System layout, cycle evaluation and system simulations of an integrated heat pump prototype for the capacity range of 3-5 kW

IEA HPP Annex 32 Workshop
9th IEA Heat Pump Conference

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Bundesministerium
für Verkehr,
Innovation und Technologie

National project @ IWT

Objective: Development of an integrated heat pump with the functions heating, DHW preparation and cooling for the application in low energy buildings

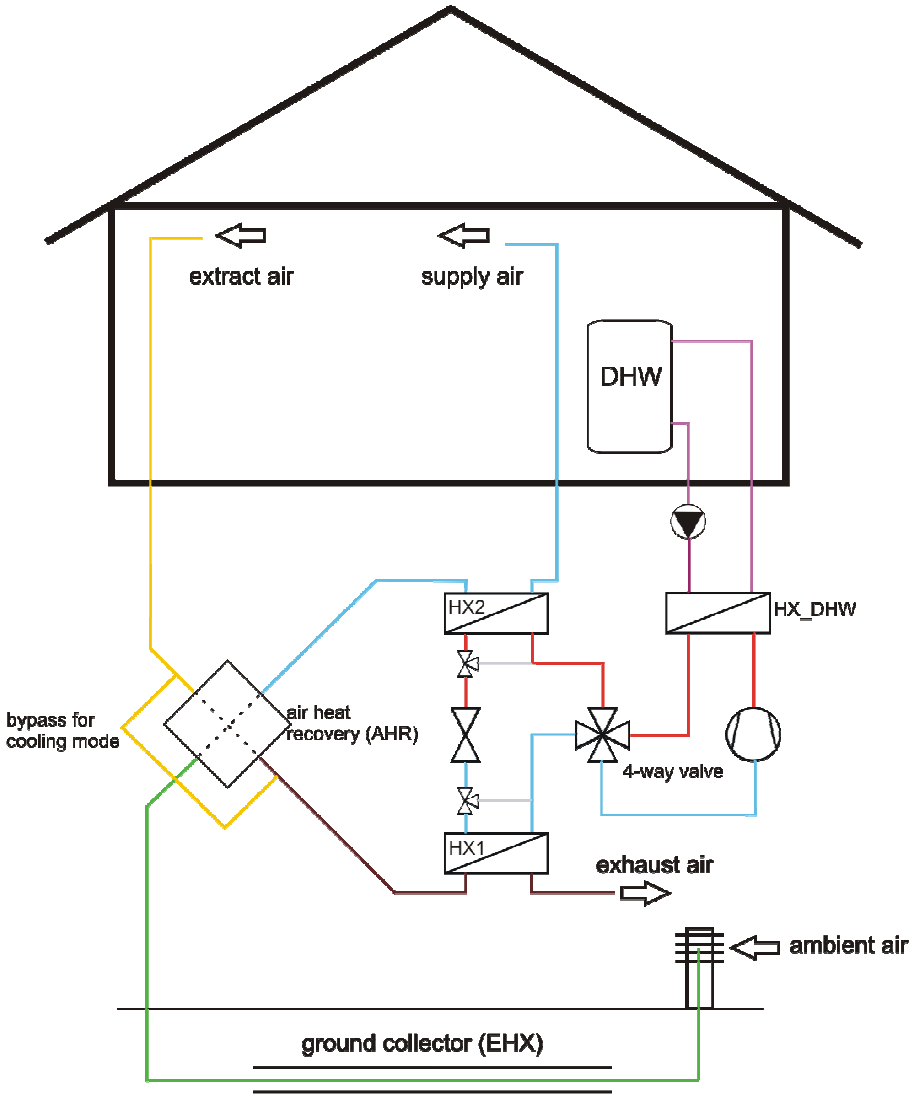
- Analysis of different concepts for integrated heat pump systems with
  - Different heat sources and
  - Different refrigerants (R744, R134, R290)
- Decision for one system / refrigerant
- Construction and detailed experimental analysis of a prototype
- Dynamic simulation of the whole system in order to analyse the interaction between the integrated heat pump, the heating system and the building
- Cooperation with national target groups and dissemination of results

  e.g. national workshops

Current status of the project @ IWT

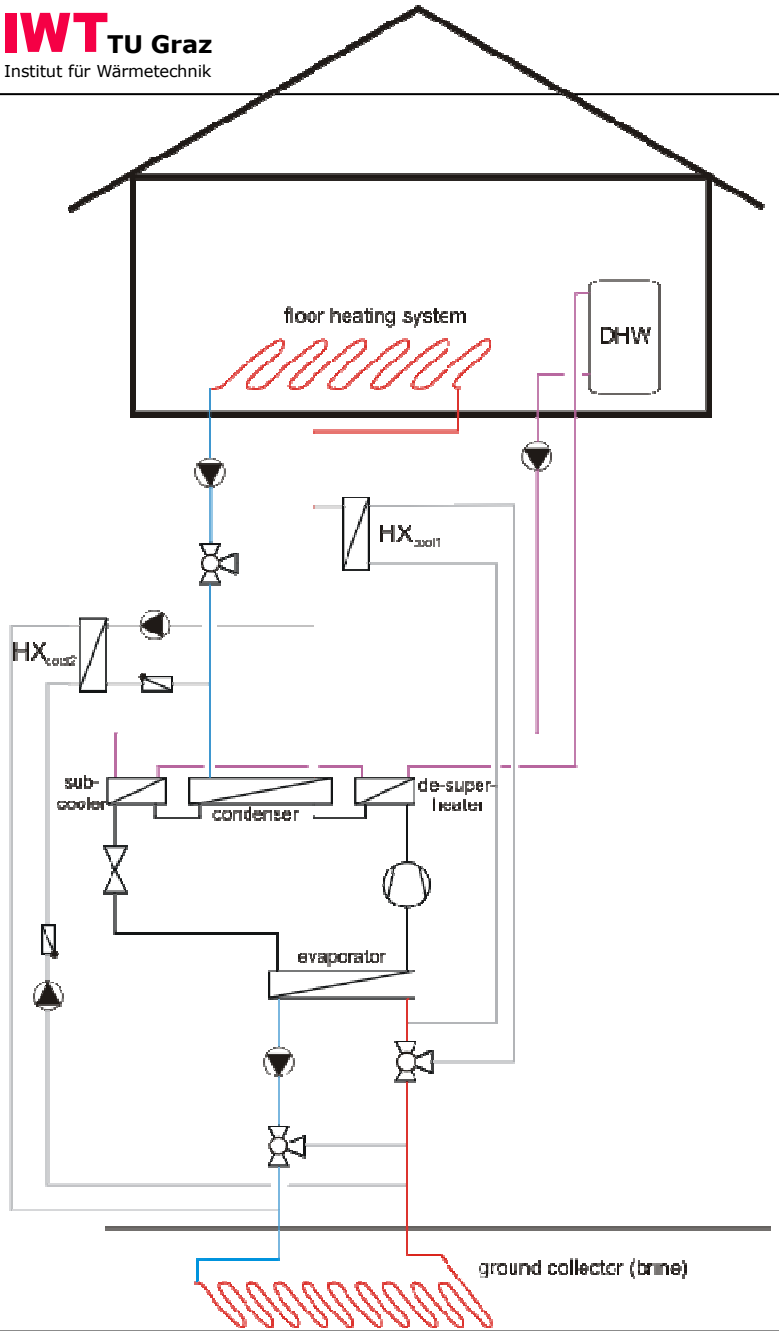
- Three concepts for integrated heat pumps were chosen for detailed investigations
- Simulation of the heat pump cycles of the individual systems with the program Engineering Equation Solver (EES)

  → comparison of different refrigerants
- Discussion @ a national workshop
- Decision for one system & refrigerant as a result of the simulations and the national workshop
- The construction of a prototype is currently ongoing



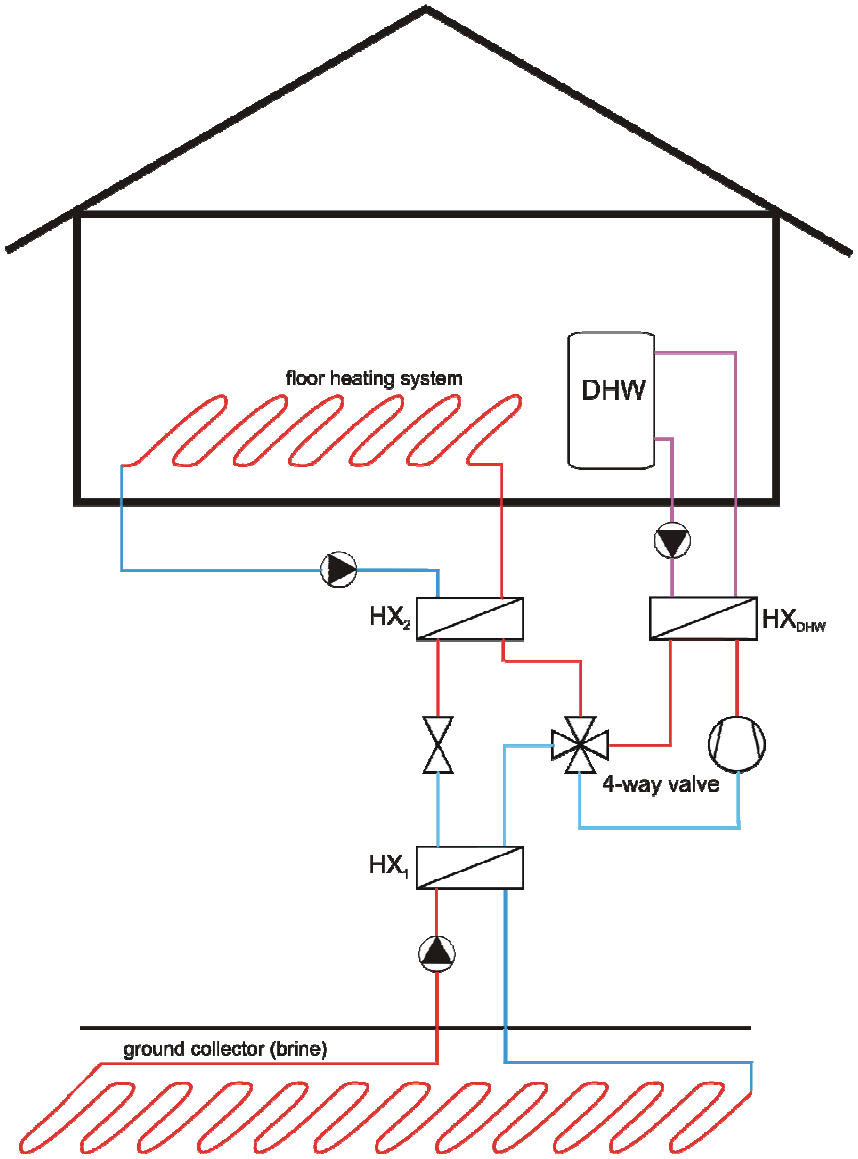
Reversible air/air heat pump, air-heating/cooling system

- Heating/cooling solely via fresh air
- Limited heating/cooling power due to
  - max./min. supply air temperature
  - air flow (air exchange rate ~ 0,4 h^{-1})
- Air heat recovery (bypass @ summer op.)
- Pre-heating (or pre-cooling) of the ambient air via a ground collector
- Optional electr. heater for reheating of air
- Heat source in heating mode: extract air (de-frosting of evaporator!)
- Cooling mode:
  - DHW preparation with condenser heat, otherwise (if the DHW tank is fully charged) discharging of condenser heat into the exhaust air
  - Passive (pre-)cooling via ground collector
  - Air exchange rate to be increased to 1 h^{-1}



Brine/water-heat pump, hydronic heating/cooling system

- Hydronic low temperature heating system
- Non-reversible heat pump cycle
- Brine ground collector as heat source/sink
- Combined heating and DHW preparation is possible
- Cooling mode:
  - Cooling via floor heating system
  - DHW preparation with condenser heat, otherwise (if the DHW tank is fully charged) the condenser heat can be discharged via the ground collector
  - Possibility of passive cooling via the ground collector



Reversible brine/water heat pump, hydronic heating/cooling system

- Hydronic low temperature heating system
- Reversible heat pump cycle
- Brine ground collector as heat source/sink
- Cooling mode:
  - Cooling via heating surfaces
  - DHW preparation with condenser heat, otherwise (if the DHW tank is fully charged) the condenser heat is dicharged via the ground collector
  - Passive cooling not possible
- Optional:
  - Additional controlled ventilation

National Workshop on the 20th November 2007 @ IWT

Participants: 1 heat pump manufacturer
1 planner
1 manufacturer of compact ventilation units
1 research institution
+ IWT staff

Purpose: presentation of
- Annex 32 and its objectives
- the participating countries and their national projects
- the national project of Austria

Discussion of the system concepts and the first results

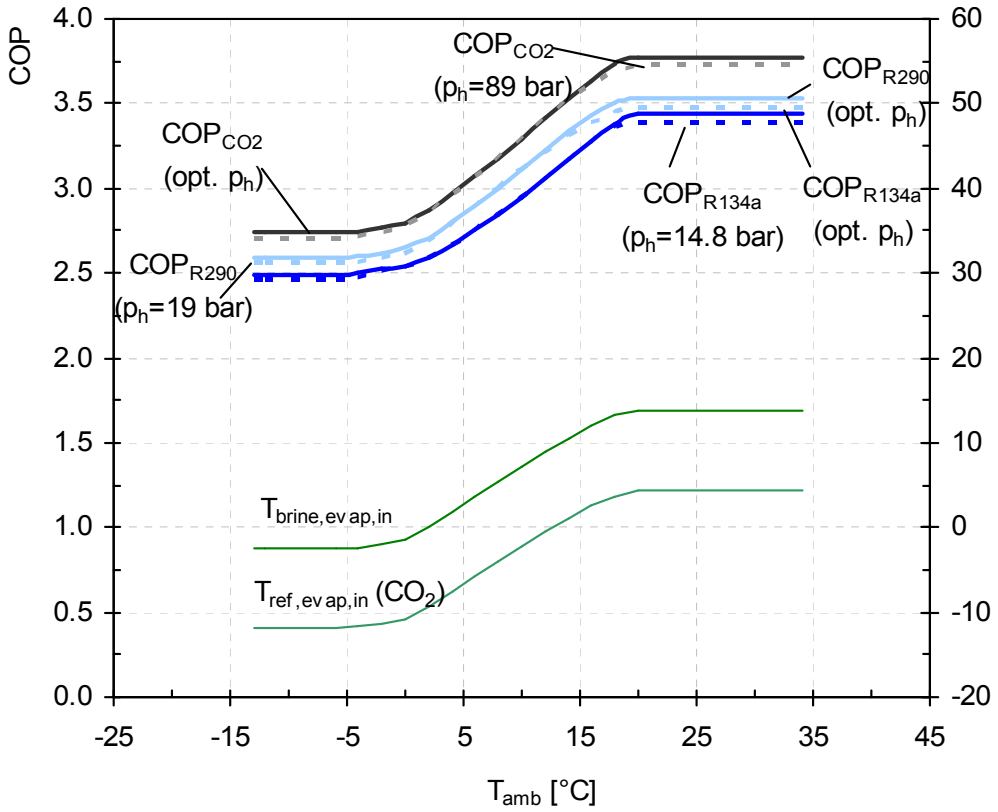
Results of the discussion:

- Heating/cooling solely via the (fresh) air is not seen as the best solution for the Austrian market (scepticism of customers because of limited heating power, absence of warm surfaces)
- Cooling: Passive cooling should be used preferably, active cooling only with simultaneous DHW preparation; the cooling demand should be limited by passive measures (shading, thermal mass)

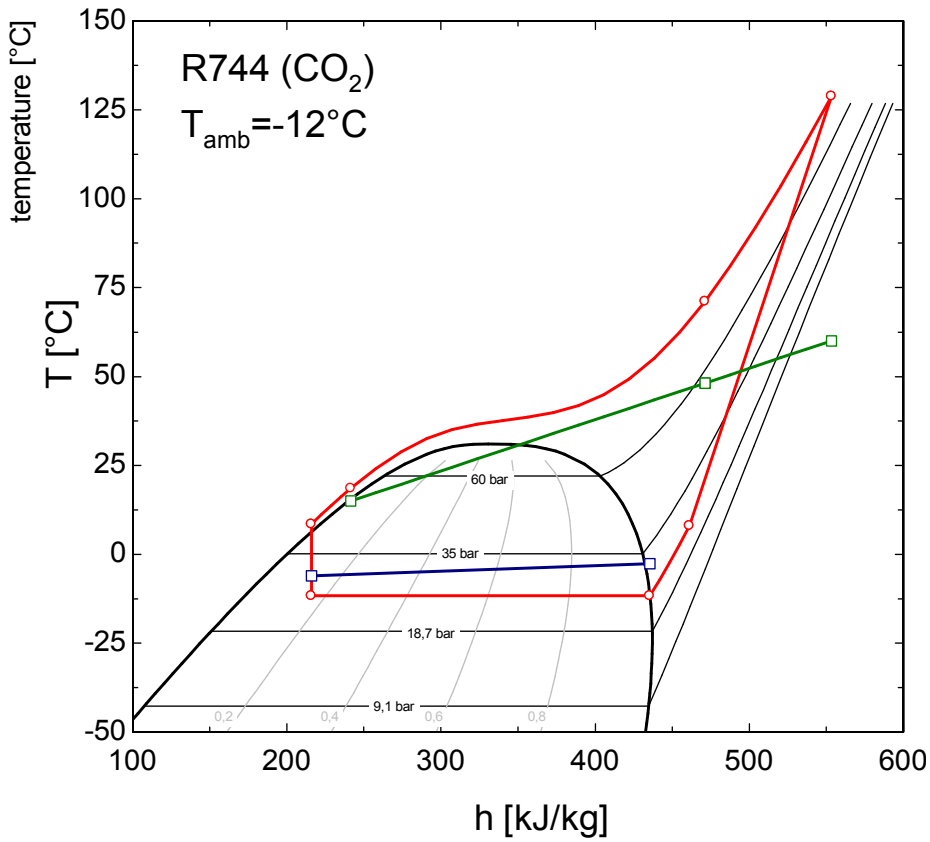
→ Preliminary system choice: System 2

Example: System 2 - COP @ DHW preparation mode

Simulation results:

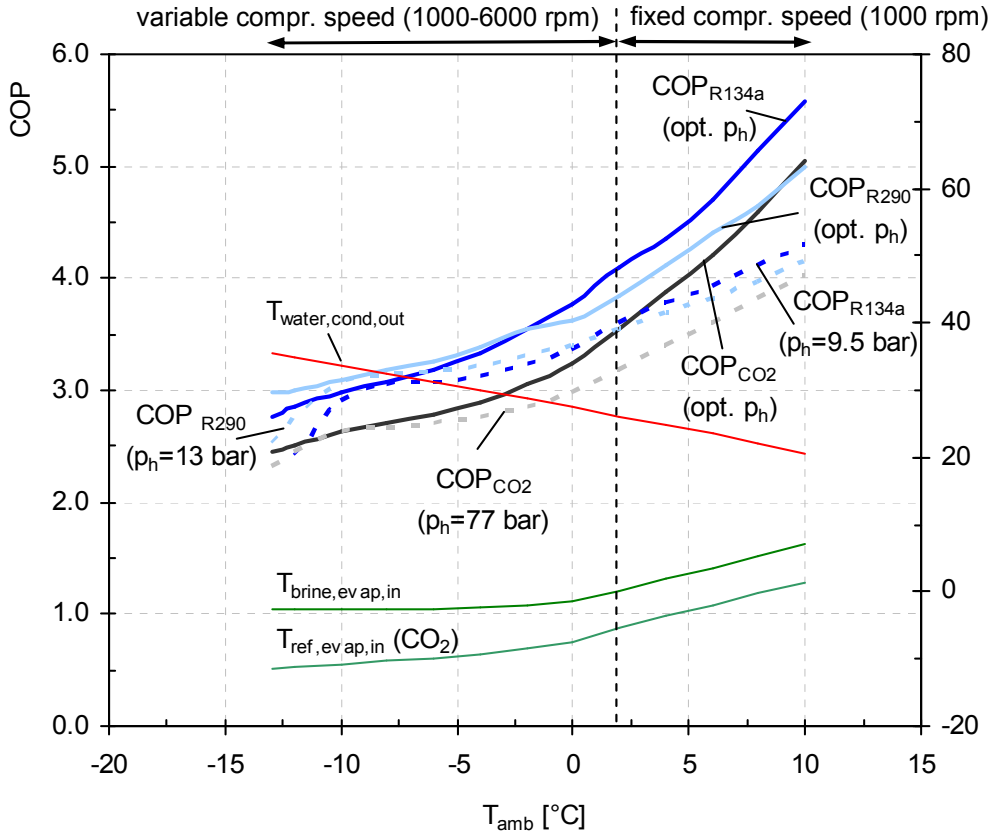


T-h diagram for R744 (CO_2):

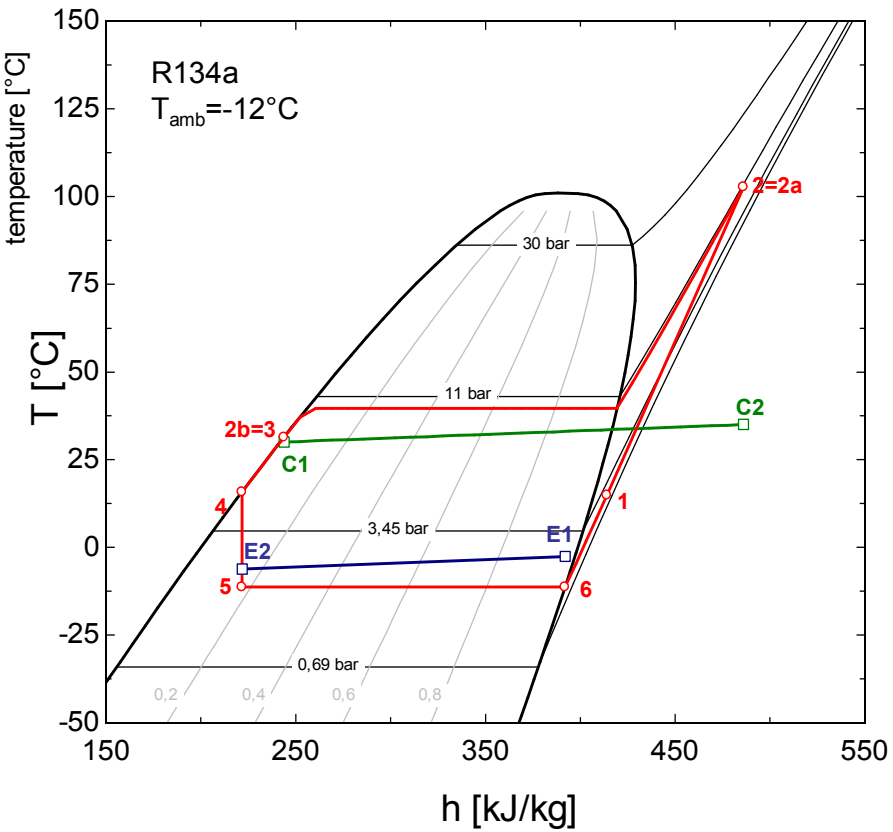


Example: System 2 - COP in the heating mode

Simulation results:



T-h diagram for R134a:



Evaluation of the seasonal performance factor (SPF):

Using the calculated COPs (based on realistic UA-values & compressor data) in the different modes of operation, and an average climate of Graz:

R134a: SPF~3.3

R290: SPF~3.6

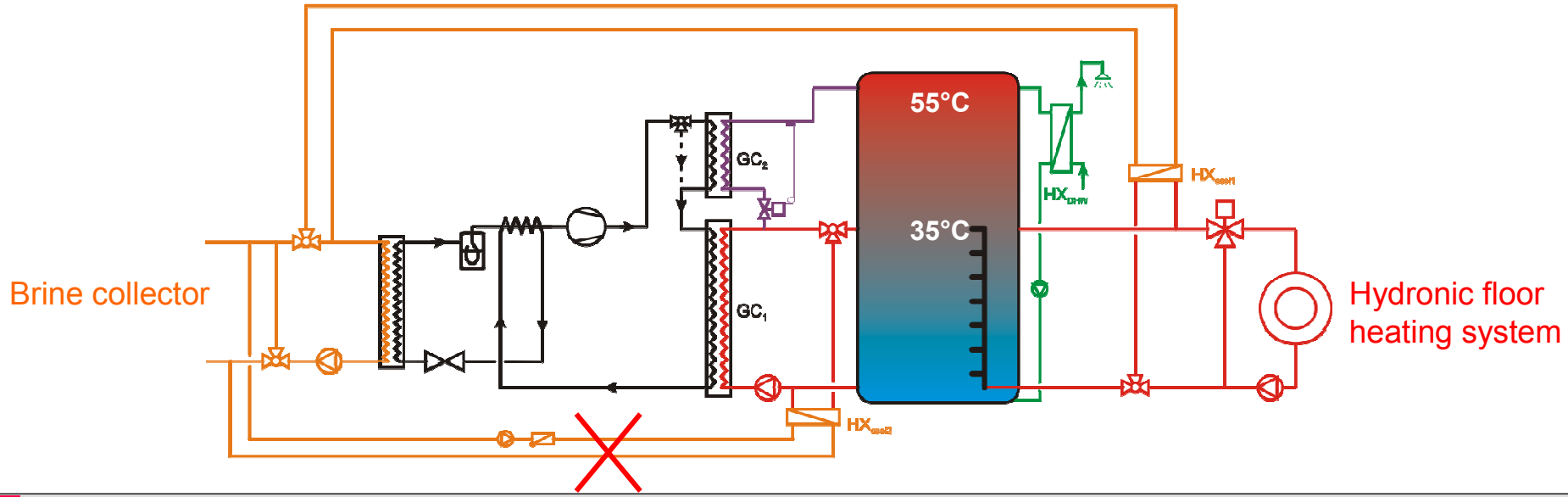
R744: SPF~3.3

	R134a	R290	R744
efficiency	😐	🙂	😐
natural refrigerant	☹	🙂	🙂
flammability / security	🙂	☹	🙂
availability of components	🙂	🙂	😐

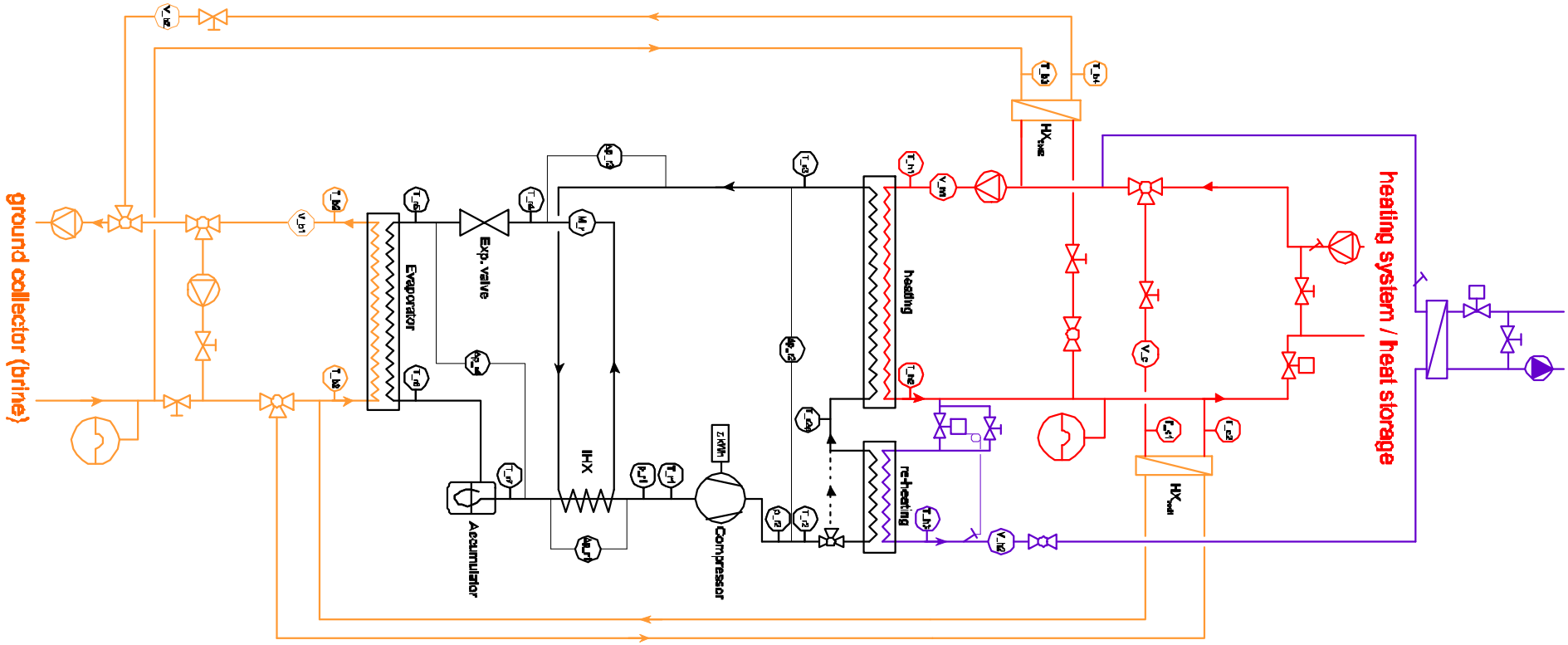
→ Refrigerant choice: R744

Concept for the prototype system with the refrigerant R744

- Buffer storage tank
- Bipartite gas cooler for combined preparation of low temperature water (35°C for space heating) and high temperature water (~55°C for DHW preparation)
- Instantaneous DHW preparation via an plate heat exchanger
- Active cooling (via the heat pump) and passive cooling (via the brine cycle) is possible



Outline of the Test Rig



Summary and Outlook

- 3 system concepts for integrated heat pumps were defined
- Simulation of the refrigerant cycles of the systems using EES
- Results for three refrigerants (R744, R134a, R290) are available
- A decision was made for a brine/water heat pump using the refrigerant R744
- The chosen system will be analysed in more detail
  - Construction of a prototype
  - Extensive experimental analysis
  - More detailed modelling of the heat pump
  - Detailed simulation of the system and its dynamic interaction with the heating system and the building

⇒For more Information on Simulation of System 2

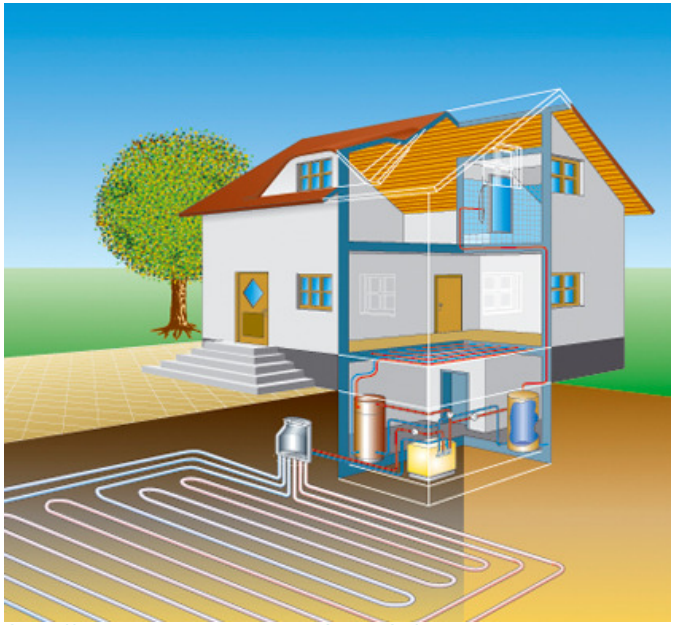
Presentation A. Heinz

Thursday, 9:10 h, Room Zürich

National project @ arsenal research

Field monitoring for 1 year:

- 10 heat pump systems in low energy buildings (heating and domestic hot water) (2007 – 2008)
- Monitoring of a compact ventilation unit for heating, cooling, ventilation and domestic hot water (2008 - 2009)



http://www.waermepumpe-bwp.de/

Thank you for your attention!

Acknowledgement

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