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Paul Klee

credit to "Mark Harden"

The role of the building's envelope in the conception of sustainable architecture

Building envelope design, energy efficiency and renewable energies

Overview

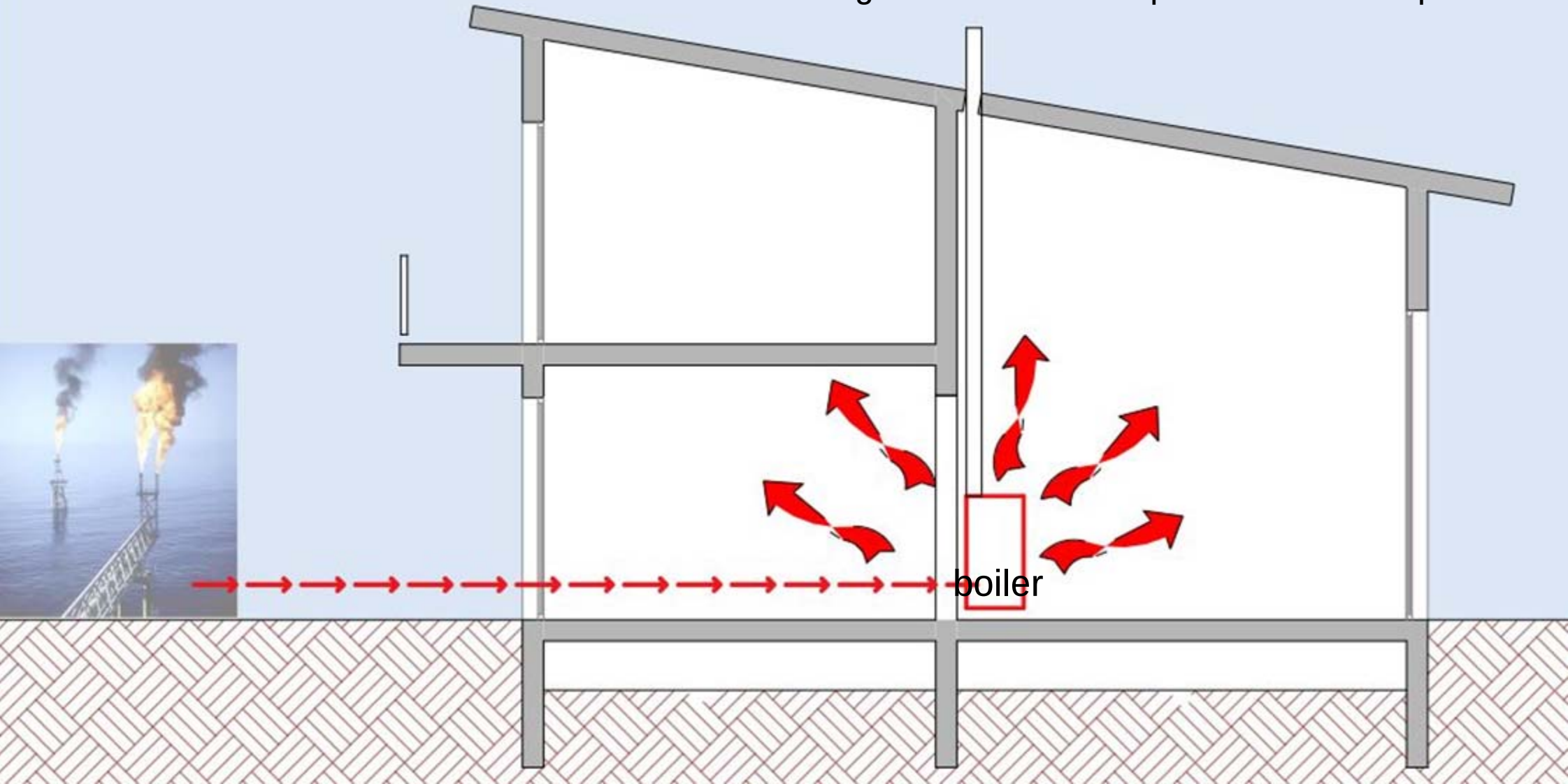
Building envelope

- quick flashback: to introduce the current situation
- envelope design: curbing energy consumption
- envelope: optimizing the use of alternative energies
- advice to make optimum use of renewable resources

Current situation

The low cost of fossil fuels

- has allowed for the quick development of technical equipment
- has led builders to neglect the thermal aspect of the envelope



Current situation

Today poorly insulated, the envelope fails to maintain temperature inside

boiler

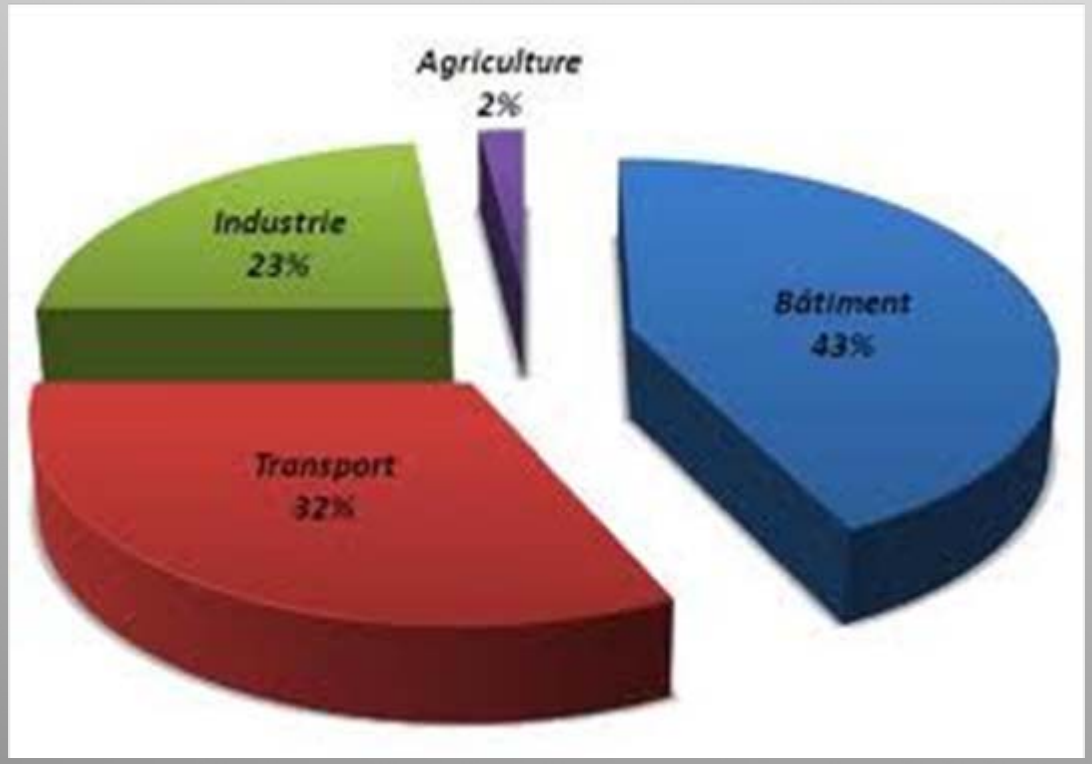
The cost of this economic model

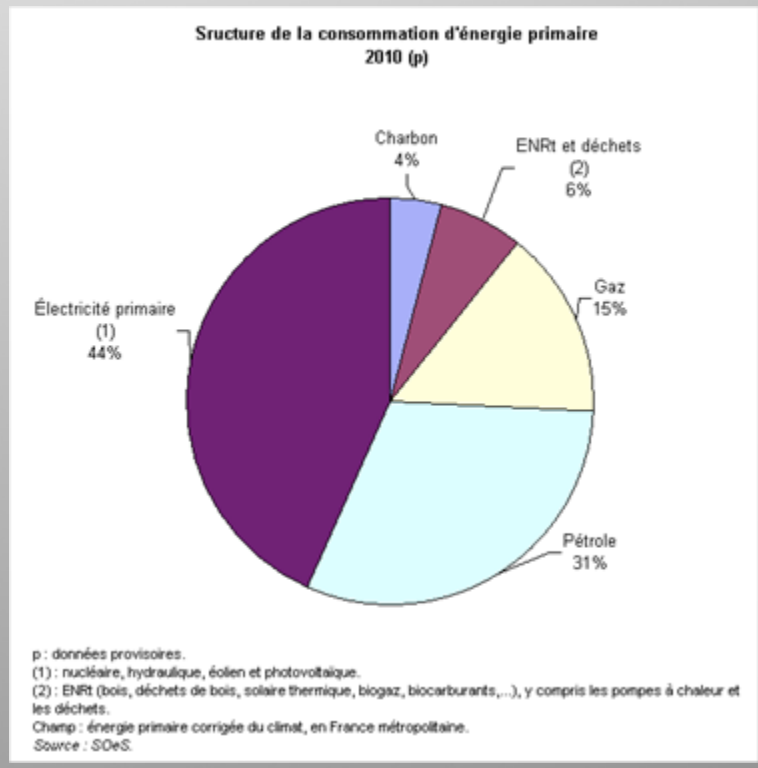
The intensive consumption of hydrocarbons has 3 heavy consequences

- a high environmental cost
  - FF combustion emits greenhouse gasses
  - FF are non-renewable resources
  - the search for new FF deposits extends the deterioration of our environment
- a high social cost → FF prices have soared
- a high human cost → FF combustion emits carbonic gas

This model is no longer viable.

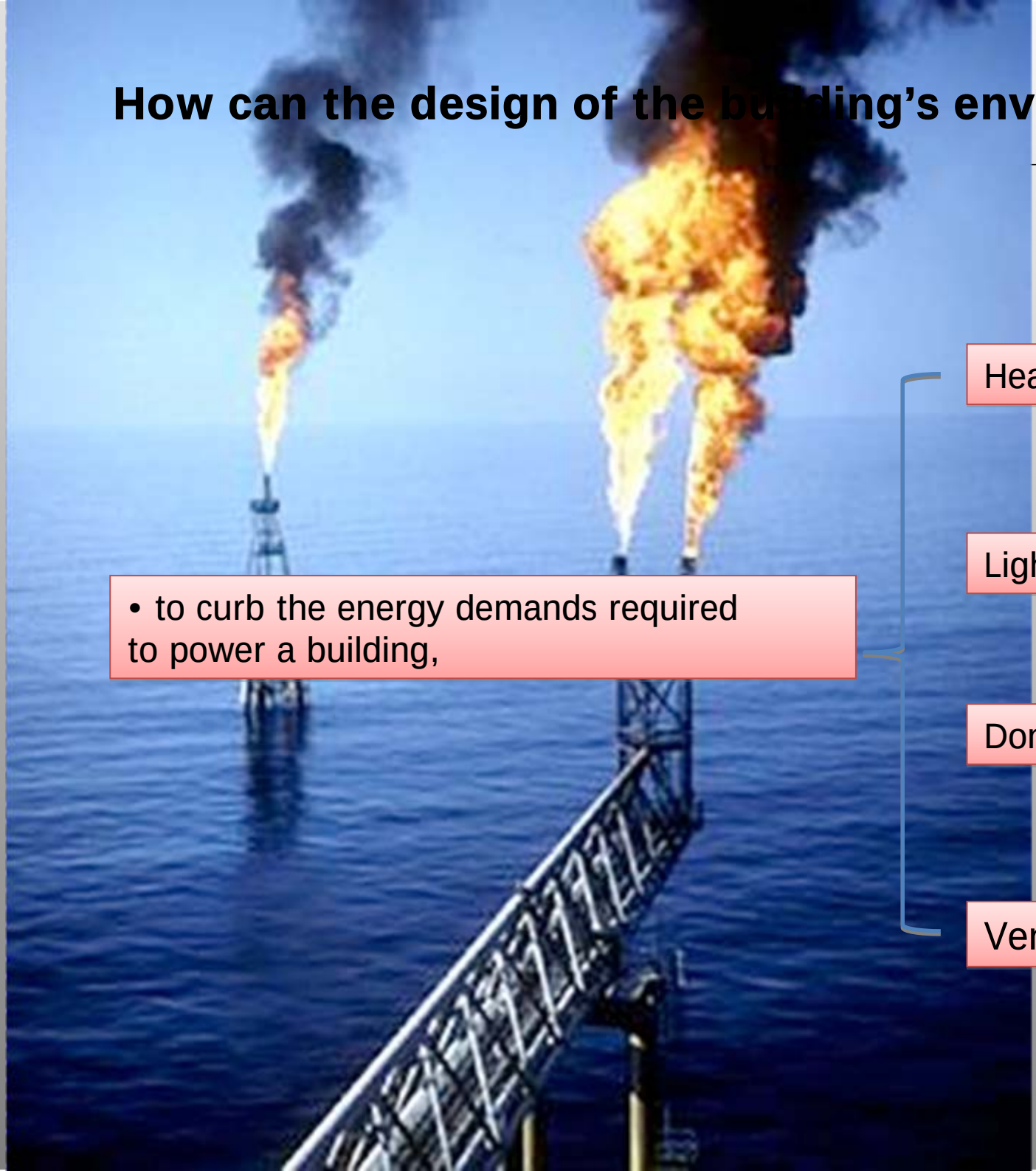
Buildings are big energy consumers





Source INSEE

How can the design of the building's envelope alone contribute?



- to curb the energy demands required to power a building,

- Heating / cooling
- Lighting
- Domestic hot water production
- Ventilation

The building's envelope must be designed

I. to be energy efficient

- to avoid unnecessary energy consumption
- to curb the consumption of all types of energies

II. to optimize the use of alternative energies

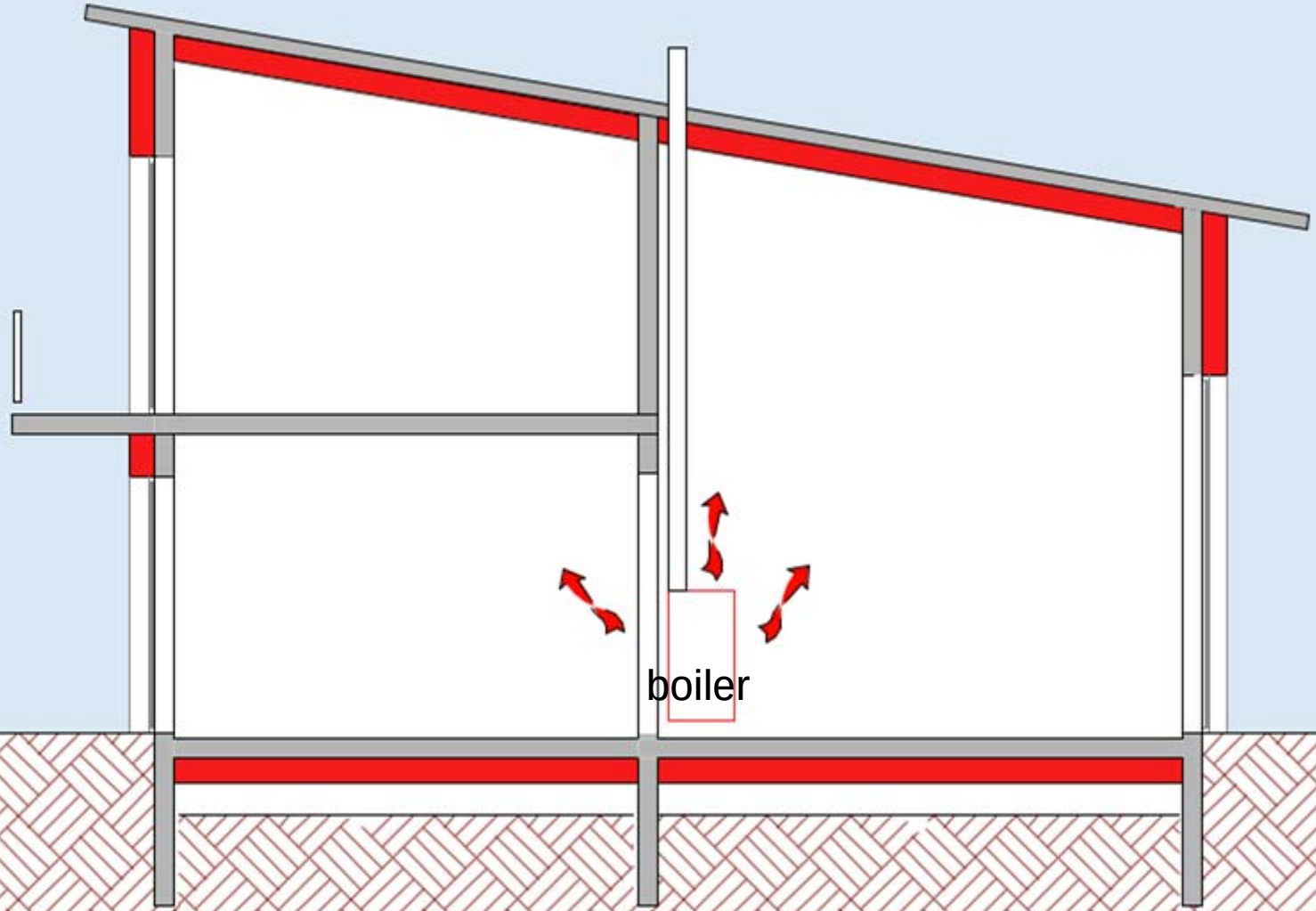
- based on local renewable resources
- to avoid using fossil fuels

I. The building's envelope must be designed for energy efficiency

5 conditions to design an energy-efficient envelope
in the aim of reducing energy consumption for

Heating / cooling

I. The building's envelope must be designed for energy efficiency



→ • by enhancing insulation on opaque walls

I. The building's envelope must be designed for energy efficiency

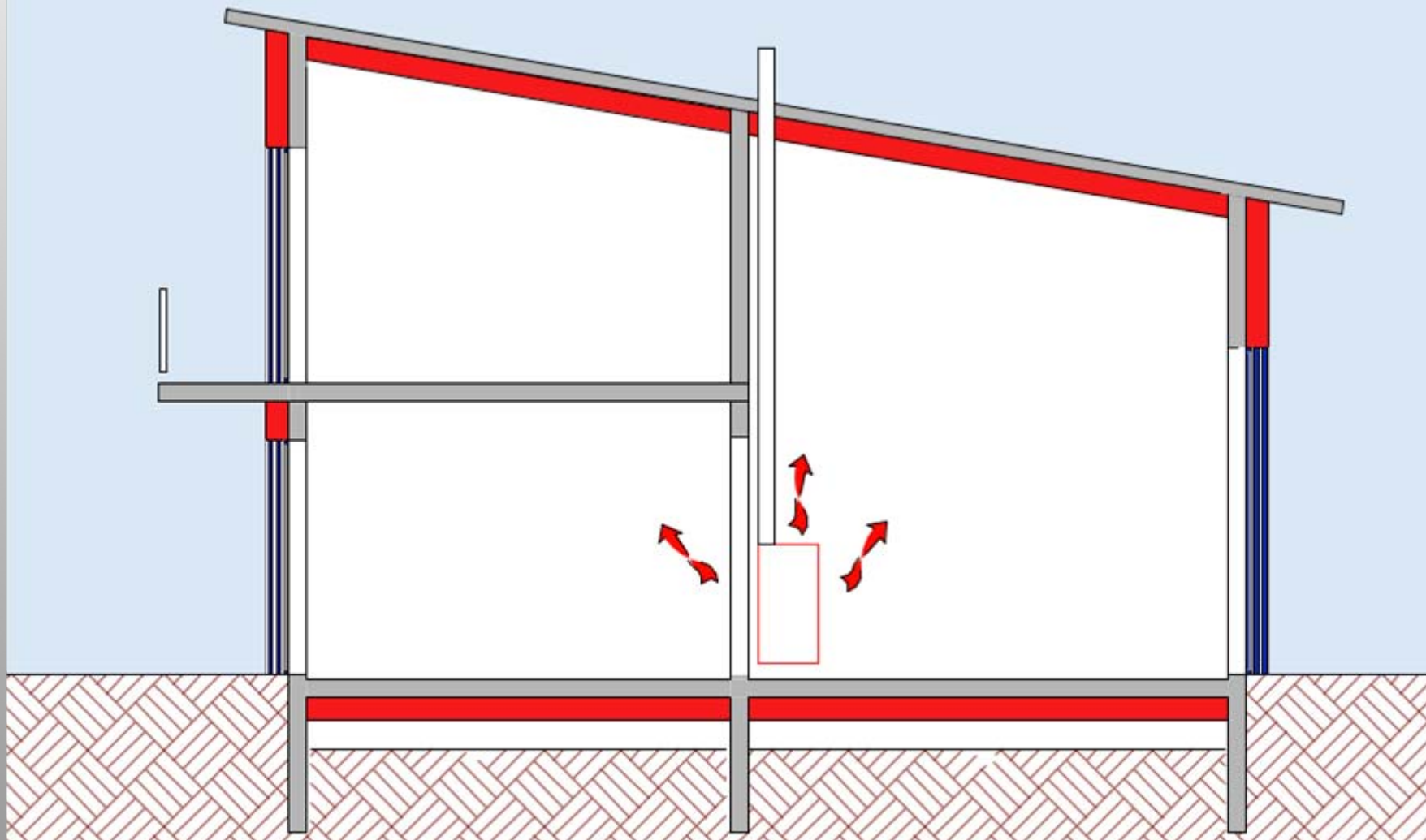
→ enhancing insulation on opaque walls

The function of insulation:
• to reduce thermal exchanges between interior and exterior

The best insulation:
• air trapped in air bubbles

Elements to be insulated:
• facades
• roofs
• grounds
• soffits

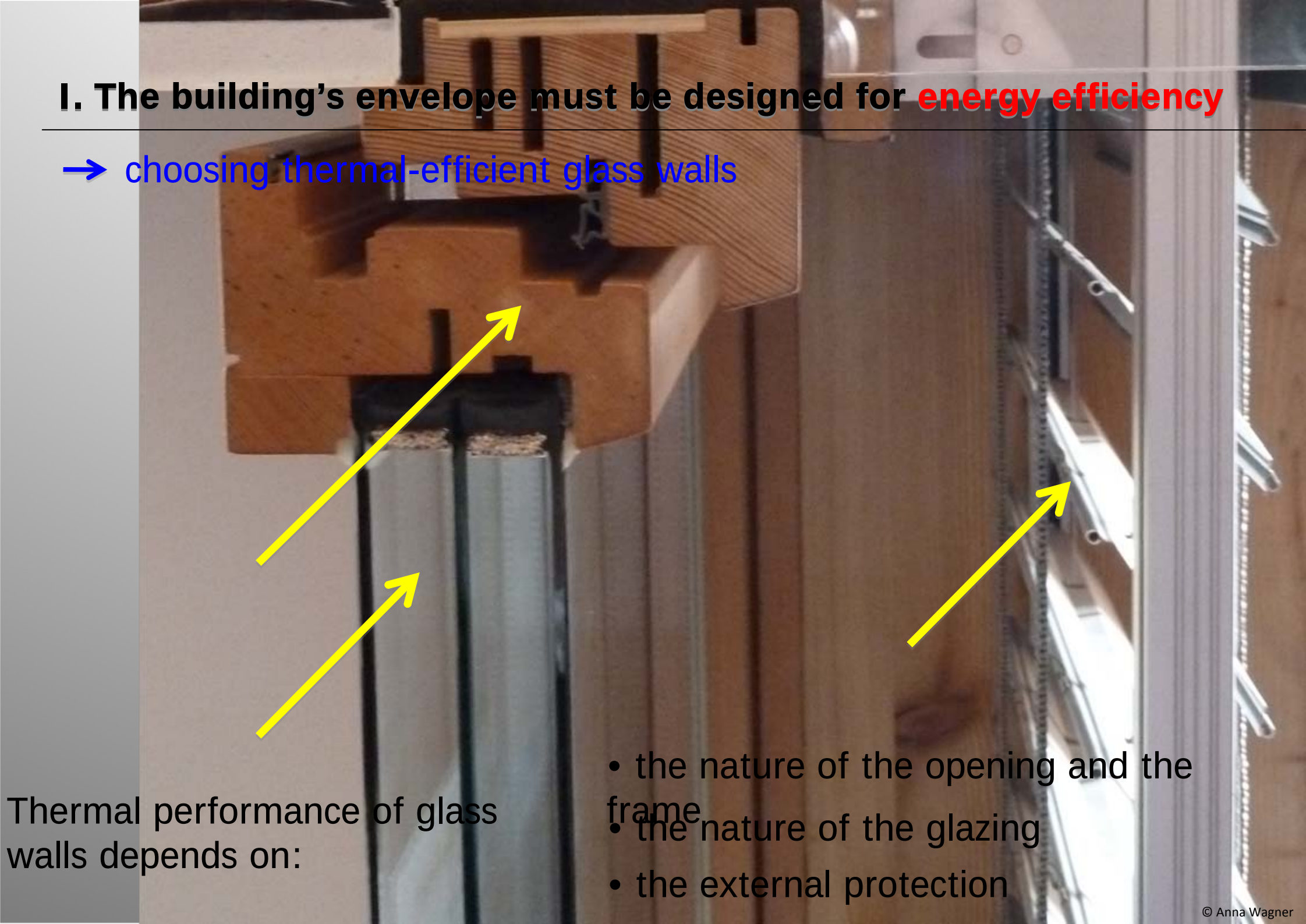
I. The building's envelope must be designed for energy efficiency



- by enhancing the insulation on opaque walls
- **by choosing thermally efficient glass walls**

I. The building's envelope must be designed for energy efficiency

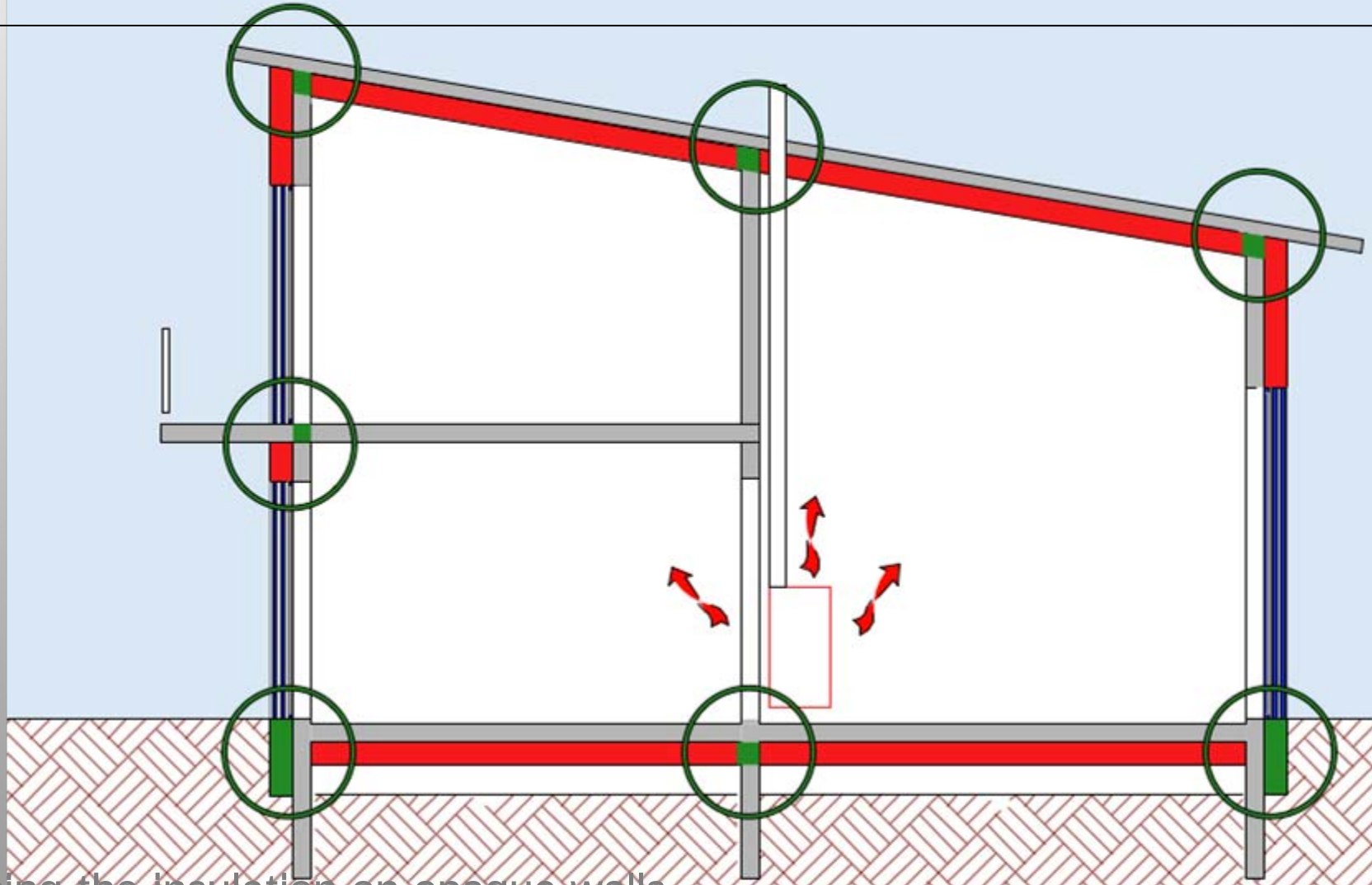
→ choosing thermal-efficient glass walls



Thermal performance of glass walls depends on:

- the nature of the opening and the frame
- the nature of the glazing
- the external protection

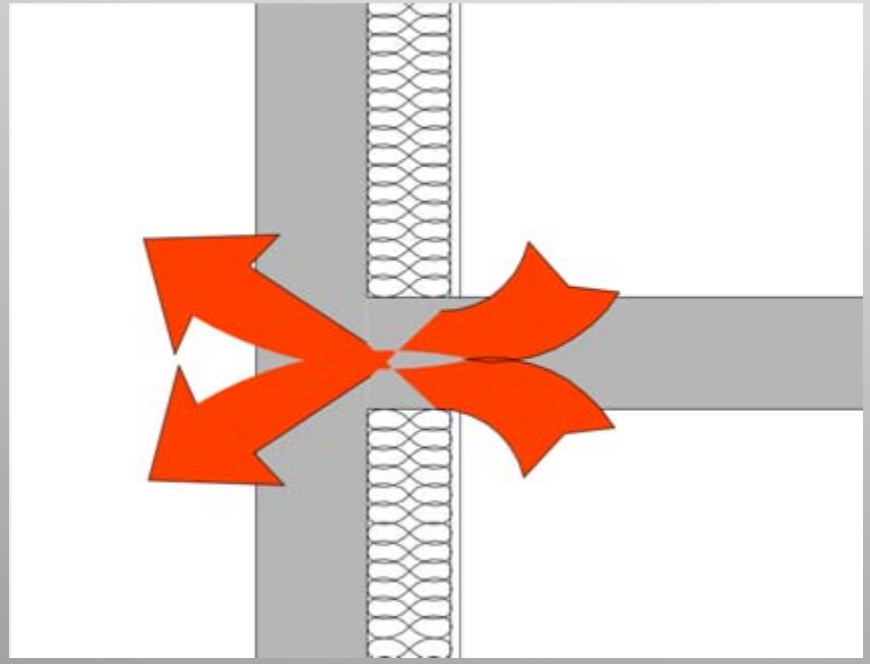
I. The building's envelope must be designed for energy efficiency

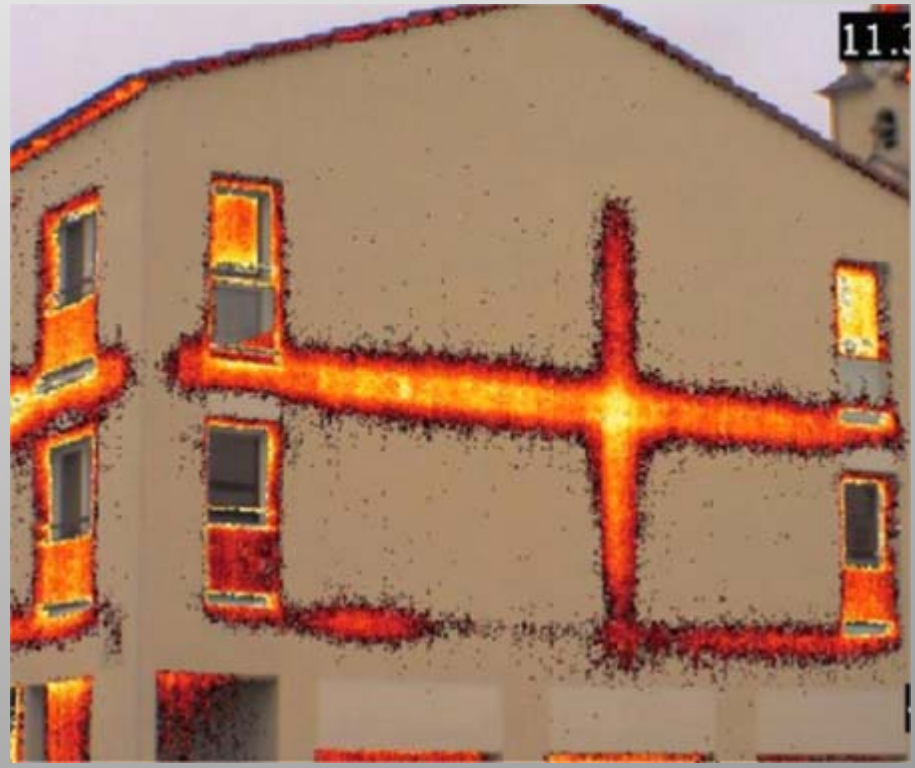


- by enhancing the insulation on opaque walls
- by choosing proper glass walls
- **by treating thermal bridges**

I. The building's envelope must be designed for energy efficiency

→ treating thermal bridges



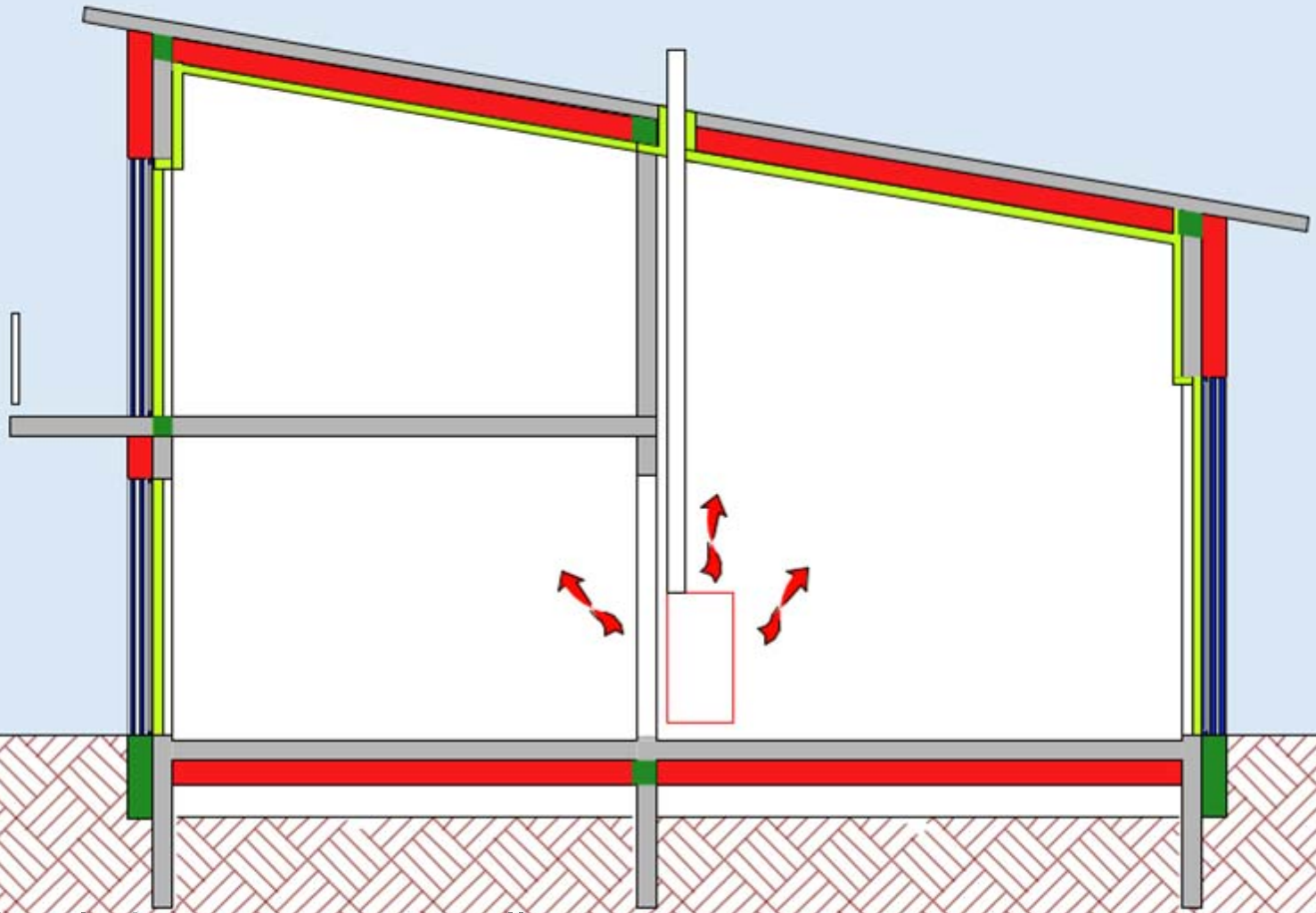


Thermal bridges are points or linear areas of construction where the insulating barrier is broken

They lie in the connections between

- facades and floors
- roofs and walls
- wherever the insulation is broken

I. The building's envelope must be designed for energy efficiency



→ • by enhancing the insulation on opaque walls

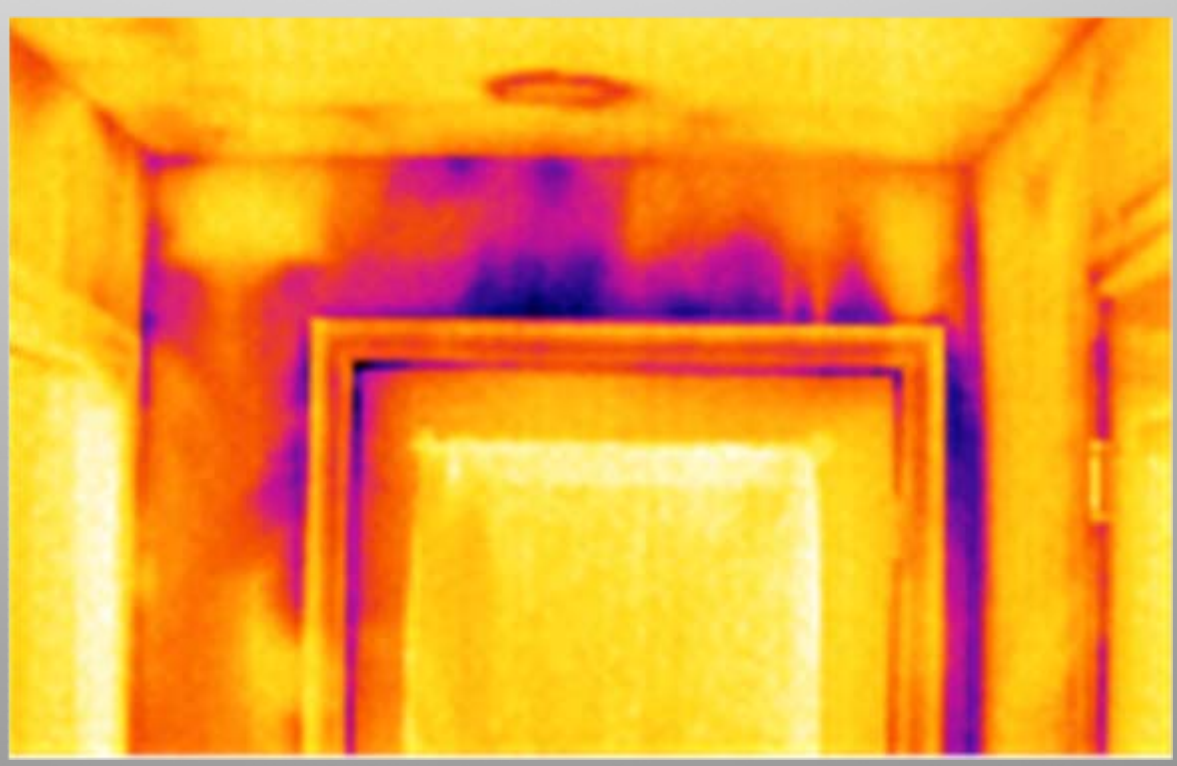
→ • by choosing proper glass walls

→ • by avoiding thermal bridges

→ • **by achieving airtightness**

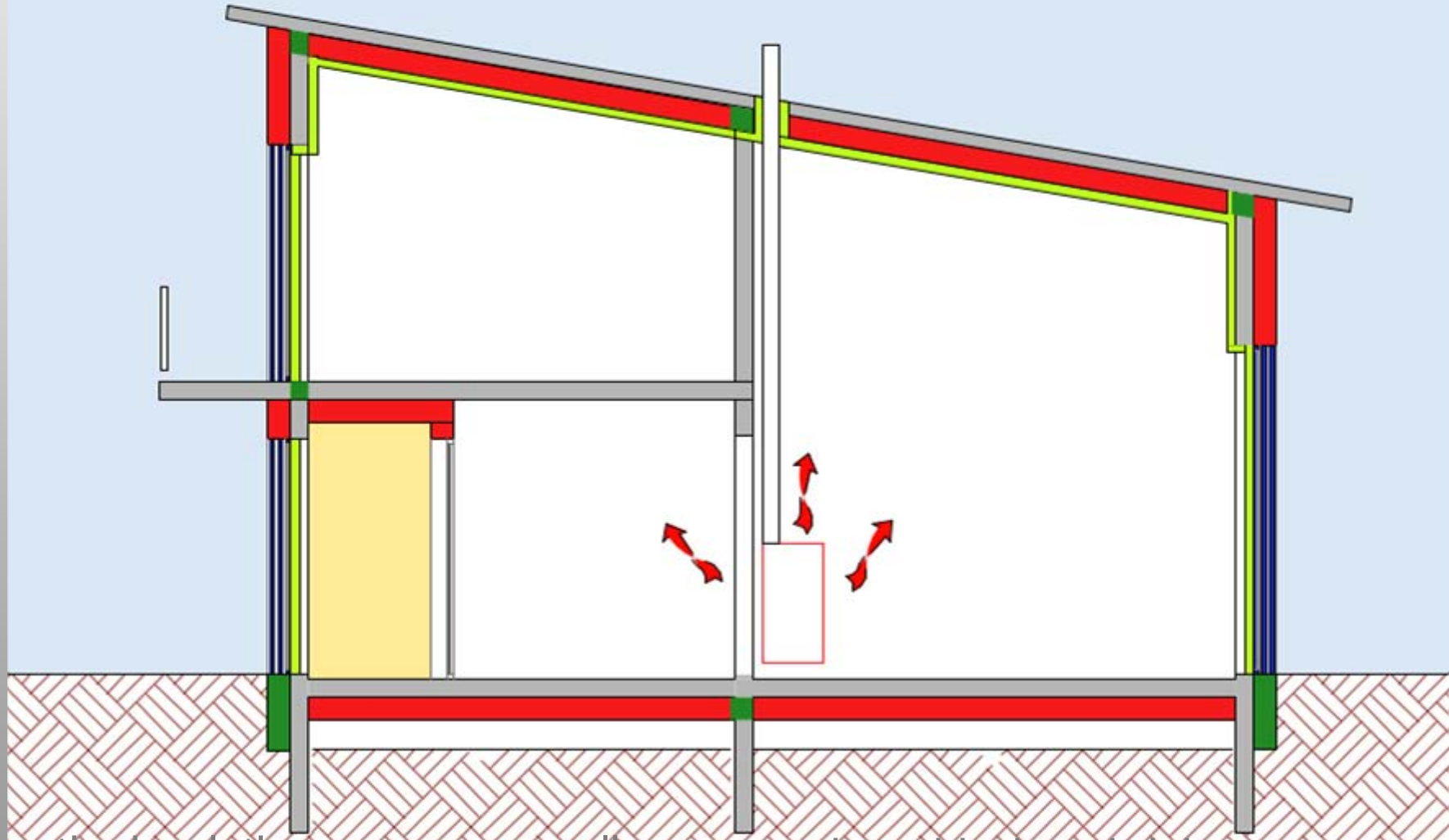
I. The building's envelope must be designed for energy efficiency

→ achieving airtightness



An airtight envelope is obtained by proper implementation of its different materials.

I. The building's envelope must be designed for energy efficiency



- by enhancing the insulation on opaque walls
- by achieving airtightness
- by choosing proper glass walls
- by avoiding thermal bridges
- **by implementing devices to reduce thermal exchanges**

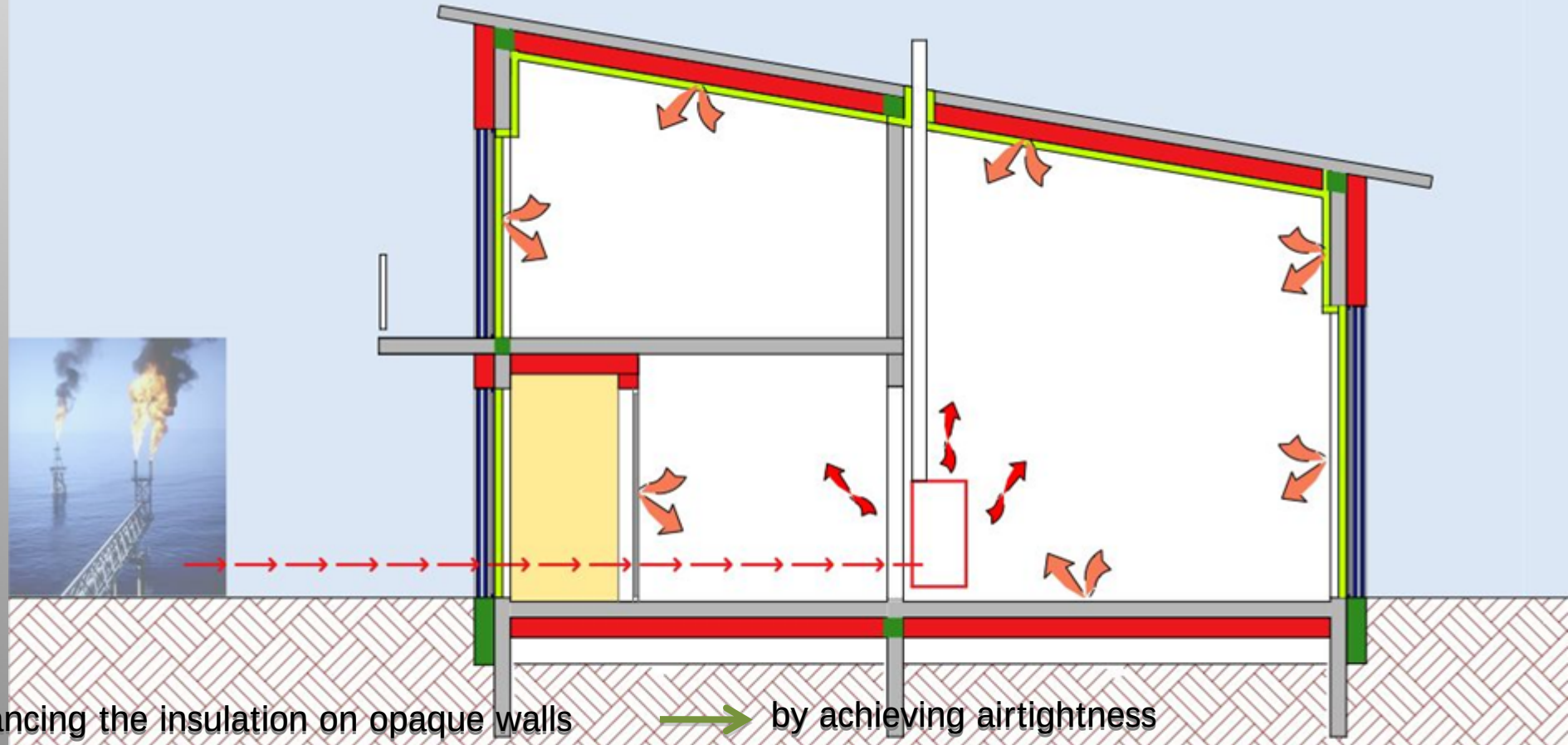
I. The building's envelope must be designed for energy efficiency

→ implementing systems to reduce thermal exchanges

There are some devices conceived
to avoid thermal exchanges.
The best known is the air lock

I. The building's envelope must be designed for energy efficiency

Compliance with these 5 conditions helps to limit thermal exchanges, thereby reducing the heating and cooling consumption of buildings



- by enhancing the insulation on opaque walls
- by choosing proper glass walls
- by avoiding thermal bridges
- by achieving airtightness
- by implementing devices to reduce thermal exchanges

I. The building's envelope must be designed for energy efficiency

The shape of the building will also play an important role in its energy efficiency

Each designer must find the best solution to solve the equation between thermal performance, energy efficiency and the building's needs.

II. The building's envelope must be designed

to optimize renewable resources

The envelope, can, by its form and design,

- optimize the natural renewable resources
- offered by its surroundings
- for the energy needs of buildings

Heating / cooling

Lighting

Domestic hot water production

Electricity production

Ventilation

II. The building's envelope can be designed to collect renewable resources

offered by the 4 natural elements

the sun, for its heat inputs and light

water, for its cooling characteristics

air, for its motion force

earth, for its thermal properties

II. The building's envelope must be designed to optimize

thermal properties of earth

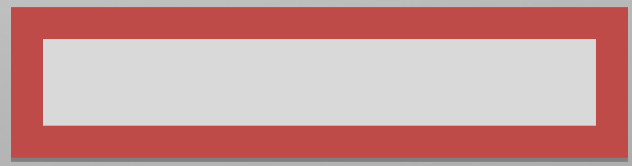
In the surface layers, earth is heated by the sun

As of a depth of 2 m: the soil temperature becomes constant:
6° C – 10° C (winter – summer)

Soil property can be optimized

→ directly, to preheat or cool air

→ by "geothermal heat pump systems"
for heating, cooling and producing
domestic hot water

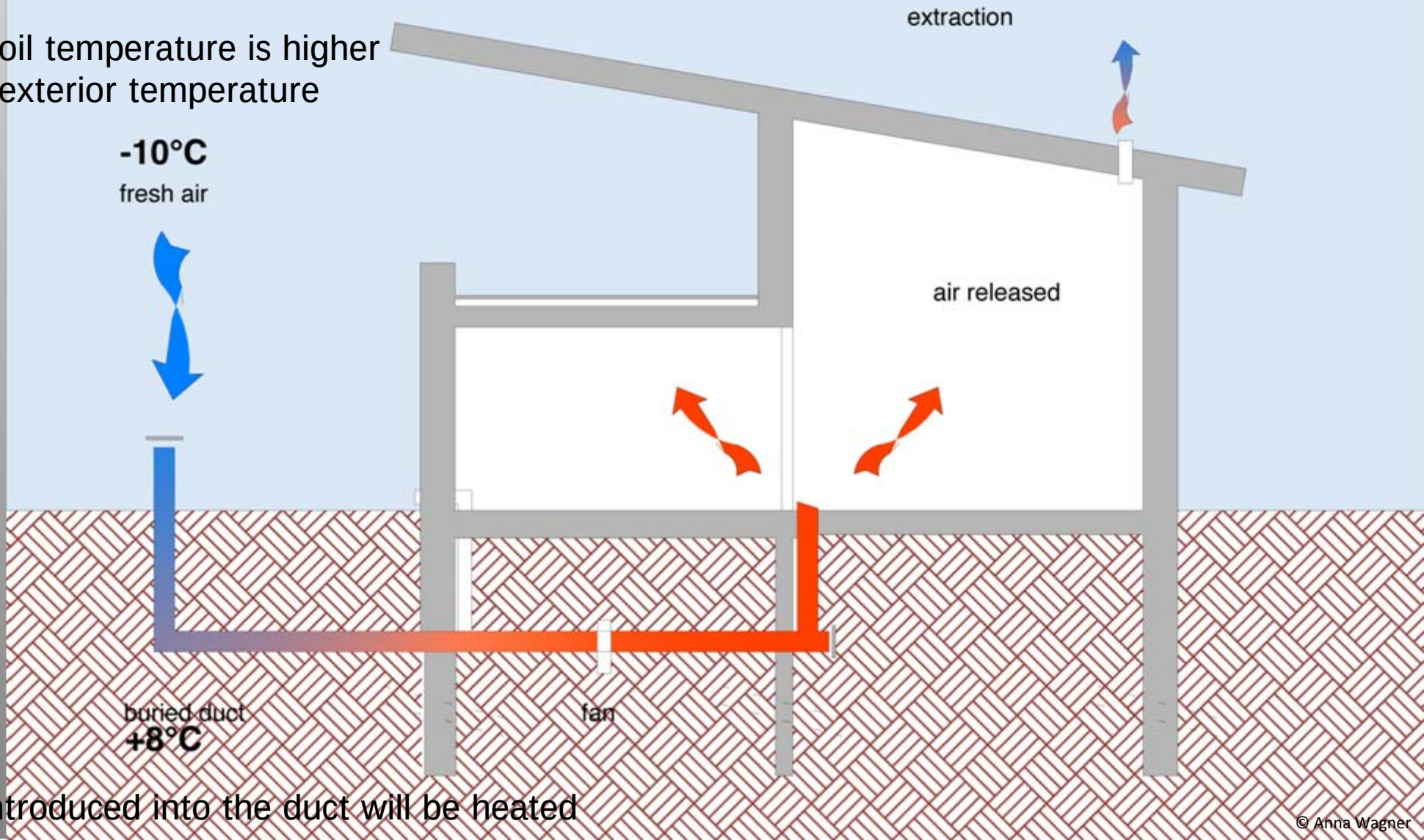


II. The building's envelope must be designed to optimize

thermal properties of earth

Canadian well. Used during the winter to preheat air

Winter: soil temperature is higher than the exterior temperature



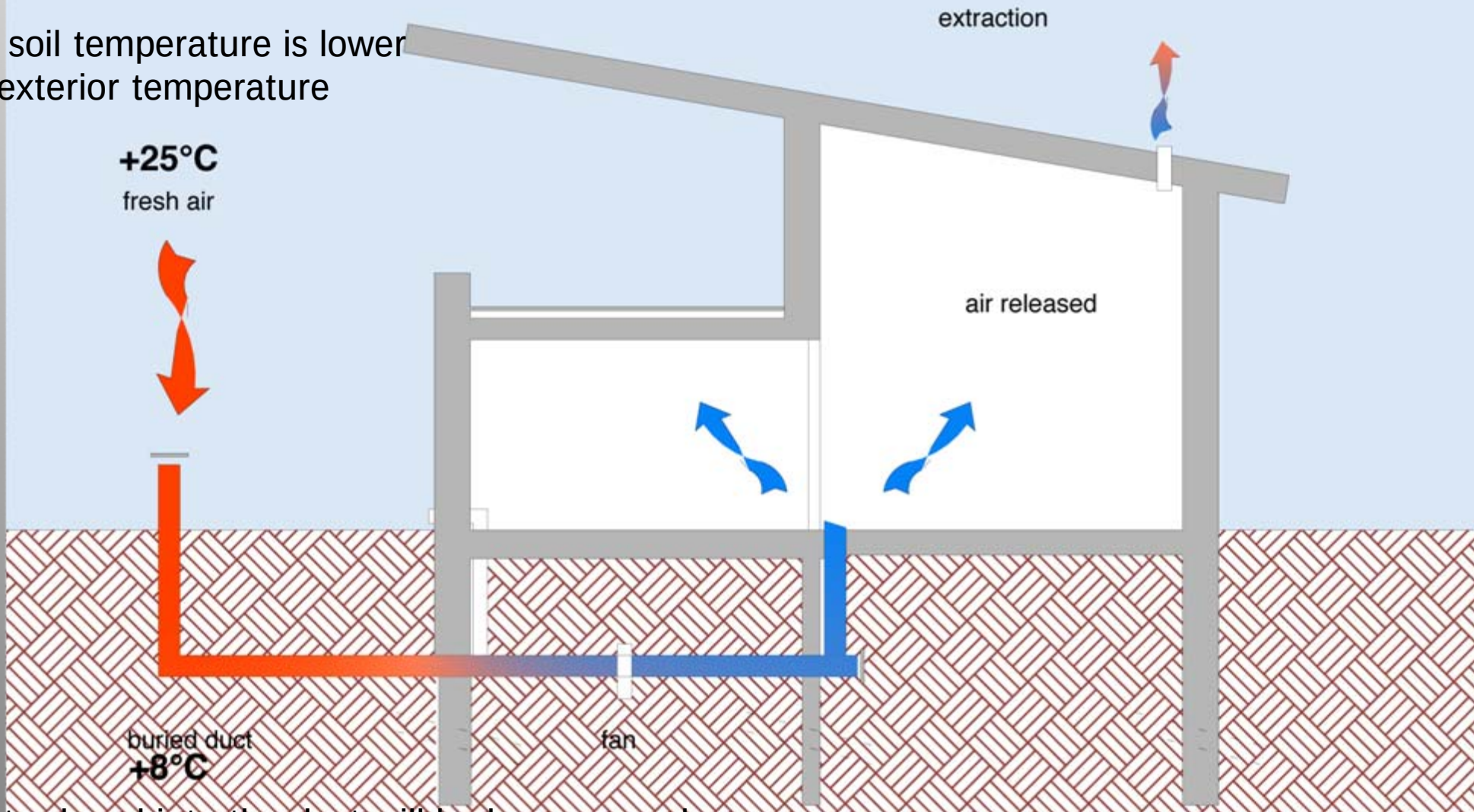
The air introduced into the duct will be heated

II. The building's envelope must be designed to optimize

thermal properties of earth

Provencal well. Used in summer to cool air

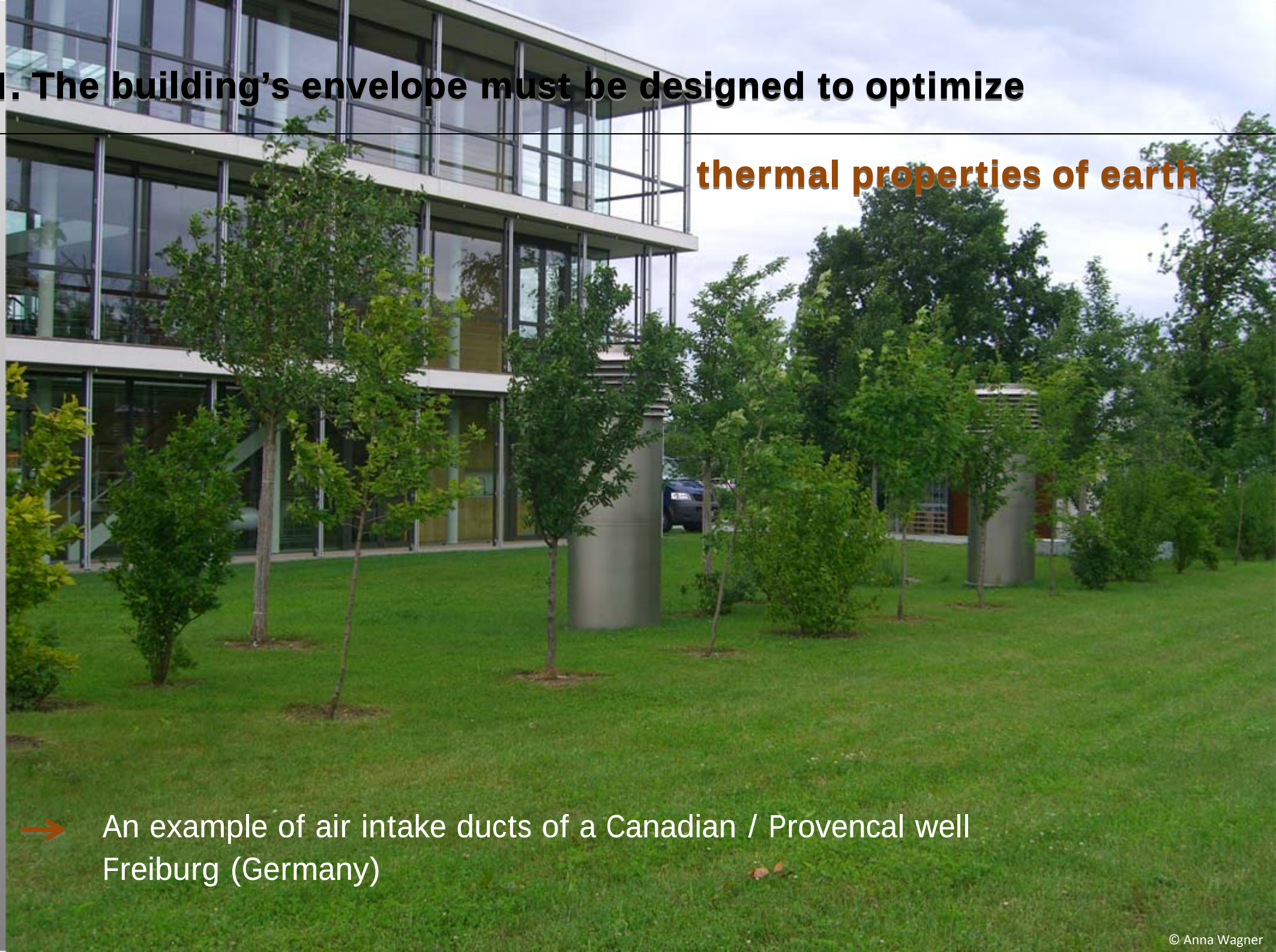
Summer: soil temperature is lower than the exterior temperature



The air introduced into the duct will be become cooler

II. The building's envelope must be designed to optimize

thermal properties of earth



→ An example of air intake ducts of a Canadian / Provencal well
Freiburg (Germany)

II. The building's envelope must be designed to optimize

thermal properties of earth

→ An example of ducts emerging inside the building
Secondary School, Klaus, Vorarlberg (Austria), Dietrich and Untertrifaller arch

II. The building's envelope must be designed to optimize

thermal properties of earth

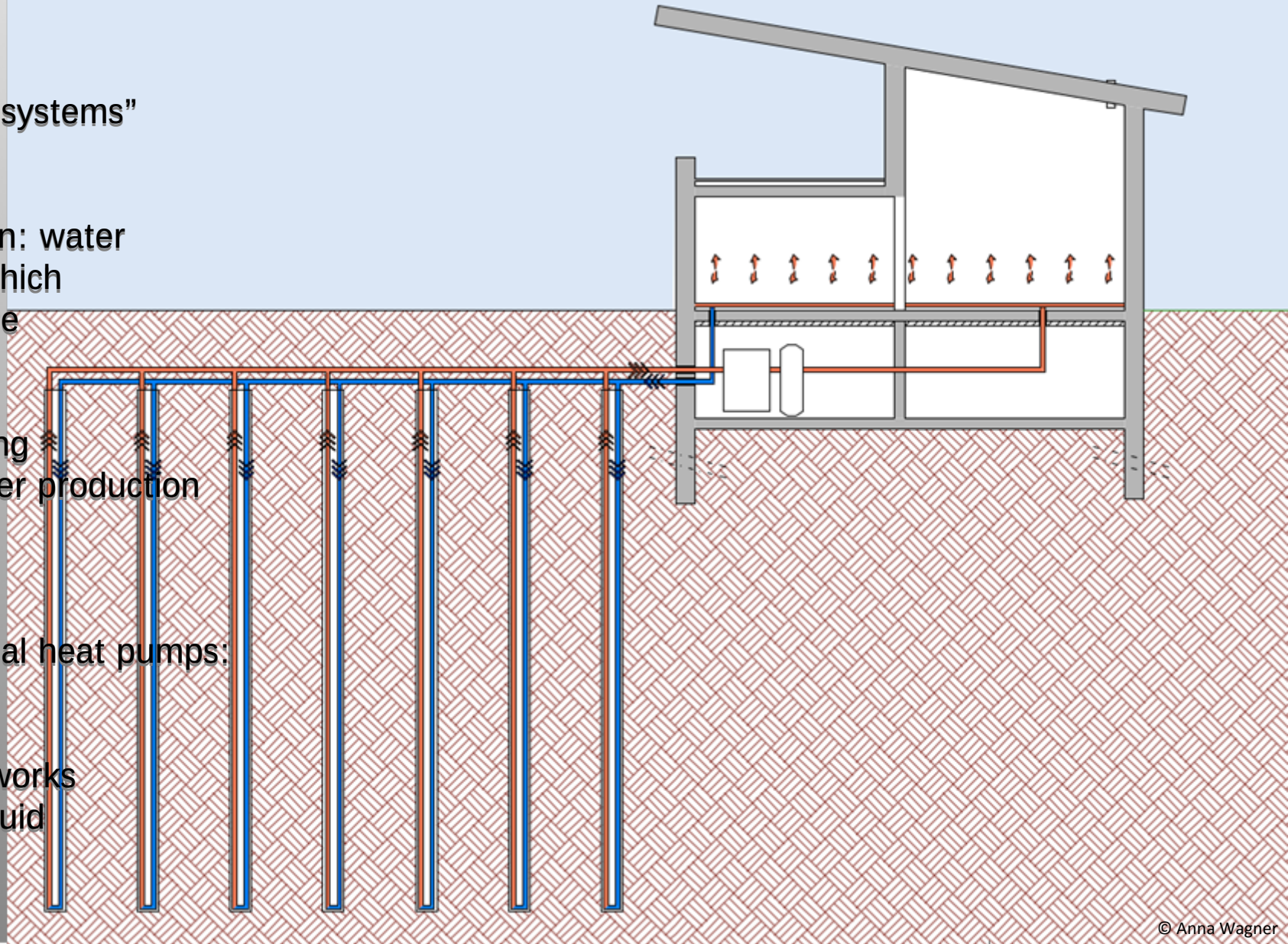
"Geothermal heat pump systems"

- Singular points
  - vector of transmission: water
  - heat pump, device which increases temperature

- Use:
  - for heating, for cooling
  - for domestic hot water production

- 2 systems of geothermal heat pumps:

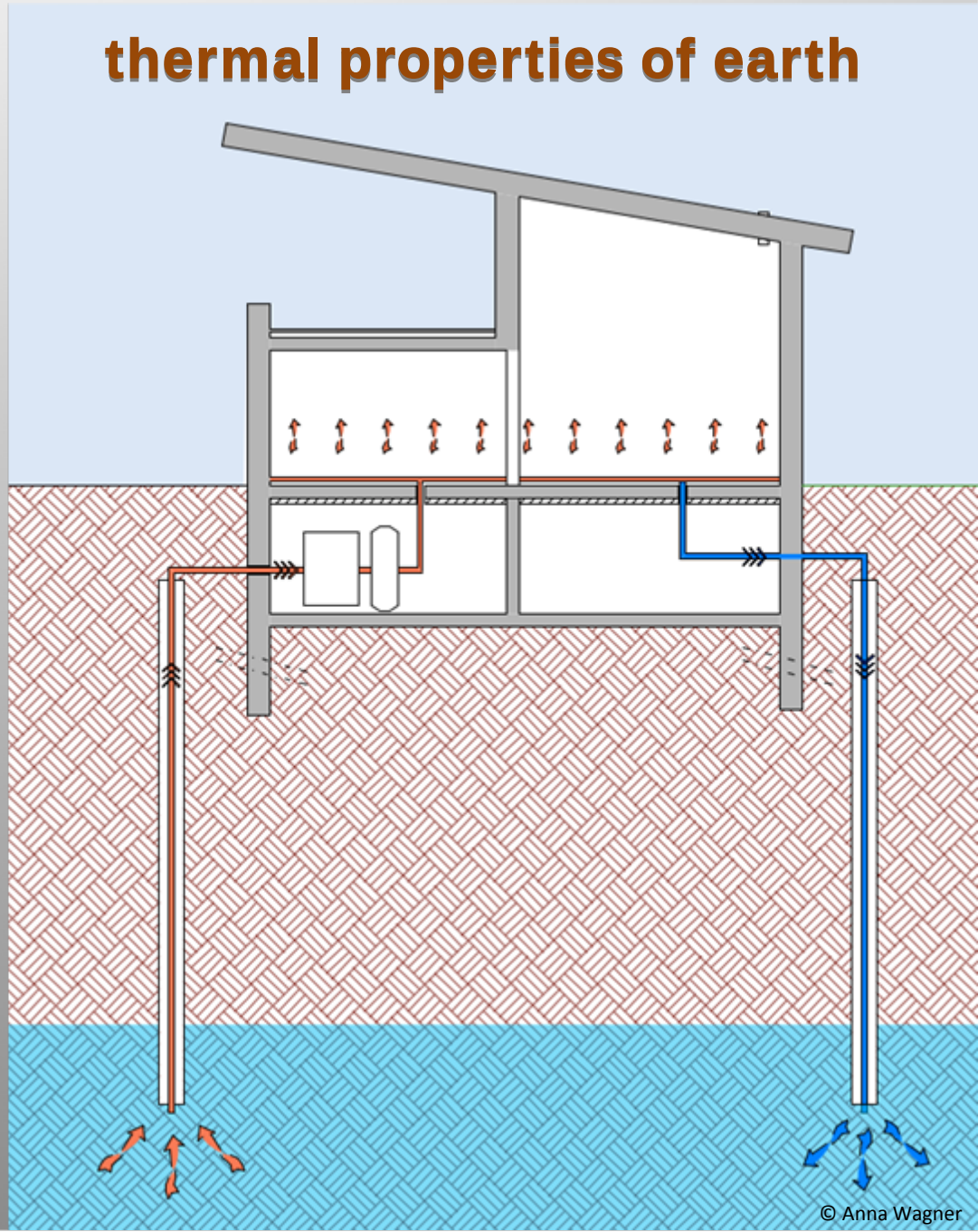
- "closed loop system" works with heat transfer fluid



II. The building's envelope must be designed to optimize

"Geothermal heat pump systems"

- "open loop system" works with ground-water

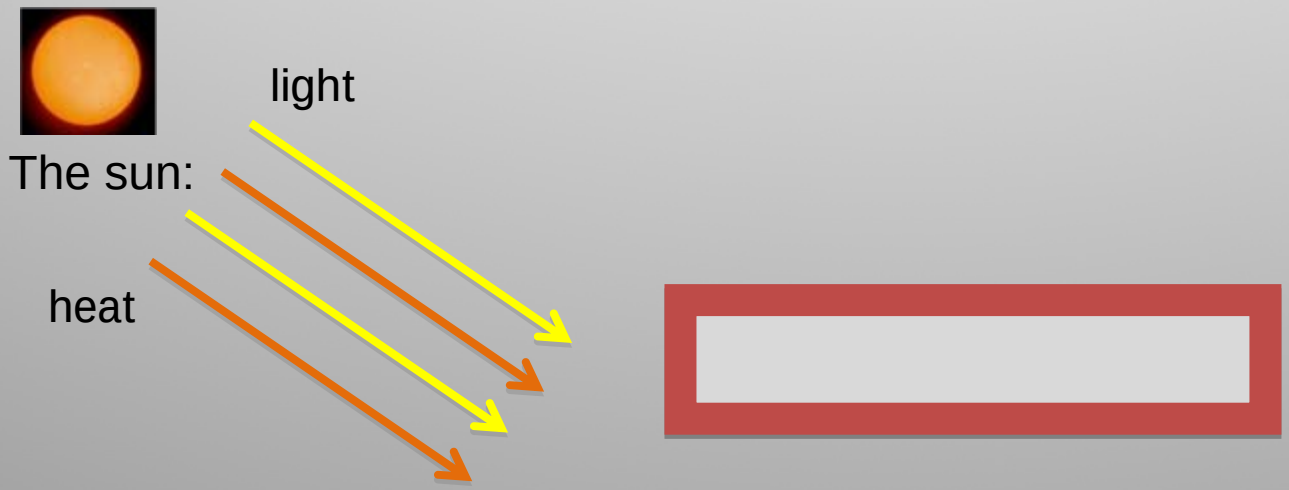


II. The building's envelope can be designed to optimize

sun resources

optimizing the sun's → heat: for heating and domestic hot water prod.

→ light: for lighting and electricity production



2 systems to optimize solar gains
- "passive solar energy"
- "active solar technology"

earth

II. The building's envelope must be designed

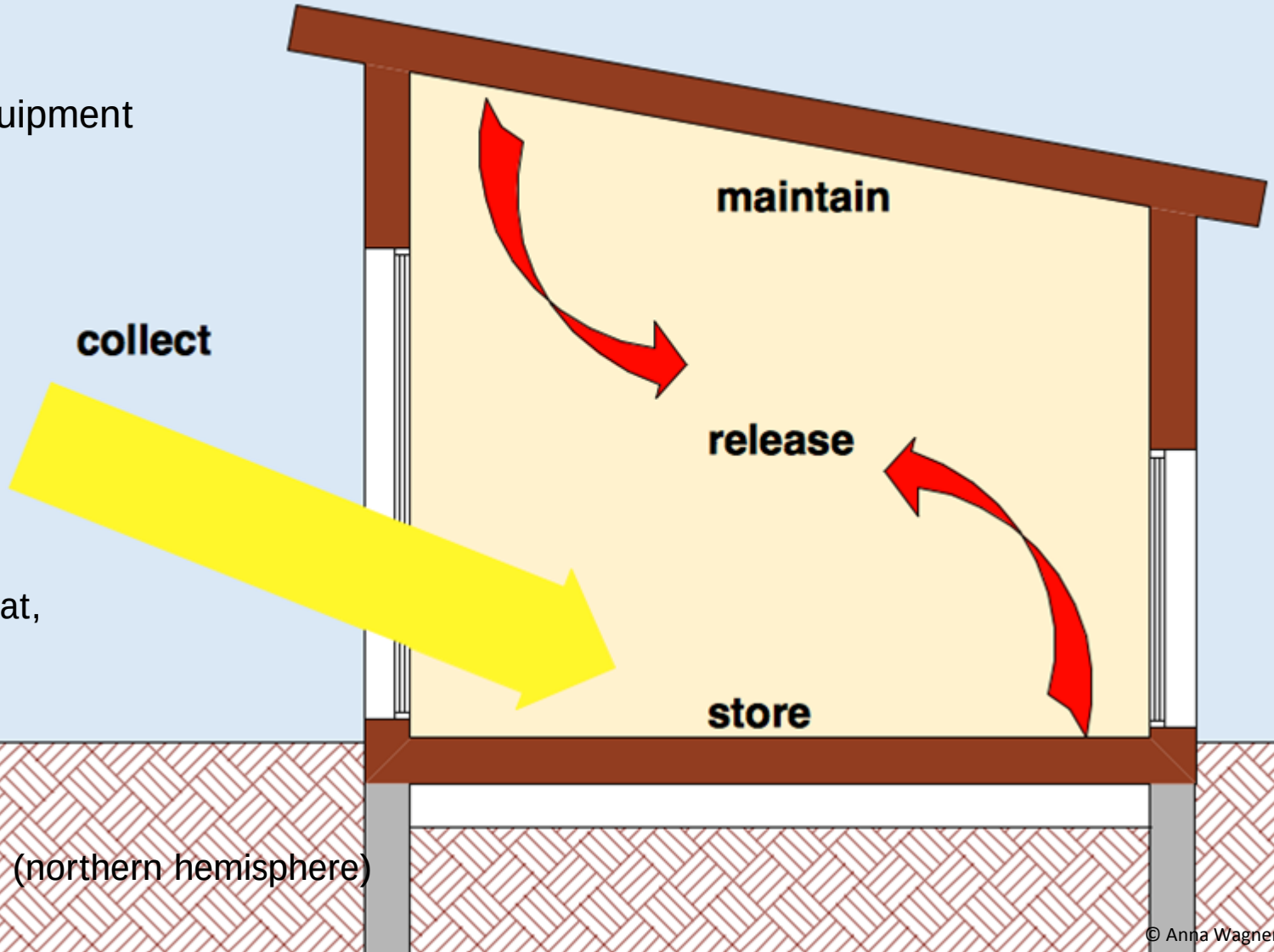
to optimize solar heat by "passive solar energy"

In the passive solar energy system the envelope must be design to:

- collect
- store
- distribute the sun's heat

without the aid of technical equipment for this conversion

Use: to preheat air



Operating principle

- envelope receives the sun's heat,
- heat is stored in the structure,
- heat is released into the room.

Very important points:

- the glass wall must face south, (northern hemisphere)
- solar masks must be avoided

II. The building's envelope must be designed

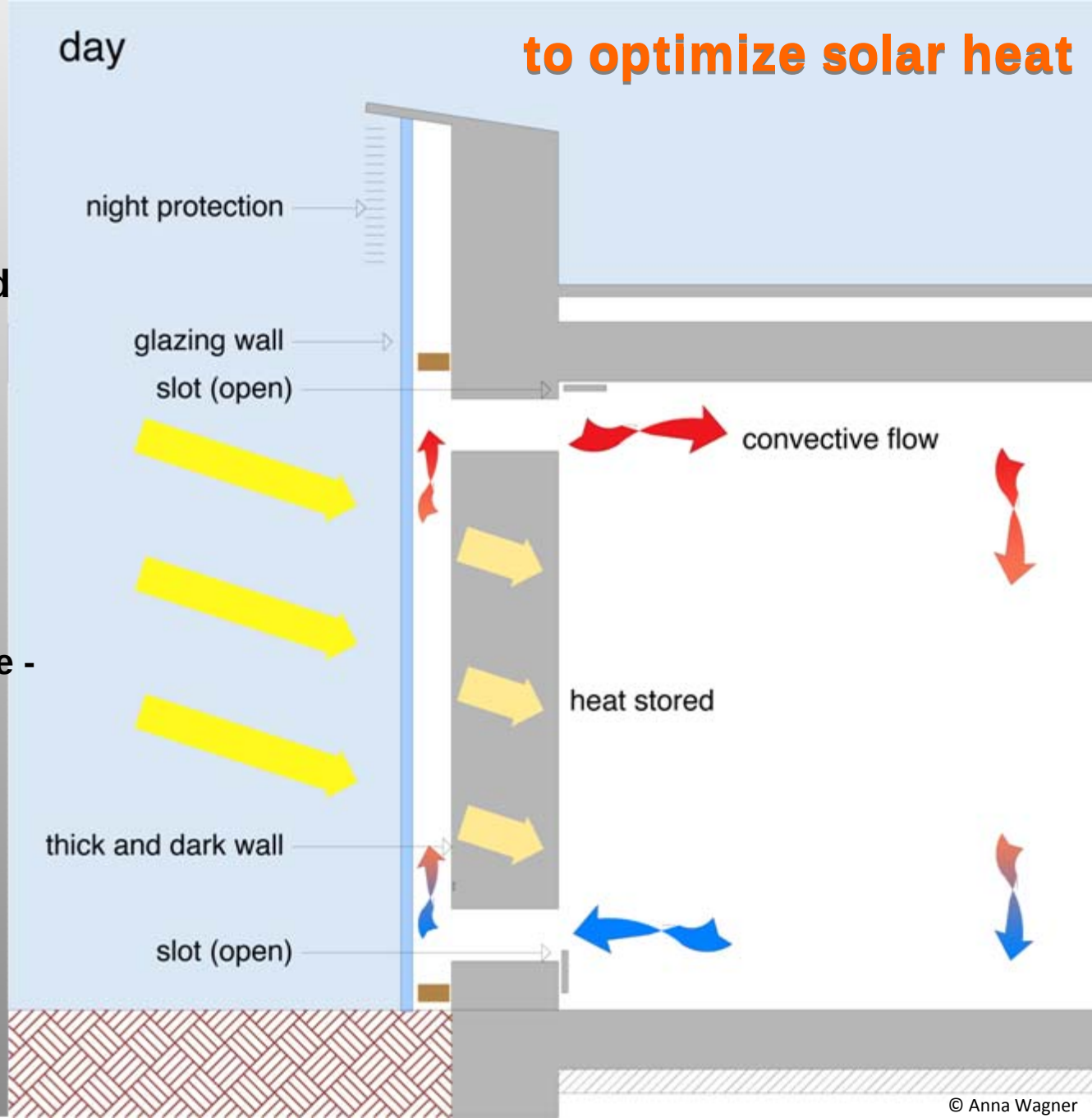
Passive solar energy
Solar heat recovery system
(hybrid system)

Envelope design: more sophisticated

South-facing envelope is composed of:
- a thick wall of dark colour
- a glazing wall
- devices allowing air to circulate
- a night protection

Operating principle: - double skin façade -
Day : the sun heats
the air trapped in the air space

2 things occur:
solar heat
- triggers a convection phenomenon
- is stored in the thick wall



II. The building's envelope must be designed

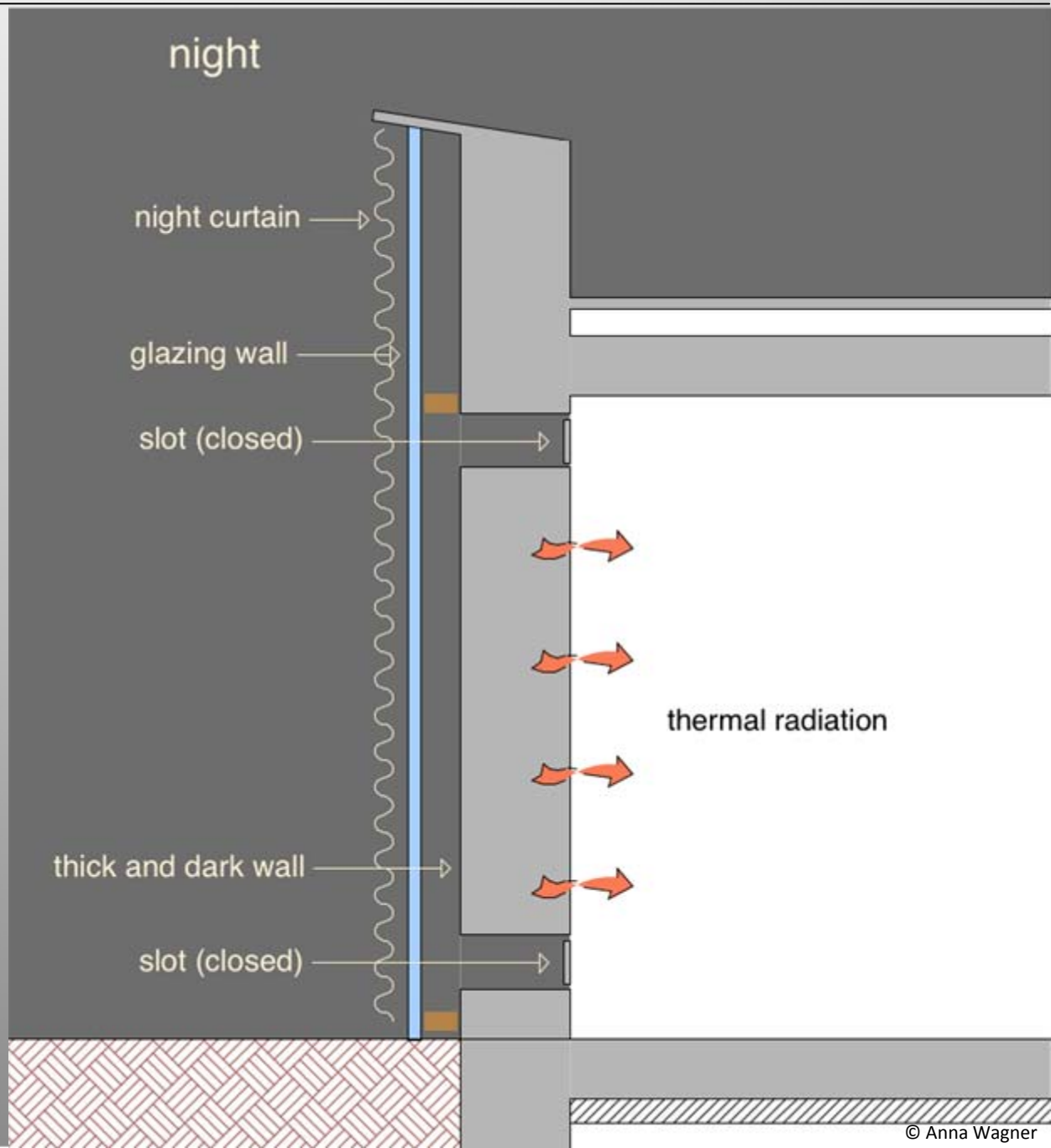
Passive solar energy

Envelope design - double skin -

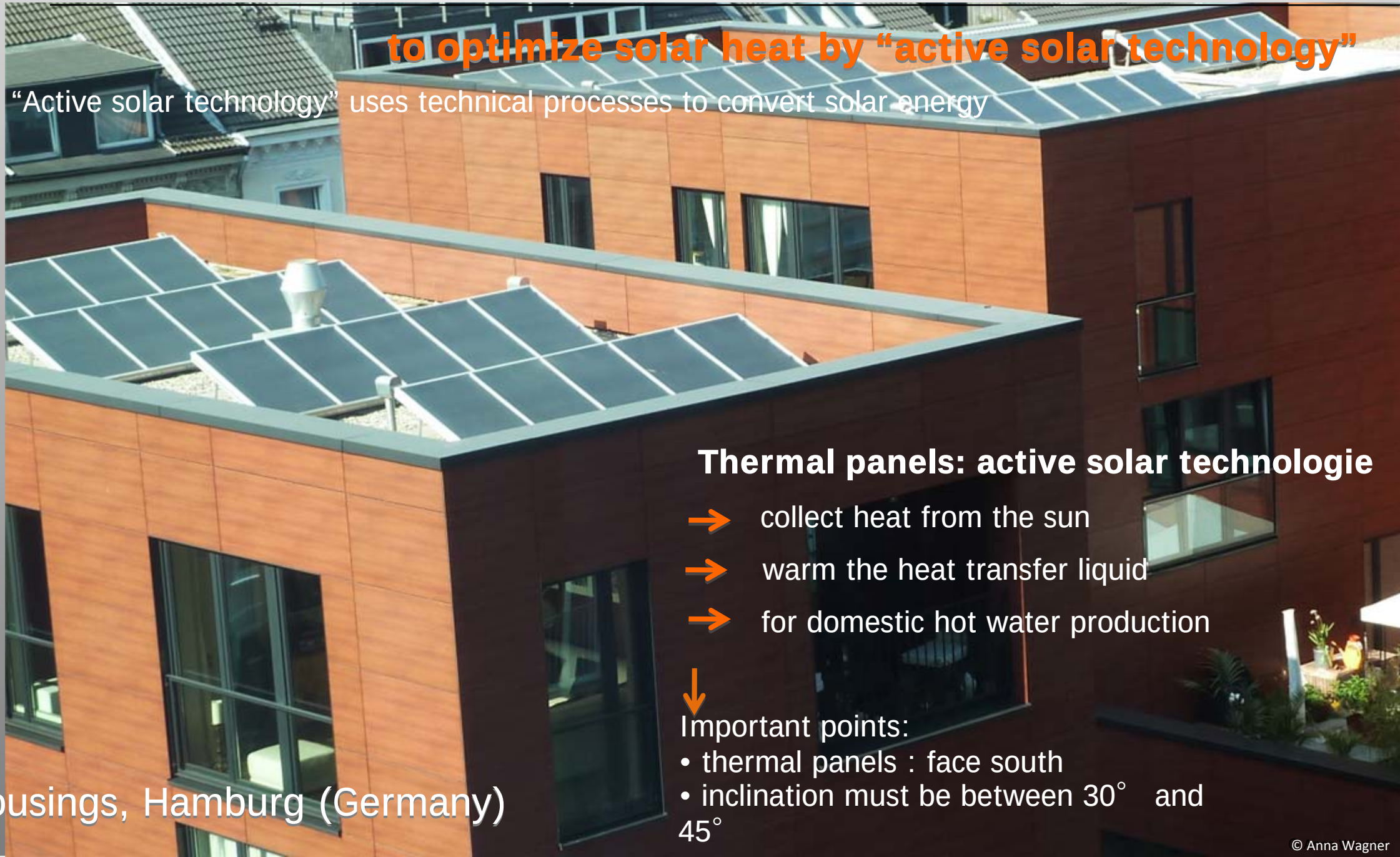
Operating principle
At night, heat will also be released

It will then be necessary:
- to close the night curtain
- to close the slots

The thick wall will continue to diffuse the heat stored during the day



II. The building's envelope must be designed



to optimize solar heat by "active solar technology"

"Active solar technology" uses technical processes to convert solar energy

Thermal panels: active solar technologie

→ collect heat from the sun

→ warm the heat transfer liquid

→ for domestic hot water production

↓

Important points:

- thermal panels : face south
- inclination must be between 30° and 45°

ousings, Hamburg (Germany)

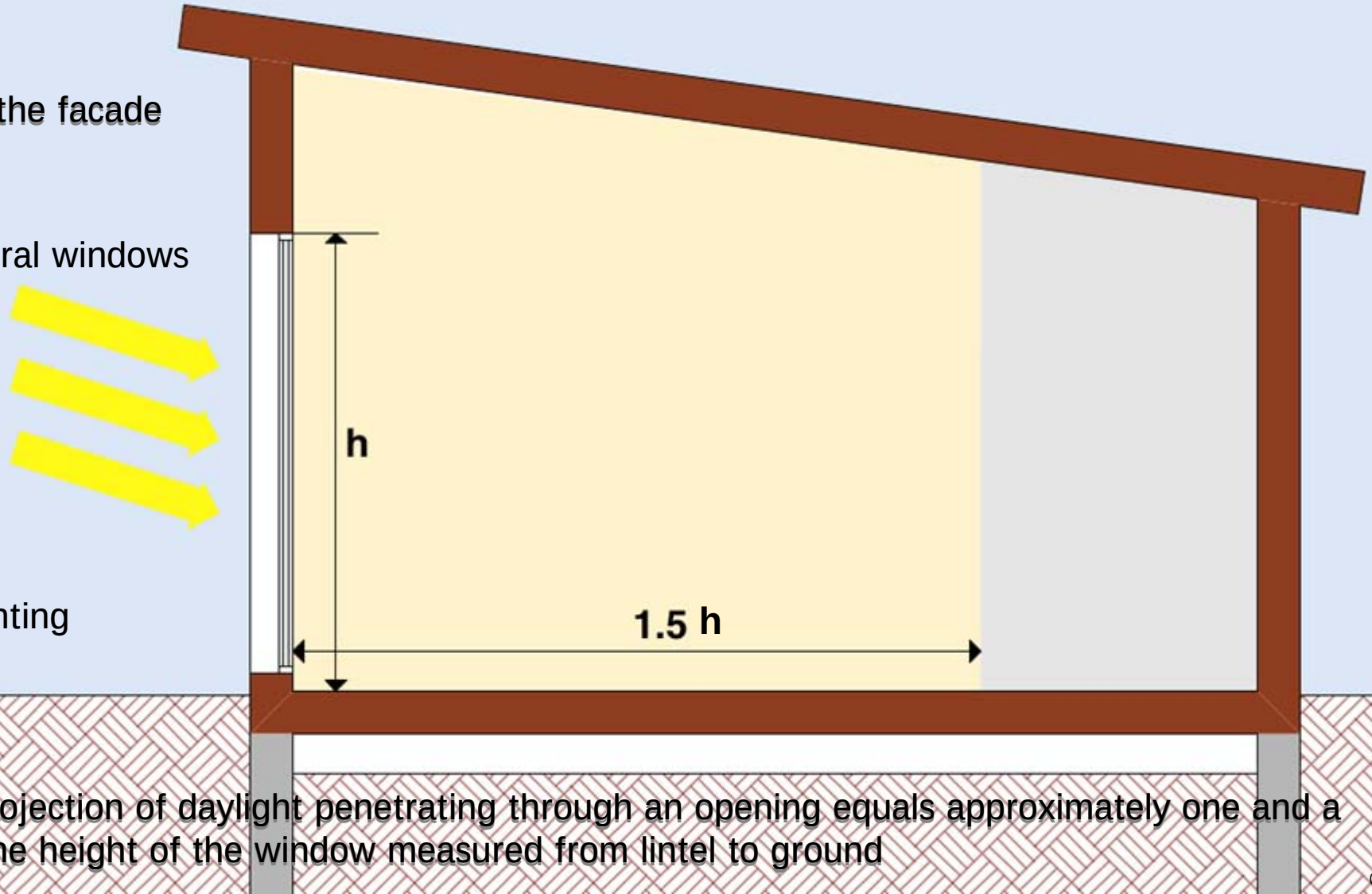
II. The building's envelope must be designed

to optimize sunlight

The light penetration into the room depends on:
- the orientation
- the location
- the size

of the window in the facade

Performance
South-facing lateral windows



Use: for lighting

Generally, the projection of daylight penetrating through an opening equals approximately one and a half times the height of the window measured from lintel to ground

II. The building's envelope must be designed

to optimize sunlight

ultipurpose room, Secondary School, Klaus, Vorarlberg (Austria)

School in Vorarlberg (Austria), Dietrich and Untertrifaller arch

II. The building's envelope must be designed

to optimize sunlight

The openings are composed of:
- large main lateral windows
- glazed panels

allowing light to penetrate

assroom, school in Vorarlberg

School in Vorarlberg (Austria), Dietrich and Untertrifaller arch

II. The building's envelope must be designed

to optimize sunlight
to avoid heat inputs

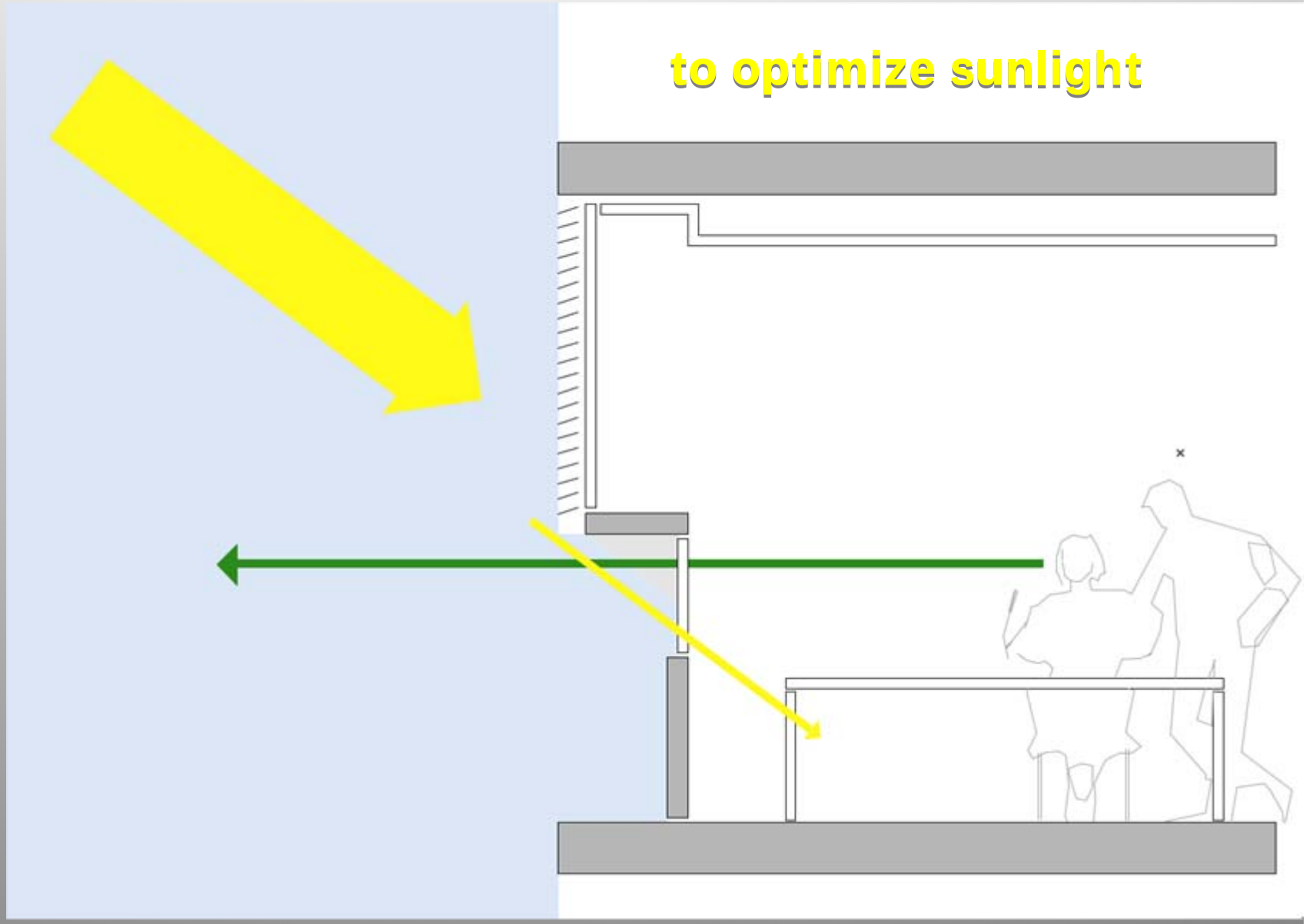
- light emitted by the sun carries heat inputs

- in summer, south and west-facing windows require external protection to stop solar heat.

School in Vorarlberg (Austria), Dietrich and Untertrifaller arch

II. The building's envelope must be designed

summer



School in Vorarlberg (Austria), Dietrich and Untertrifaller arch

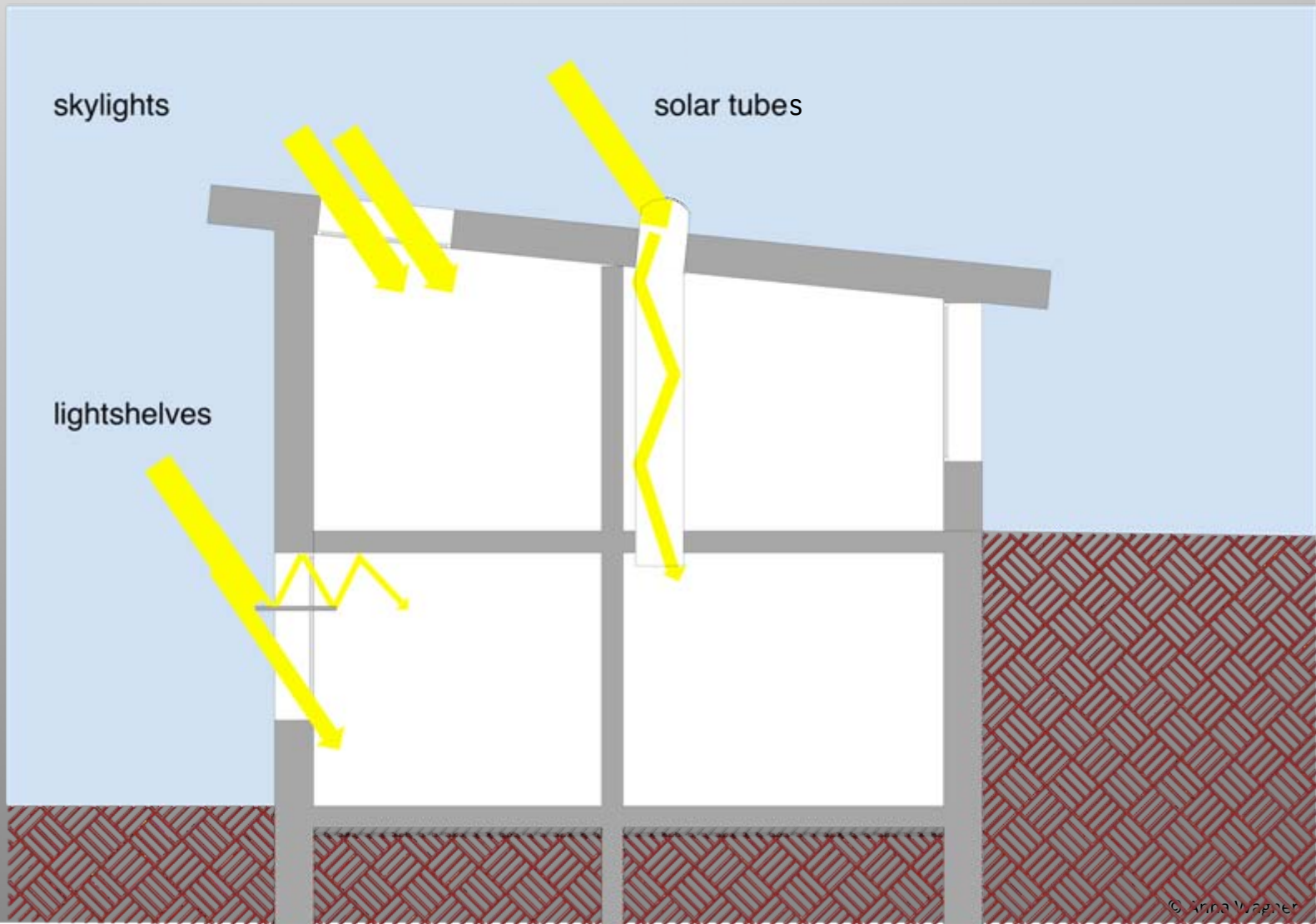
II. The building's envelope must be designed

to amplify sunlight

Building's envelope devices to amplify daylight in interior spaces

The main ones are:

- lightshelves
- skylights
- light or solar tubes



II. The building's envelope must be designed

to amplify sunlight

→ lightshelves

white or reflective devices placed outside the windows

South-facing windows fitted with lightshelves let in 50% more light than non-equipped windows.

Porticullis House, London (UK) Hopkins arch.

II. The building's envelope must be designed

→ skylights

windows located on roofs

to diffuse sunlight

Advantage:
skylights provide very uniform light
performance is better on cloudy days

Disadvantage:
skylights offer poor thermal efficiency

. Maria Magdalena-Kirche, Church, Freiburg (Germany)
ster, R. Scheithauer, S. Gross, arch.

II. The building's envelope must be designed

→ skylights

to diffuse sunlight

skylights light specific areas

ho-French Center at Tongji University, Shanghai (China)

ng Bin, Atelier Z+, arch.

II. The building's envelope must be designed

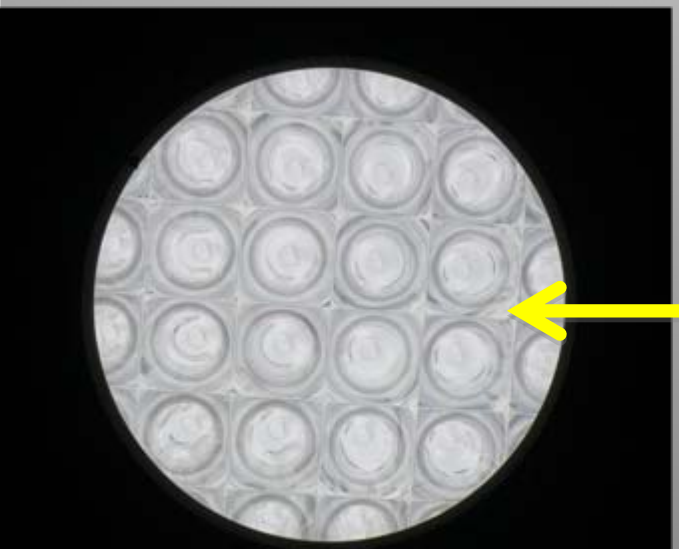
→ solar tubes

to amplify sunlight

pipes lined with highly reflective material that lead the light rays through a building

3 elements

- an external collector
- a pipe light system
- a light diffuser



Urban Planning Institute, Shanghai (China)

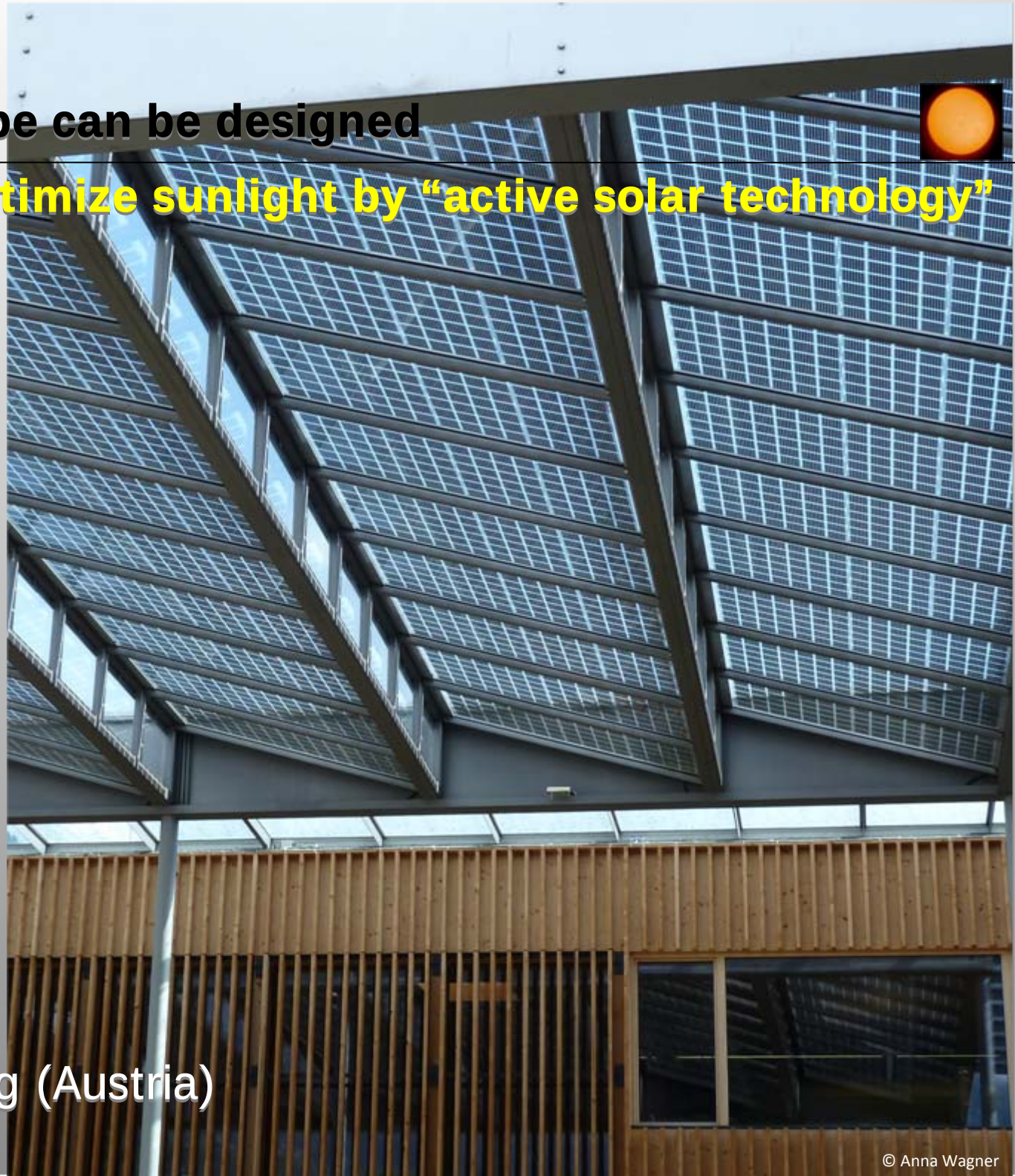
Advantage: given their small surface area they don't allow as much heat transfer as skylights do

II. The building's envelope can be designed

- **to optimize sunlight by "active solar technology"**

Solar panels:
- active solar technology system
- convert light into electricity

They must be installed:
- on the roof facing south
- at an inclination of 30° and 35°
- without being masked



Municipal building in Vorarlberg (Austria)

H. Kaufmann, arch.

II. The building's envelope must be designed

Example of the use of solar panels

- they produce electricity
- they provide shade
- they allow light to enter.

Municipal building in Vorarlberg (Austria)

H. Kaufmann, arch.

II. The building's envelope must be designed to optimize

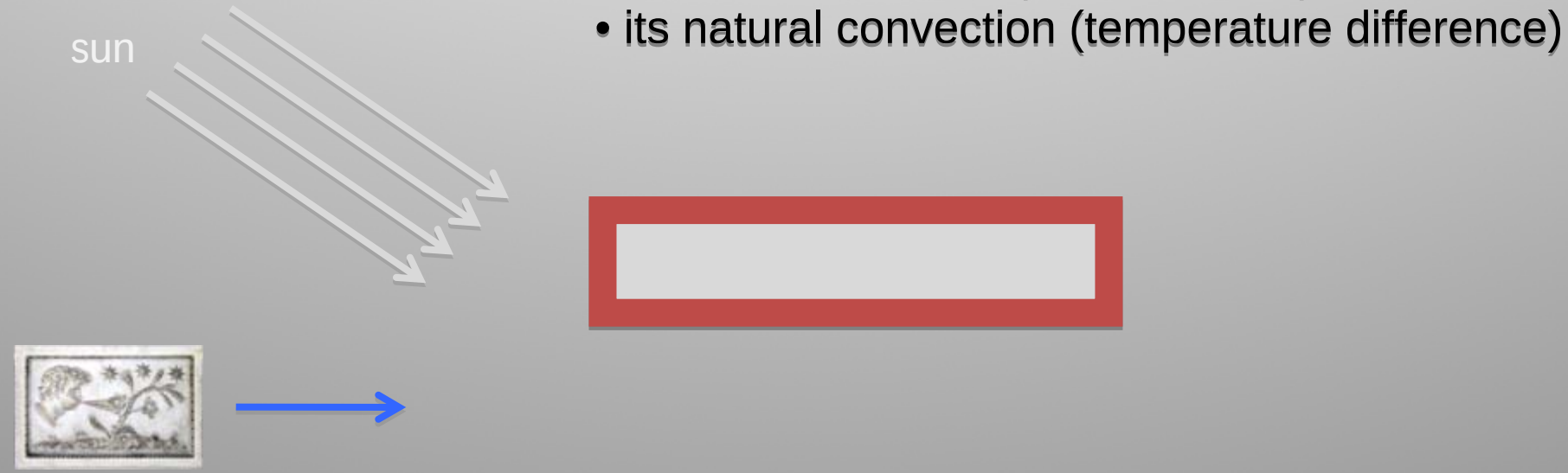
air resources

Air properties are used

- to ventilate naturally
- to cool in summer
- to produce electricity

Main characteristics:

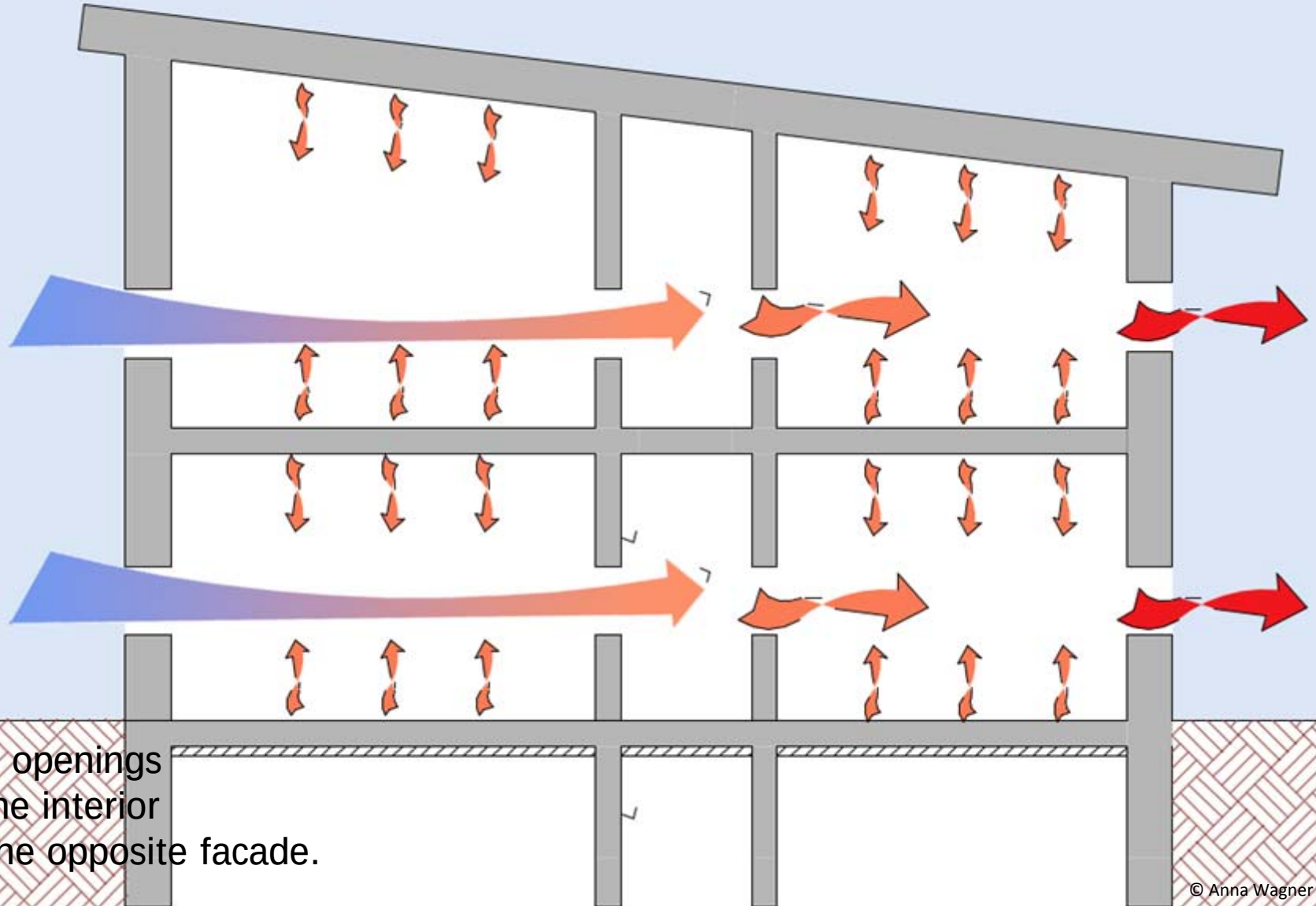
- its acceleration (Venturi effect)
- its natural convection (temperature difference)



II. The building's envelope must be designed for

To optimize air resources for natural ventilation
a facade must be exposed to prevailing winds

natural ventilation



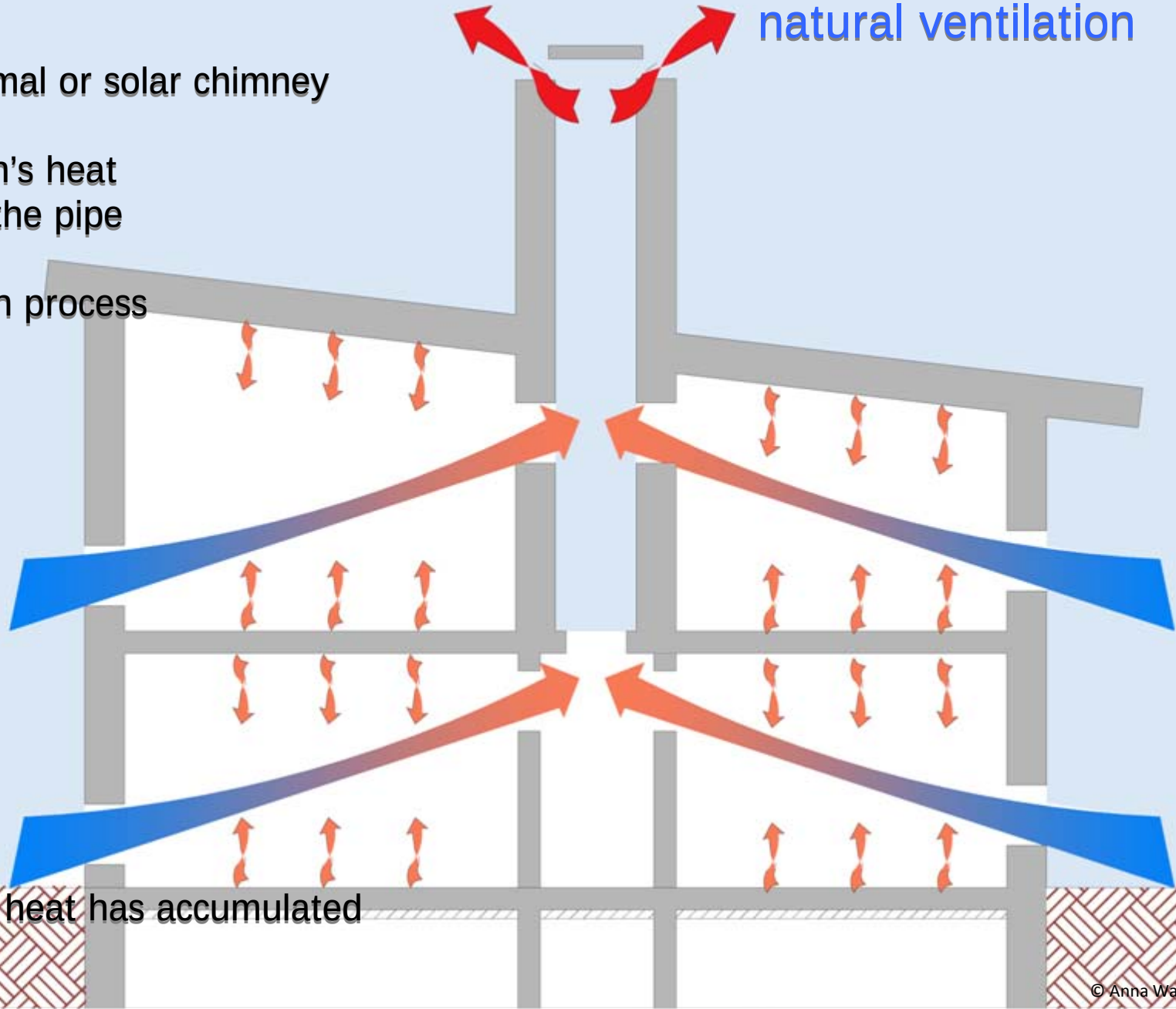
- air enters through openings
- sweeps through the interior
- is sucked out by the opposite facade.

II. The building's envelope must be designed for

To improve the draw
implementation of a thermal or solar chimney

A pipe exposed to the sun's heat
by heating the air inside the pipe

Heat triggers a convection process
"a chimney effect"



System used:
- to extract stale air,
- to cool volumes where heat has accumulated

II. The building's envelope must be designed for

natural ventilation

3 devices to naturally ventilate
- a Canadian / Provencal well
- a ventilation shaft
- towers, solar chimneys

oventry University, Lanchester (UK)
n Shot, arch.

II. The building's envelope must be designed for

natural ventilation

the bottom of the ventilation shaft
- located at the ground level
- allows the arrival of fresh air

ventry University, Lanchester (UK)
Shot, arch.

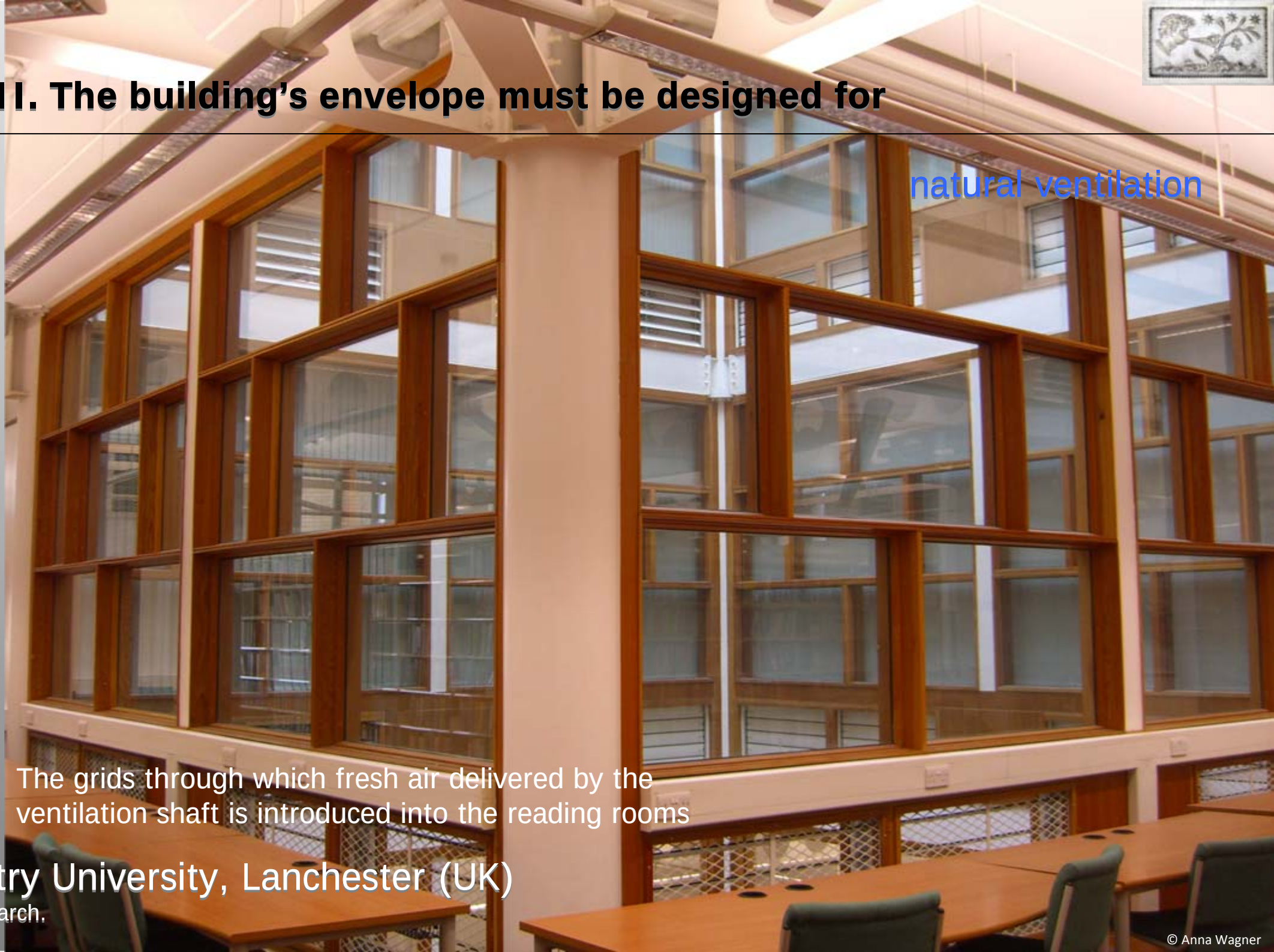
Upper part : glass roof
- heated by the sun
- warms the air of the shaft
- generates a convection process

The temperature difference causes:
the air diffused can rise naturally

central body of the ventilation shaft

II. The building's envelope must be designed for

natural ventilation



The grids through which fresh air delivered by the ventilation shaft is introduced into the reading rooms

oventry University, Lanchester (UK)

Shot, arch.

II. The building's envelope must be designed for

natural ventilation

After sweeping through the reading rooms, stale air is removed by solar chimneys

ventry University, Lanchester (UK)
Shot, arch.

II. The building's envelope must be designed for

natural ventilation

Solar chimneys: metal scales on top
Heated by the sun, increase the draw
> extract stale air and heat

oventry University, Lanchester (UK)
n Shot, arch.

II. The building's envelope can be designed

Two towers shaped like wings facilitate the acceleration of wind

Shape : increases the efficiency of wind turbines: benefit from the Venturi effect, to produce electricity

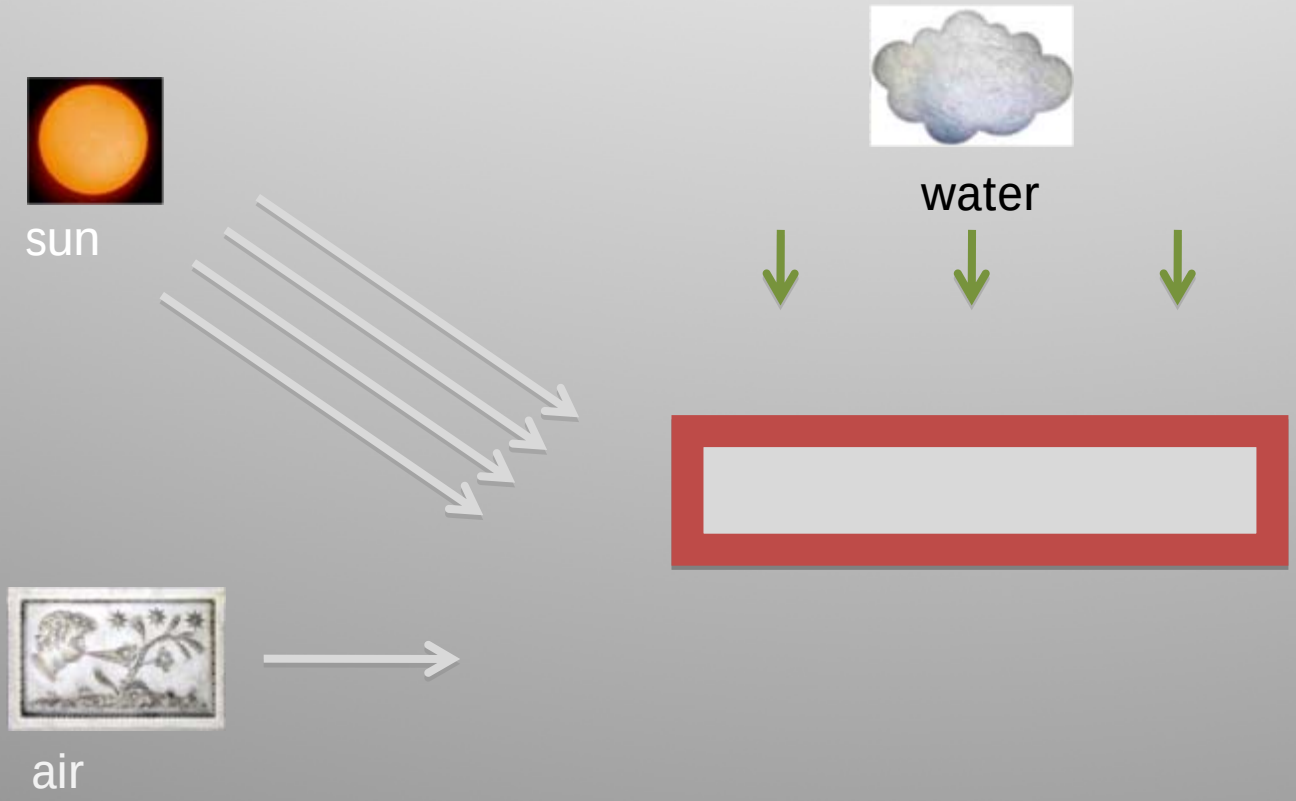
Other property of Ventury effect: as air is accelerated it is also cooled

orld Trade Center, Manama (Bahrain)

ns arch.

II. The building's envelope must be designed to optimize

water resources



Water is valued
- for its driving force
- for its capacity

to evaporate on contact with heat
Evaporation: temperature decreases

This characteristic can be optimized to cool interior spaces

It becomes an increasingly expensive resource, rain water must be collected for multiple purposes

II. The building's envelope must be designed

for cooling

The pool contributes to cool the lobby space
As it evaporates water vapour
- lowers the temperature
- cools air

Solar Fabrik, Freiburg (Germany)
F. Rolf, M. Hotz / R. Amann

II. The building's envelope must be designed

for cooling

Rainwater collected at the top is used to
- water the garden
- fill the pool

Vegetation like water:
- to cool air in summer
- to maintain a constant hygrometry level during all seasons.

Institute for Forestry and Nature Research in Wageningen (Netherlands)
Behnisch arch.

II. The building's envelope must be designed

to regulate hygrometry

for cooling

A variant for cooling and regulation of hygrometry: by green roofs

Plants store moisture from rain and release it gradually

ilding, Utrecht (Netherlands)

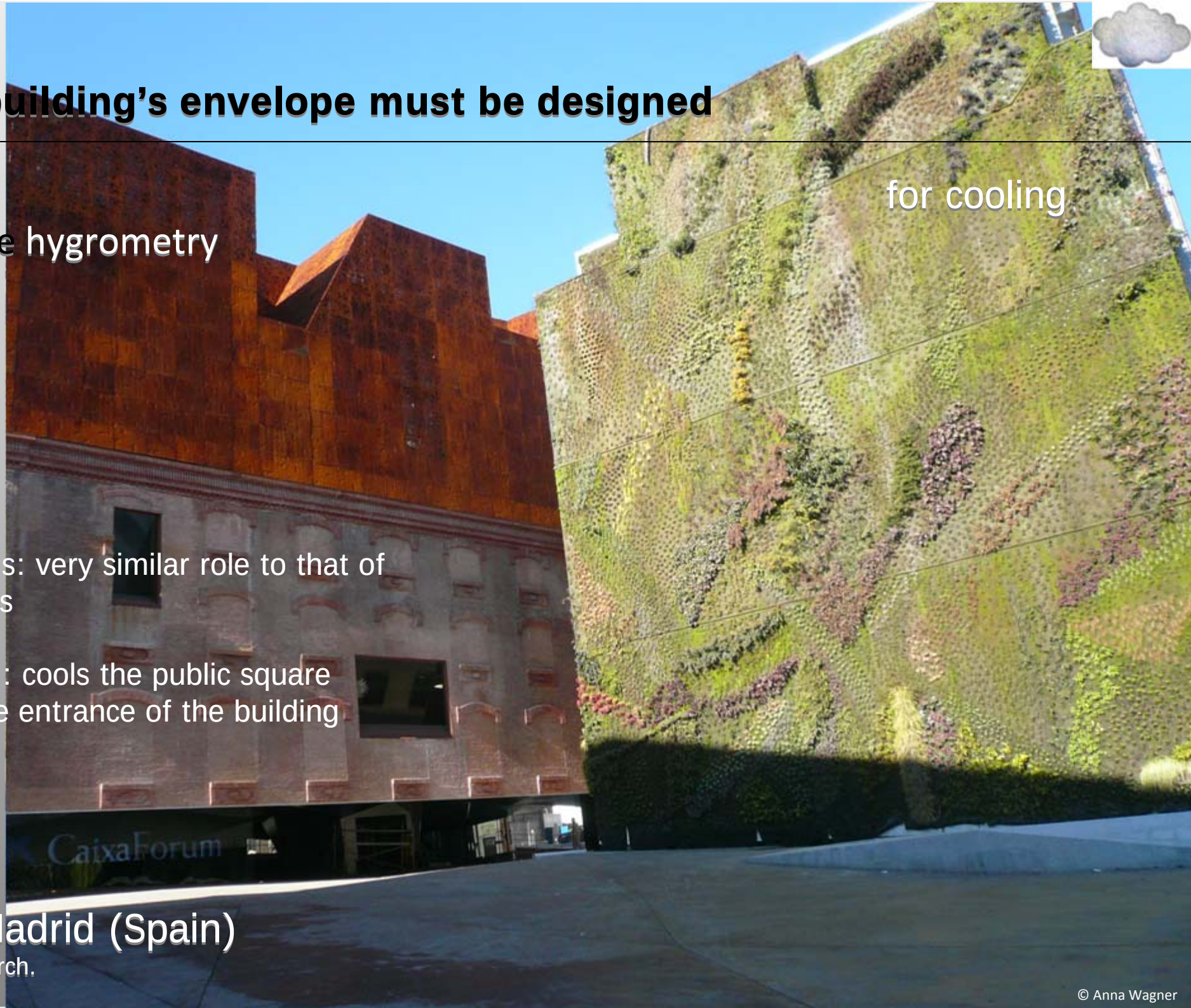
II. The building's envelope must be designed

to regulate hygrometry

for cooling

Green walls: very similar role to that of green roofs

Green wall: cools the public square outside the entrance of the building



aixa Forum, Madrid (Spain)
erzog, P. de Meuron arch.

Advice

To make optimum use of natural resources

1**. analyse the site's potential** (select the most efficient resources)

An environmental study of the site should be conducted, including:

. a soil survey (conductivity and the hydrology system)

. a study of solar exposure (the best orientation)

. a wind study, the "wind rose" (detect the prevailing winds)

. a rain study (estimate the amount of retrievable water)

2. If possible, **consider several systems to optimize renewable resources** in relation to the building's needs

3. **Avoid implementing expensive devices if benefits is not conclusive**

4. **Collect also information** about the context (urban, legislative etc)

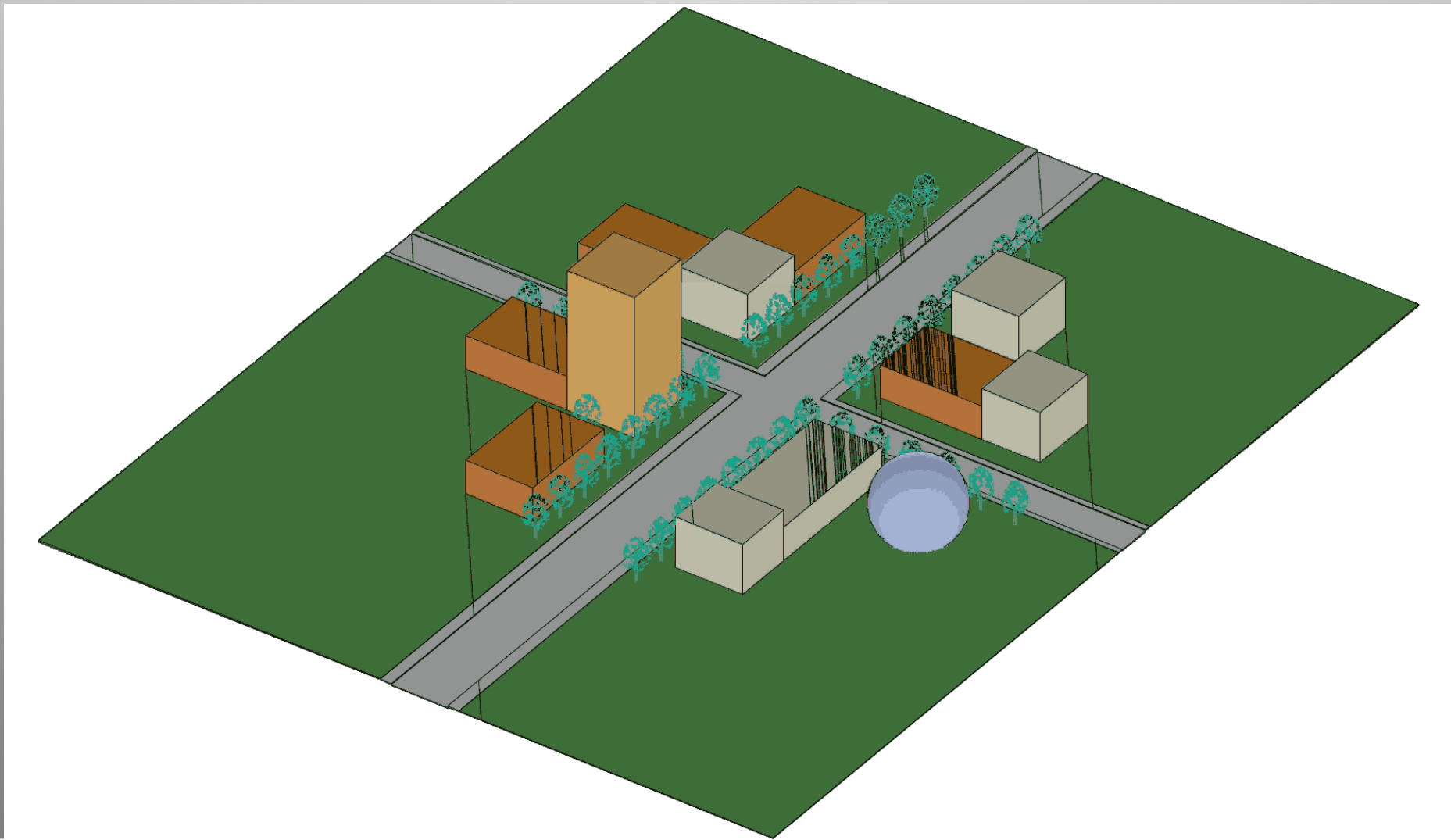
. in case of natural ventilation: check that air intakes are properly placed

. in case of rainwater retrieving: check that this is compatible with national legislation.

5. **Ask for specific studies**, such as the heliodon, (detect solar masks)

Example of heliodon

calculated on the 21st of June (summer solstice), in Paris
from sunrise to sunset



To conclude

- The building's envelope: in relation with the local climate.

- Role of climate today: a major player as it provides alternative energies.

- Retrieval of this energy remains more expensive.

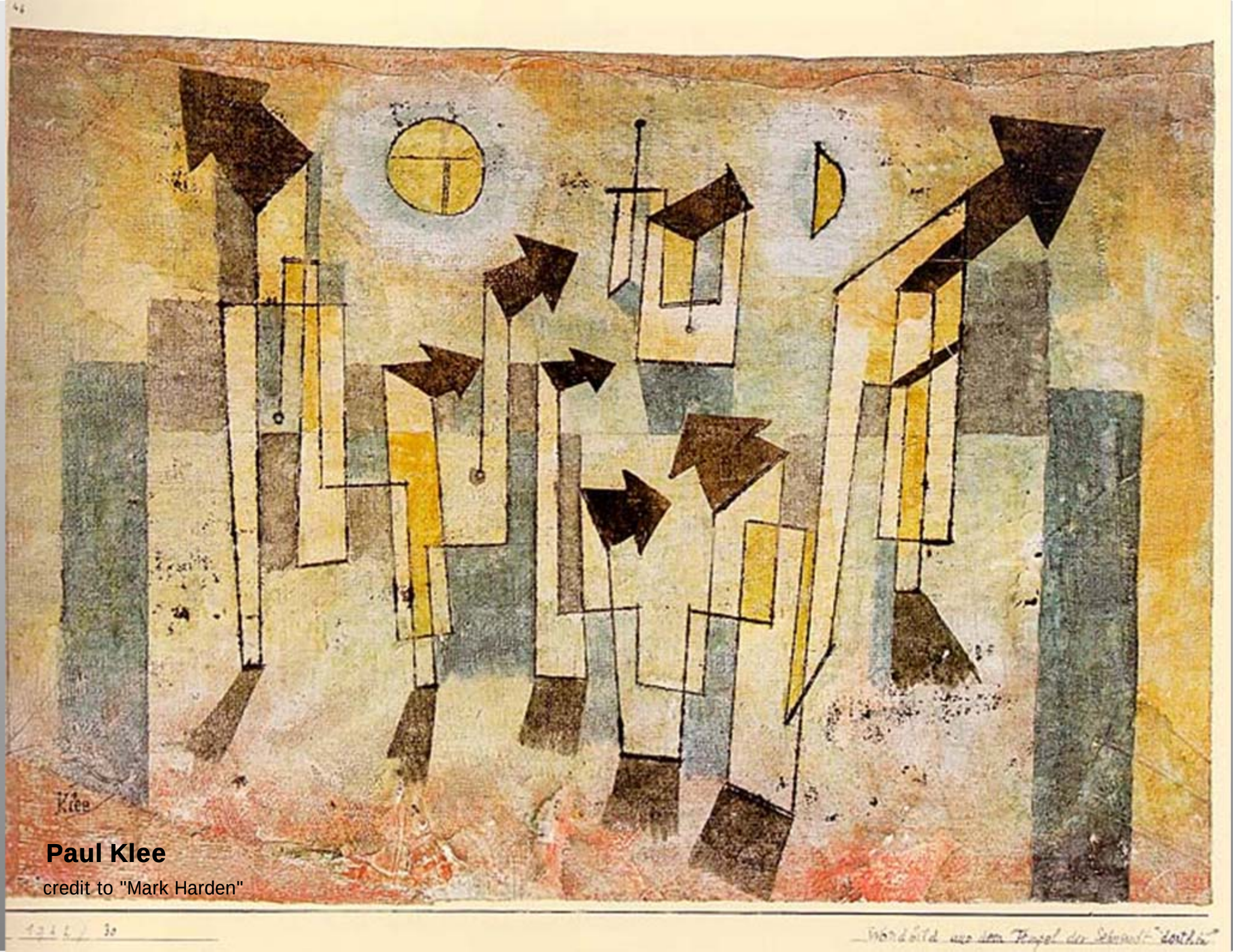
- The building's envelope must be energy-efficient in order to avoid
  - burning fossil fuels
  - wasting this costly energy.

- Actions are of limited use: if we fail to consider the logical design of envelope.

- This conception demands strict rules of use: not to upset the efficient natural mechanism

- Similarly, the maintenance of these buildings: an understanding of the relation between the building's envelope and climate,

- so as not to counteract the building's logic and therefore its energy performance.



Paul Klee

credit to "Mark Harden"