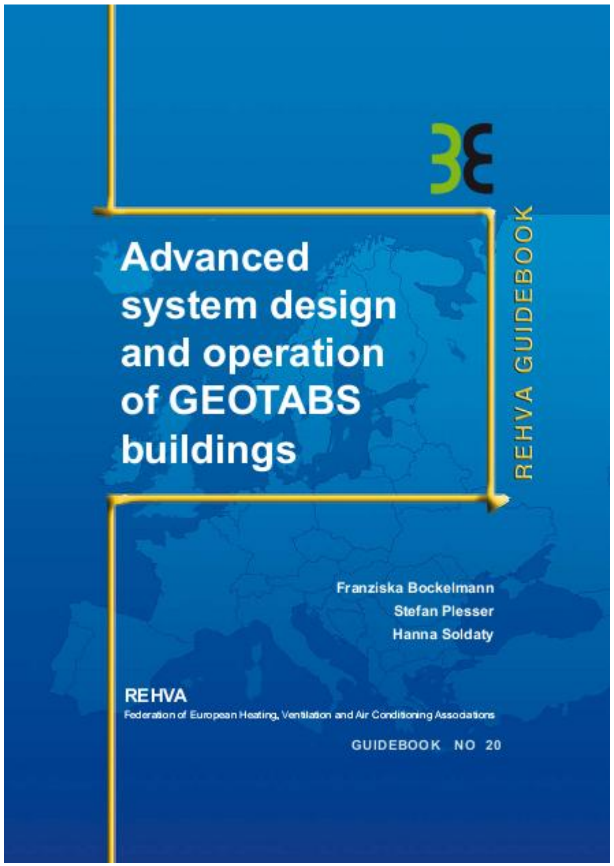
REHVA

Federation of European Heating, Ventilation and Air-conditioning Associations

Address:
Rue Washington 40
1050 Brussels
Belgium

- **www.rehva.eu**
- **info@rehva.eu**
- **Tel: +32 2 514 11 71**
- **Fax: +32 2 512 90 62**

REHVA Guidebook No 20
Advanced system design and operation of GEOTABS buildings



Franziska Bockelmann

Stefan Plesser

Hanna Soldaty

List of content

Terminology

Geothermal energy

Energy stored below the surface of the solid earth in the form of thermal energy.

Heat pump

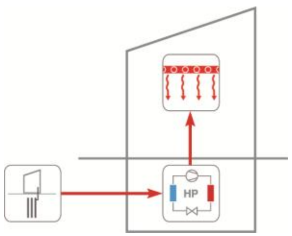
Heat pumps are thermodynamic cycles by means of which low temperature ambient energy can be upgraded such that it can be utilized for heating (heat pump) or cooling (chiller) buildings. The ambient energy is extracted from the ambient air, the groundwater or the ground soil. By using electrical power the temperature is brought to the desired temperature.

Thermally Activated Building System (TABS)

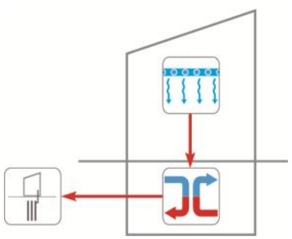
Radiant heating and cooling systems with pipes embedded in the building structure (slabs, walls).

What is GEOTABS?

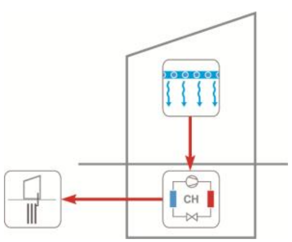
GEOTABS is an acronym for a **geo**thermal heat pump combined with a **t**hermally **a**ctivated **b**uilding **s**ystem, used for conditioning of a building in three possible modes:



heating with a heat pump



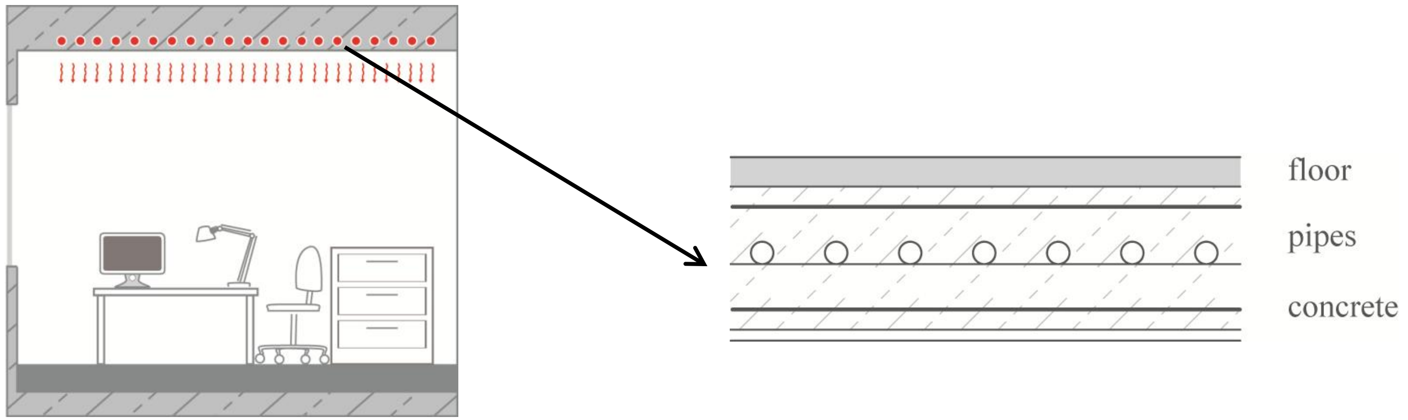
passive cooling



active cooling with a reversible heat pump

TABS

The TABS is a building component with embedded water based pipes used for heating and cooling the building.

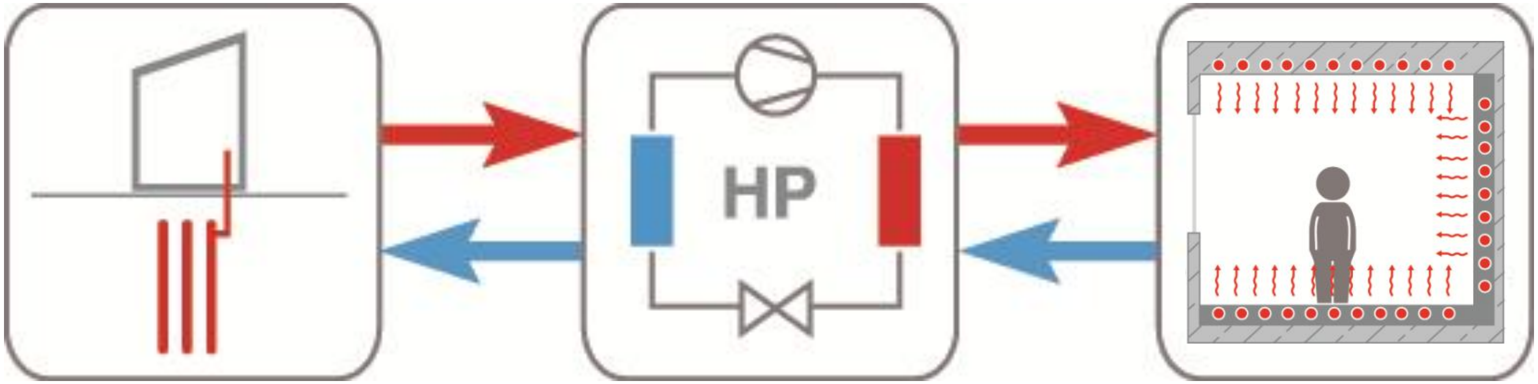


The principle of the system is to activate the thermal mass of the building to transfer heat to or from the zone to assure thermal comfort in the rooms.

TABS

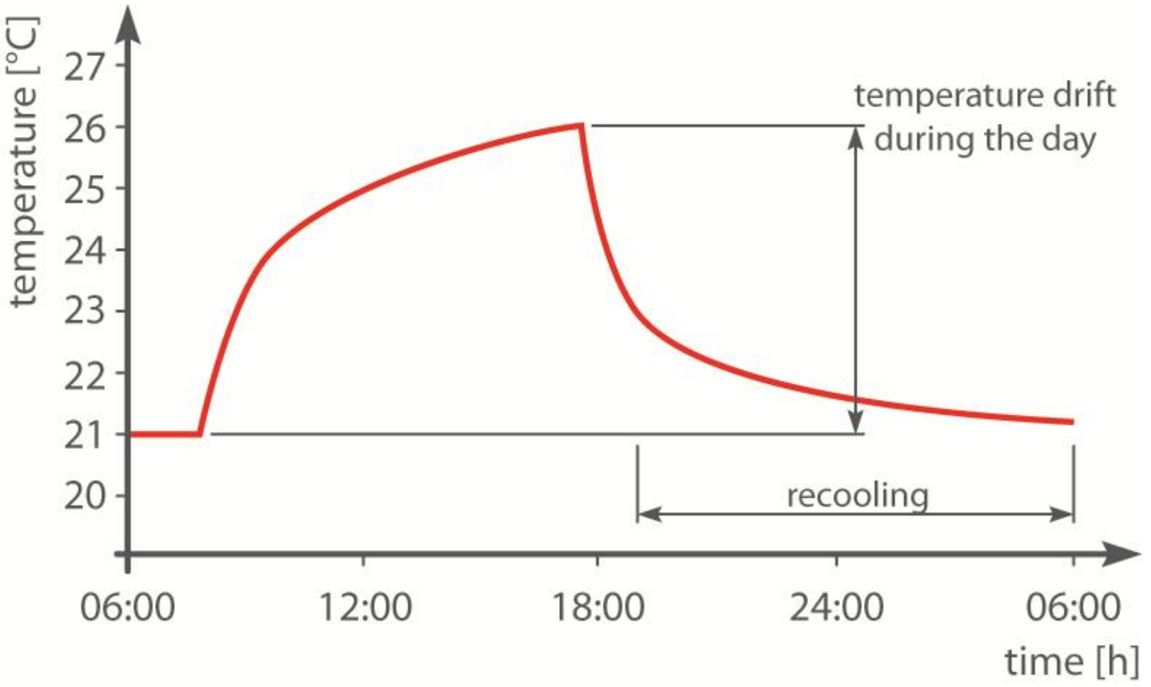
The system can be effectively used in combination with renewable energy sources and heat pump for:

- low temperature heating (27 - 29°C)
- high temperature cooling (18 - 22°C)



TABS

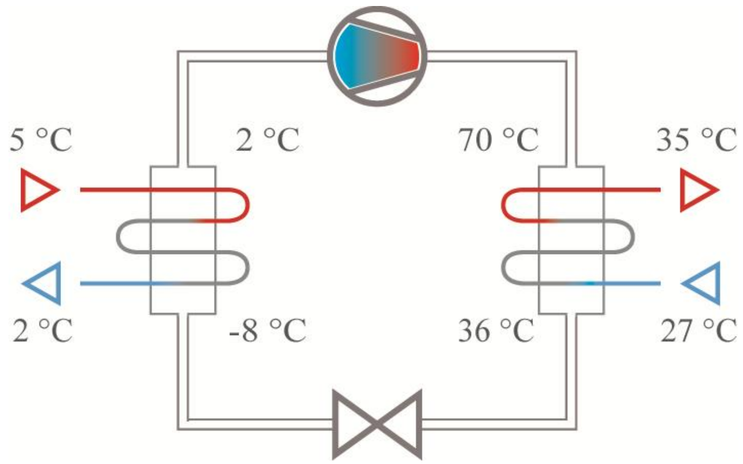
- Drift of the indoor temperature in a TABS building (example: summer)



- TABS should be used for zone control - not for individual room control !

Heat pump

Principle of the heat pump:

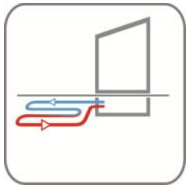


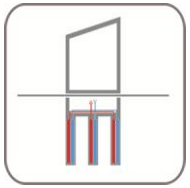
Types of heat pumps:

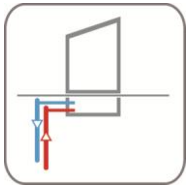
- in regard to heat source: air, water or ground coupled heat pumps
- in regard to supply energy source: electrical, gas or oil combustion
- in regard to conversions: compressor, absorption or adsorption

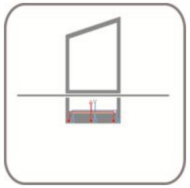
Near surface geothermal energy systems

Closed systems

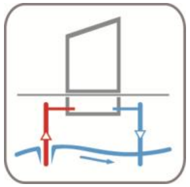
 Horizontal heat exchanger

 Energy piles

 Borehole heat exchanger

 Slabs as ground absorber

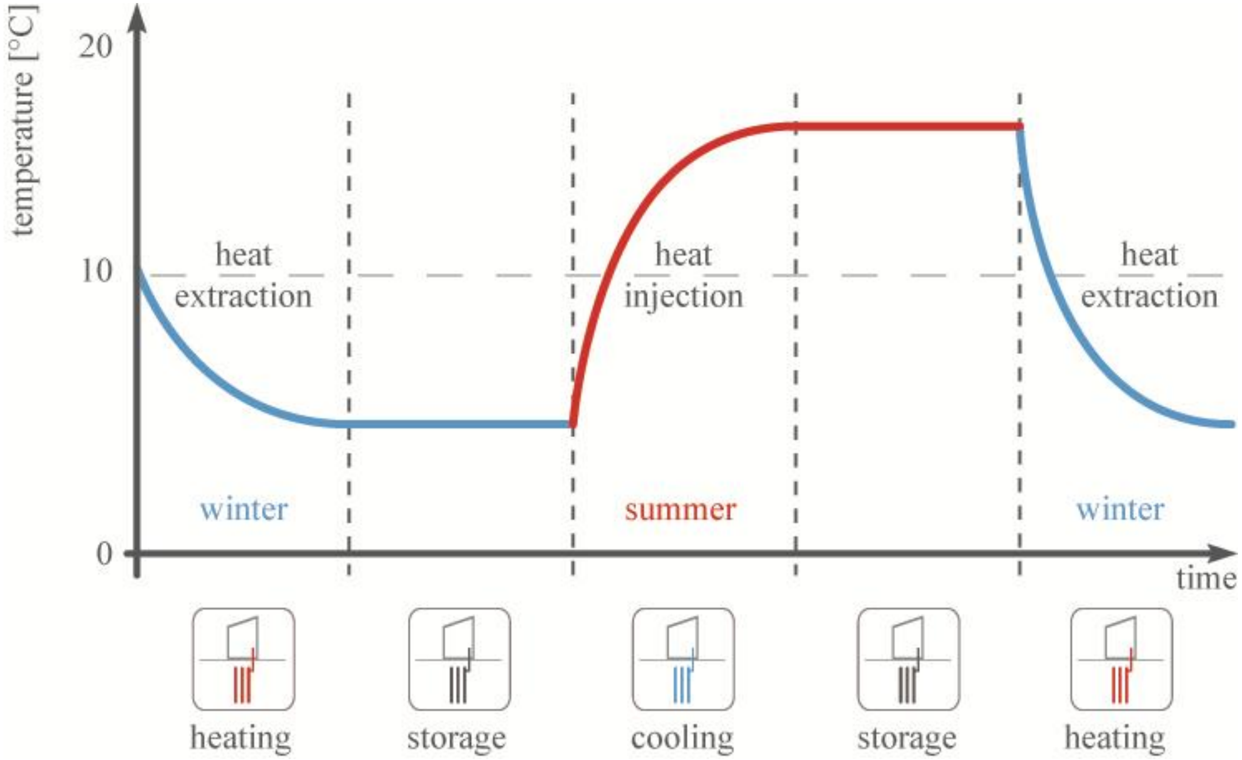
Open systems

 Wells

Seasonal thermal balance in the ground

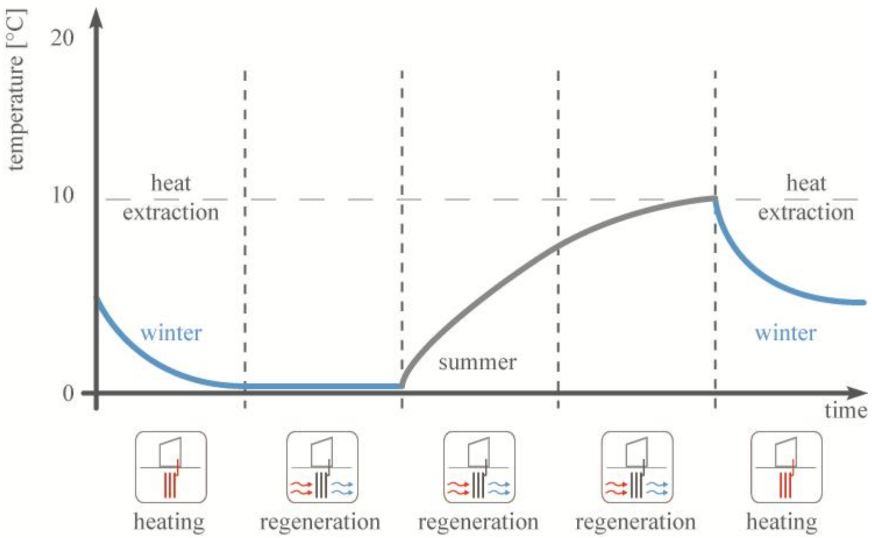
Underground Thermal Energy Storage (UTES)

- combined heat source and heat sink

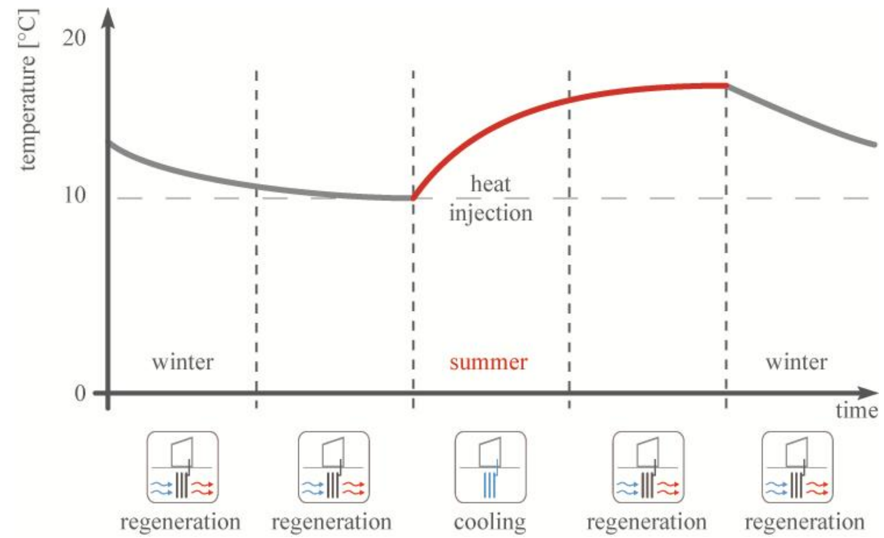


Seasonal thermal balance in the ground

Only heat source



Only heat sink



Regeneration of the natural thermal balance of the soil must be assured!

Possibilities and limitations of GEOTABS

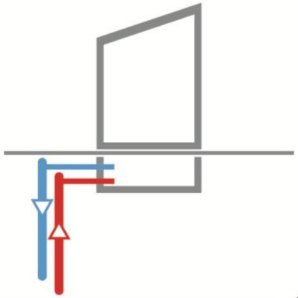
Strength	1. Water supply temperatures: • <30°C for heating • >15°C for cooling exploiting environmental energy: (ground coupled) heat pumps, passive cooling and night cooling. 2. Large thermal capacity (time constants of 10-15h) to shift TABS operation to time periods when heat and cold production is most energy (or cost) efficient. 3. Increased thermal comfort by radiation heat exchange. 4. Reduced building height compared to buildings with full AC.	**Weakness**	1. Limited average thermal power output of 40 to 50 W/m². Allow temperature drifts within the specified comfort range or provide an additional, fast reacting system. 2. Limited individual room control. 3. Not useful to change set-point during a day. 4. Acoustic control - limited suspended ceiling.
Opportunities	1. Suitable for low energy, passive or zero-energy buildings. 2. Increased share of efficiently generated heat and cold. 3. Less expensive and more energy efficient form of cooling than full air-conditioning.	**Threats**	1. Careful system and control strategies design is required. 2. Additional fast reacting system must not overrule or counteract the TABS operation. 3. The limits of the system regarding the achievable thermal power should be specified.

Design process

integral design process

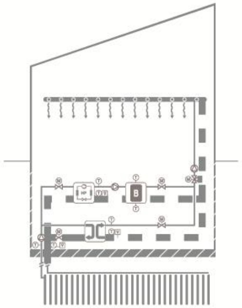
feasibility study (estimation of feasibility):
- building type, concept and location
- specification of requirements
- heating and cooling demand
- availability and properties of the ground
- local regulations
- financial constrains

method: estimation, rule of thumbs



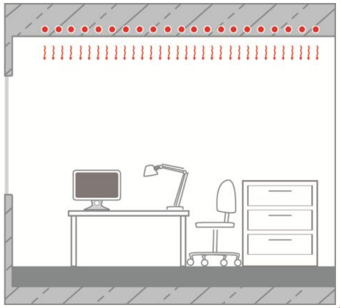
pre-design (rough sizing):
- building design and performance (base and peak loads)
- thermal balance (internal and external heat gains and loses)
- thermal storage mass of the building
- type of ground heat exchanger
- GEOTABS concept
- additional and back-up system (if required)

method: calculations, norms and standards



detailed design (detailed sizing):
- zoning and rooms characteristics
- TABS design
- heat pump and geothermal system design
- hydraulic system design
- integration of the systems
- control strategy

method: dynamic simulations, performance simulations

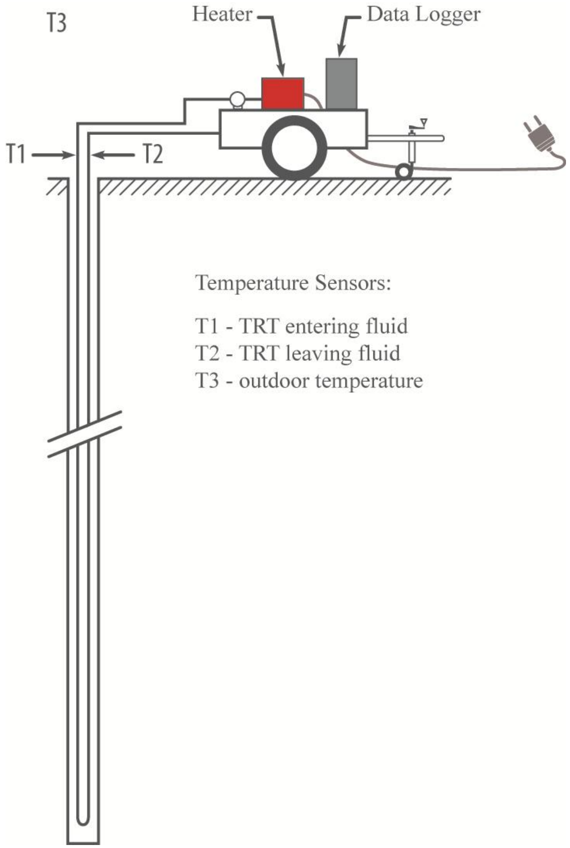


Designing the ground system

Realization of a geothermal system requires adaptation to the geological constraints on site:

- rock type and hardness
- ground thermal characteristic
- groundwater situation
- natural ground temperature

A thermal response test (TRT) and exploration of the soil can provide information on the suitability for geothermal systems.



Simulation of the ground system

Simulation is particularly useful to study:

- the thermal response of different borehole configurations
- interference between boreholes
- annual energy balance of the ground

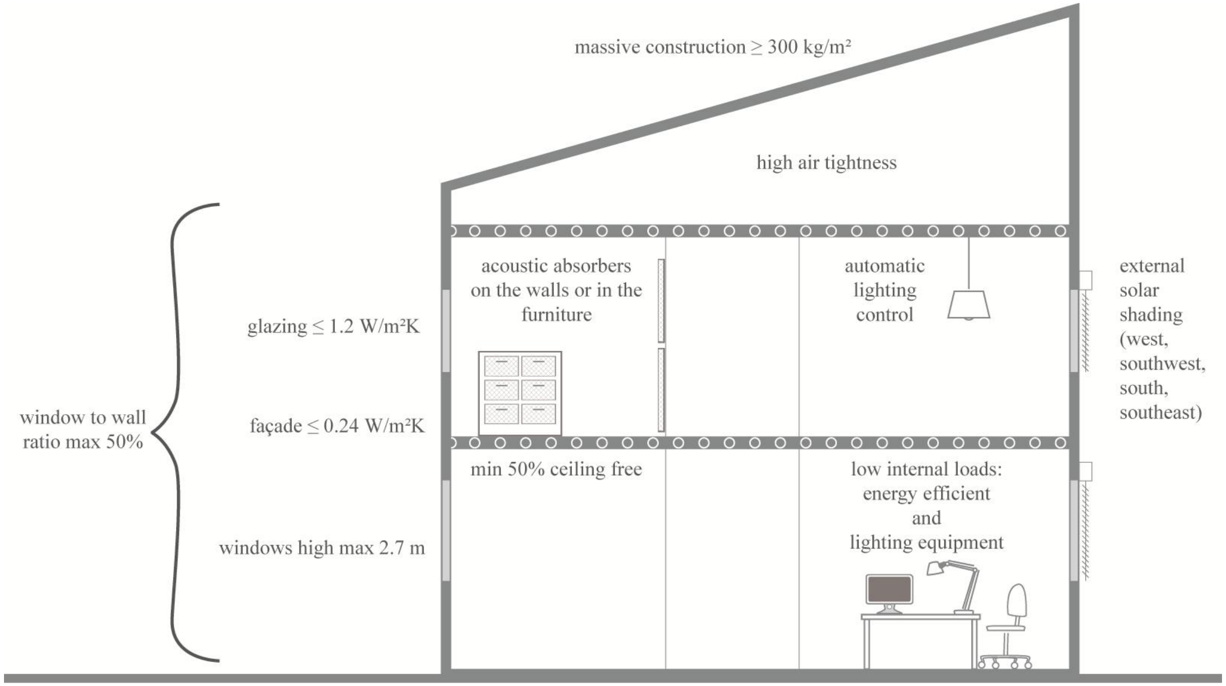
Types of simulations:

- coupled simulations (TRNSYS, eQuest, EnergyPlus, Modelica)
- decoupled simulations (Earth Energy Designer – EED, EWS – Erdwärmesonden)

Designing the building

The main restrictions for the design are related to:

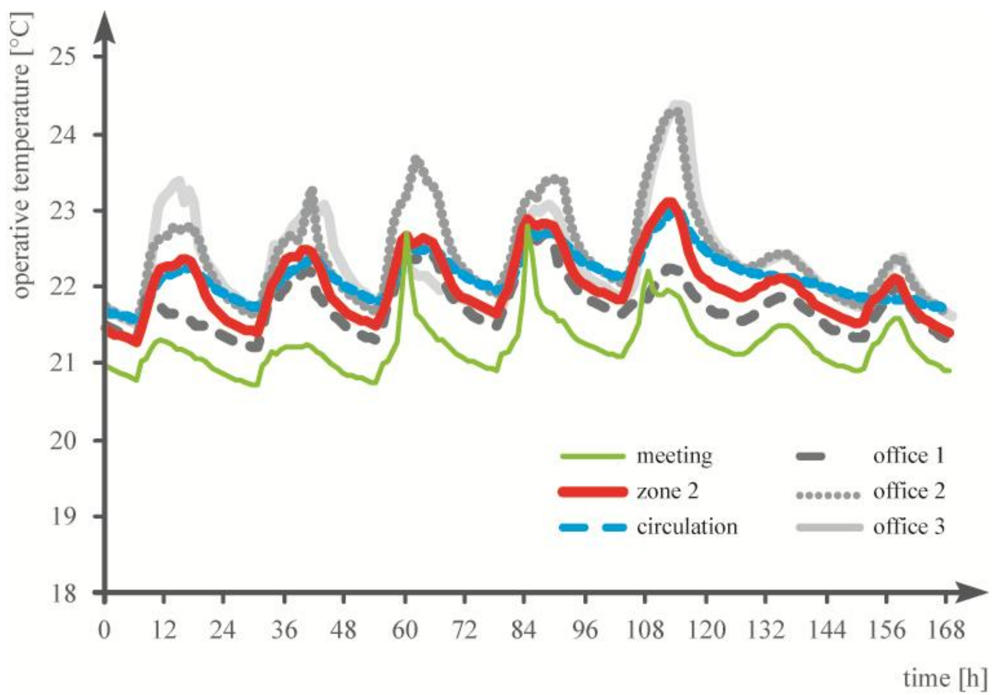
- mass of the building
- external gains and losses related mostly to location, orientation, layout (internal, external and corner rooms), ventilation and solar radiation
- internal loads
- transmission



Simulation of the building

Simulation in design of the GEOTABS building on:

- building level
- room level
- TABS level

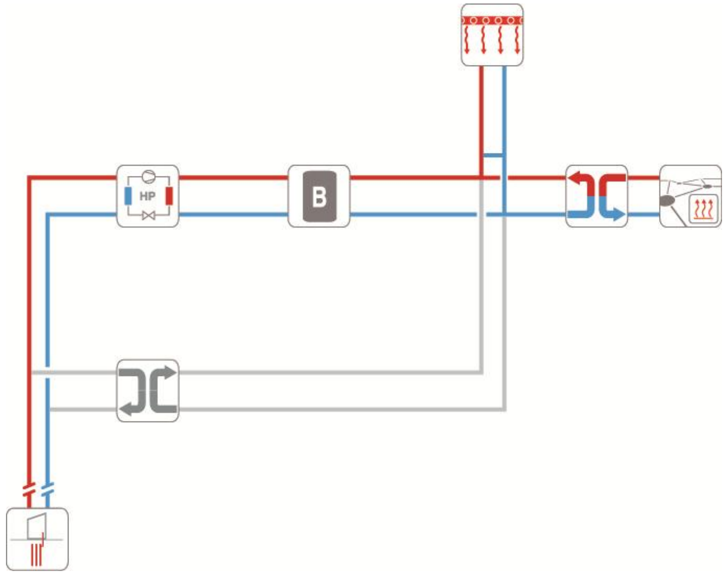


Example of the temperature profile output of building simulation with TABS

System integration

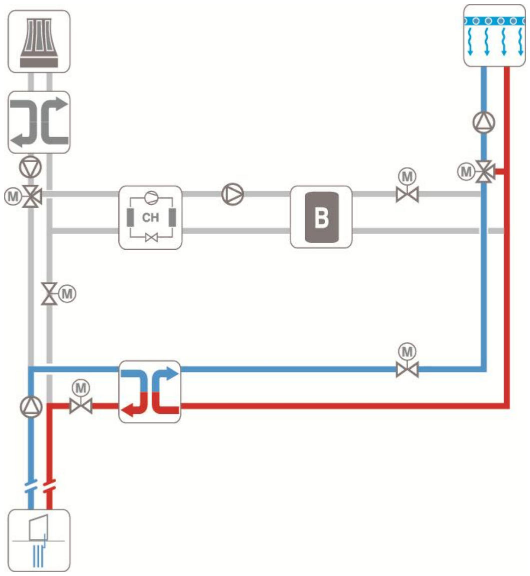
Heat pump in combination with the additional heating or cooling system – operation modes:

- monovalent
- bivalent – alternative
- bivalent – parallel
- bivalent – partially parallel
- monoenergetic

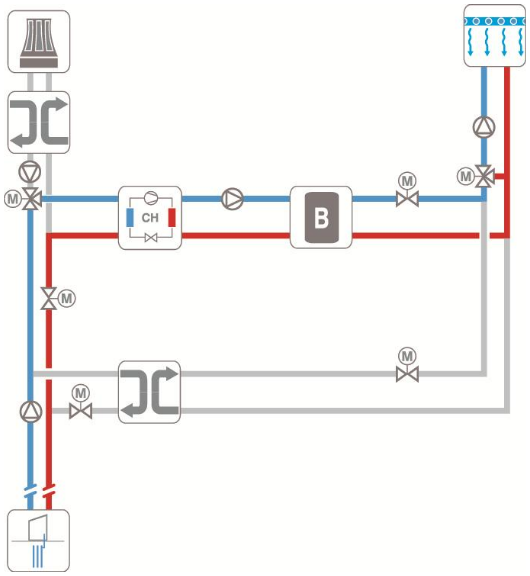


Heating with integrated district heating

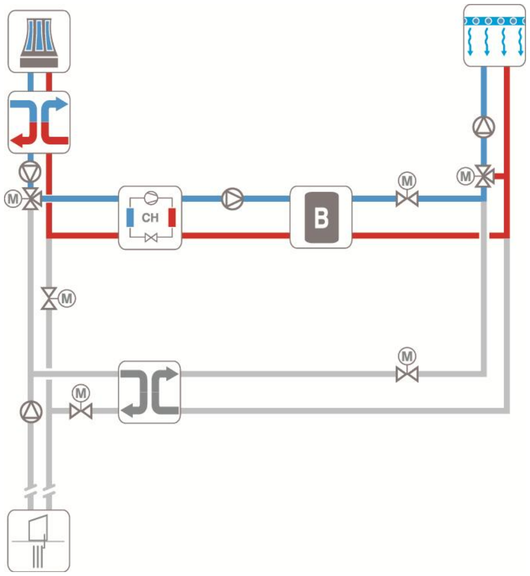
System integration



Passive cooling



Active cooling

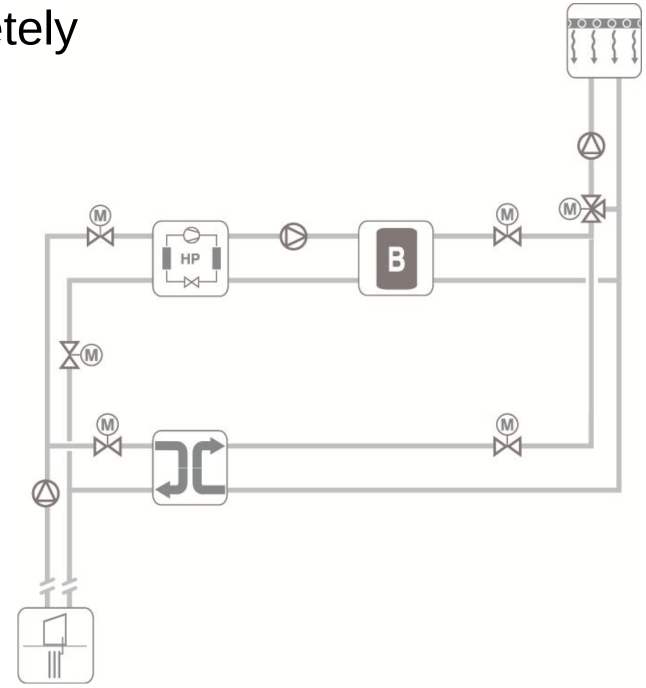


Cooling with integrated cooling tower

System integration – buffer tank

Buffer tank to avoid frequent on/off switching of the heat pump, when:

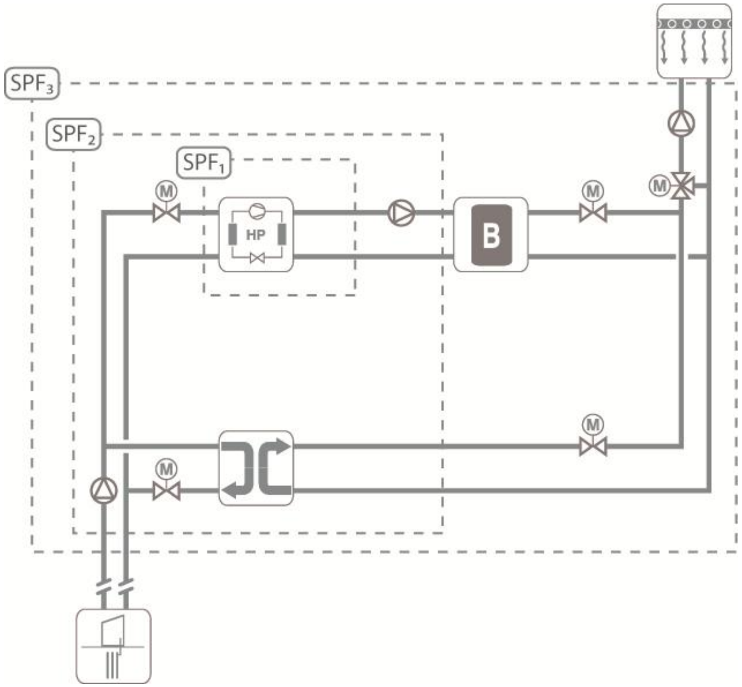
- the supply system contains only a small amount of water
- it is running at very low loads
- the supply system can be turned off completely



Efficiency of the system

- **Coefficient of Performance (COP)**
  the ratio of heat power to electric power referred to particular boundary conditions (calculated value)

- **Seasonal Performance Factor (SPF)**
  the ratio of annual thermal energy output to the annual consumed electrical energy (measured value)



Control strategies for the ground system

Conventional control strategies:

Intermittent operation with defined schedules:

- with a dead band for a specific range of temperatures or with seasonal downtime
- only during occupation hours (night setback)
- independent from occupancy time, when the energy tariffs are lower (night cooling)

Rules for ground system control:

- avoid frequent switching between operation modes
- decrease unnecessary consumption of auxiliary energy

Control strategies for TABS

Conventional control strategies:

- Time based control
- Zone temperature control
- Weather dependent supply/average water temperature control
- Intermittent pump operation control
- Constant concrete core temperature control
- Dead band for switching between heating and cooling mode

Control strategies for TABS

Rules for TABS control:

- keep TABS at a constant temperature
- concrete surface temperature is the controlled variable, water temperature is the manipulated variable
- heating on, if average outdoor temperature is lower than set point
- cooling on, if average outdoor temperature rises above the set point
- heating/cooling curve +3K / -3K

Control strategies for additional systems

Conventional control strategies:

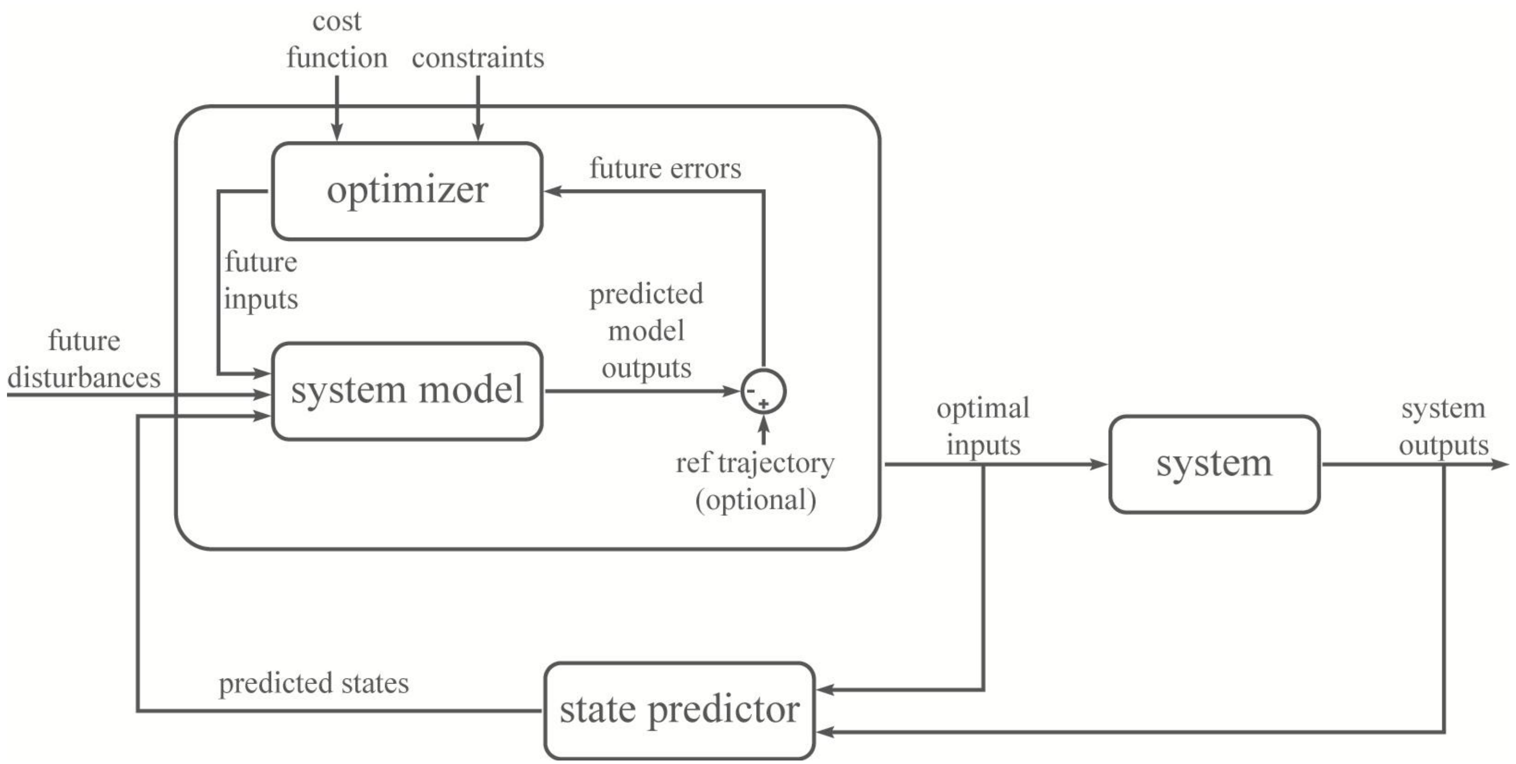
- operation of the TABS system during night and use fast reacting system during daytime
- operation of fast reacting systems at moderate ambient air temperatures
- activation of the TABS when the building is constantly in heating or cooling mode

Rules for fast reacting system control:

- fast reacting systems must not overrule the TABS in regular operation
- simultaneous heating and cooling must be avoided
- frequent changing between heating and cooling must be avoided

Control strategies – Model Predictive Control

Model Predictive Control (MPC) framework:



Commissioning, operation & maintenance

Commissioning is an essential requirement for GEOTABS systems in commercial buildings to ensure that the system operates in the intended way!

Commissioning process

Step 1: Definition of objectives

Step 2: Definition of measurement and verification concept

Step 3: Initial Commissioning

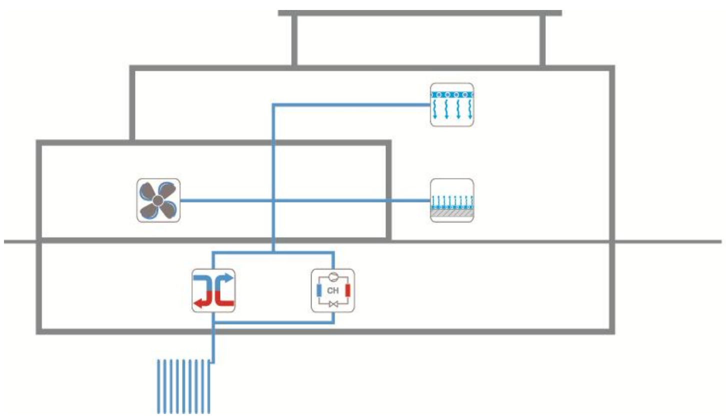
Step 4: On-going Commissioning

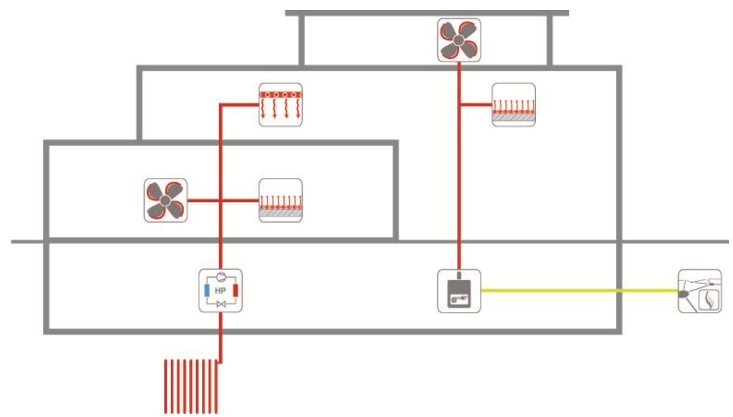
Real cases

Hollandsch Huys

Location	Hasselt, Belgium	
Year of construction	2008	
Net floor area (NFA)	4 090 m²	
Gross volume	12 975 m³	
Geothermal system	Borehole Heat Exchanger (22 à 75 m)	
Design values		
Total heating load	37 kWh/m^2_{NFA}	
Total cooling load	27 kWh/m^2_{NFA}	
Fraction of geothermal system	Heating: 100%	Cooling: 100%

Summer and winter energy concept



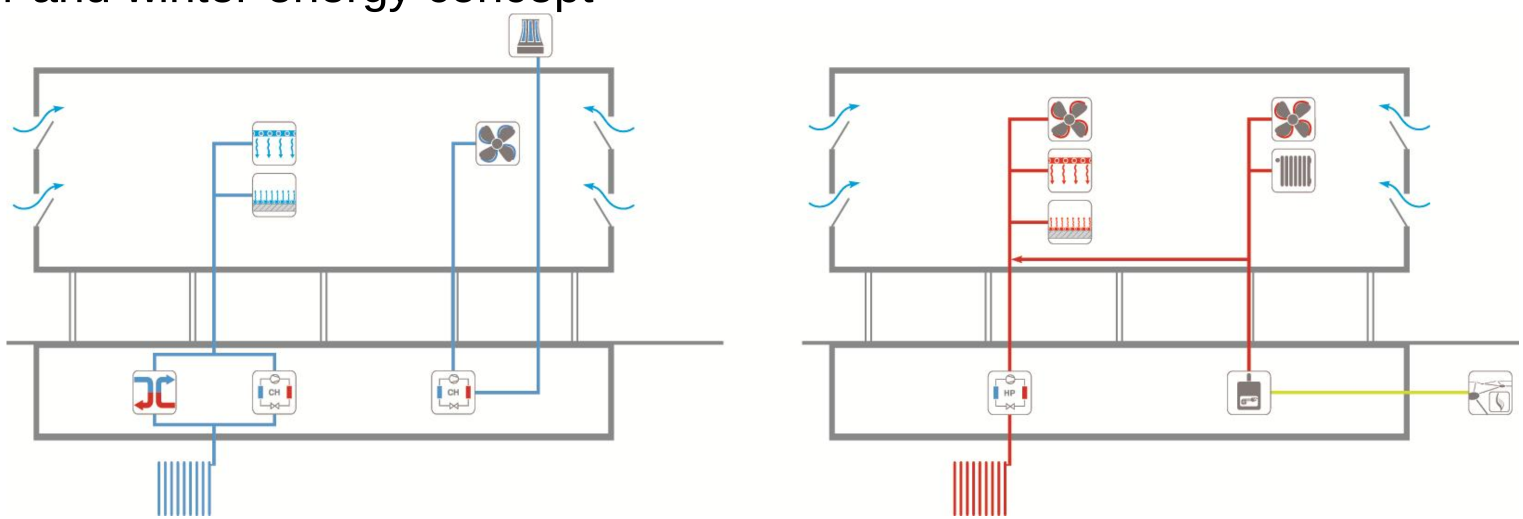


Real cases

INFRAX West

Location	Torhout, Belgium	
Year of construction	2009	
Net floor area (NFA)	4 014 m²	
Gross volume	21 484 m³	
Geothermal system	Borehole Heat Exchanger (24 à 130 m)	
Design values		
Total heating load	409 kW	71 kWh/m^2_{NFA}
Total cooling load	242 kW	49 kWh/m^2_{NFA}
Fraction of geothermal system	Heating: 69%	Cooling: 67%

Summer and winter energy concept










More GEOTABS cases with building characteristic and operation data at:

www.geotabs.synavision.de







Thank you
for your
attention

To order the REHVA guidebooks :
www.rehva.eu / section Bookstore
or through your national member