

Improving Geothermal Heat Pumps Performance

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WP3 – Heat pumps

SITE	HEATING LOAD	COOLING LOAD	AUXILIARY	MANUFACTURER	REFRIGERANT	SANITARY WATER
HIREF	14.1 kW	14.4 kW	N	Hiref	R410A	Y
UPV	18 kW	16 kW	N	Hiref	R410A	N
UOR	40 kW	30 kW	Y	Ochsner	R407C	N
EDRASIS	55 kW	55 kW	Y	Ochsner	R407C	N
GEJZIR	24 kW	10-19 kW	Y	Ochsner	R407C	N



DELIVERABLE 3.1

REPORT ON METHODS FOR IMPROVING HEAT PUMPS COP

Deliverable 3.1 has been completed by UNIPD in collaboration with KTH, UPV, UCD, GROENH and ISR.

1. Performance factors
2. Refrigerants
3. Thermodynamic cycle
4. Condenser and evaporator
 - Heat exchangers influence on performance
 - BPHE optimization study
5. Secondary fluids
6. Compressor and motors
7. Partial load operation and reverse mode
 - On/off cycling energy losses
 - Variable speed control
 - Multiple compressors
8. BHE design and optimization



Outline

Motivation

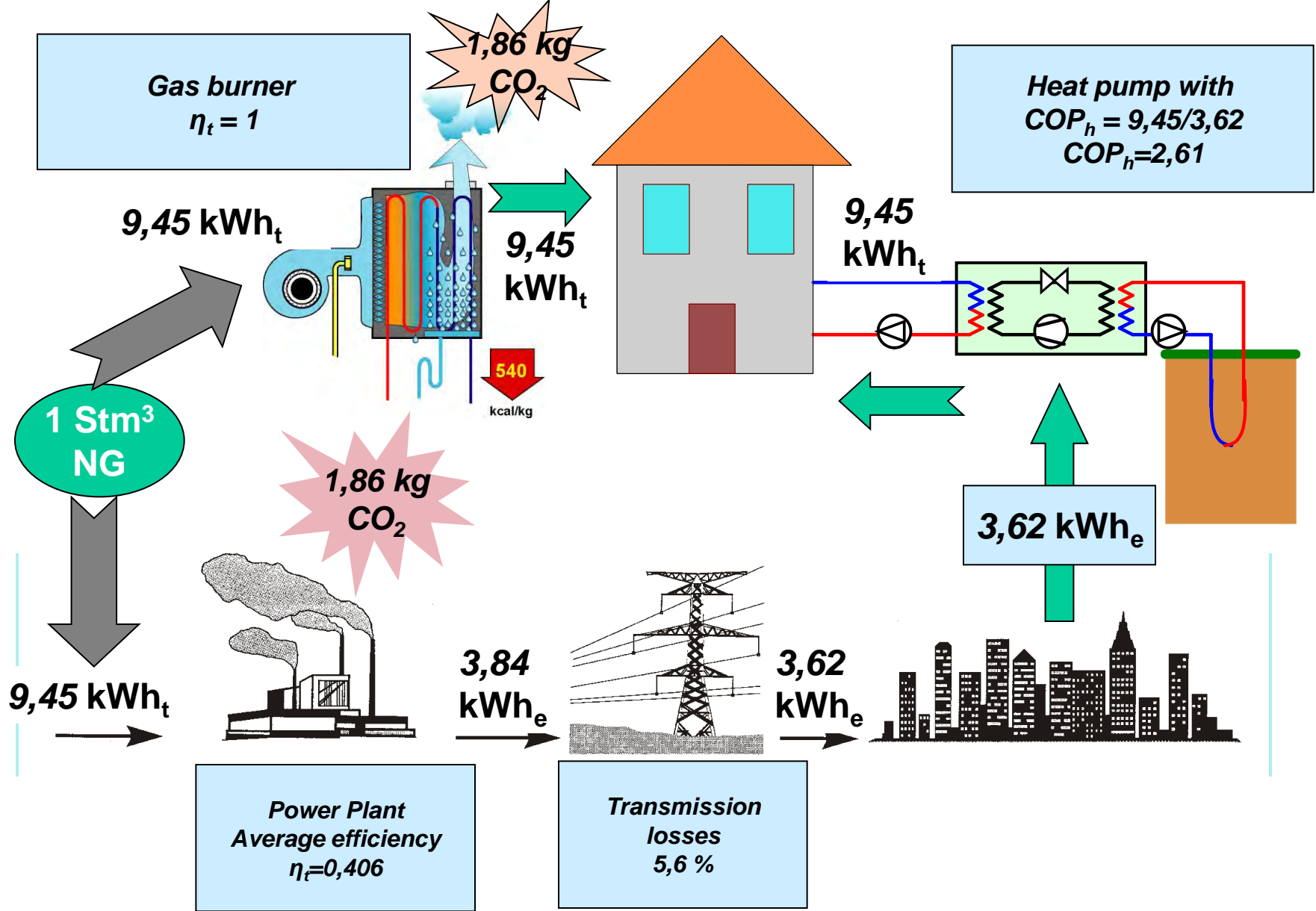
System and temperature levels

Heat pump components

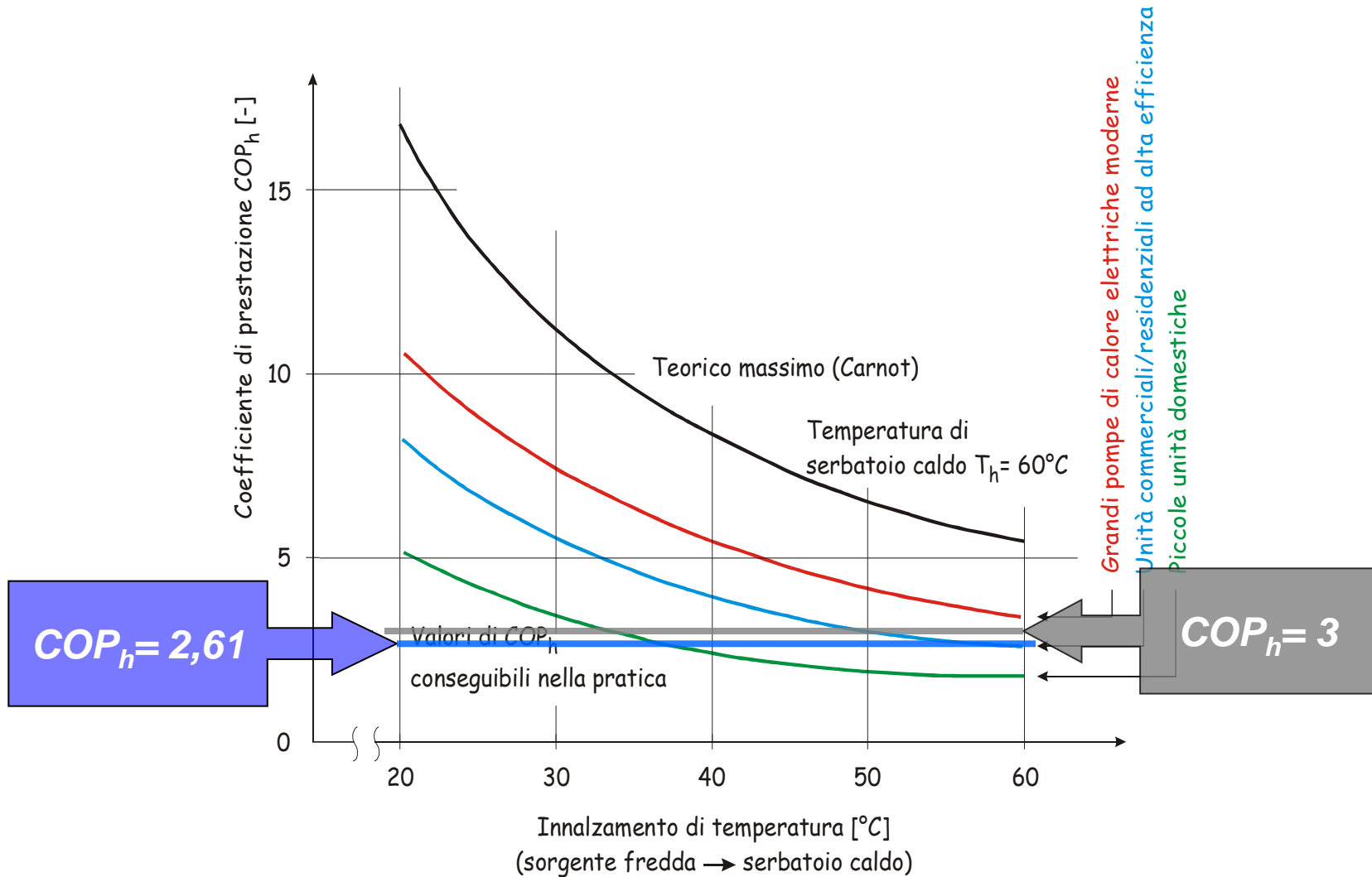
Reversing methods

Part load

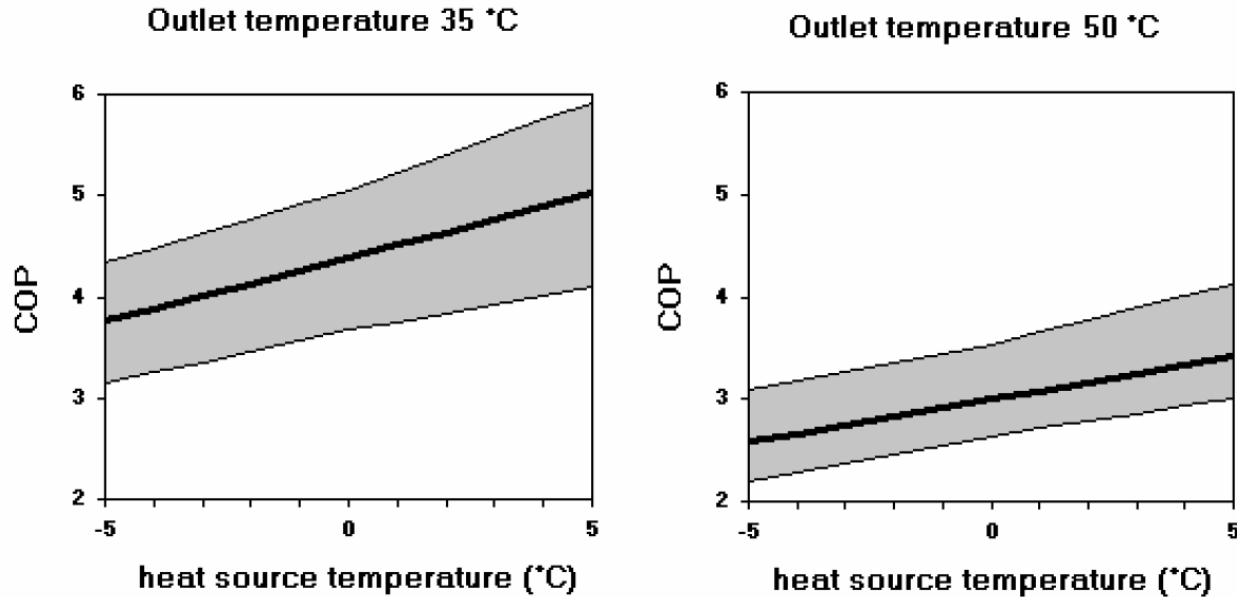




EFFECT OF TEMPERATURE LEVELS



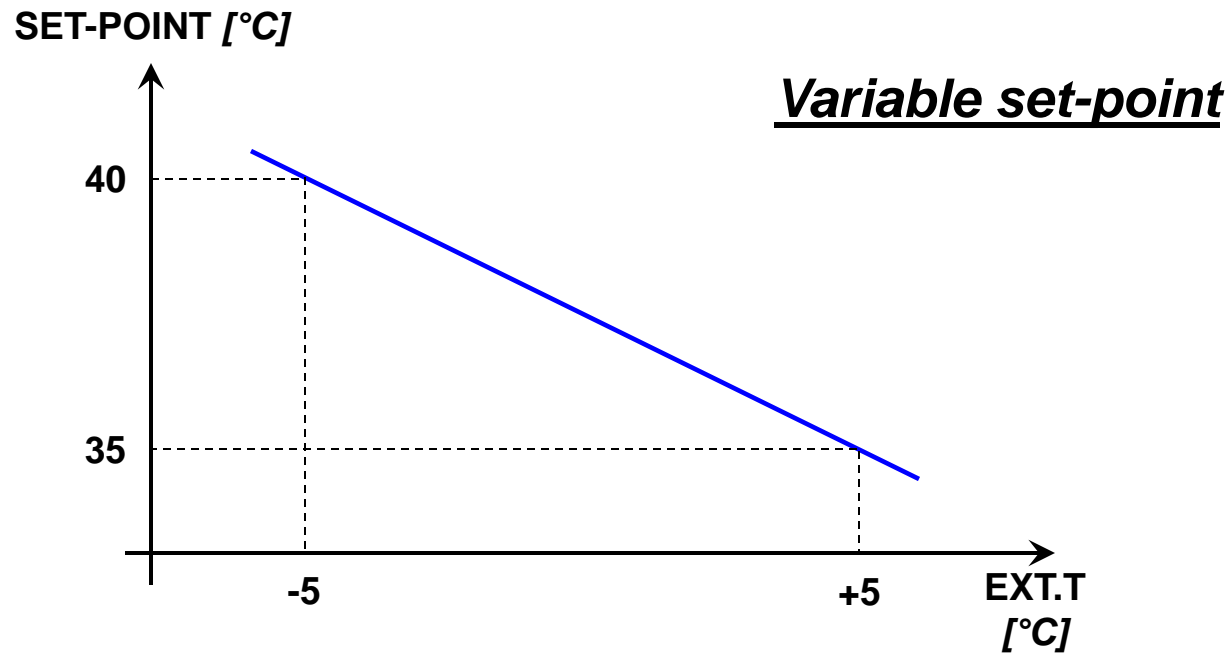
TEMPERATURE LEVELS



- The energy performance is enhanced when the difference between condensing and evaporating temperatures is reduced.
- Choice of heating/cooling system: wall/floor, fan coils, radiators ...
- Temperature compensated set point will improve COP.



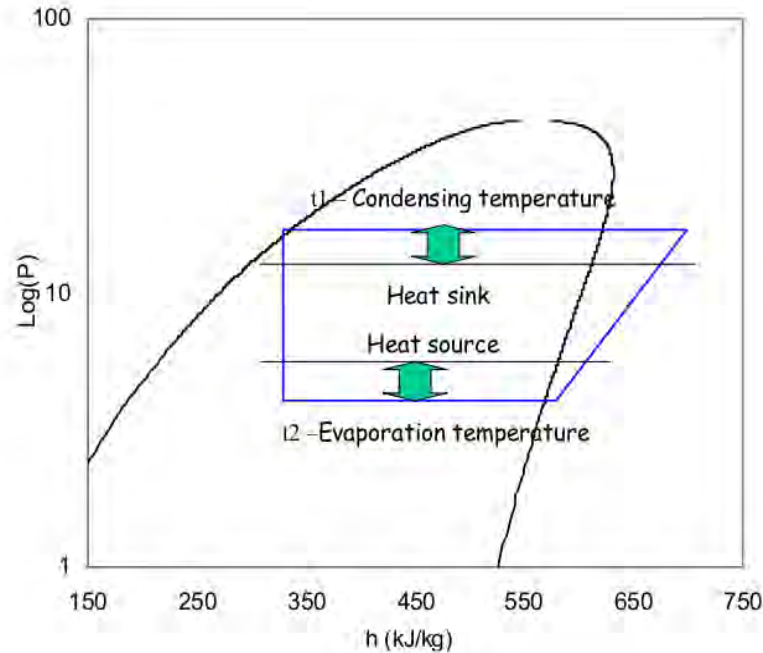
Temperature levels: Set-point compensation



Temperature compensated set point will improve COP.



TEMPERATURE LEVELS



A temperature difference must exist between:

- 1. GROUND & WATER in the BHE**
- 2. REFRIGERANT & WATER in the evaporator and condenser**
- 3. WATER & AMBIENT in the distribution system**



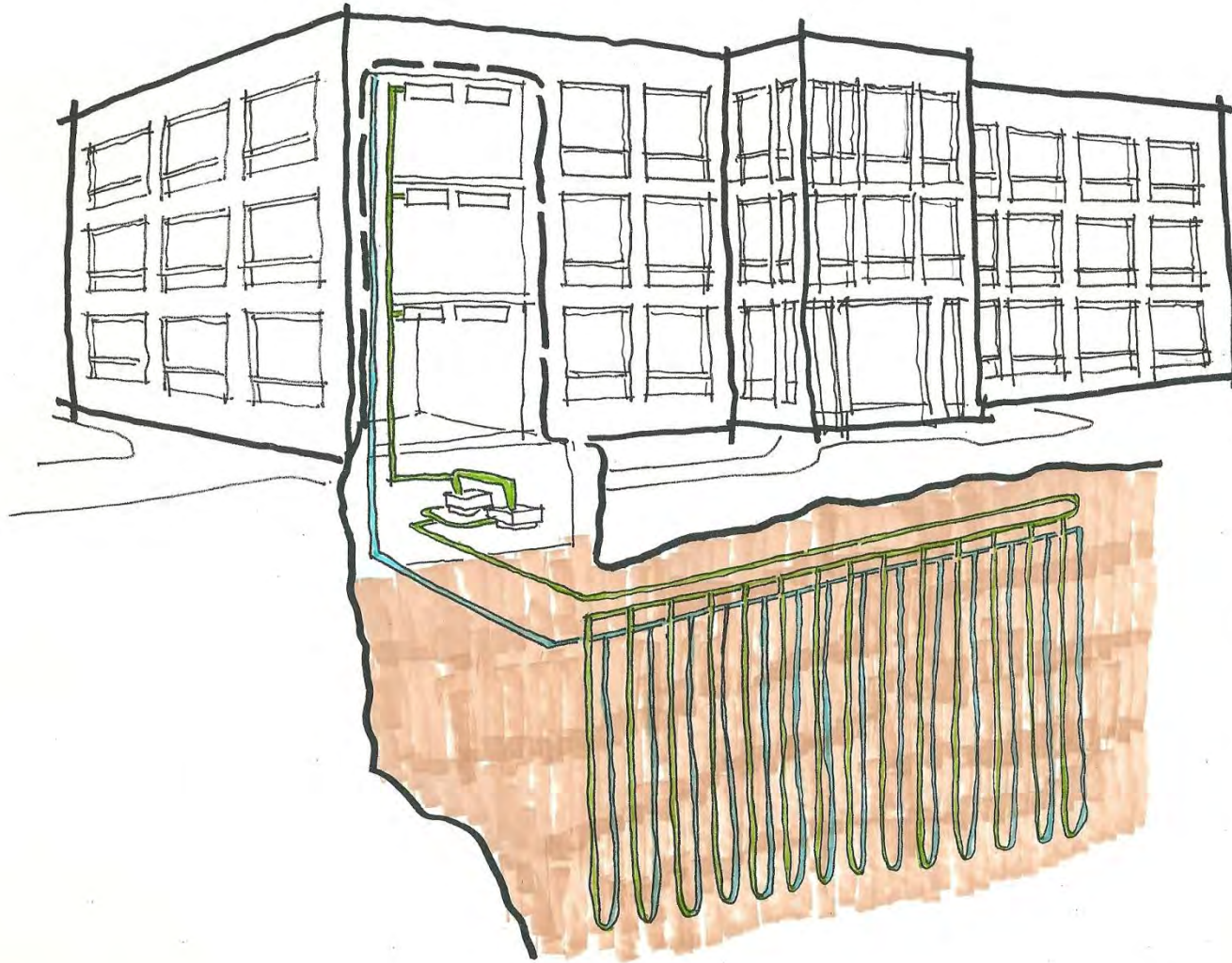
TEMPERATURE LEVELS

Table 1: Influence on COP_{heating} of decrease in temperature difference by 1°C

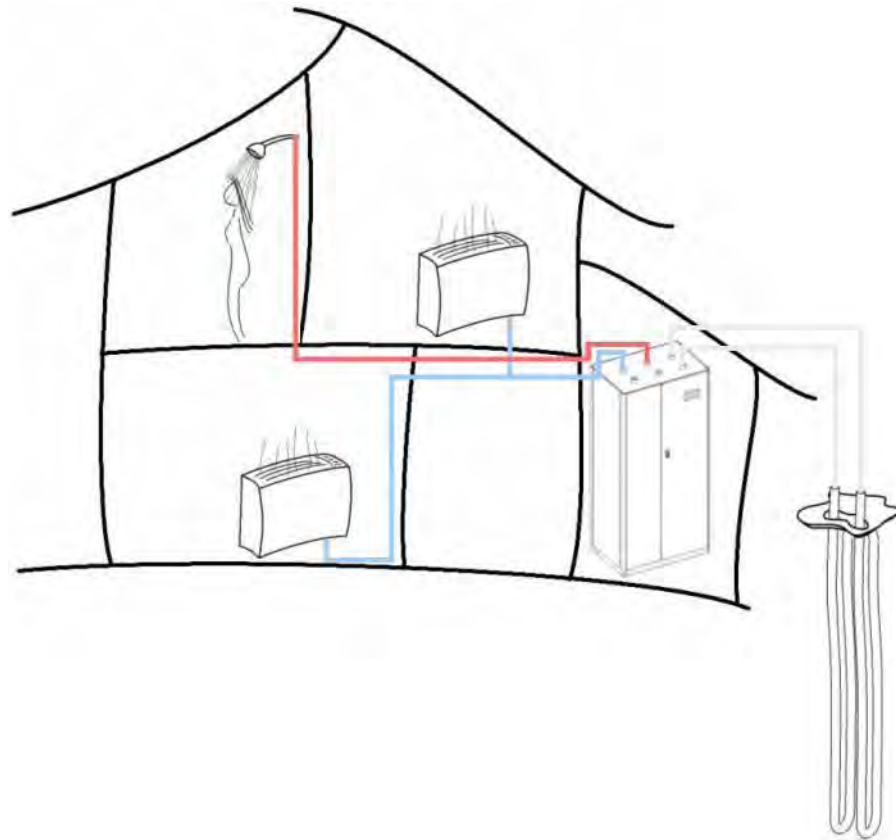
$T_{\text{evaporation}}$	$T_{\text{condensation}}$	COP_{heating} assuming 60% of Carnot	Change in COP_{heating} with 1K higher evaporation temperature	Change in COP_{heating} with 1K lower condensing temperature
-10	+40	3.8	2.0%	1.7%
0	+40	4.7	2.6%	2.2%
5	+40	5.4	2.9%	2.6%
-10	+30	4.5	2.6%	2.2%
0	+30	6.1	3.5%	3.1%
5	+30	7.3	4.2%	3.8%



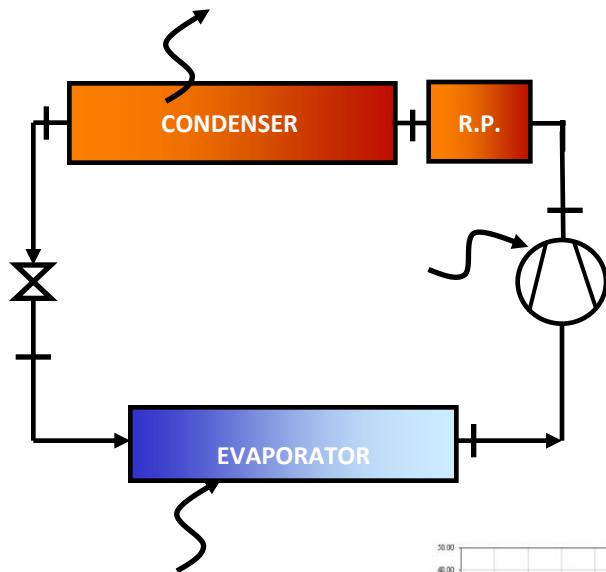
FREE COOLING



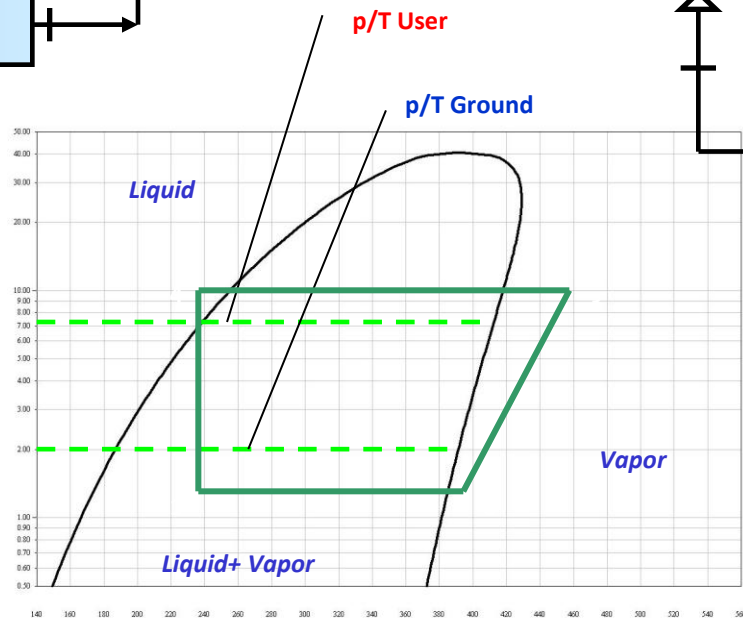
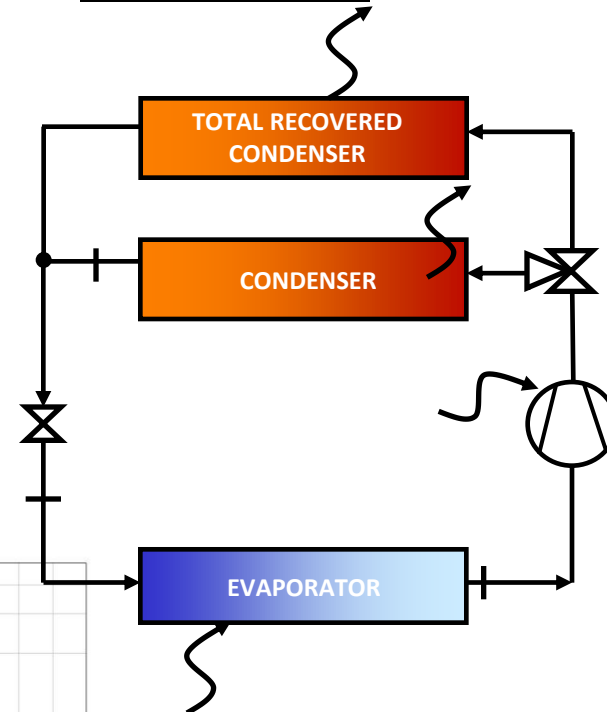
HEAT RECOVERY FOR SANITARY HOT WATER



Partial Recovery



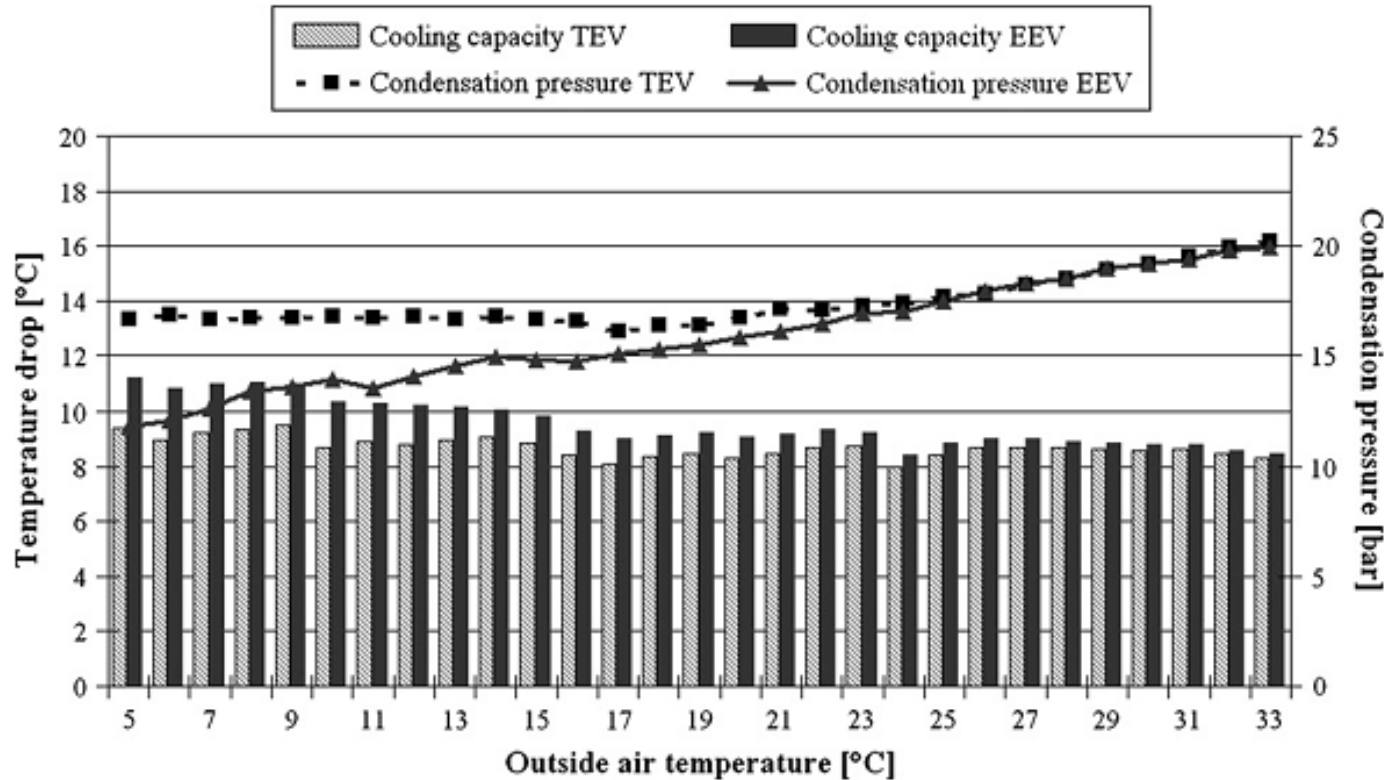
Total Recovery



EXPANSION VALVE

Temp. drop
of the air
through
the air-
conditioner

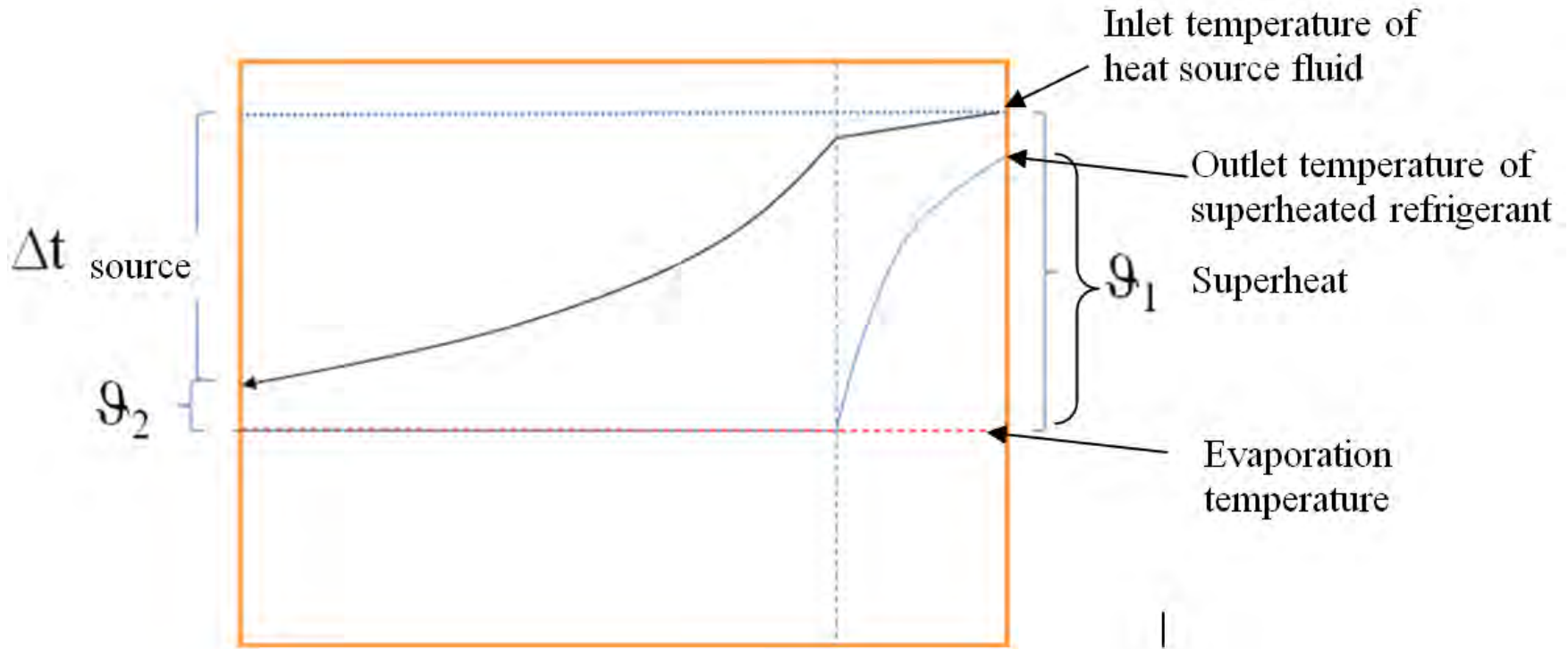
(Lazzarin &
Noro, 2008)



TEV needs a minimum pressure drop to operate properly. This limit can reduce the system performance.



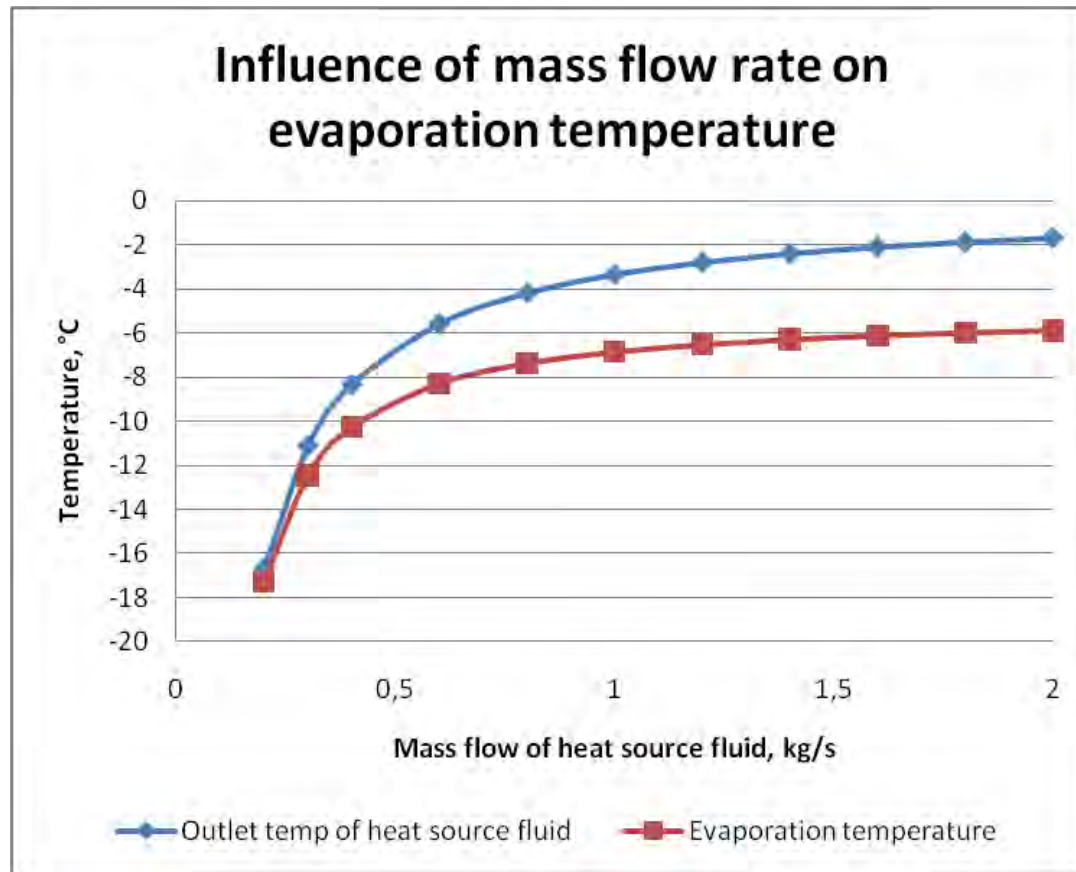
EVAPORATOR: SUPERHEATING



Typically, the superheat is set to 5 – 7 K in commercial heat pumps. However, experiments have shown that plate heat exchangers can be run stably with considerably lower superheats.



EVAPORATOR: INFLUENCE OF MASS FLOW RATE

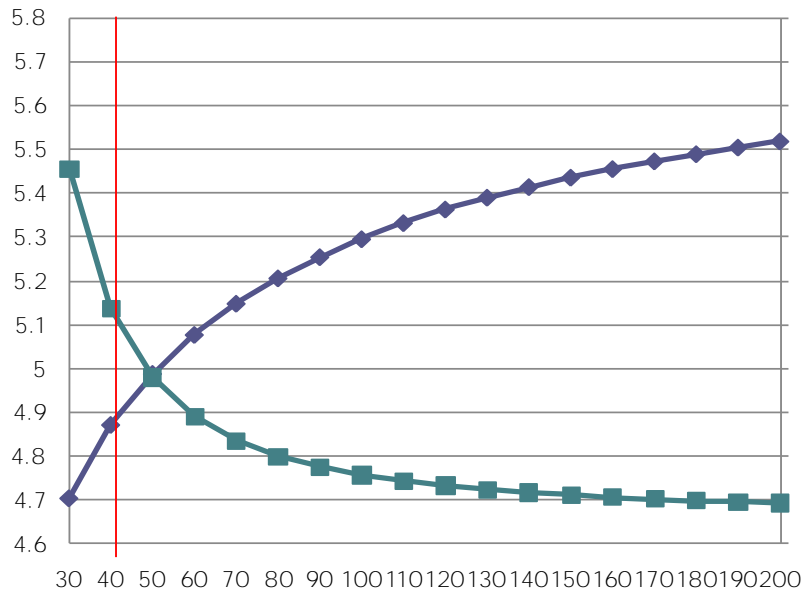


The choice of the flow rate is an optimization problem, as increasing mass flow rate requires higher pumping power.



EFFECT OF HEAT EXCHANGER SIZE

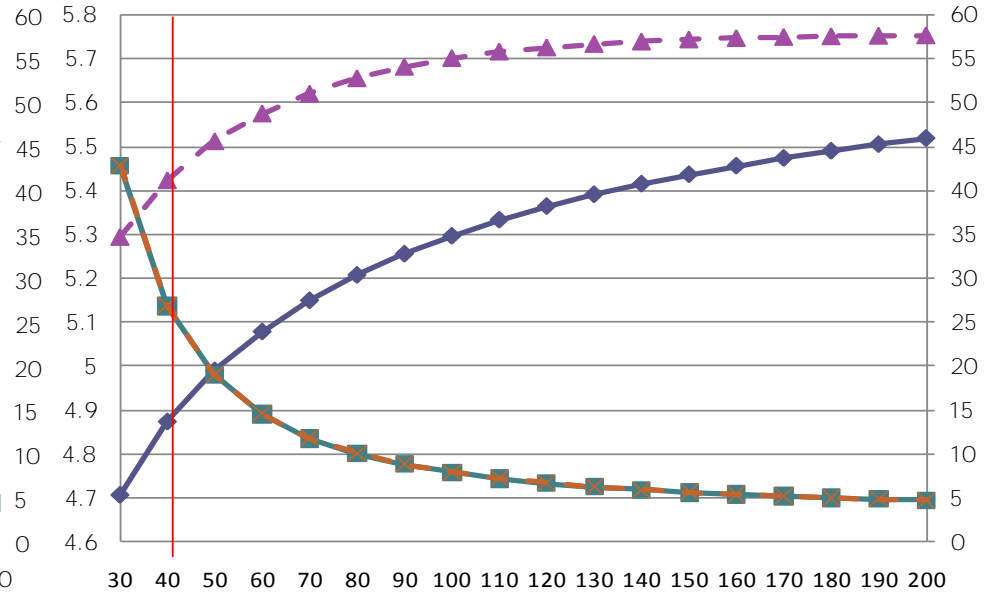
CONDENSER OPTIMIZATION STUDIES AT FULL LOAD:
 $b=2$ $W=265$ mm. $\alpha=120$.NP influence



Number of plates

◆ COP(HPA) ■ Dpwater(kPa)

CONDENSER OPTIMIZATION STUDIES AT FULL LOAD VS PART LOAD:
 $b=2$ $W=265$ mm. $\alpha=120$. NP influence



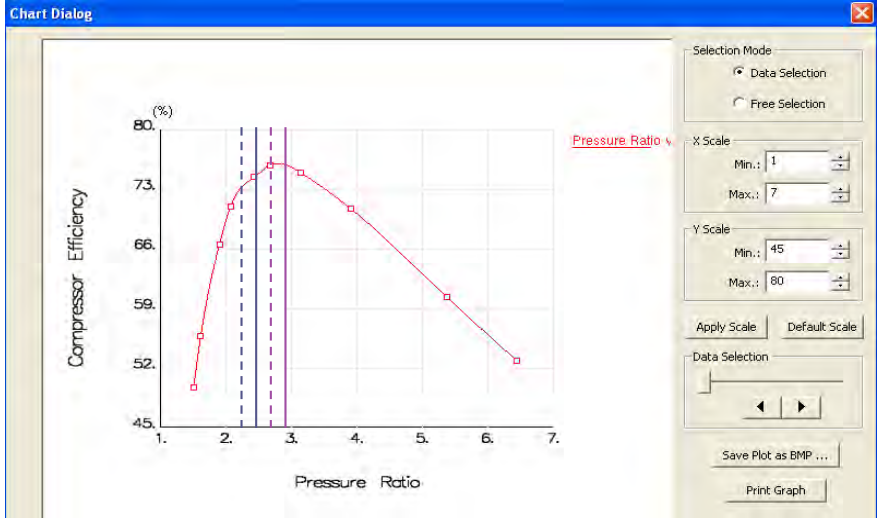
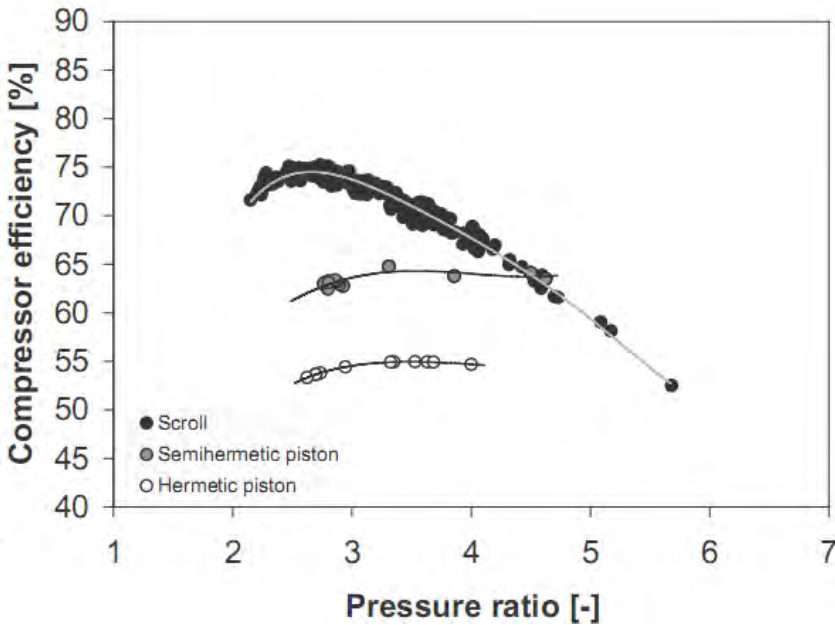
Number of plates

▲ COP(HPA) part load ◆ COP(HPA)
■ Dpwater(kPa) × Dpwater(kPa)_part load

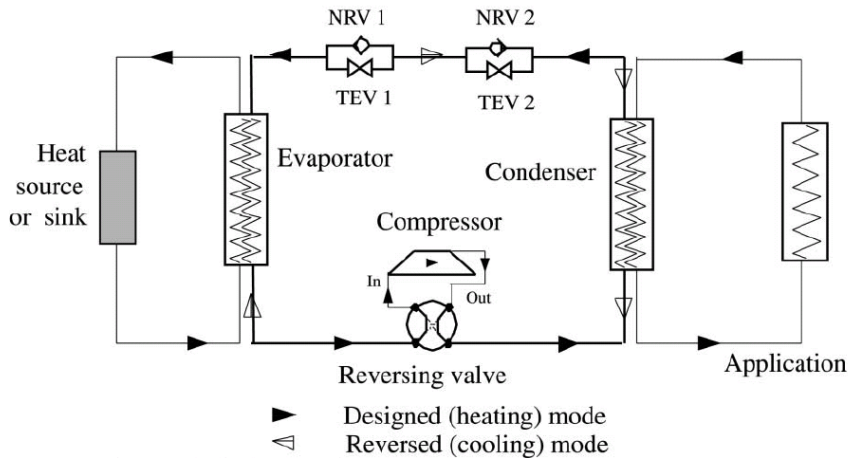


COMPRESSOR PERFORMANCE / PRESSURE RATIO

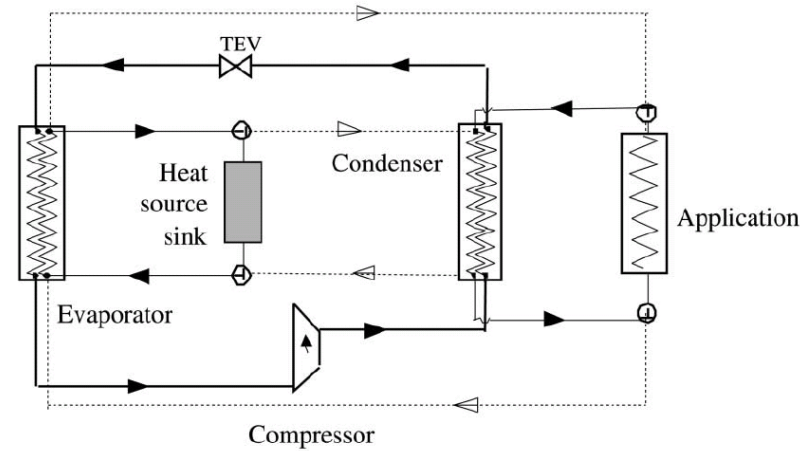
	Water temp. to building	Water temp. from ground	Evaporating temperature	Condensing temperature	Pressure ratio R410A	Pressure ratio R407C
Winter	40 °C	8 °C	3 °C	45 °C	3.1	3.4
Summer	10 °C	30 °C	5 °C	35 °C	2.2	2.4



REVERSING METHODS



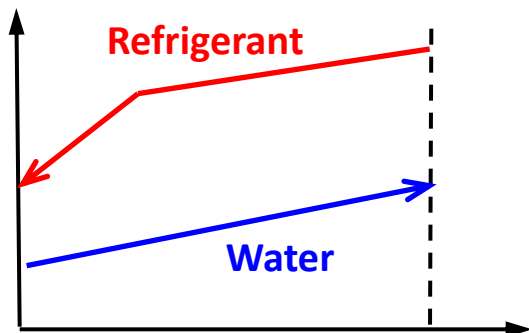
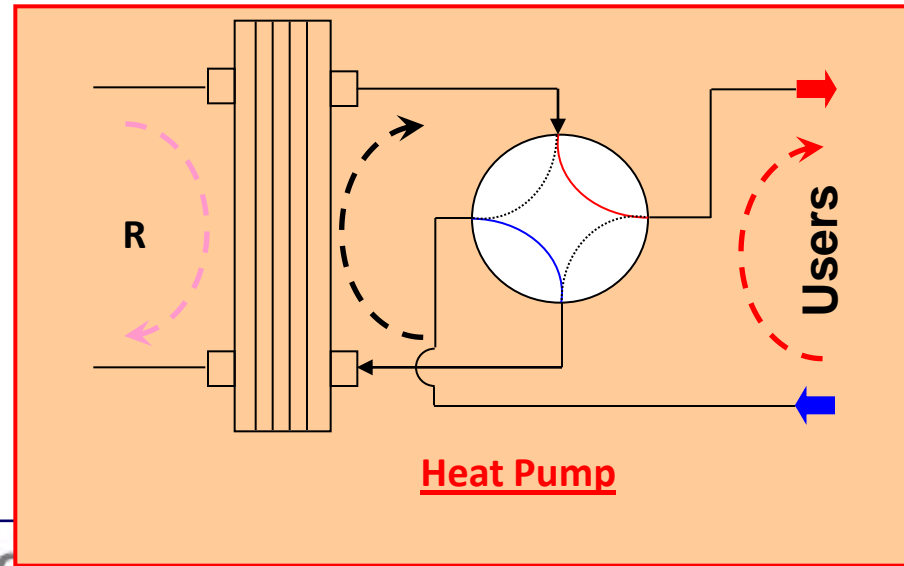
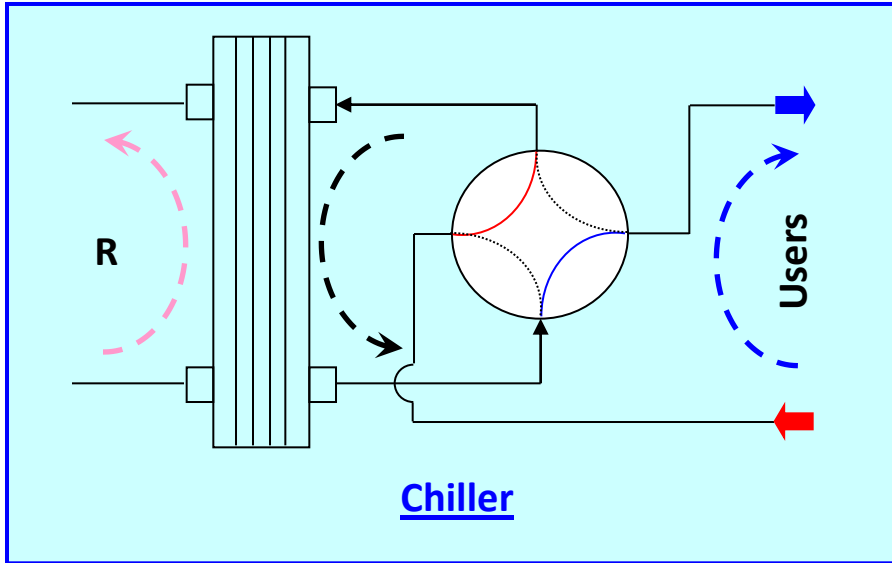
a) Reversing method: 4-way valve



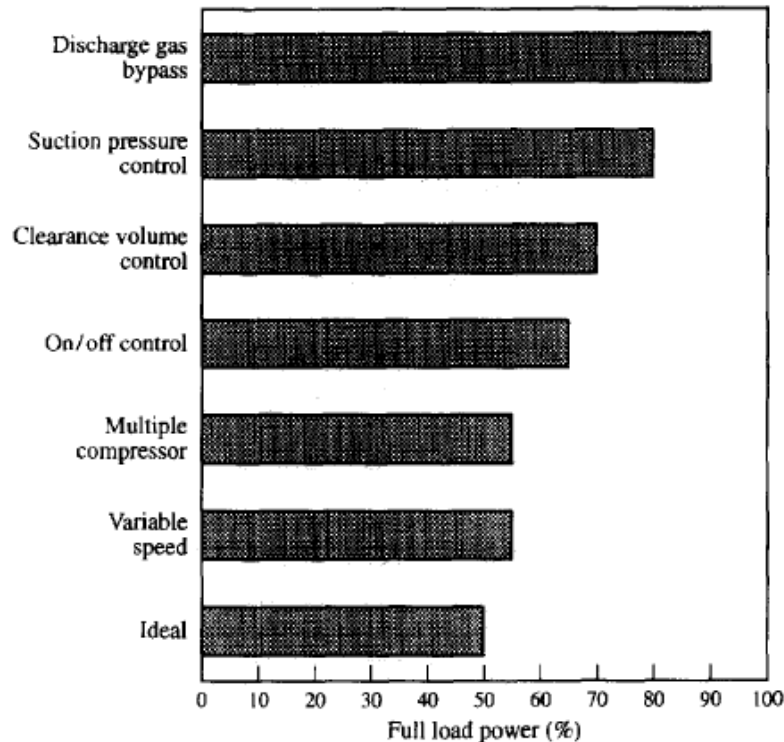
b) Reversing method: Switching HTF

- The reversing mode should be obtained by shifting the secondary fluid from the evaporator to the condenser.
- Nevertheless, 1. the cost may be higher in comparison to the use of a refrigerant four-way valve; 2. this may not be appropriate when two different secondary fluids are used in borehole heat exchanger and building loop).

Internal double reverse cycle: Refrigerant and Water



PARTIAL LOAD OPERATION

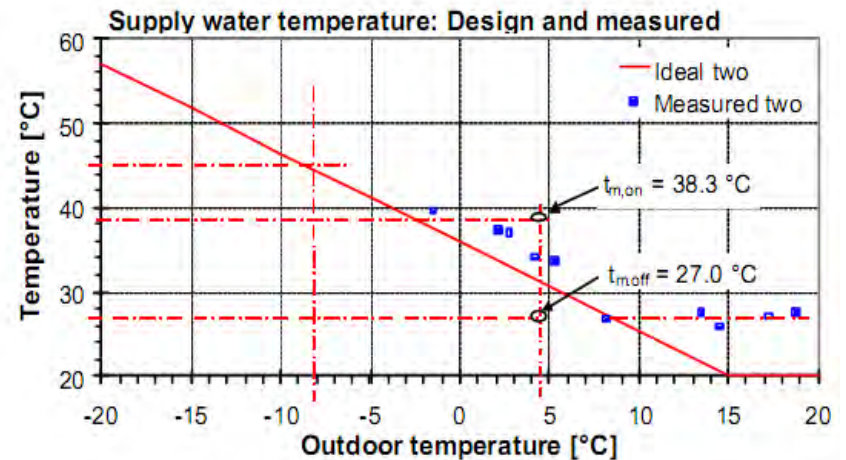
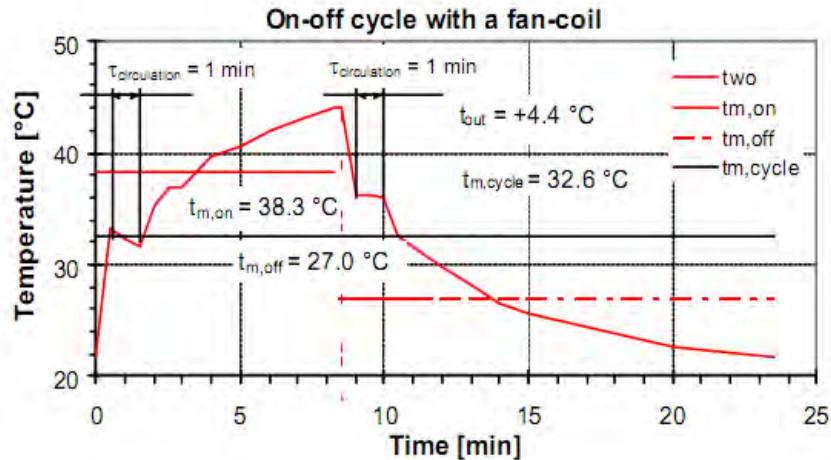


Comparison at various capacity control techniques at half load (Qureshi and Tassou, 1995)

- Matching capacity and load is one of the most critical factor for a heating and air-conditioning system.
- The largest unknown is often the actual load profile of the building.



ON/OFF ENERGY LOSS



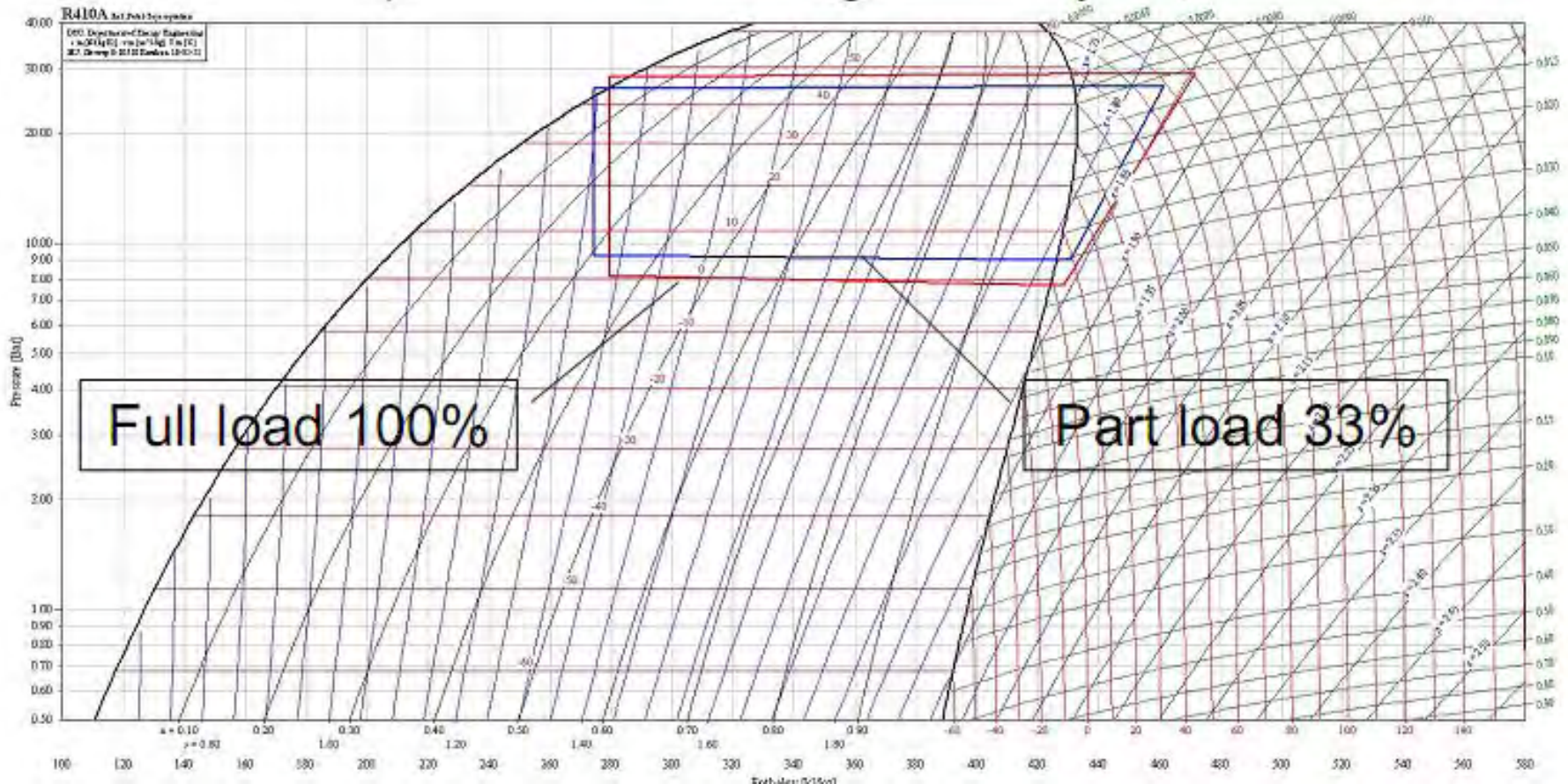
From Karlsson and Fahlén (2007)

Since the heat pump operates intermittently, it must supply heat at higher temperature than necessary when in the on mode

In the figure the mean temperature during on-time is 5.7°C higher than the mean temperature needed by the system



VARIABLE SPEED: HXS UNLOADING



INVERTER DRIVEN INDUCTION MOTOR VS BRUSHLESS D.C. MOTORS

Motor type	IM	SPMSM	IPMSM	SRM
Structure				
Efficiency at low speed	poor	good	excellent	fair
Rated Efficiency	fair	good	excellent	fair
Flux weakening control	good	poor	good	good

IPMSM : Interior Permanent Magnet Synchronous Motor

