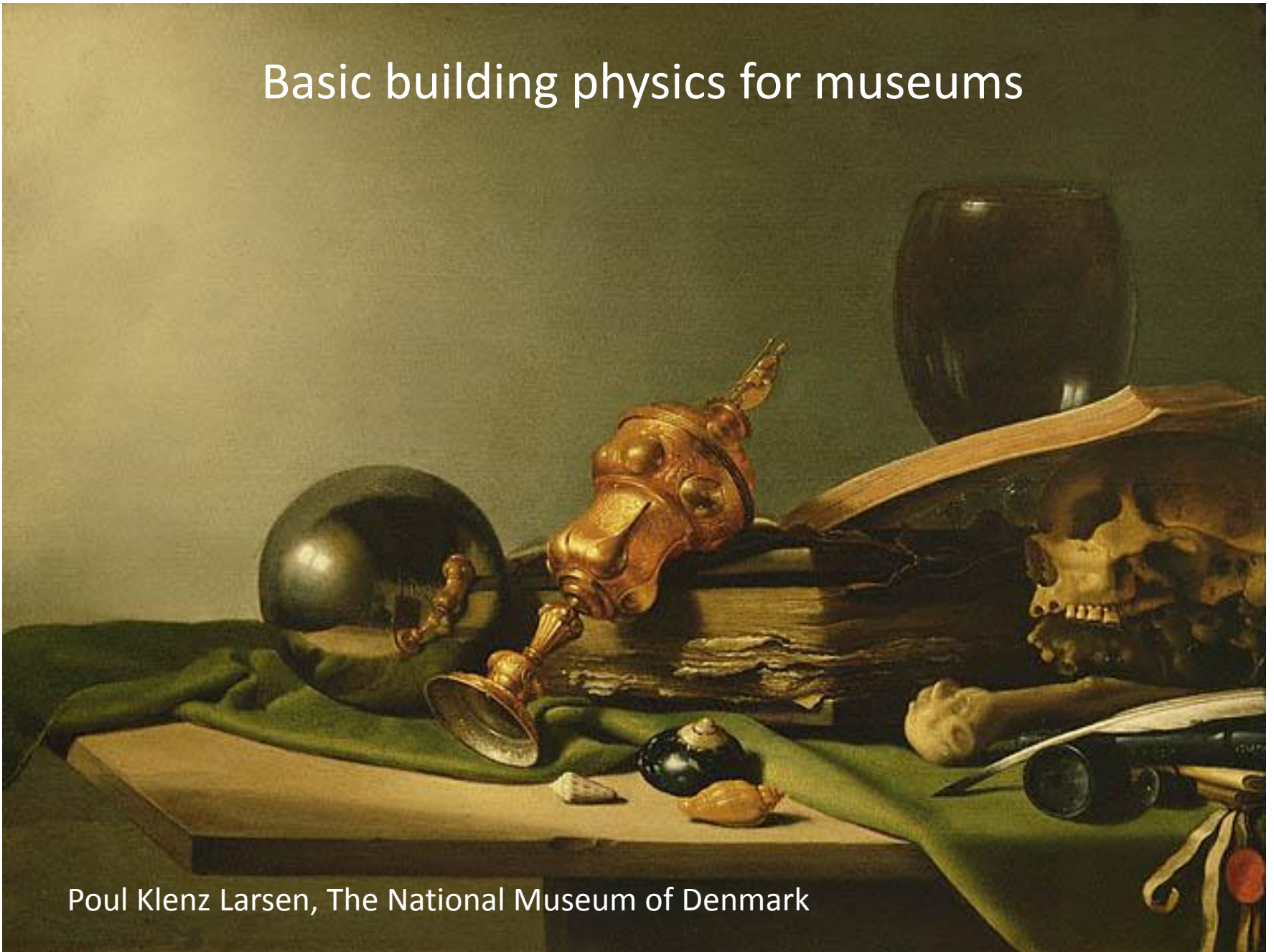


# Basic building physics for museums



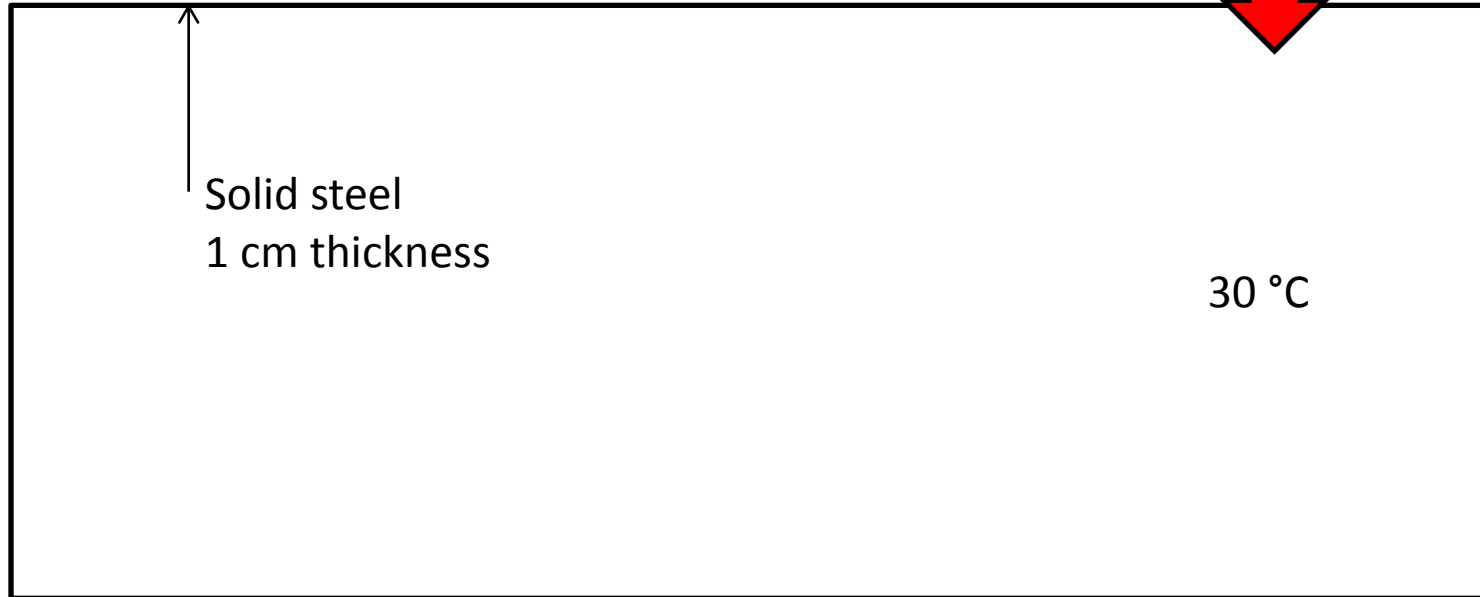
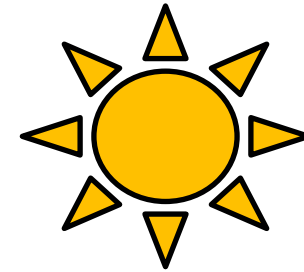
Poul Klenz Larsen, The National Museum of Denmark



# Temperature control

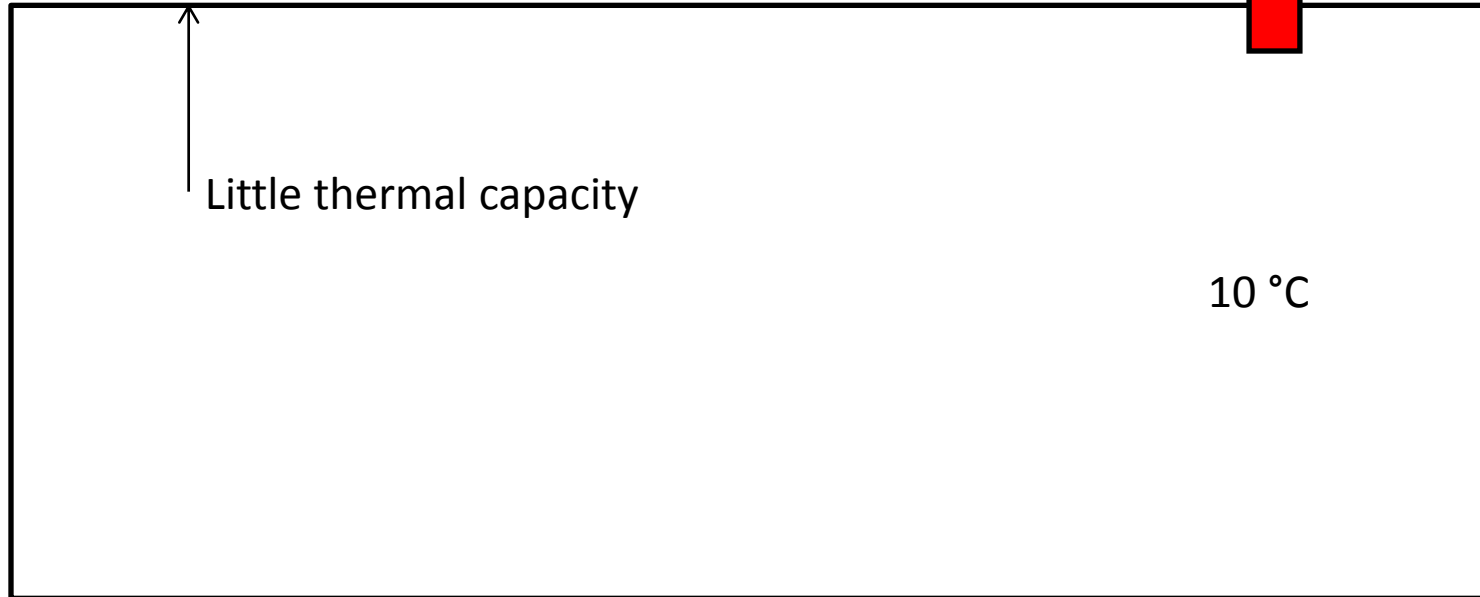
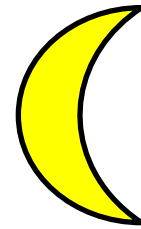
Little thermal stability on daily cycle

Heat radiation warms up the interior during the day



# Temperature control

... and cool it during night

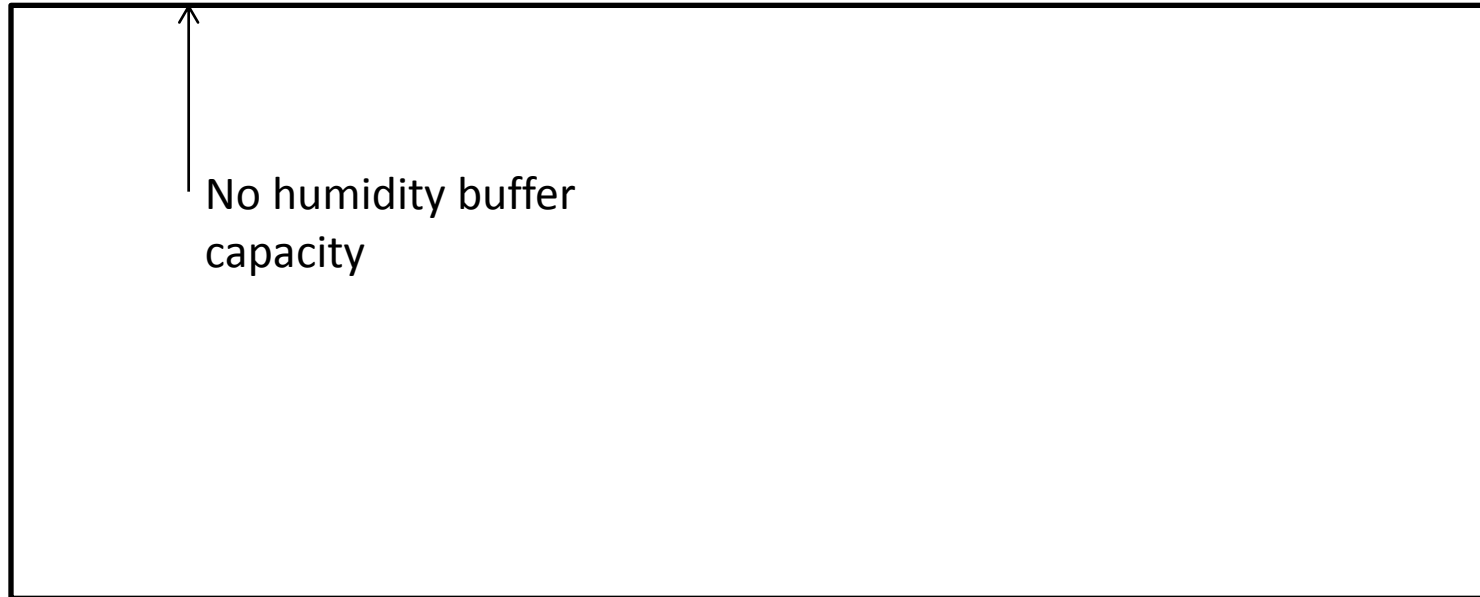
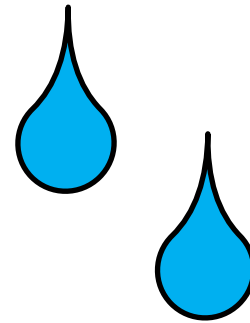




# Humidity control

The structure is water tight

The surface is impermeable to water vapour

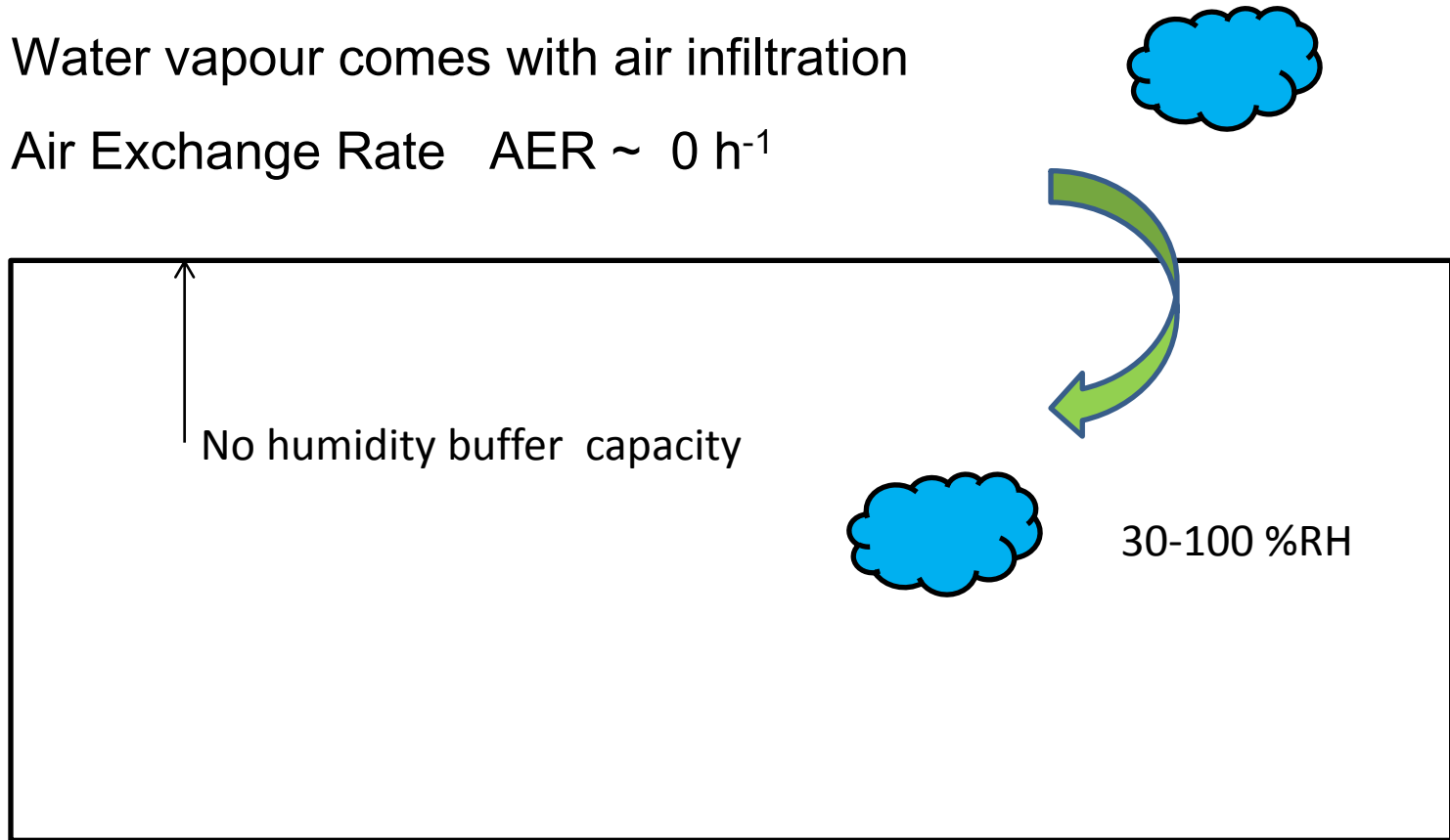


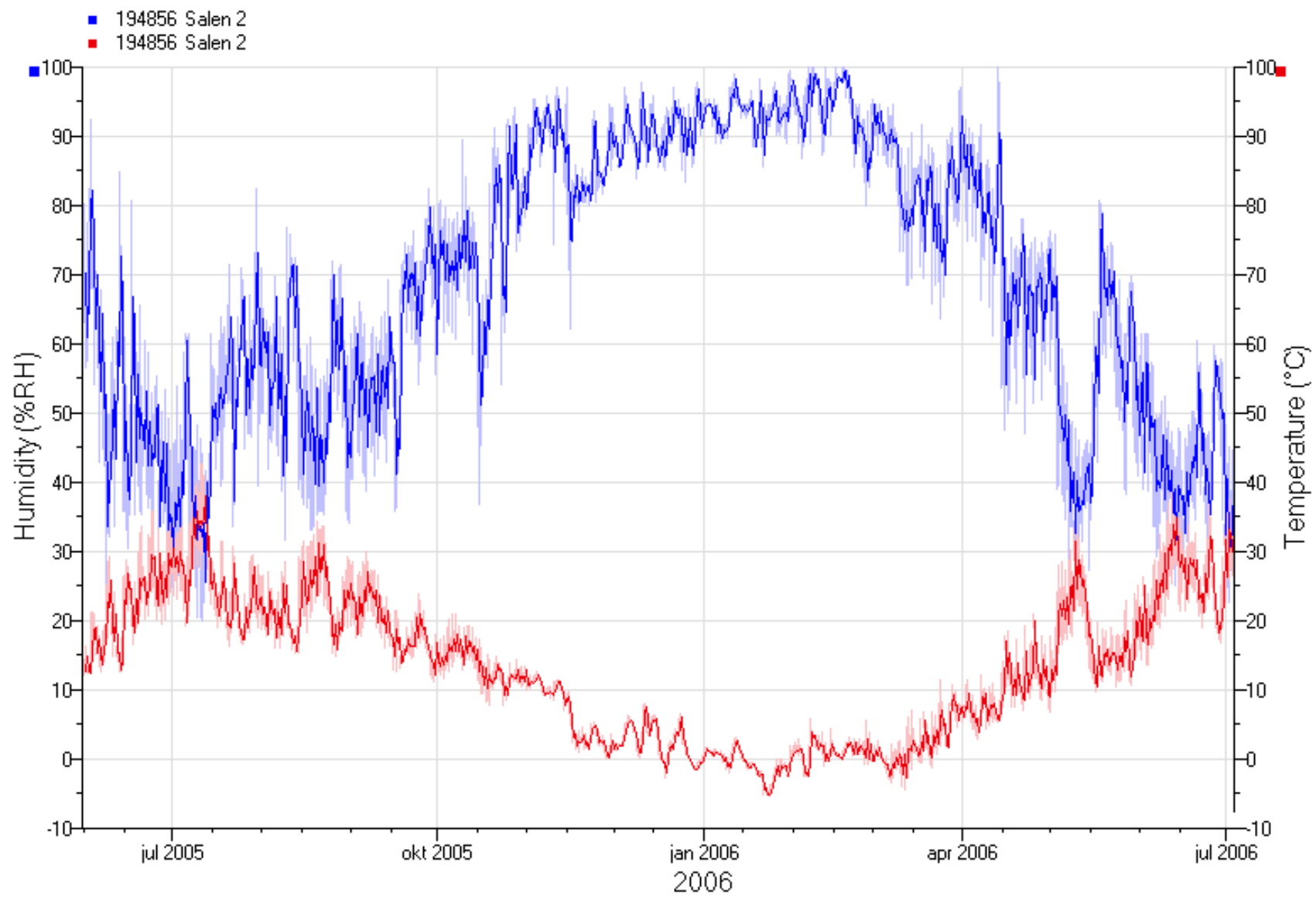
No humidity buffer  
capacity

# Humidity control

Water vapour comes with air infiltration

Air Exchange Rate  $AER \sim 0 \text{ h}^{-1}$





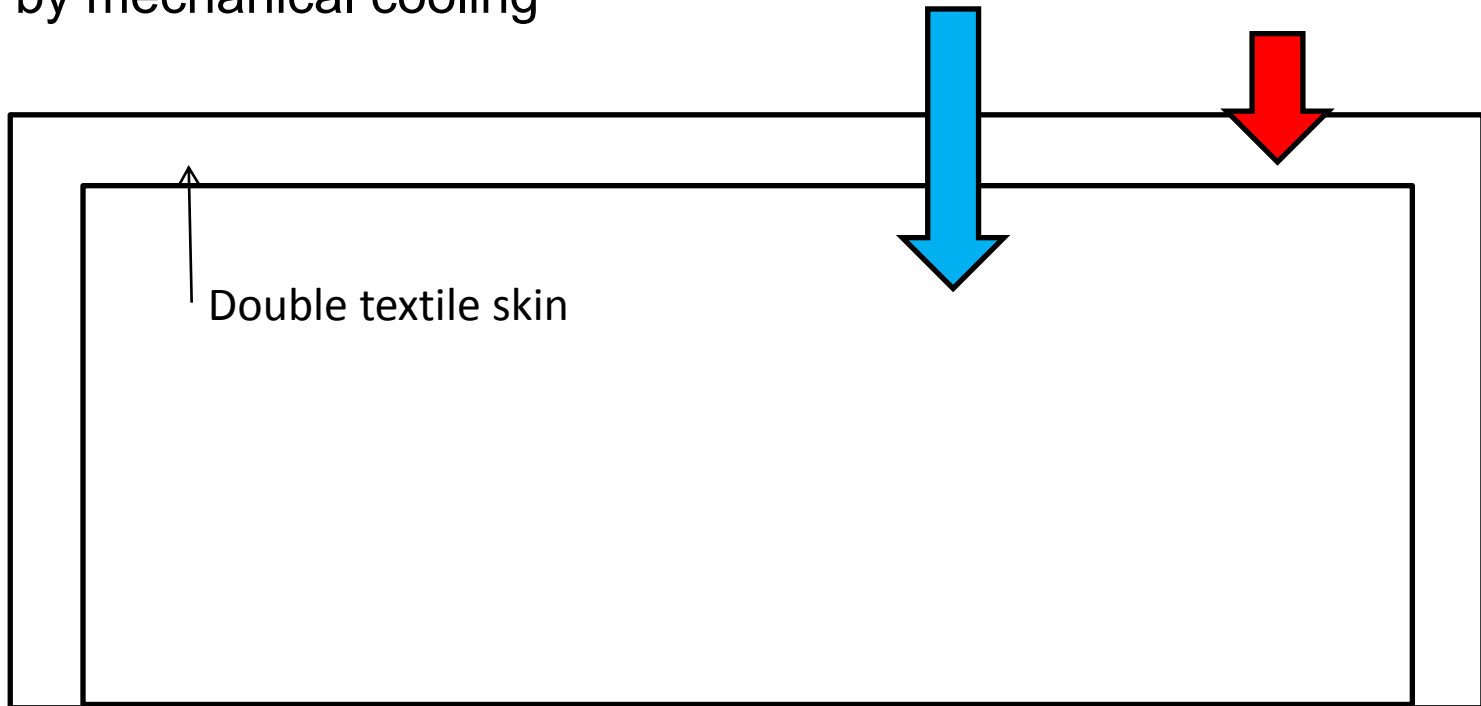
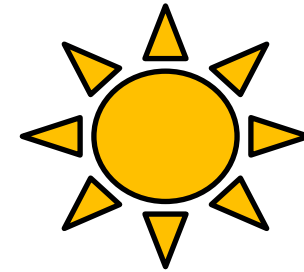




# Temperature control

Little temperature stability

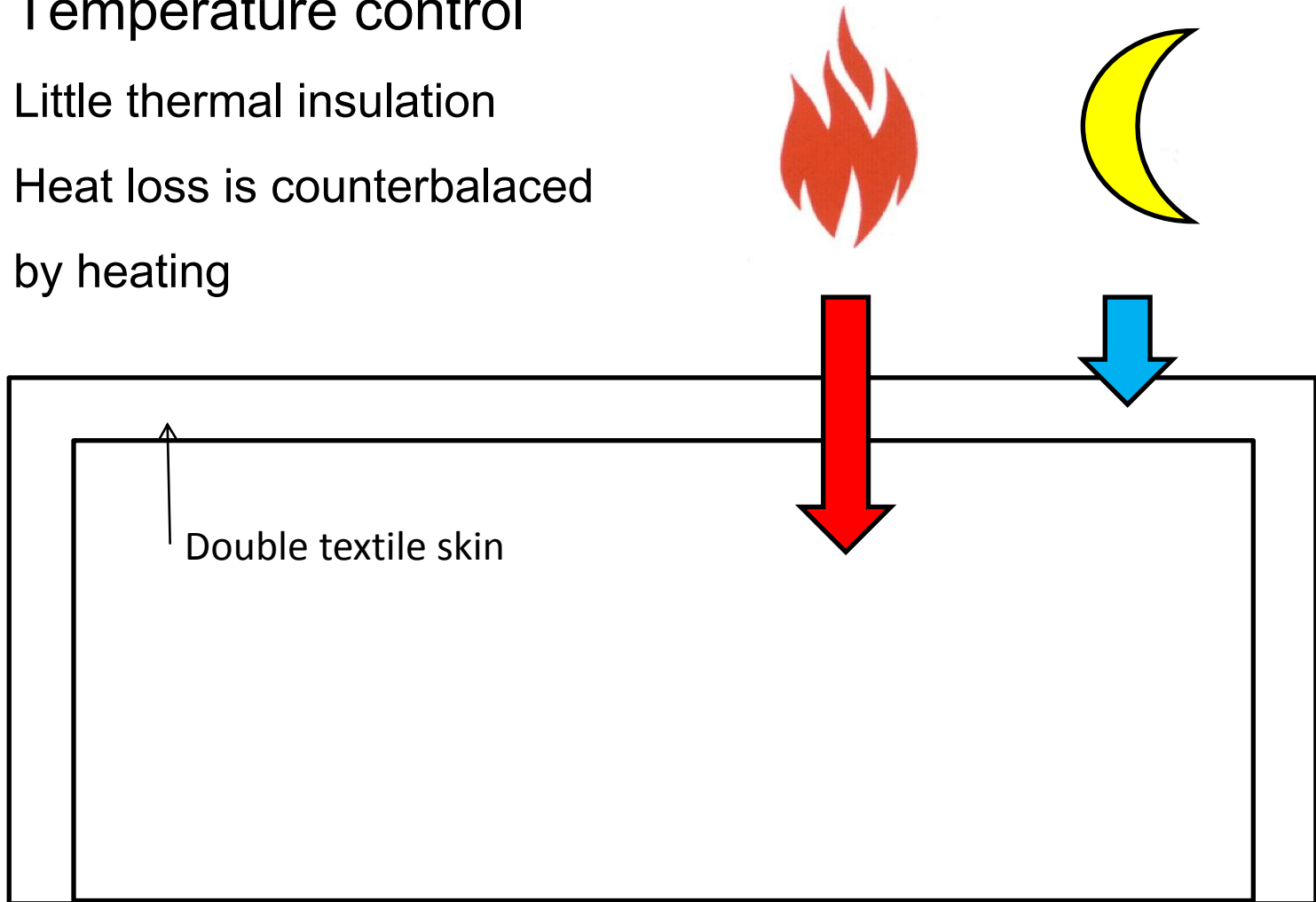
Heat radiation is counterbalanced  
by mechanical cooling



# Temperature control

Little thermal insulation

Heat loss is counterbalanced  
by heating

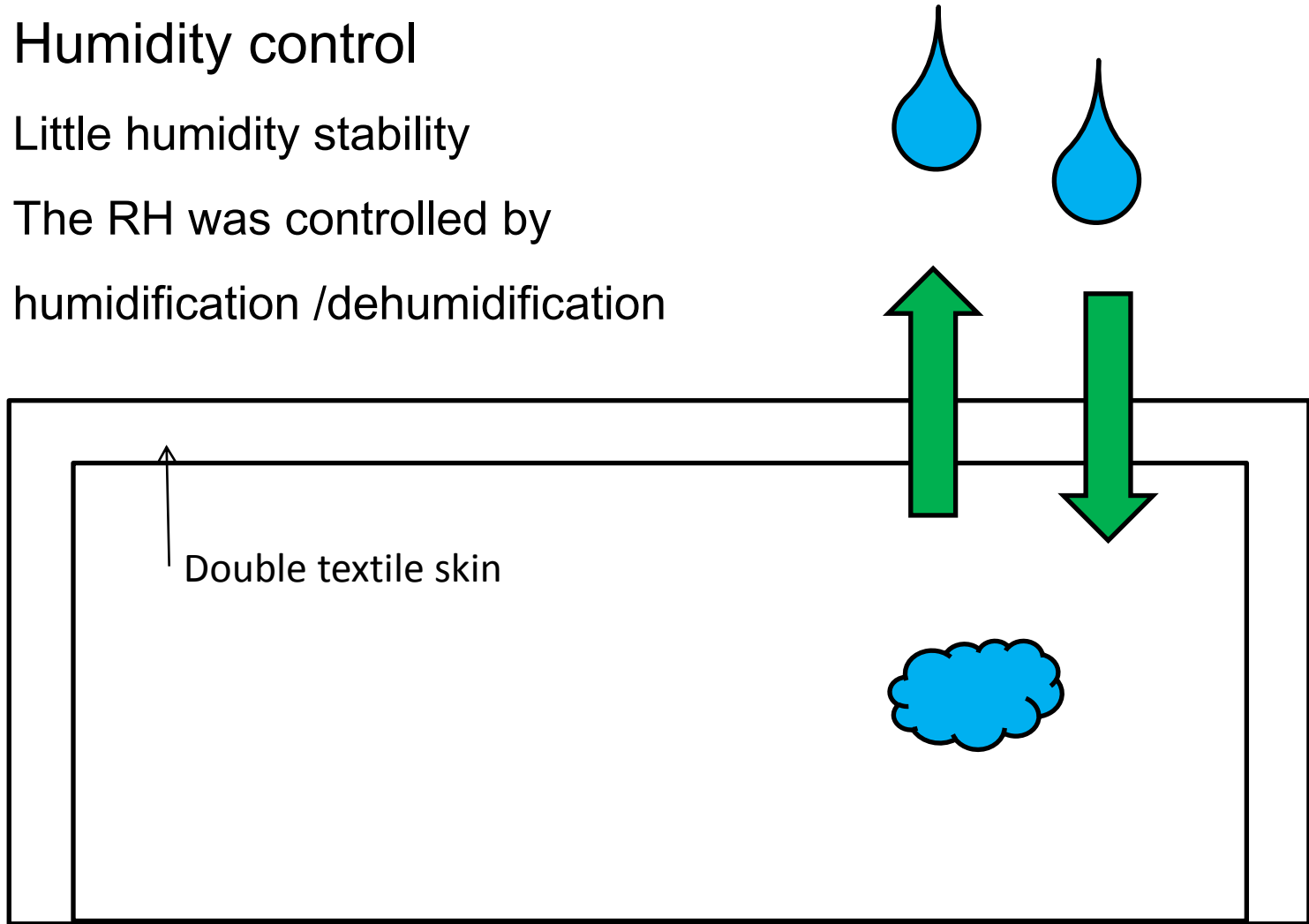




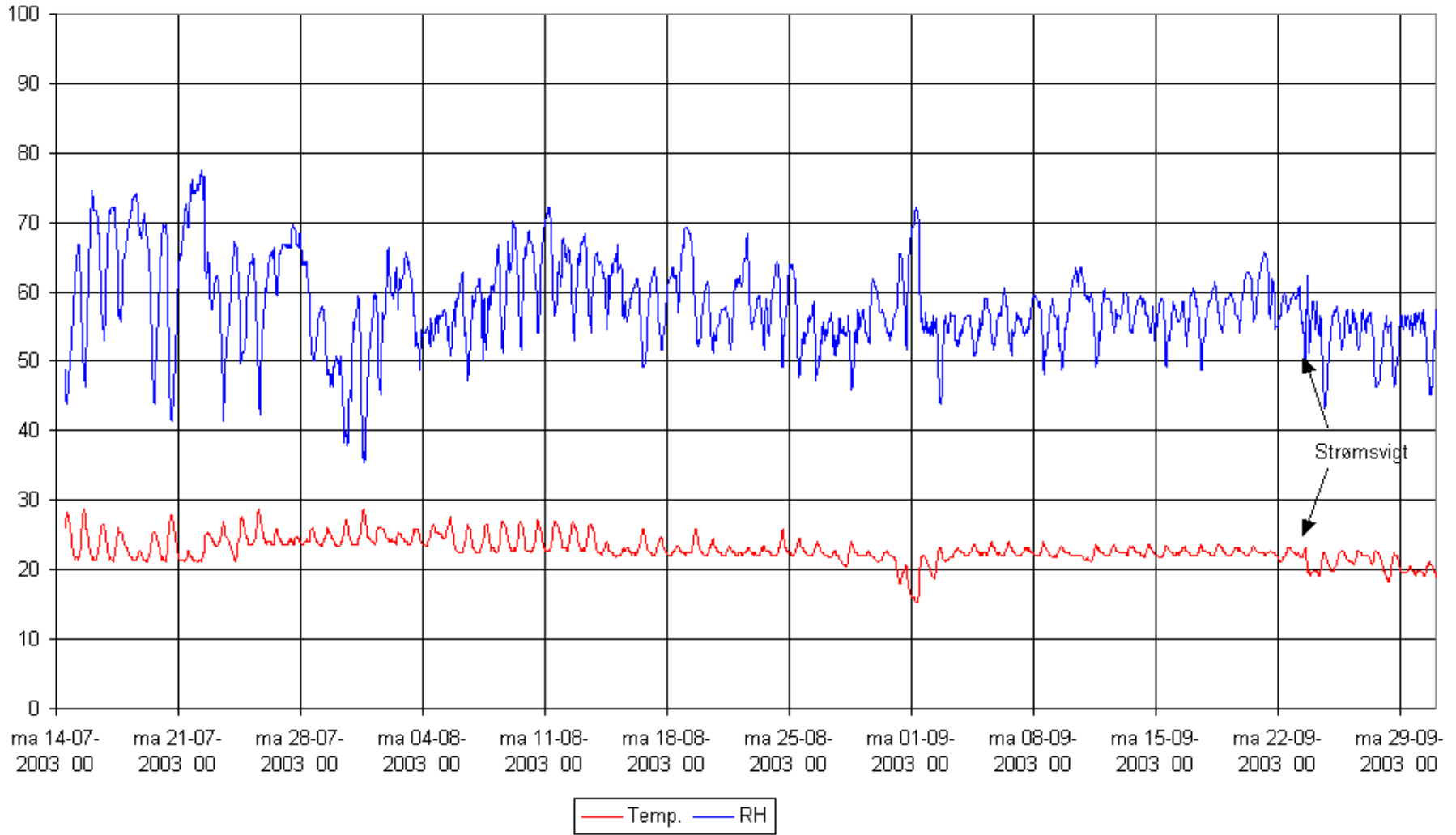
# Humidity control

Little humidity stability

The RH was controlled by  
humidification /dehumidification



# Nydambåd 14-07-2003 til 01-10-2003

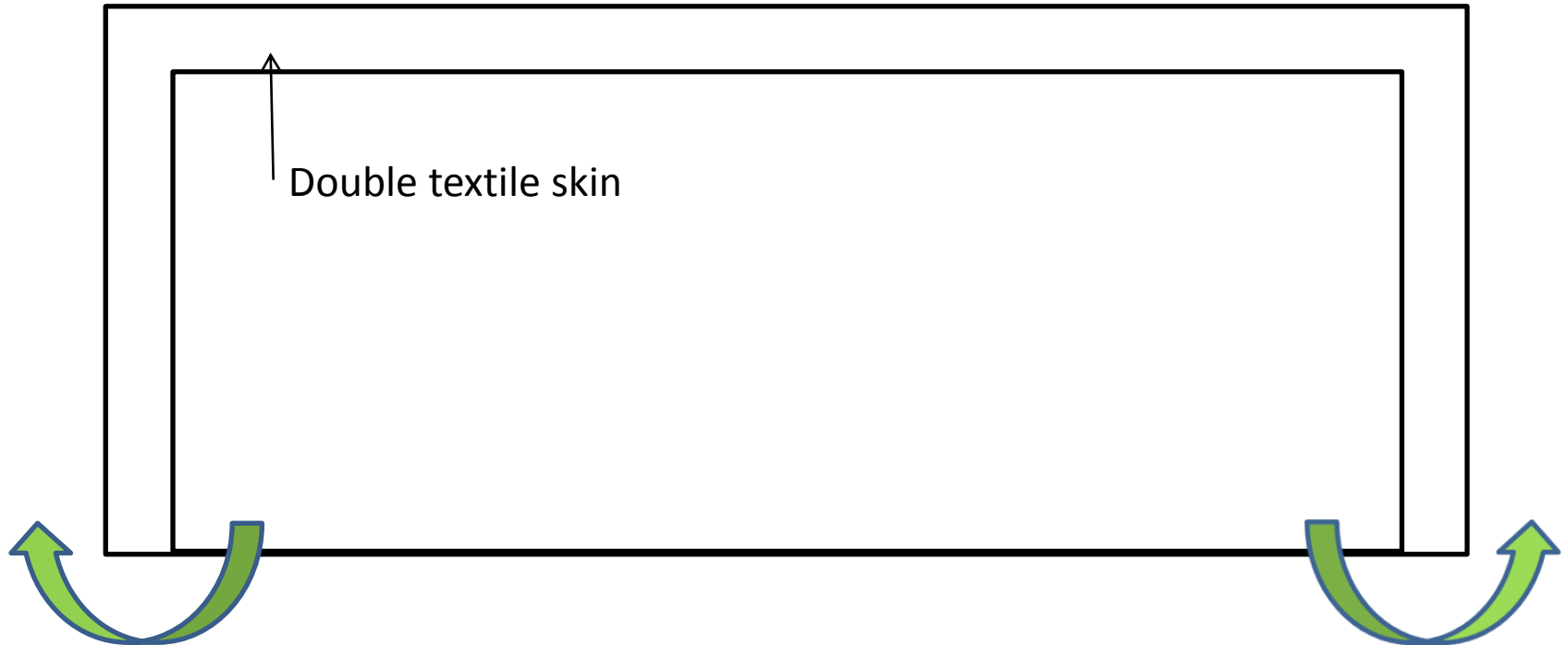




# Climate control

The 'building envelope' was very leaky

Poor climate control – large energy consumption





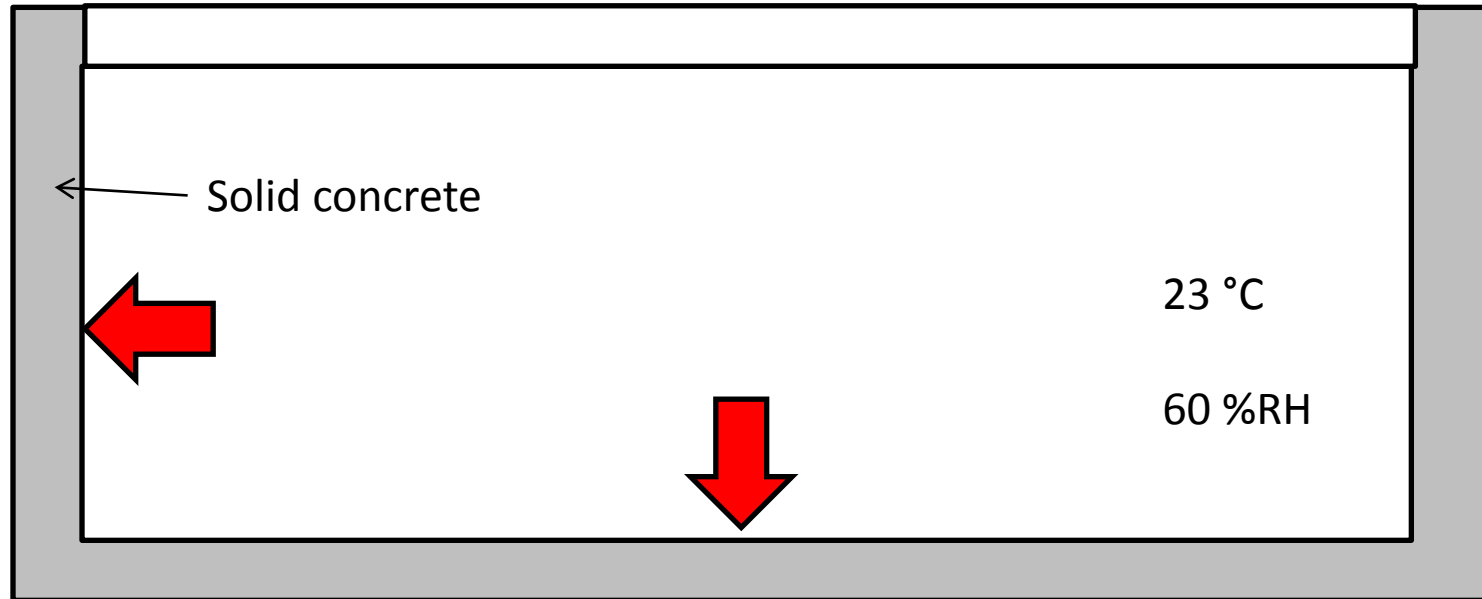
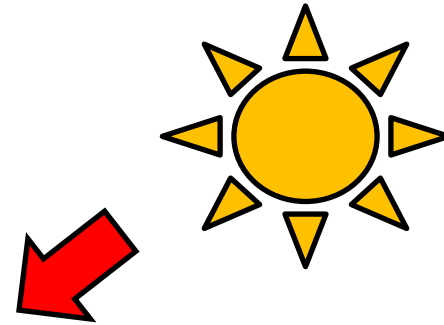




# Temperature control

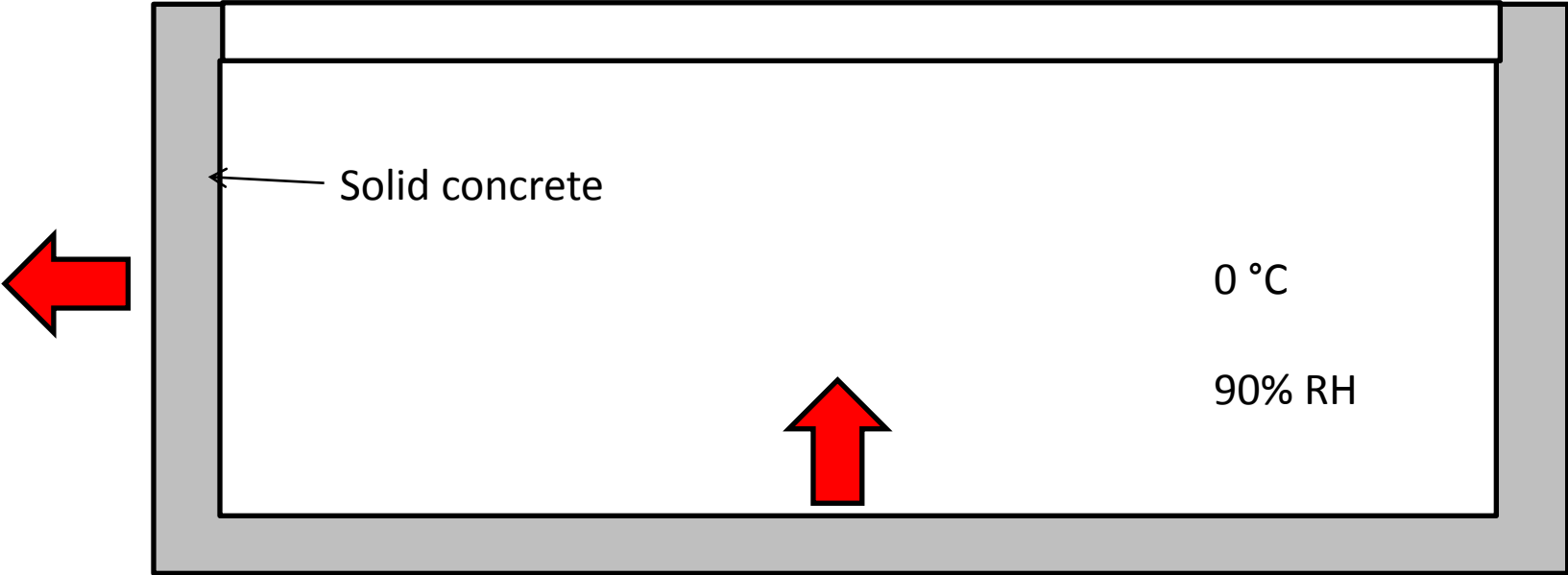
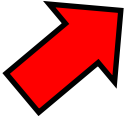
Solar heating through the glass roof

Heat absorption in walls



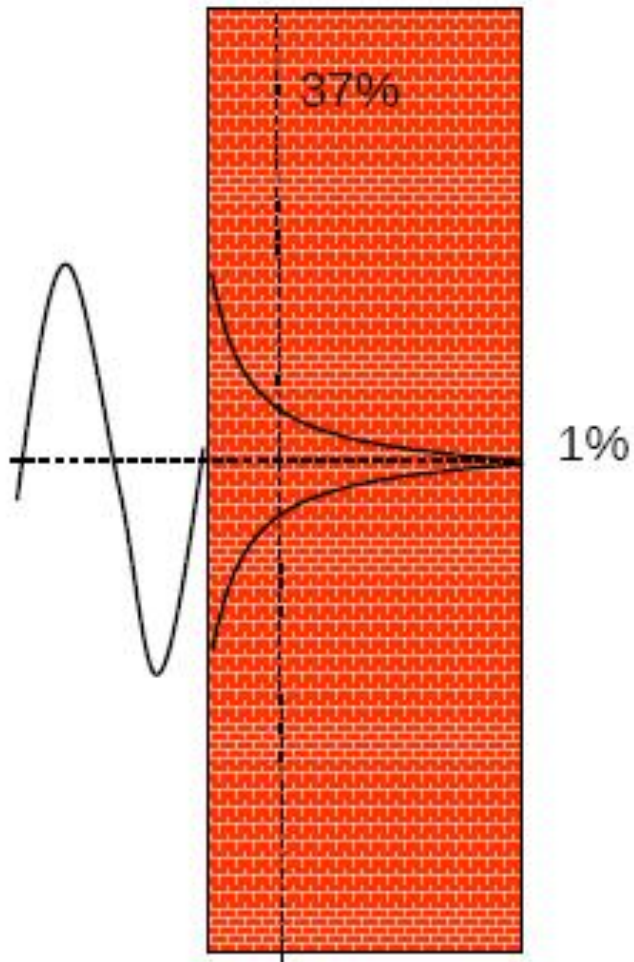
# Temperature control

Heat loss is large in winter

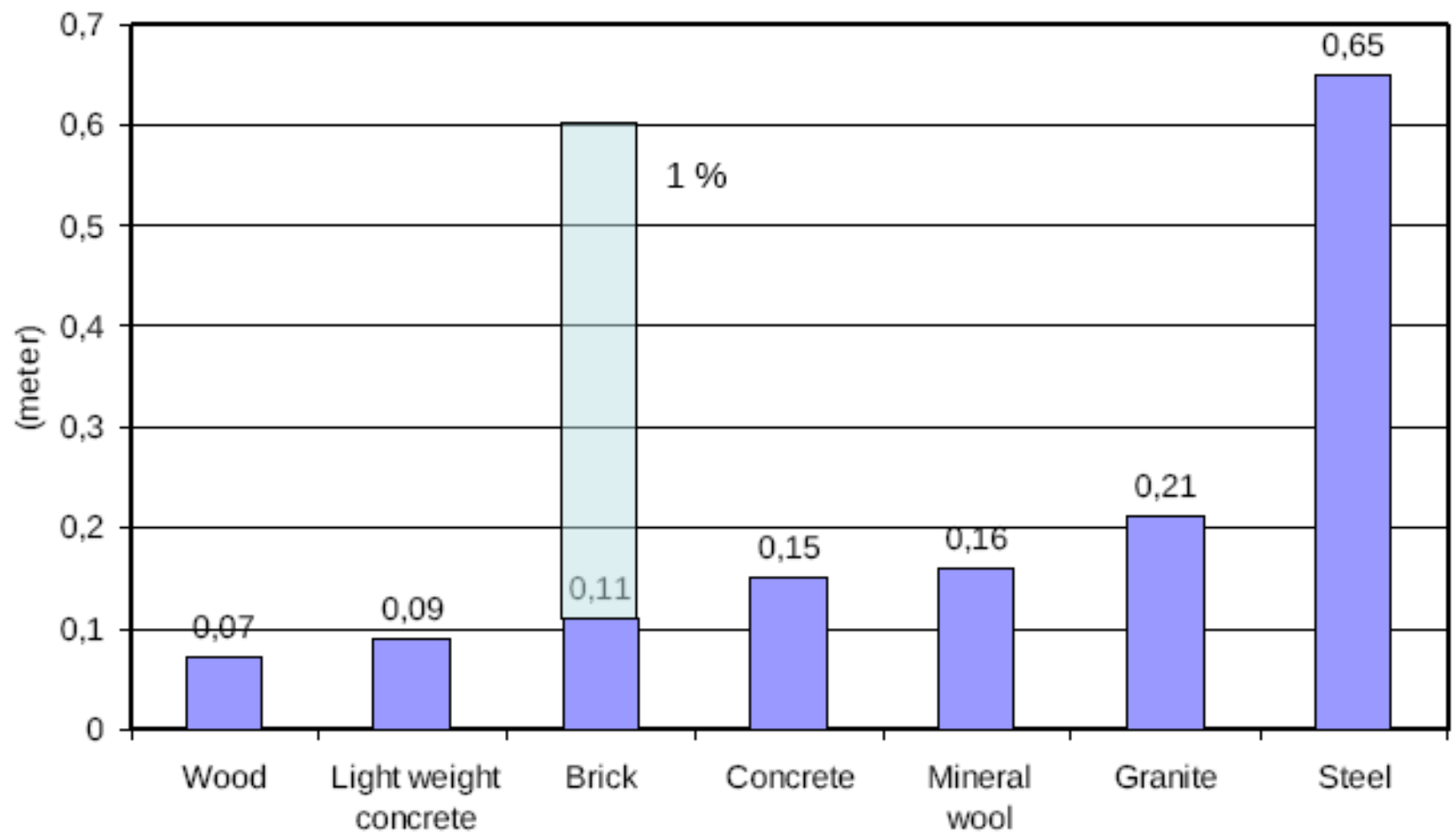


Temperature and  
humidity buffering

Harmonic cycles

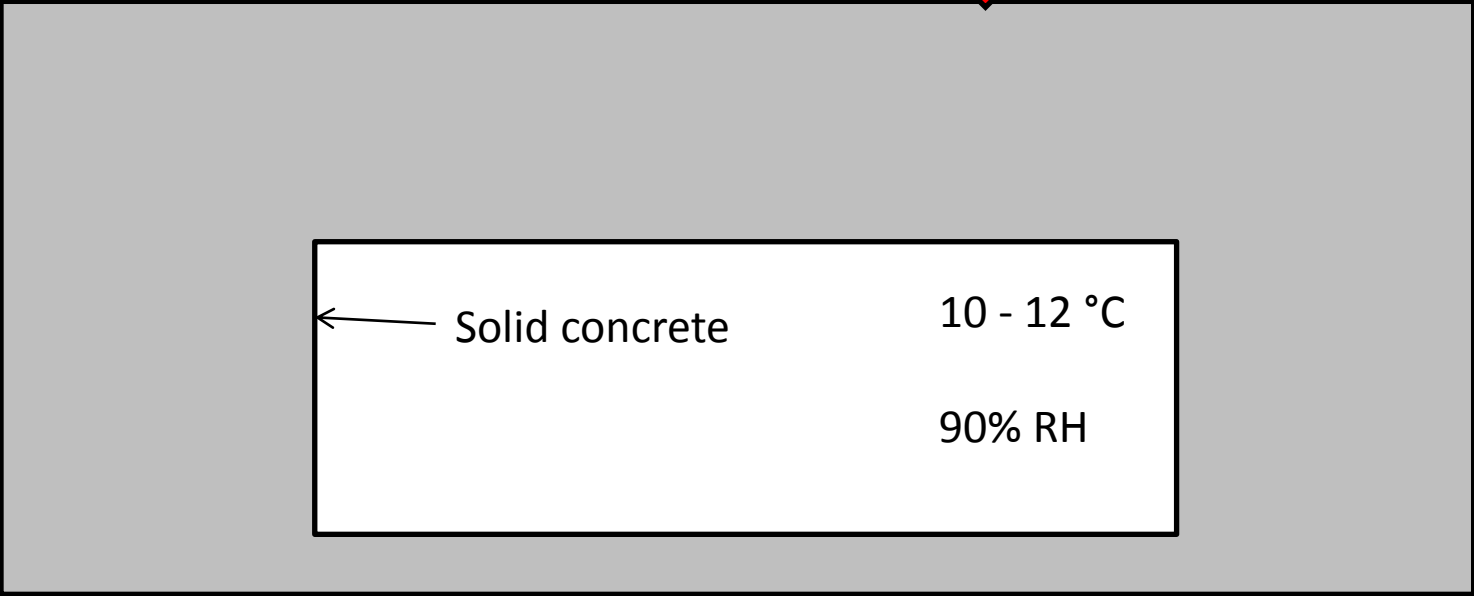
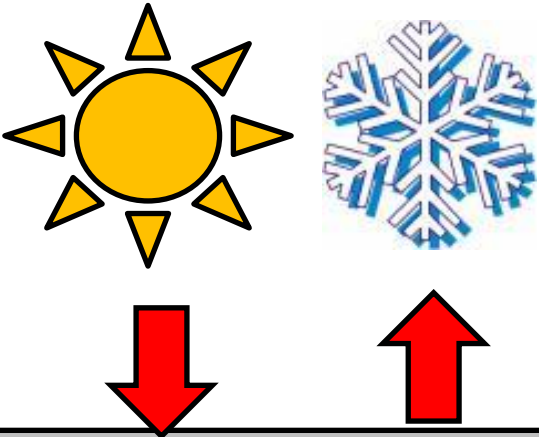


Periodical penetration depth (37%) for a 24 hours harmonic swing



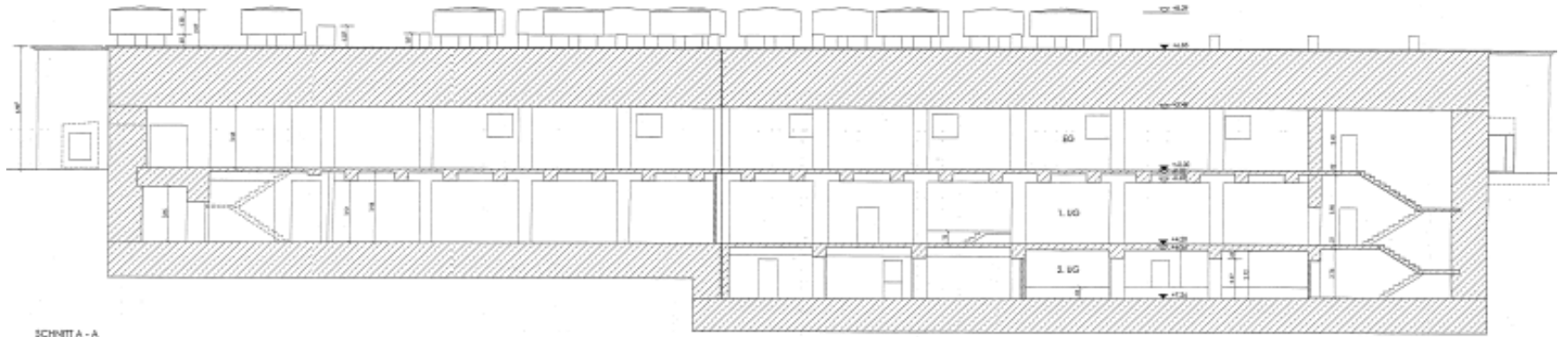
# Temperature control

Walls and roof must be 4 m thick to even out annual variation

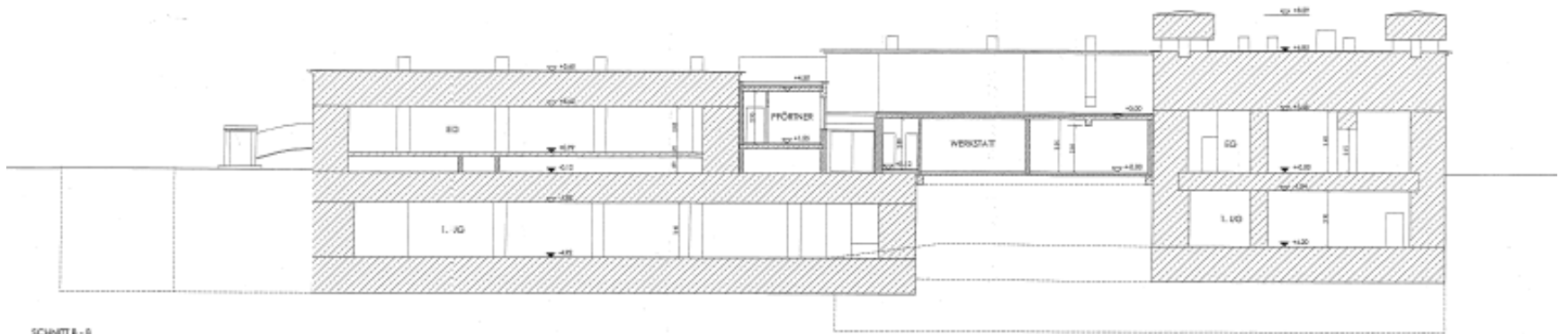






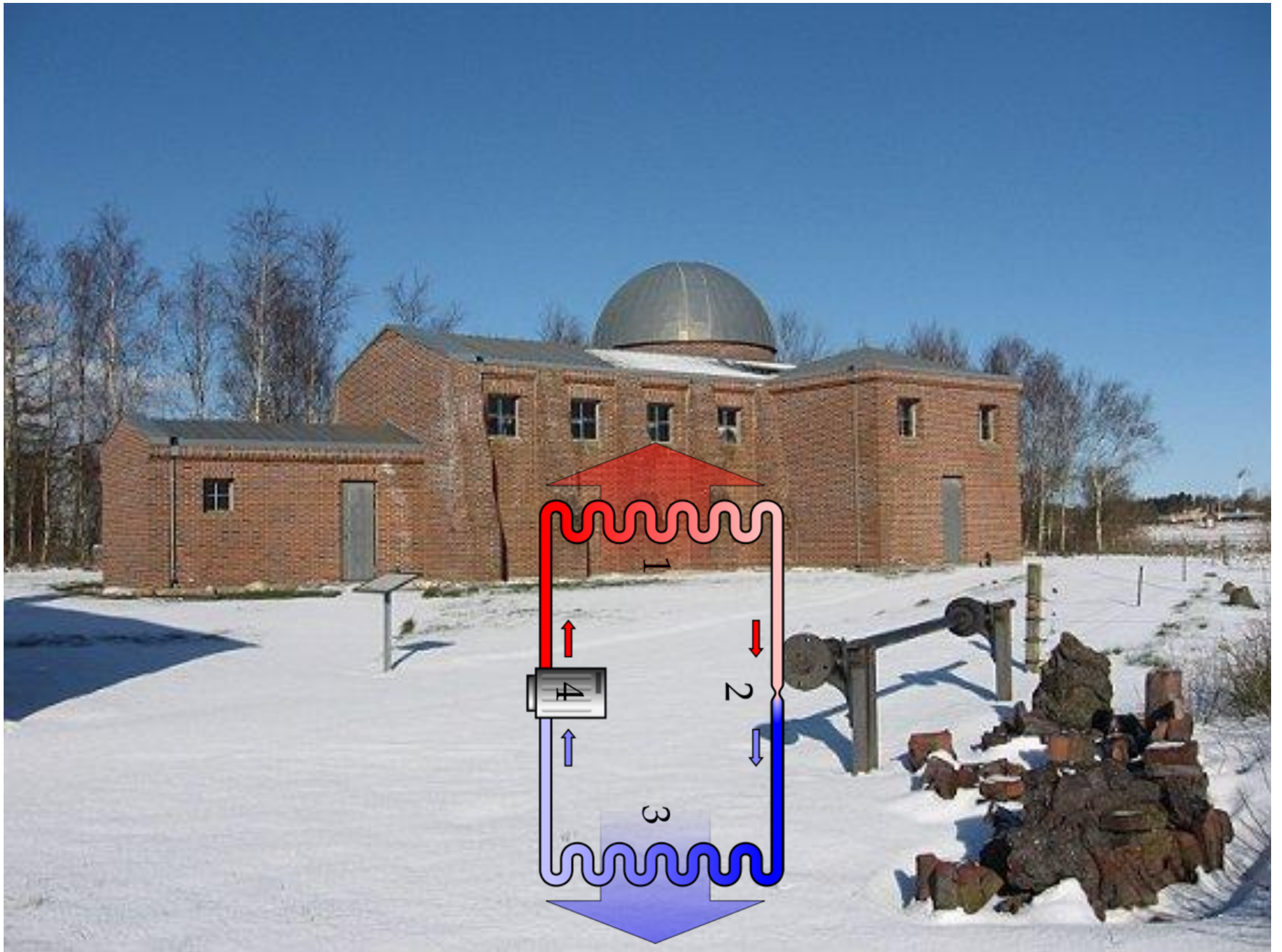


SCHNITT A-A



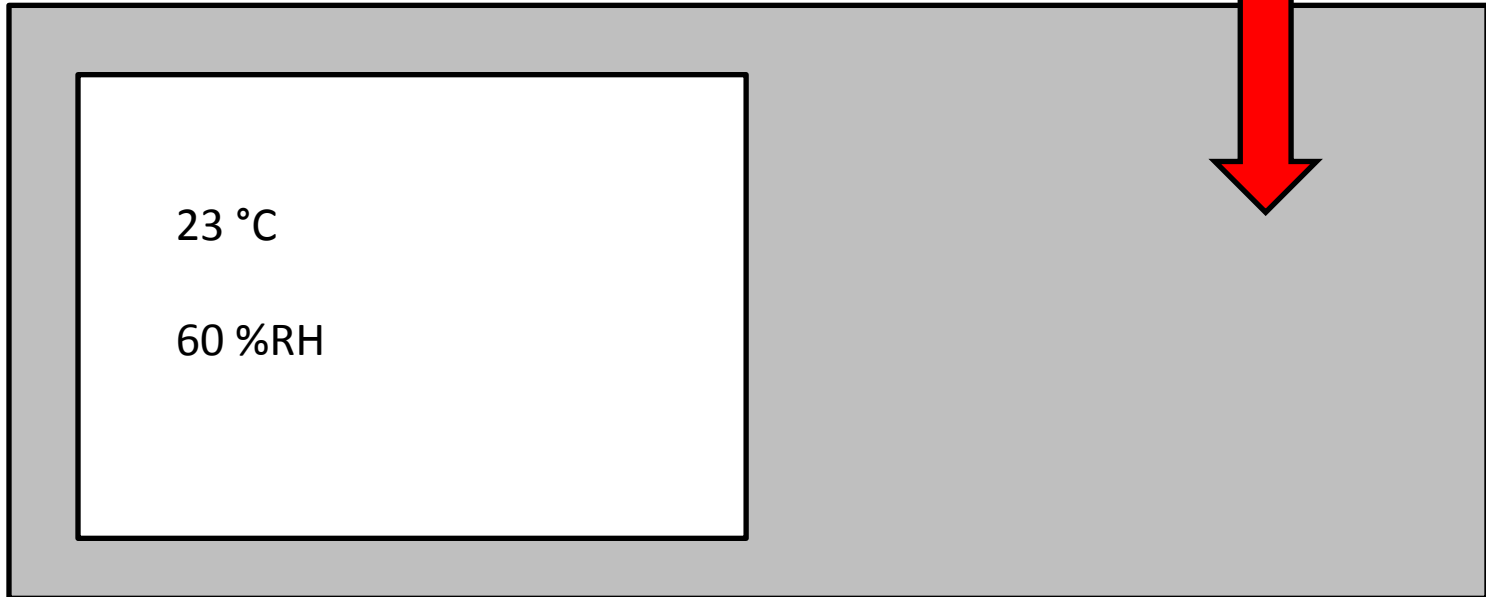
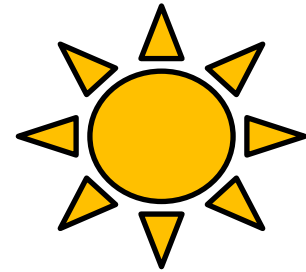
SCHNITT B-B





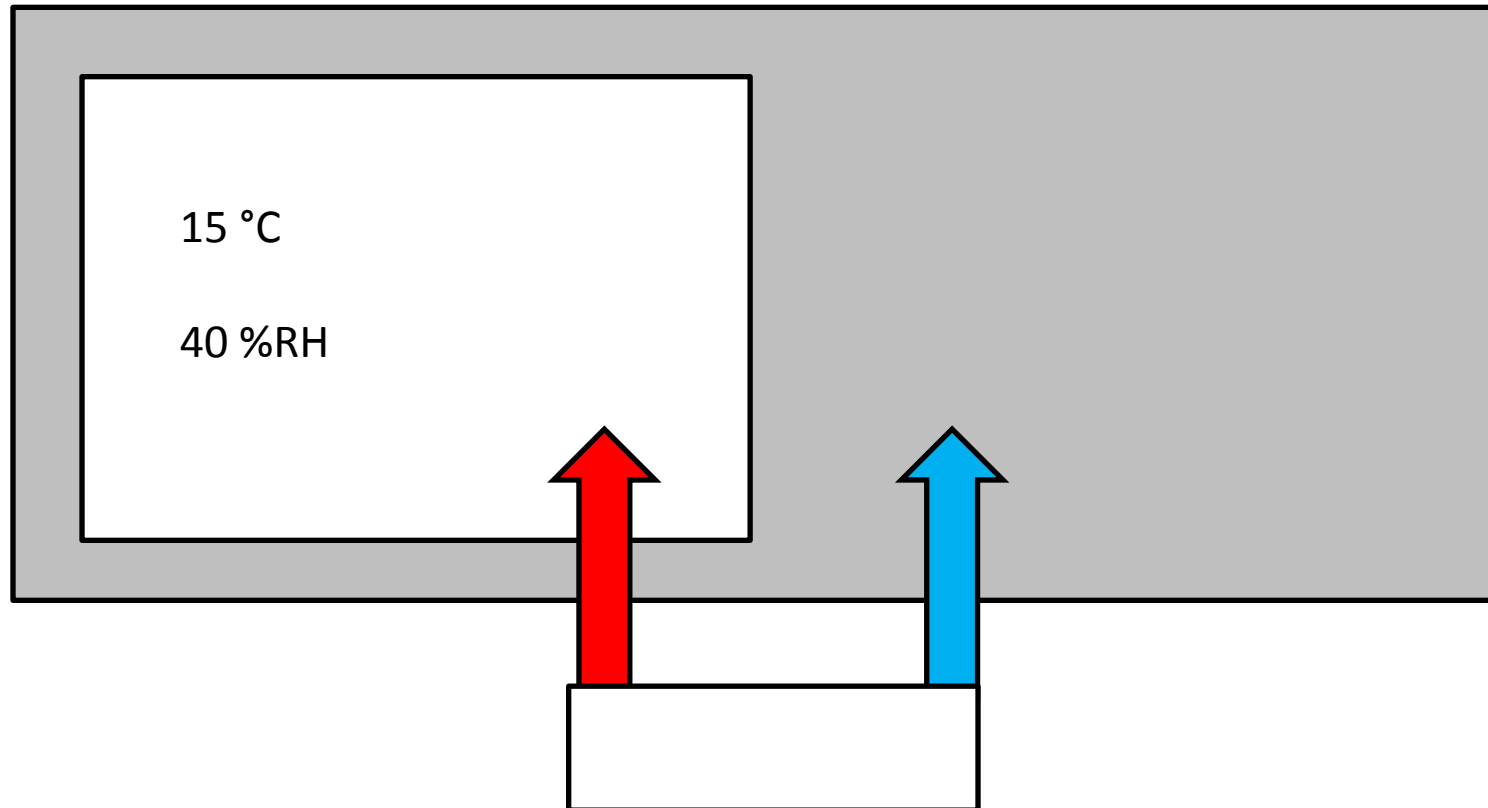
# Temperature control

Solar heating of the ground in summer



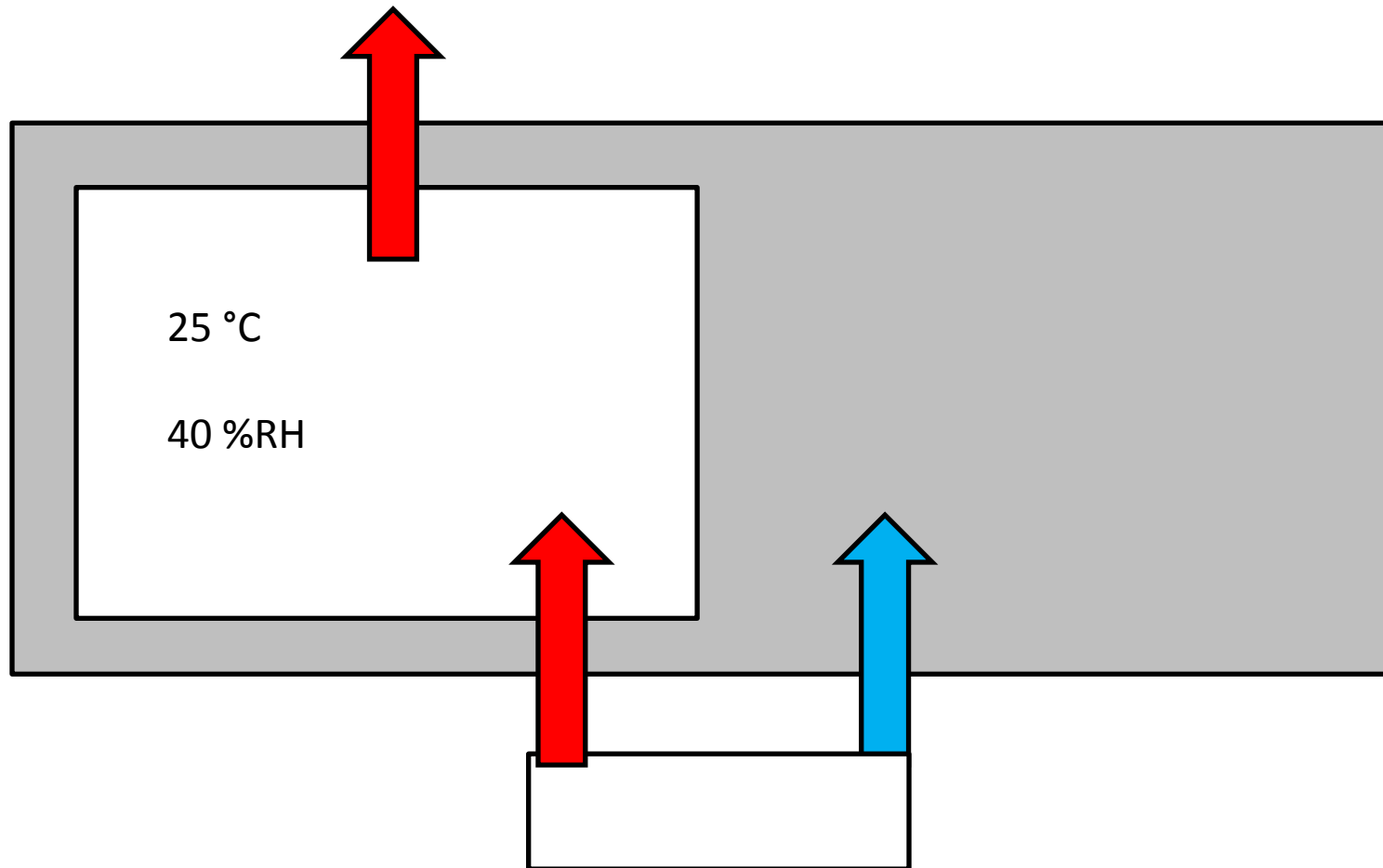
# Temperature control

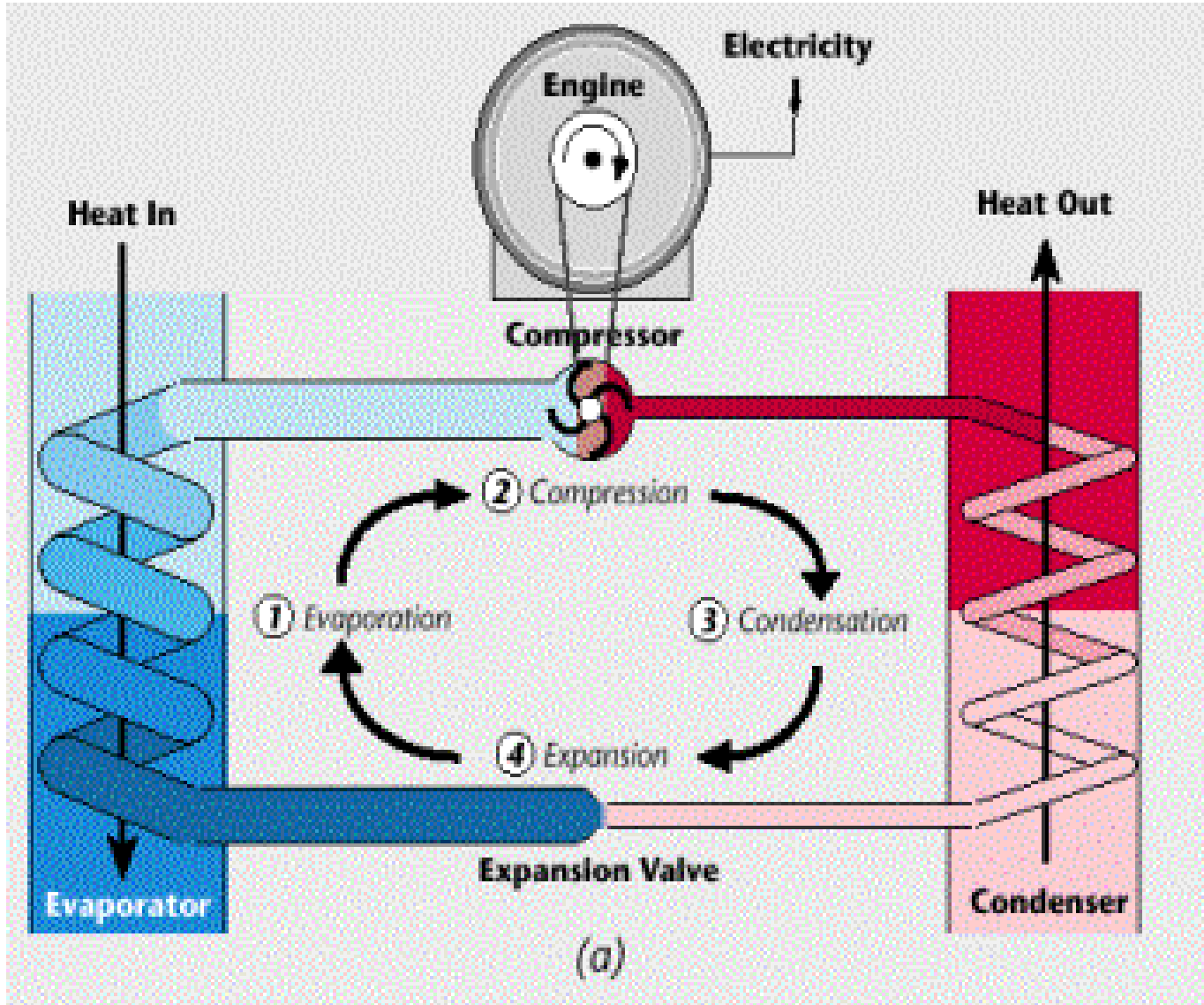
Floor heating with ground heat pump in winter

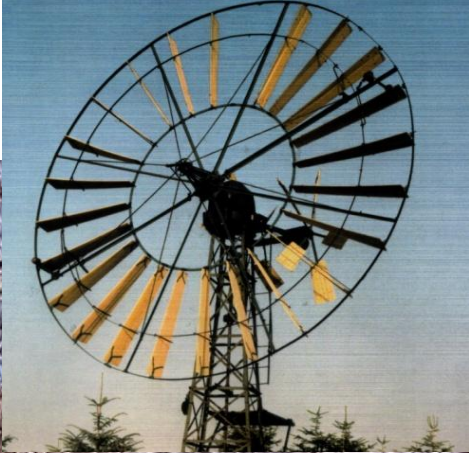


# Temperature control

Heat loss through solid masonry is large



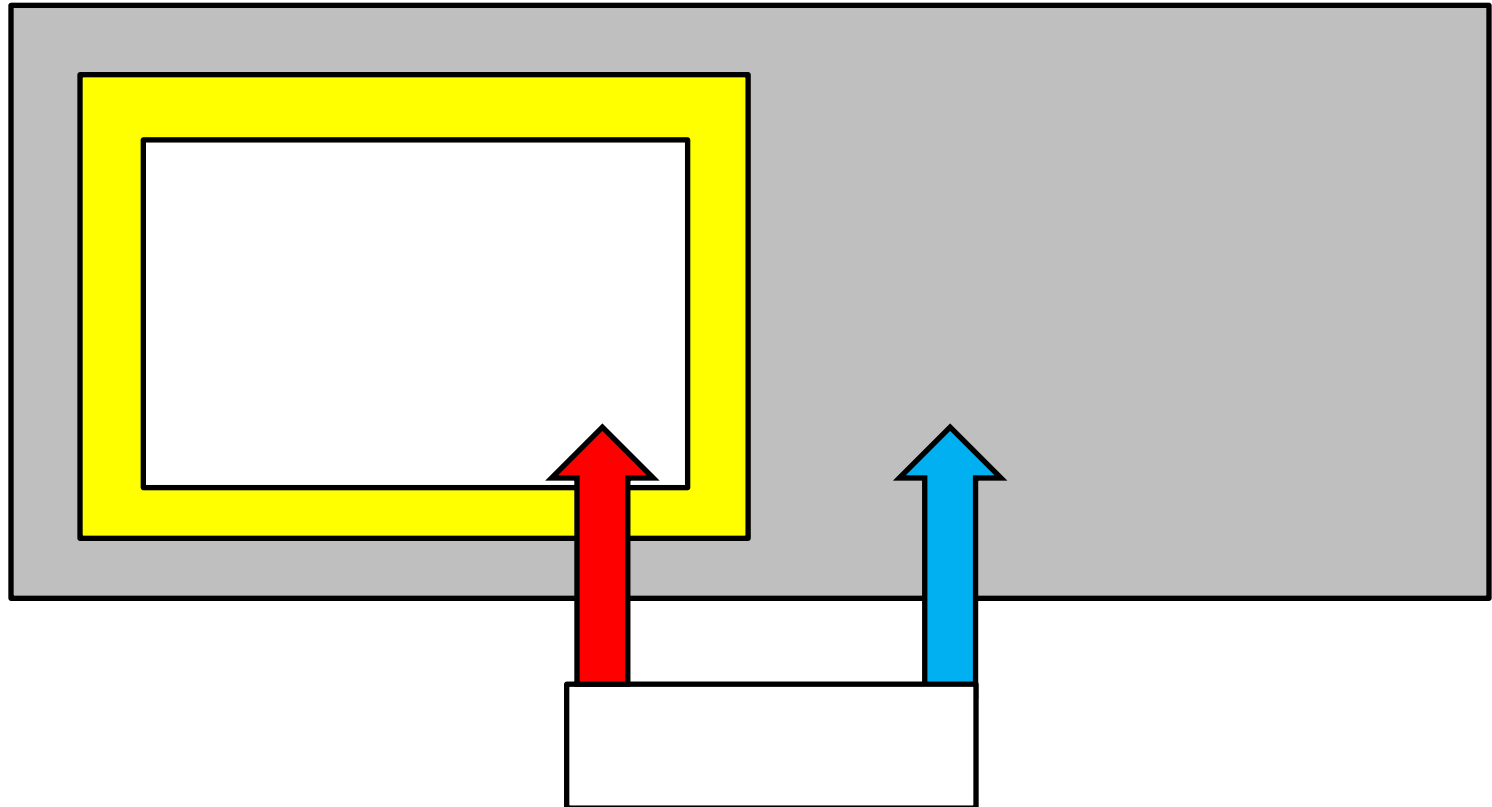






# Temperature control

Thermal insulation to reduce heat loss

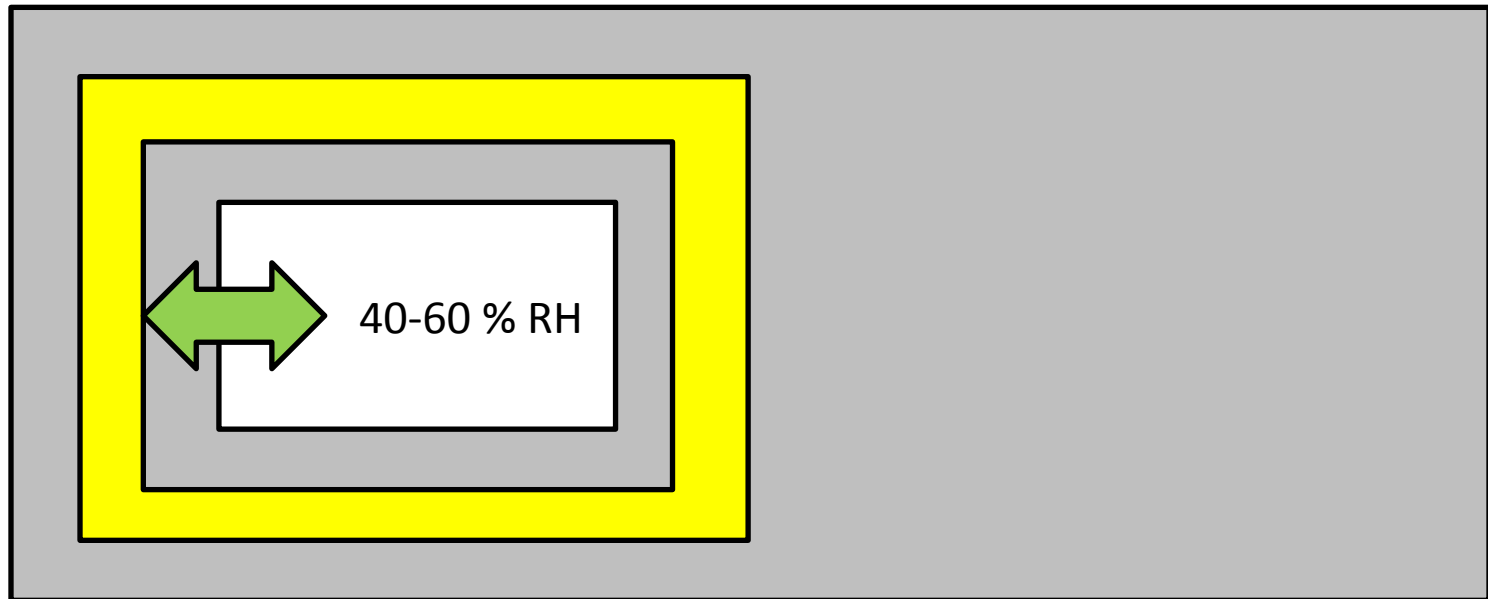


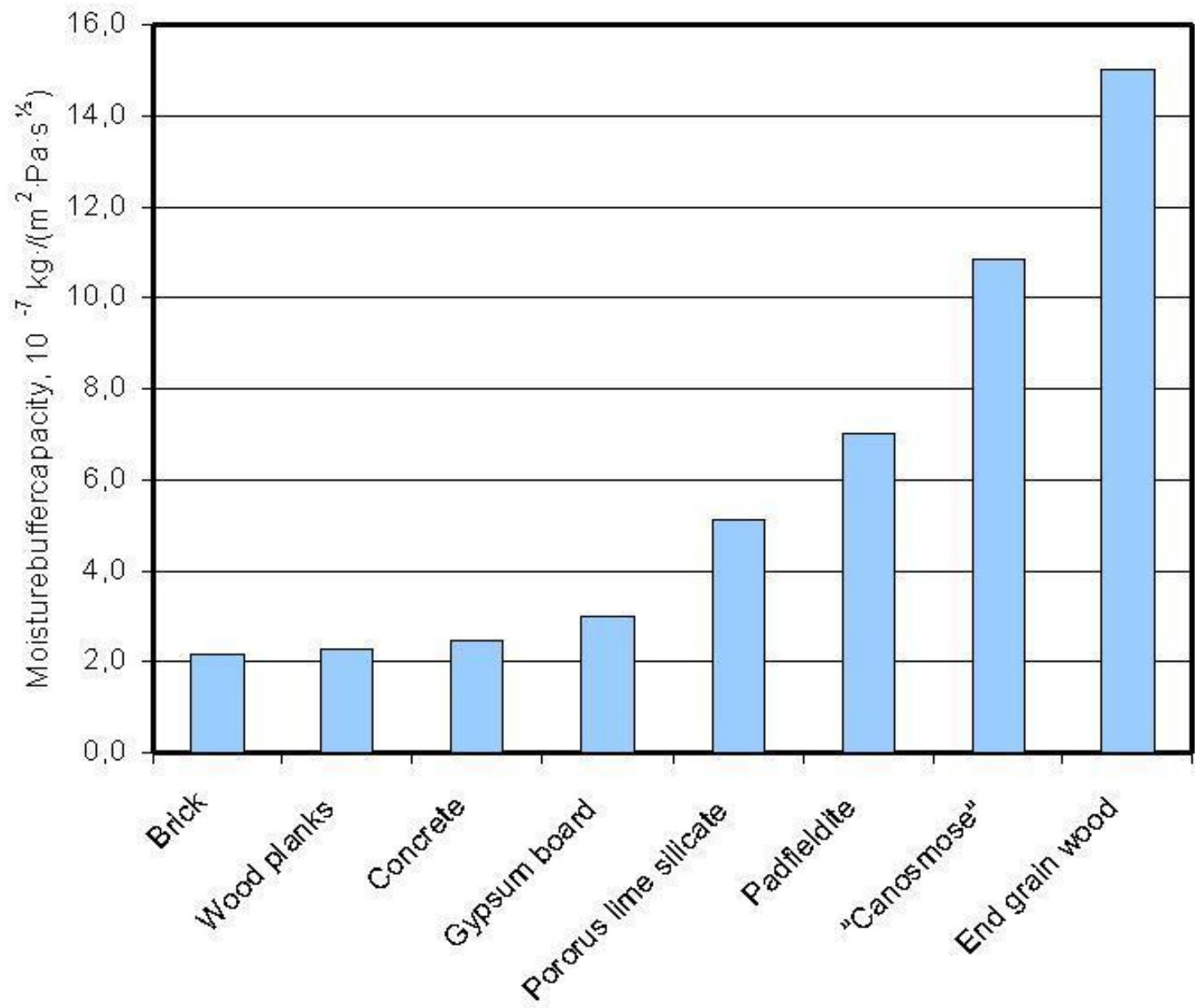


# Humidity control

Conservation heating moderates RH on an annual cycle

Humidity buffer in walls on a daily cycle







Humidity buffer



Humidity buffer



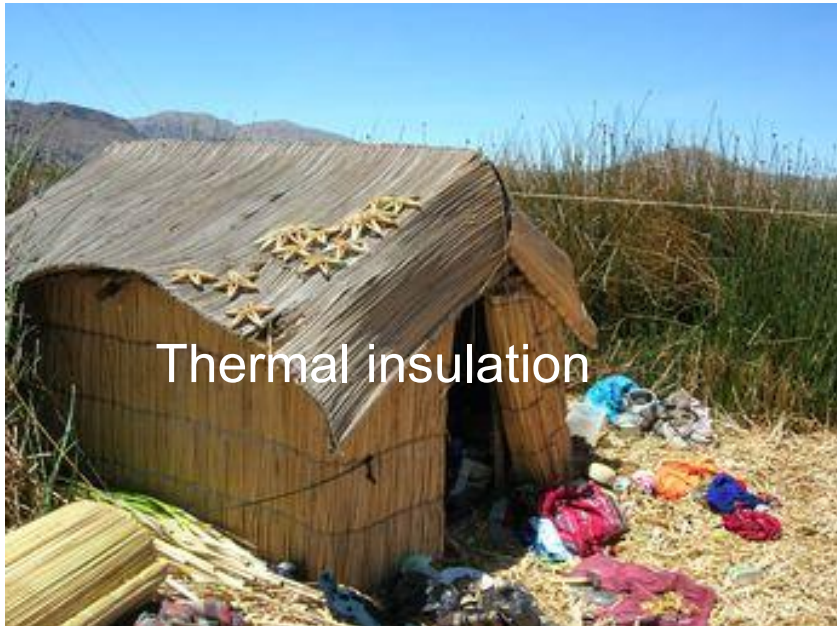
Thermal capacity



Humidity buffer



Thermal capacity



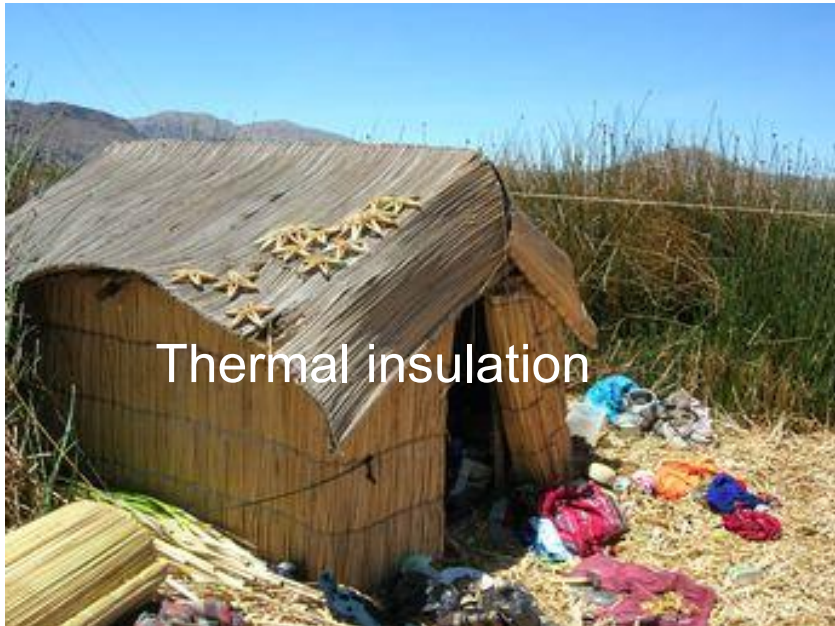
Thermal insulation



Humidity buffer



Thermal capacity



Thermal insulation



Air tightness



