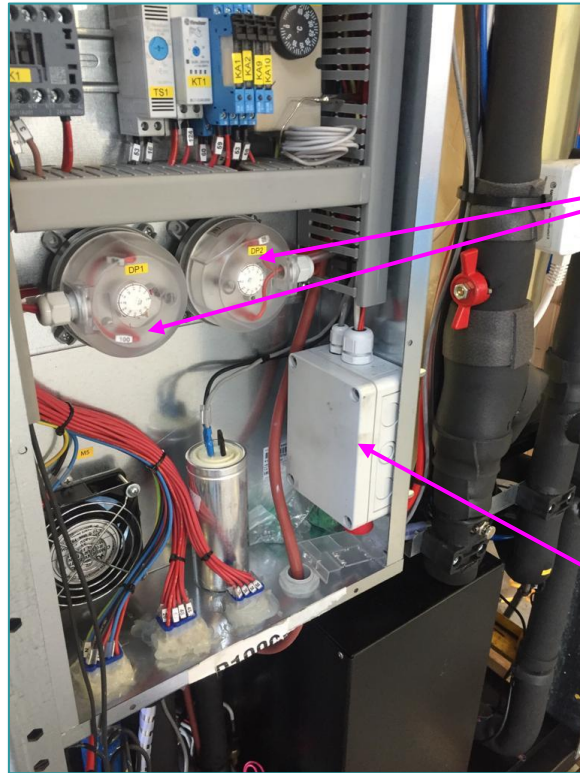
- LOW PRESSURE refrigerants - reference fluid R134a

Fluid	GWP	ASHRAE Safety Class [27]	Composition (wt %)	T _{crit} (K)	P _{crit} (MPa)	T Glide (K)	NPB (K)
R134a	1430	A1	R134a (100)	374.15	4.100	-	247.15
R513A	631	A1	R1234yf/R134a (56/44)	369.65	3.766	-	243.95
R1234yf	4	A2L	R1234yf (100)	368.15	3.400	-	252.25
R1234ze	7	A2L	R1234ze (100)	382.50	3.635	-	254.15

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- Safeties installed for A2L refrigerant

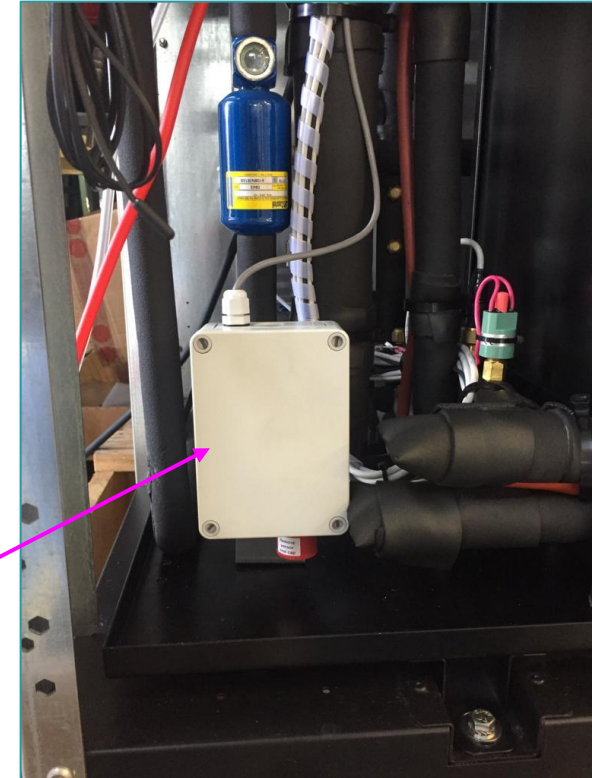
Electrical panel



Air Pressure
Switches

Leak
Detectors

Compressor Compartment



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Testing in the Pilot facility n.1 at CNR (Padua-ITALY)

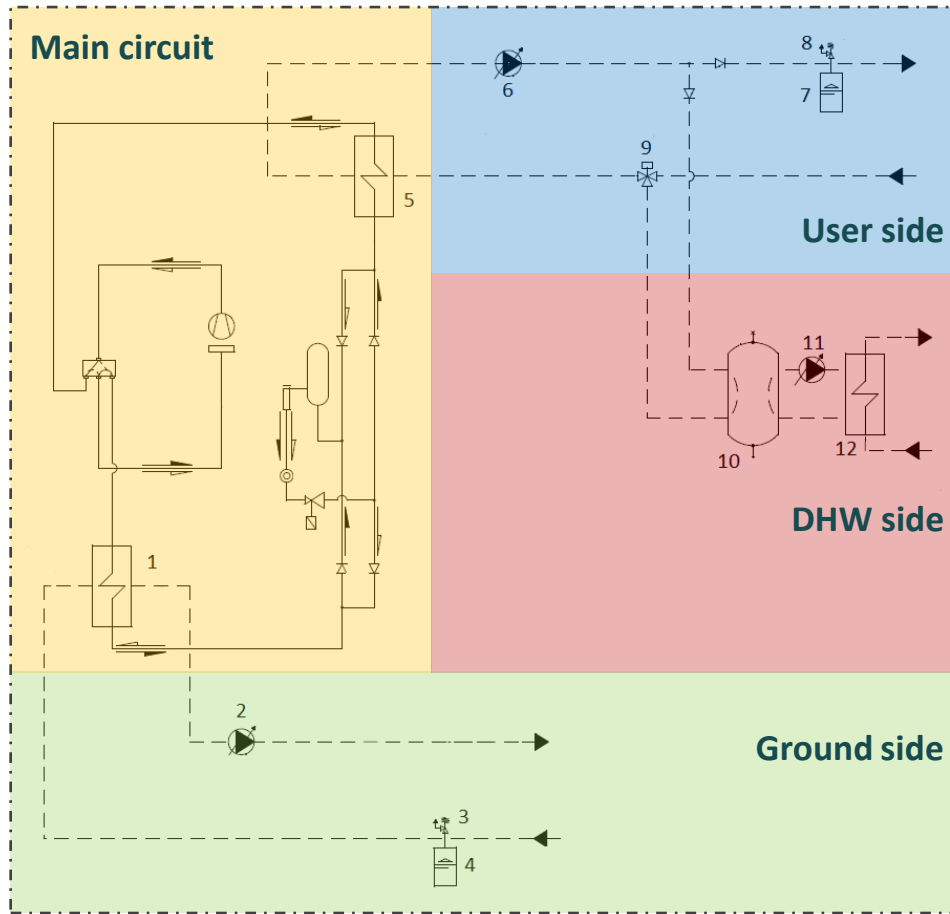


Requirements for the design of the HPs:

- Water to Water heat pump
- **Medium temperature** Heating (Fancoils)
- Cooling needed
- Single source (Multiple technologies Ground source)
- New refrigerant: **R454B** alternative of R410A with low environmental impact
- Partial load management: **Variable speed** and **ON/OFF**
- **Plug & Play** installation includes:
 - Ground source circulation
 - User circulation
 - DHW instantaneous producer
 - Hydraulic accessories
 - Solar panel connection (as option)

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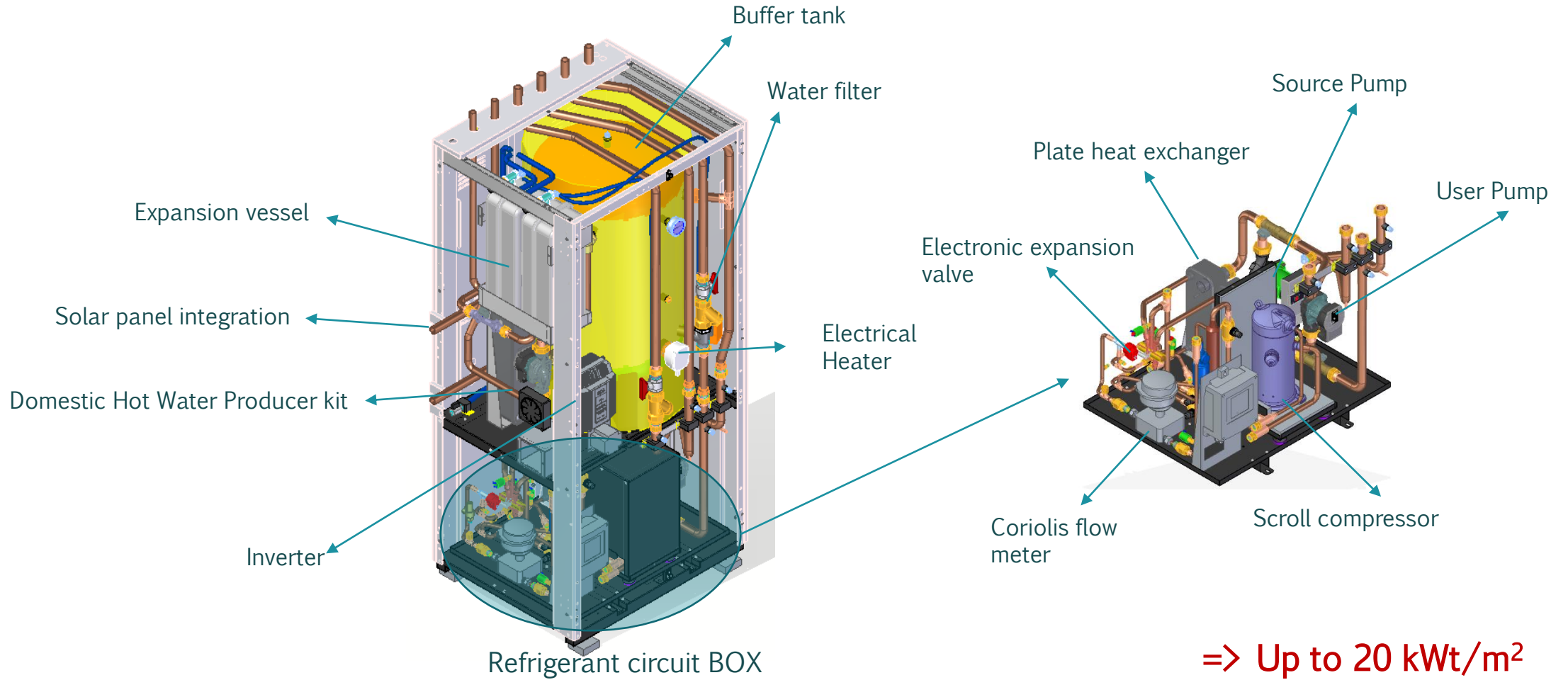
- Refrigerant and hydraulic layout



1. Source heat exchanger
2. Source modulating water pump
3. Safety valve source side
4. Expansion vessel source side
5. User heat exchanger
6. User modulating water pump
7. Expansion vessel user side
8. Safety valve user side
9. 3-way valve changing DHW/USER mode
10. Internal Buffer tank
11. Modulating water pump for DHW production
12. DHW heat-exchanger

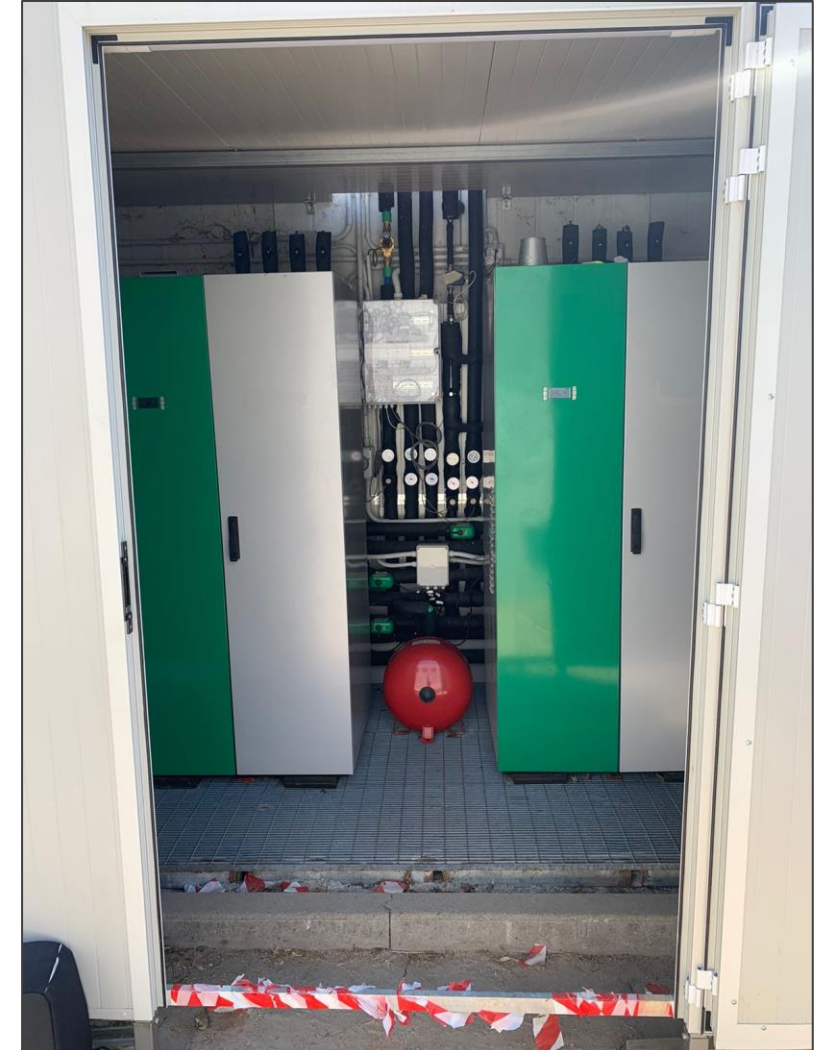
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- Mechanical design :**



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Second International Workshop – June 24th, 2021
Geotherm Offenburg Congress and Exhibition



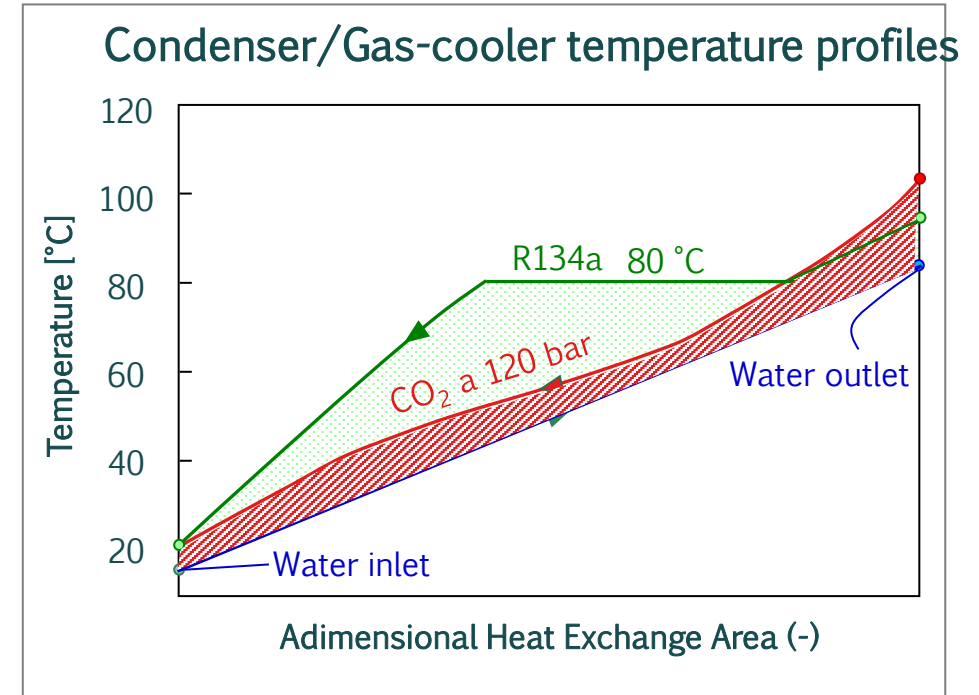
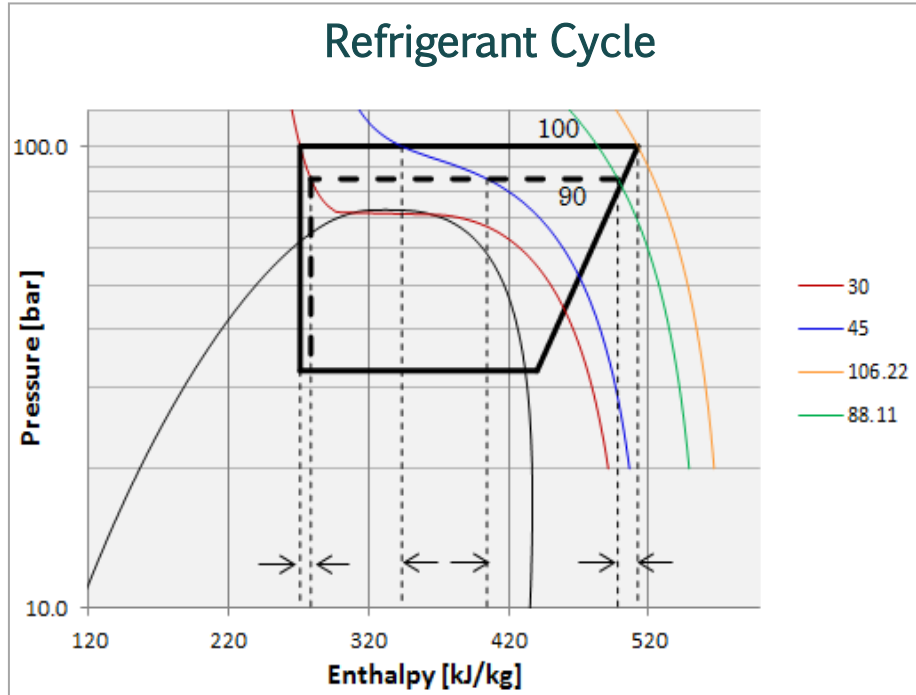
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LONG TERM SOLUTION: back to the future...



Development of Ground-Source Heat Pumps with natural refrigerant for the reduction of the impact in historical buildings

CO₂ as operating fluid for heat pumps



- Natural Fluid
- Large availability => Sustainable
- Low Price
- Low GWP = 1
- High Operating pressure



- Good Thermodynamic proprieties
- Gas-cooling process opt. the thermal profile
- Efficiency strictly linked to the outlet temp. from the gas-cooler => Water inlet
- High COP only for DT over 40°C

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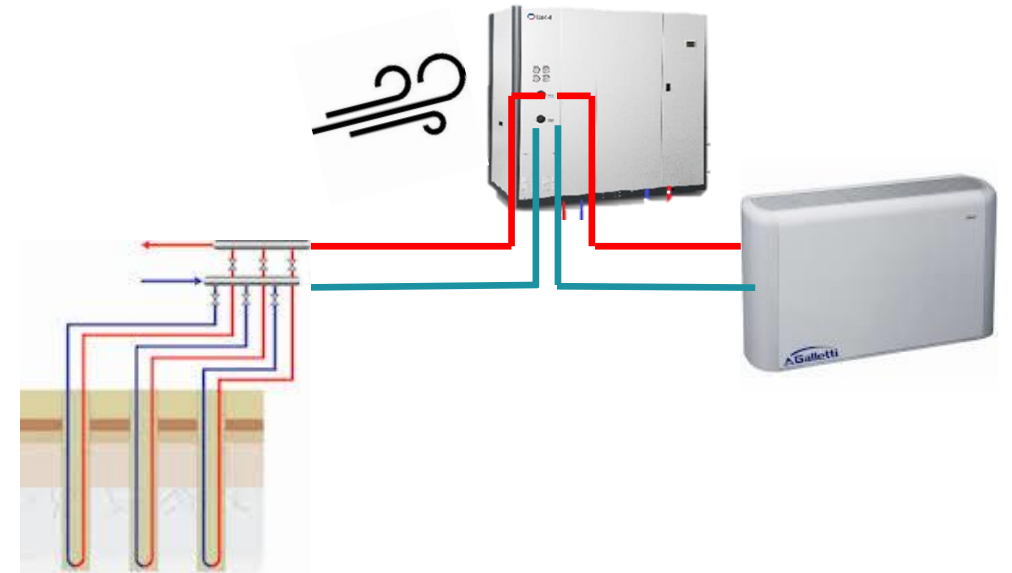
Testing site:

“The Angels gate”
Ferrara (FE)
Italy



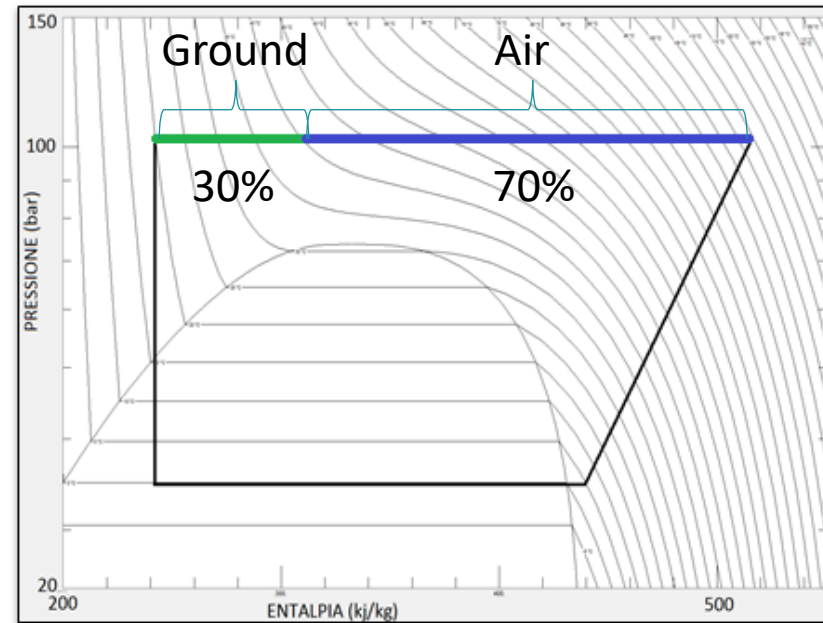
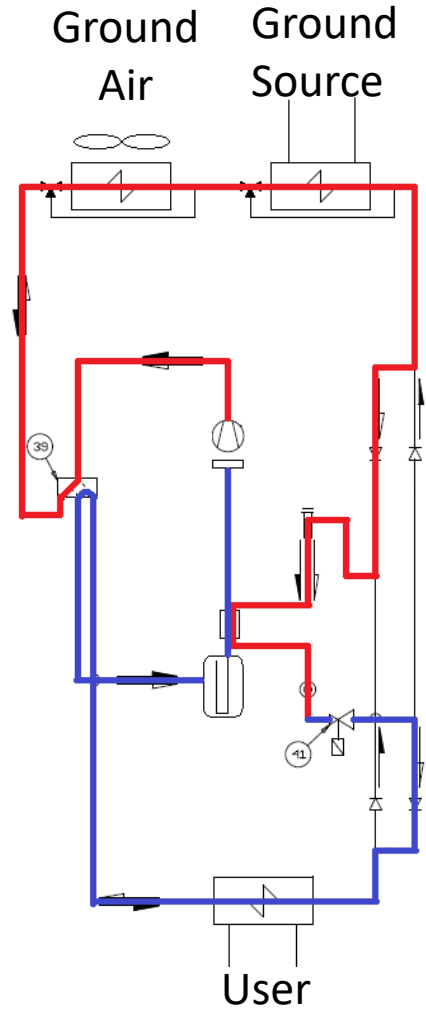
Refurbishment of historical building:

- Removing of existing boiler
- High Temperature terminals
- Cooling/Heating
- **Dual Source: Air & Ground Source => reduced investment in ground heat exchanger**
- Refrigerant: Natural **CO₂** (R744)
- Reduce the aesthetic impact of the plant



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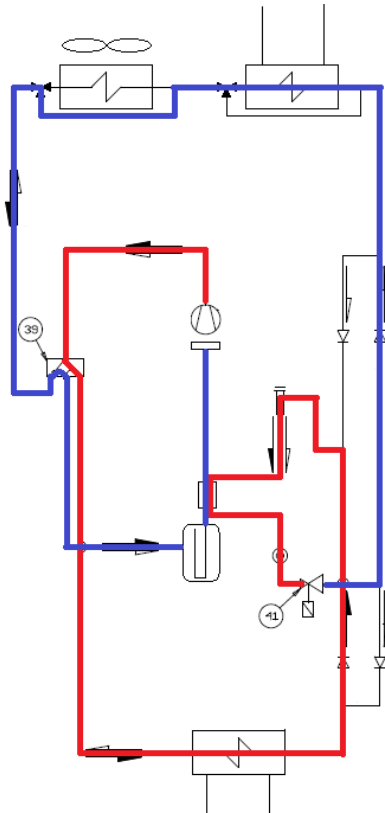
- **Summer Mode:** → Source in Series



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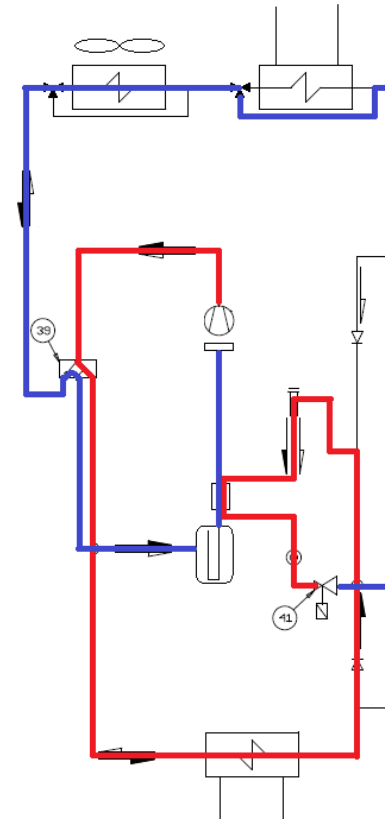
- **Winter Mode:** → Sources in Parallel

$T_{air} < T_{ground} + \Delta T$
Ground source



OR

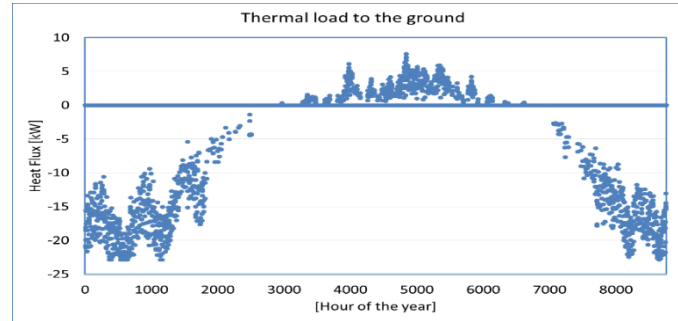
$T_{air} > T_{ground} + \Delta T$
Air source



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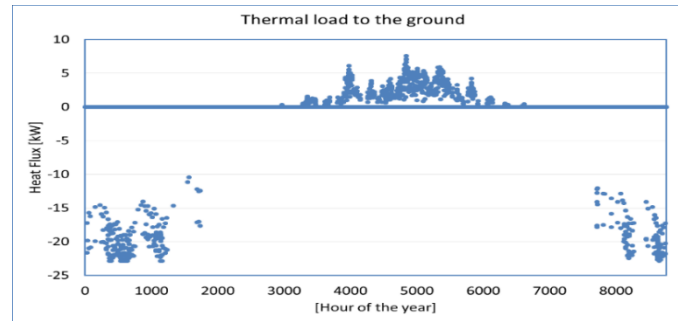
Annual simulation:

A $T_{\text{switch}} = 7^{\circ}\text{C}$
 $\Delta Q = -9678 \text{ kWh}$



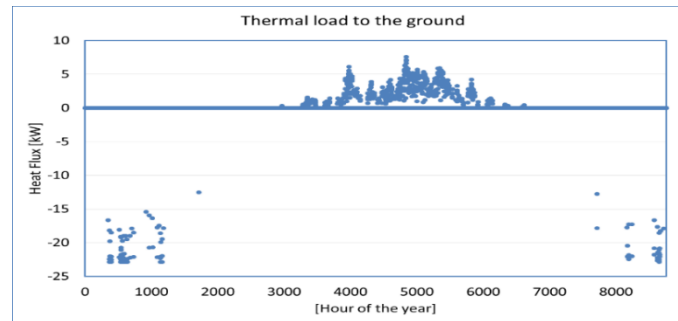
- No defrost cycles
- Higher efficiency
- High negative ground deviation

B $T_{\text{switch}} = 0^{\circ}\text{C}$
 $\Delta Q = -135 \text{ kWh}$



- Only few defrost cycles
- Medium efficiency
- No Ground deviation

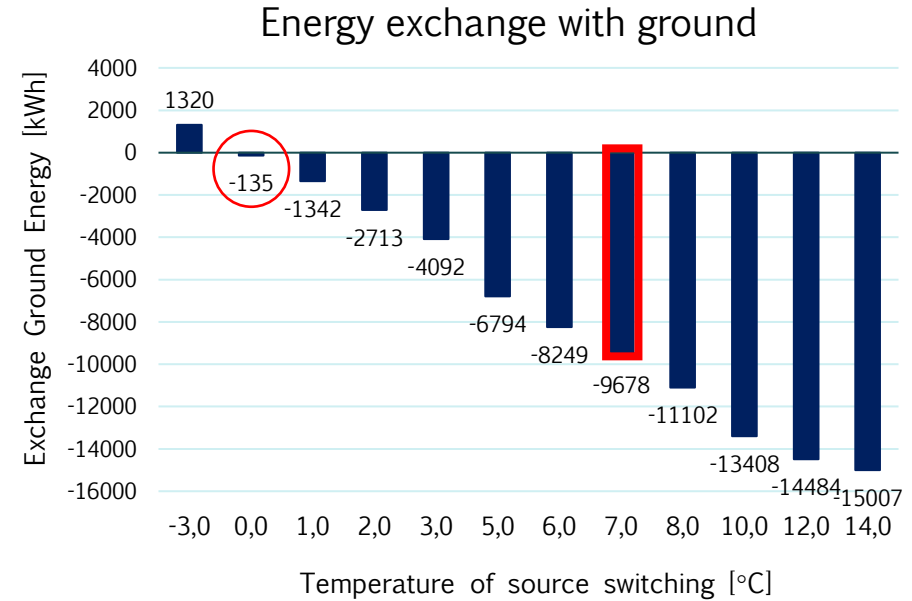
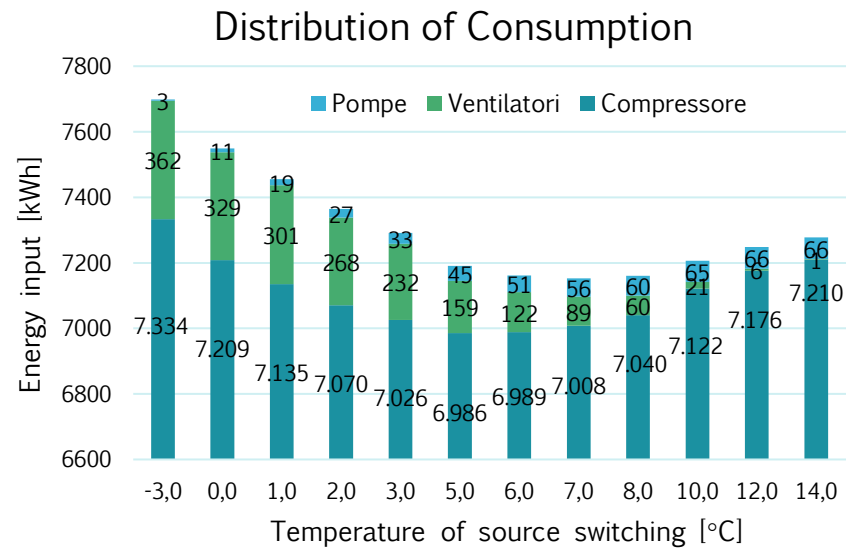
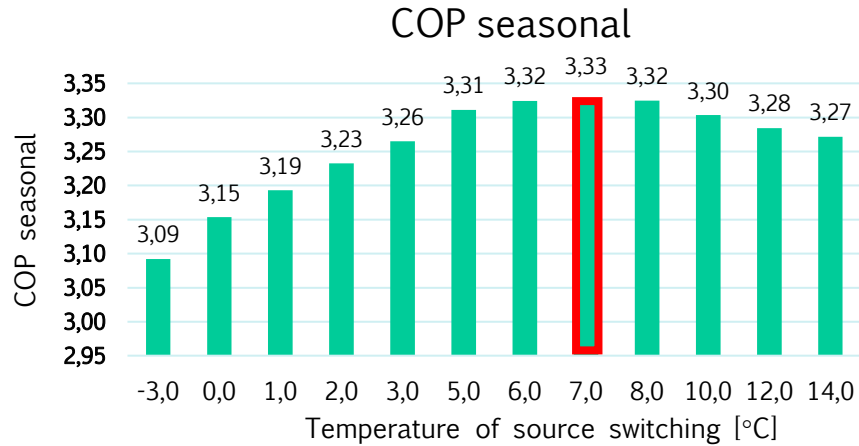
C $T_{\text{switch}} = -3^{\circ}\text{C}$
 $\Delta Q = +1320 \text{ kWh}$



- A lot of defrost cycles
- Low efficiency
- Small Ground deviation

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- Optimization of control parameter:**

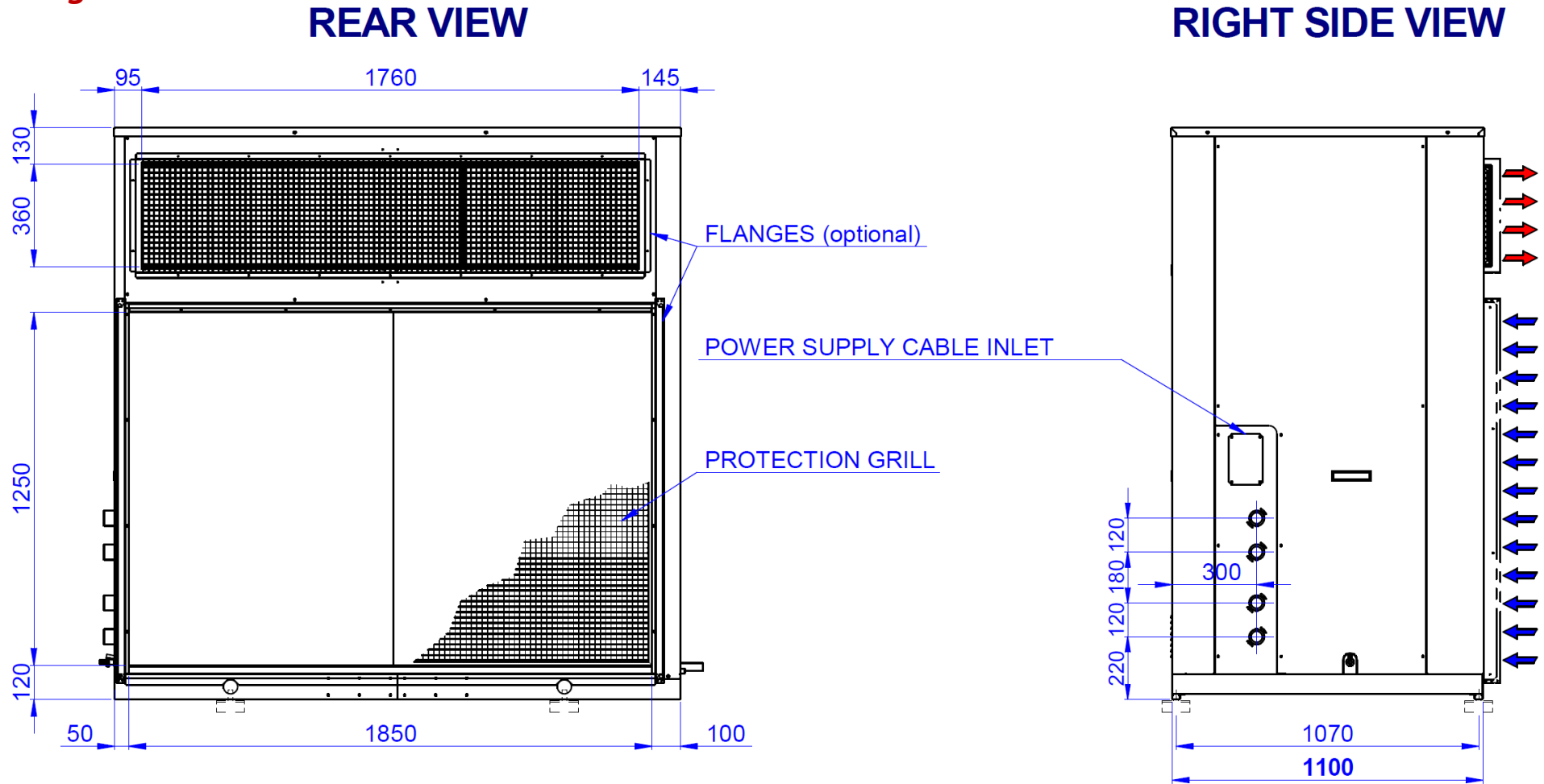


➤ Temperature of source switching:

- COP seasonal maximum with $T_s=7^\circ\text{C}$
- Balancing of energy exchange with the ground $T_s=0^\circ\text{C}$

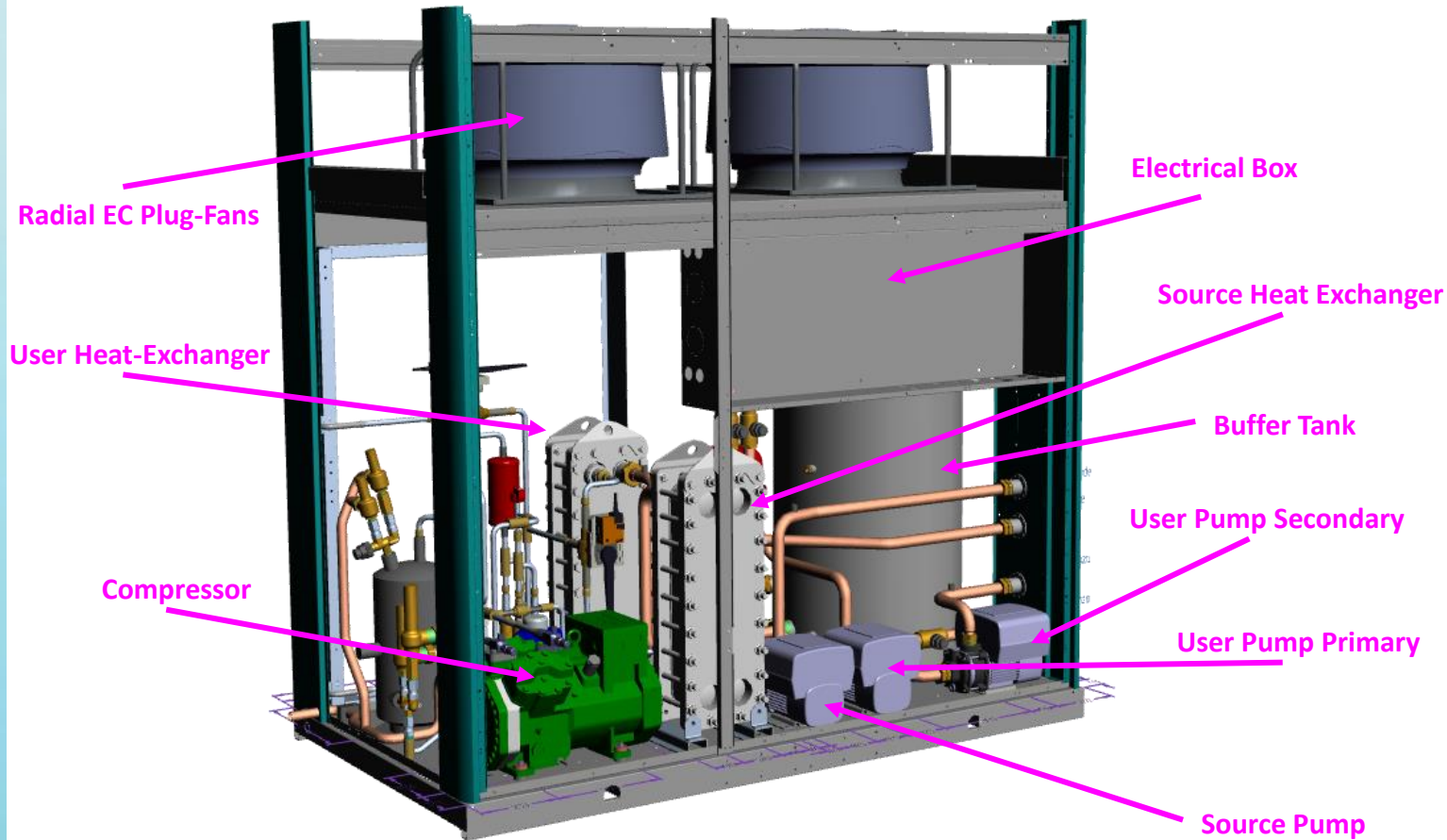
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- Final Design:**



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Conclusions and Next steps:

- **CO₂ as refrigerant is an optimal choice** for heat pumps especially in the combination with ground source
- Now the CO₂ technology is still an high price solution due to the **reduced diffusion** in the HVAC market
- Compact Heat-Pumps and **Hybrid-Source are the most promising solutions** for the **reduction of the investments** and enable the diffusion of efficient and sustainable heating and cooling systems
- The **field tests are just started**: by the end of the project we will have results about the real seasonal performances





Thank you for your attention

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