P5 presentation
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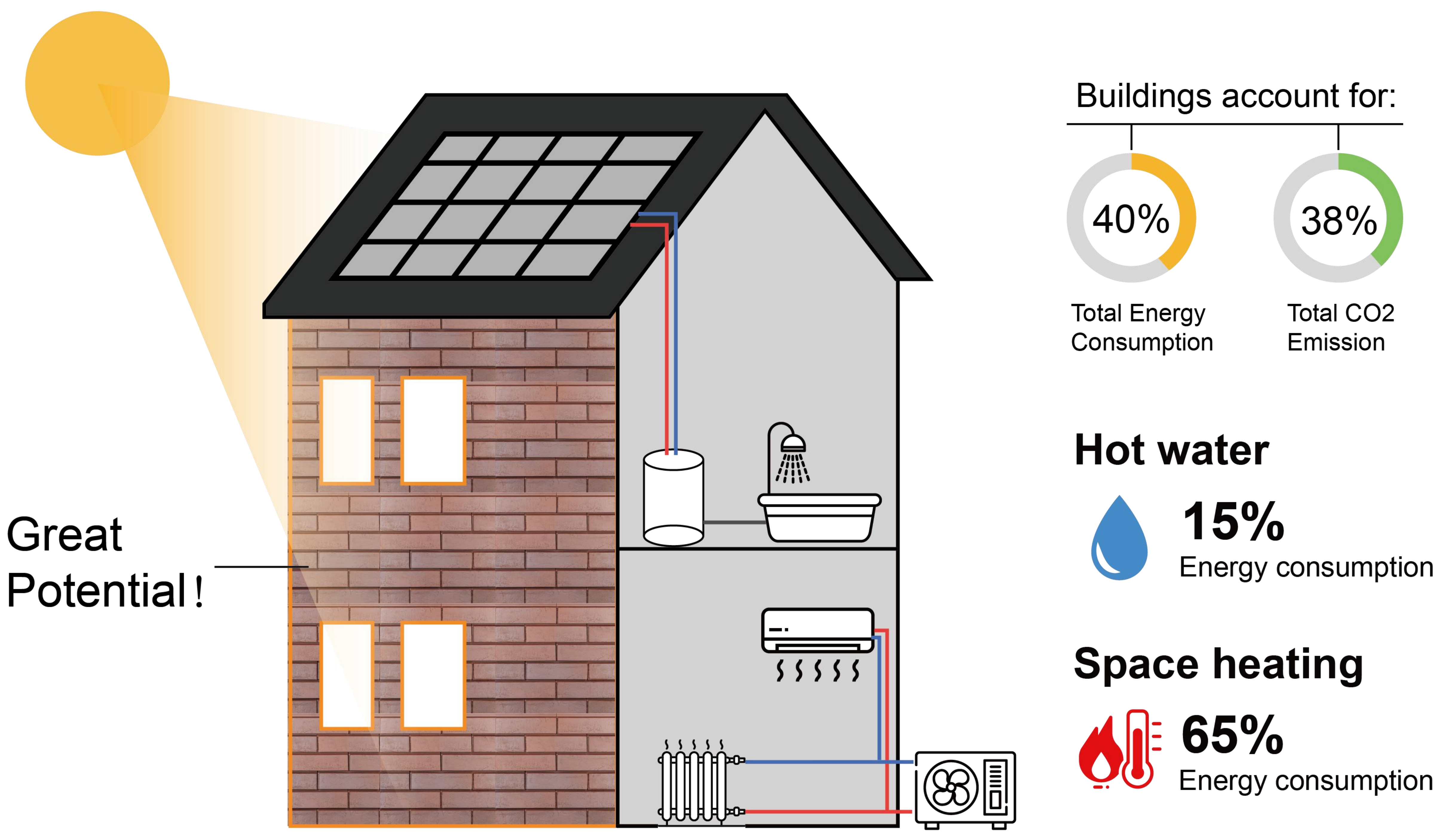
A-Brick ASTF

Exploring feasibility of engineering A-Brick system as an Active Solar Thermal Façade (ASTF)

Chapter 1 Research background

Challenge and opportunities

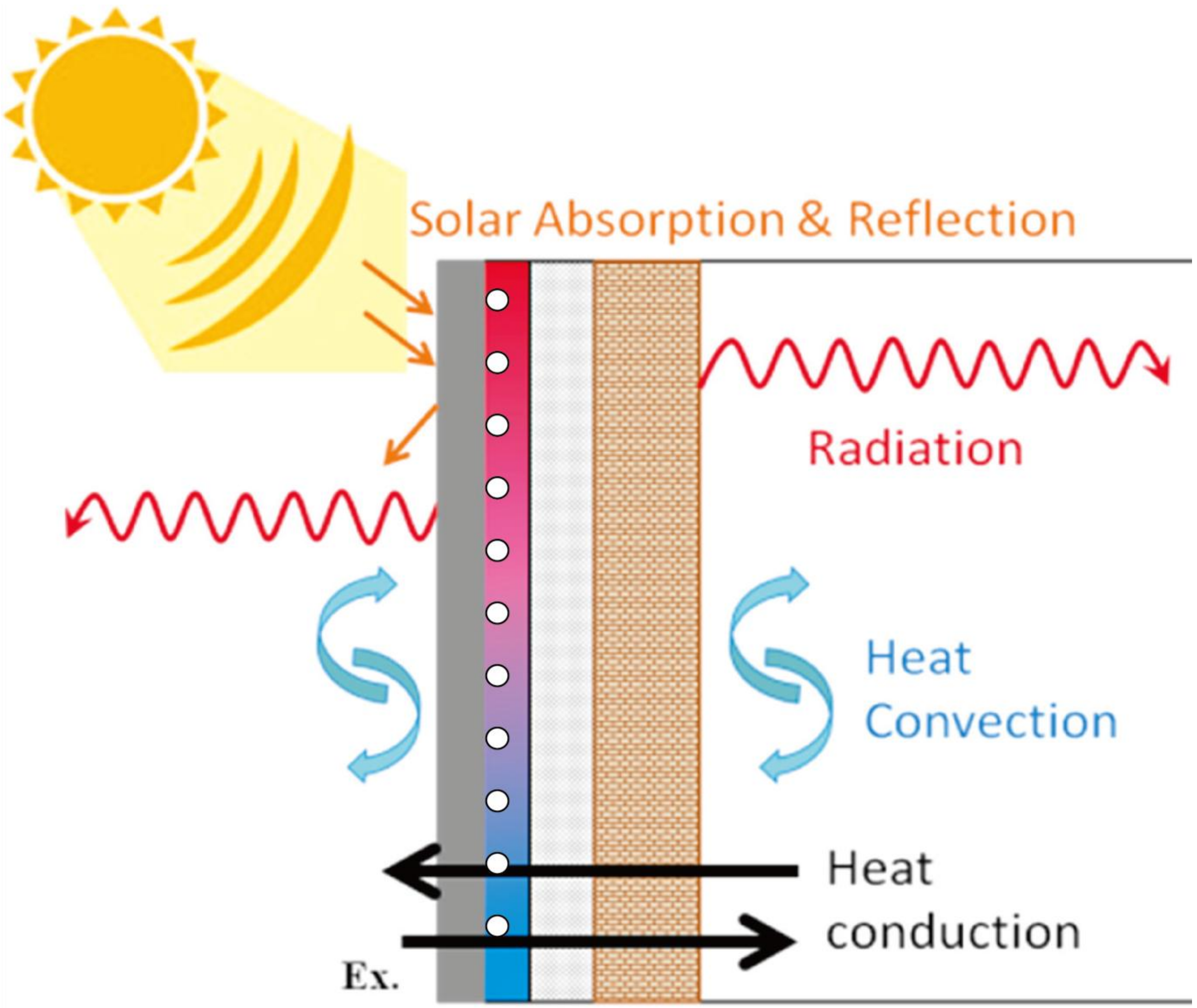


Can we use building façade to collect solar energy?

Challenge and opportunities

Can we use building façade to exchange heat?

Solution: Active Solar thermal façade (ASTF)



Active solar thermal facade

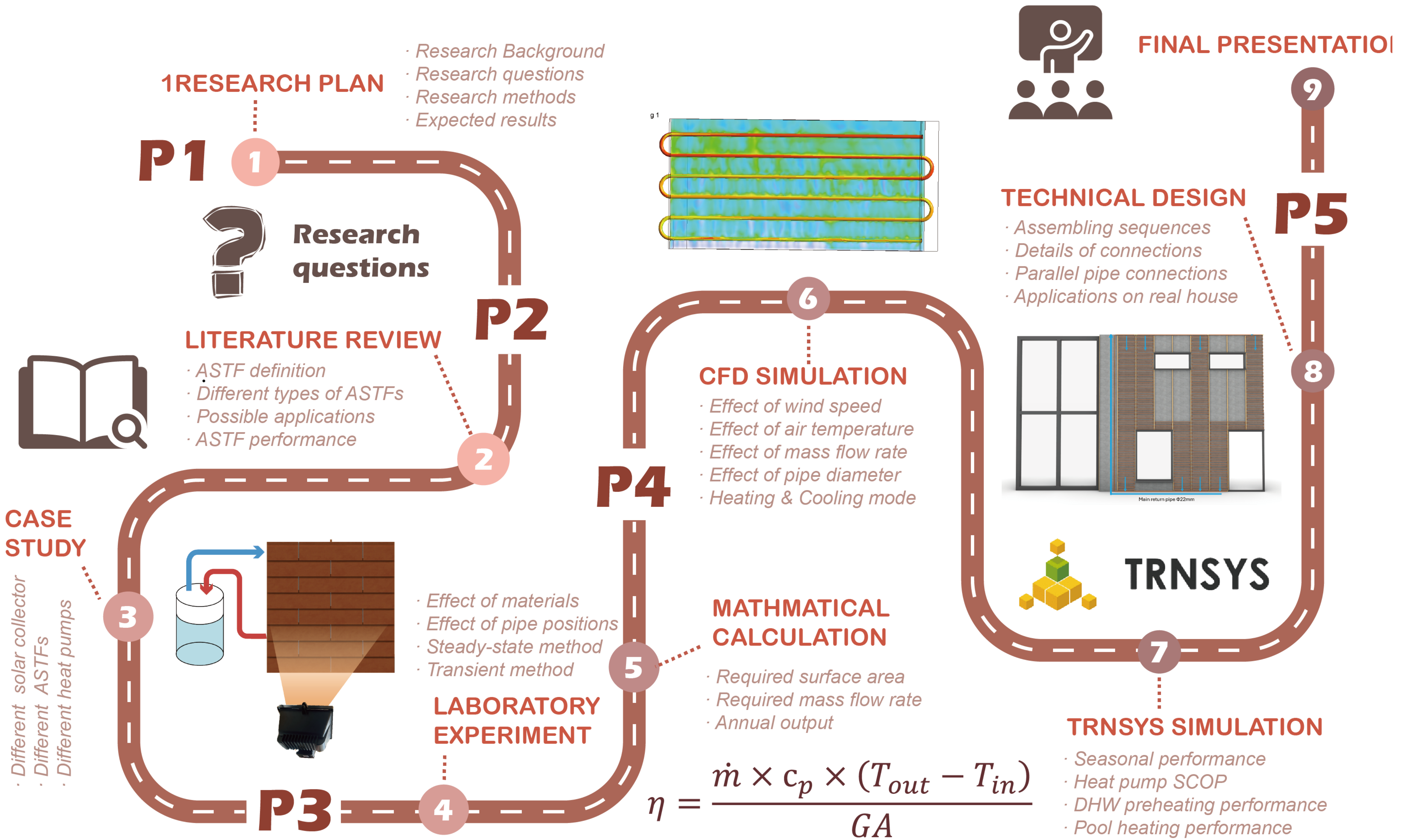
A-Brick ASTF concept

What **building energy systems** are applicable?

What is the **thermal performance** of A-Brick ASTF?

What is the **technical design** of A-Brick ASTF?

Research Road map



Chapter 2 Literature & case studies

*"What **building energy systems** are applicable?"*

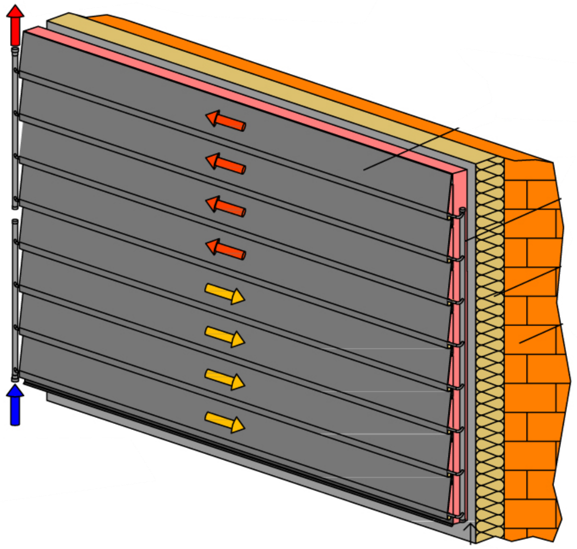
Features of A-Brick ASTF

A-Brick ASTF (Ceramic unglazed ASTF):

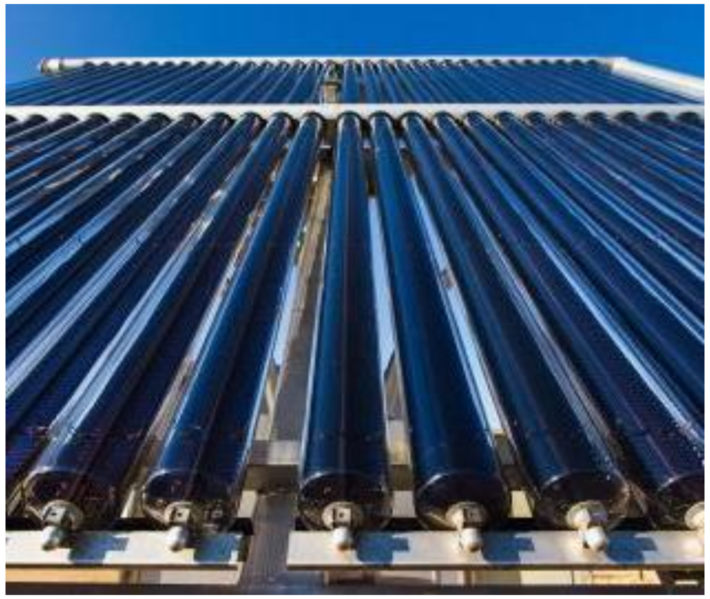
1. Lower temperature (30-50 °C)
2. Both collect and release heat
3. Large thermal mass

Categorized By **structure**:

Glazed ASTF (60-80°C)



Unglazed ASTF (30-60°C)



Vacuum tube ASTF (80-100°C)

Categorized By **material**:

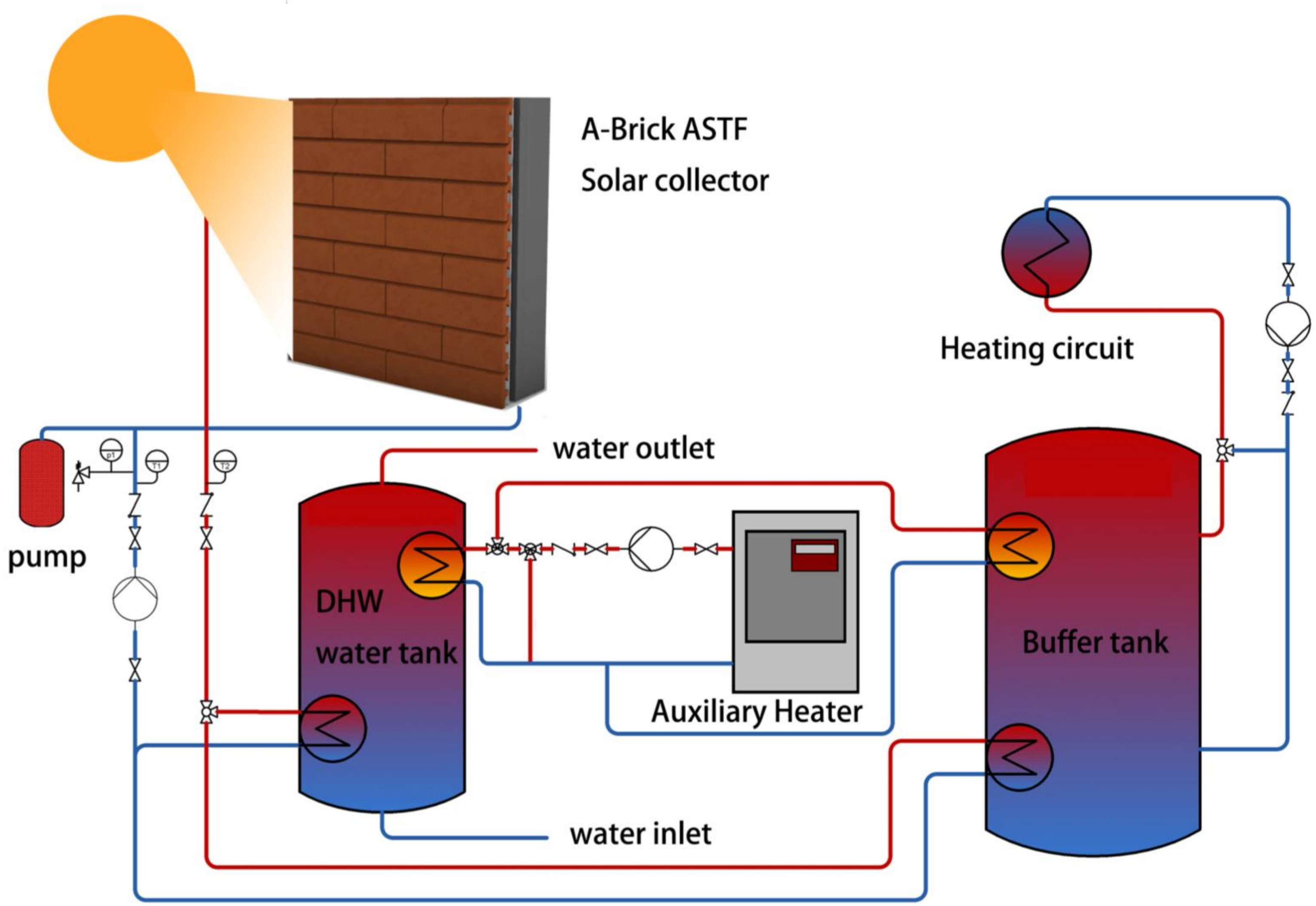
Metal-plate ASTF

Concrete ASTF

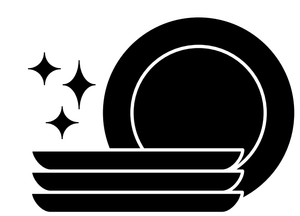
Ceramic ASTF

Dometic hot water preheating

1. DHW preheating: **25-40 °C** , further heated up to **60 °C** by **auxiliary heater**
2. Might provide **20–40%** of annual water heating load
3. Seasonal operation during **March to September**



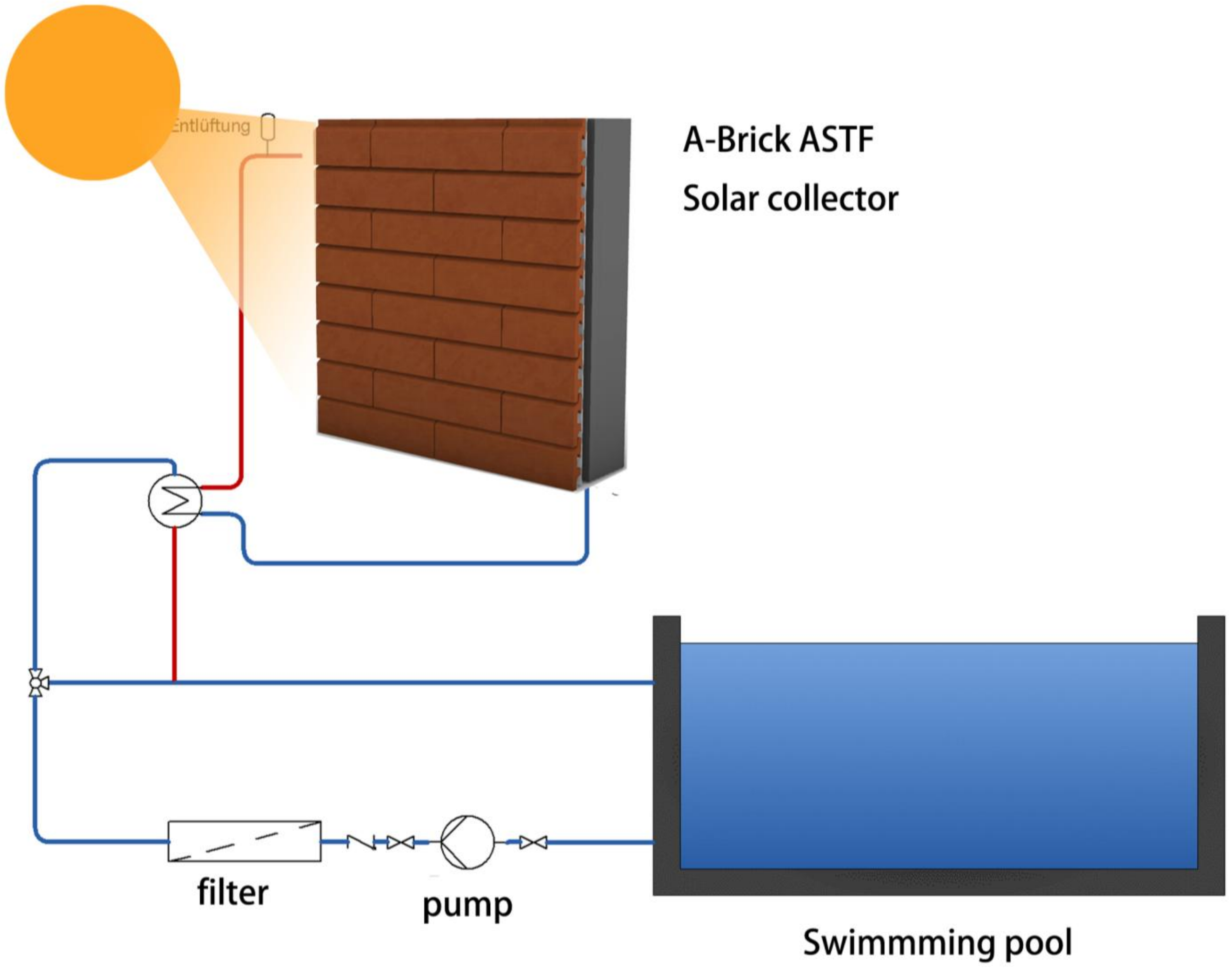
Shower



Washing

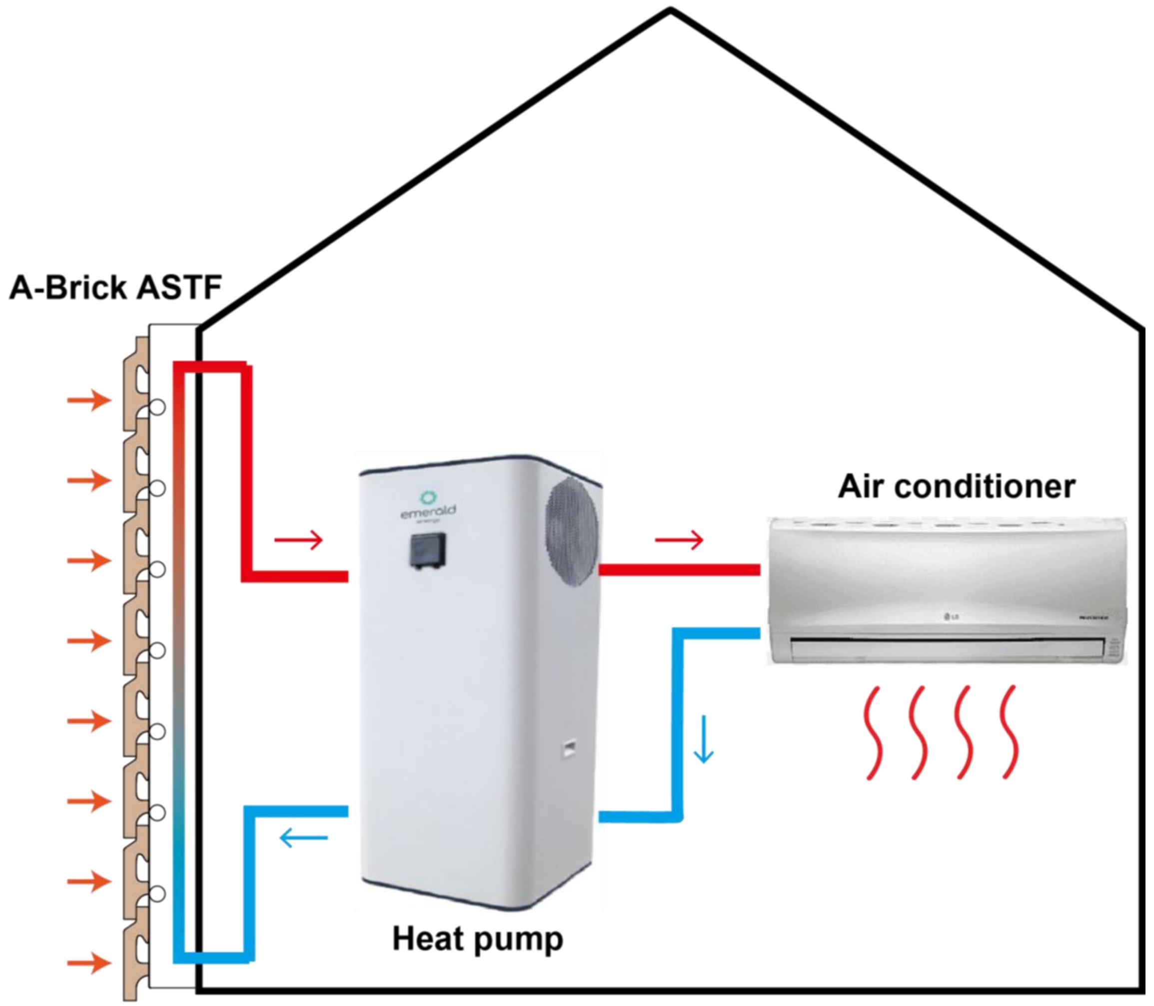
Swimming pool heating

1. Swimming pool generally demands between 28°C and 31°C water.
2. Need 4000L/h water flow, might need large surface
3. Seasonal operation during **March to September**



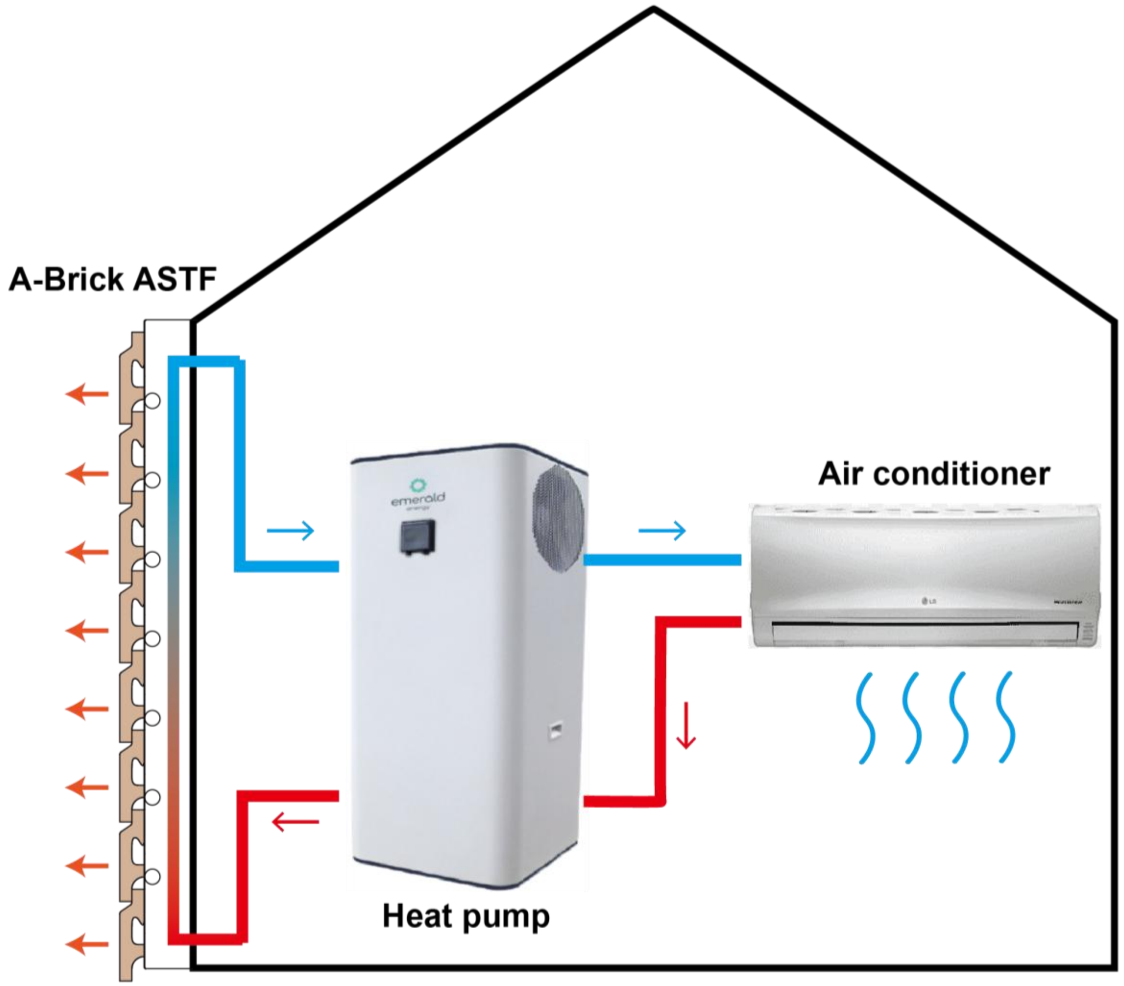
Air source heat pump

1. Heat pump use **electricity** to transfers **heat** from a **low-temperature source** to a **higher-temperature sink**
2. ASTF serve as an **outdoor unit**, enable both space **heating** and **cooling**.



Winter heating mode

Absorbing heat

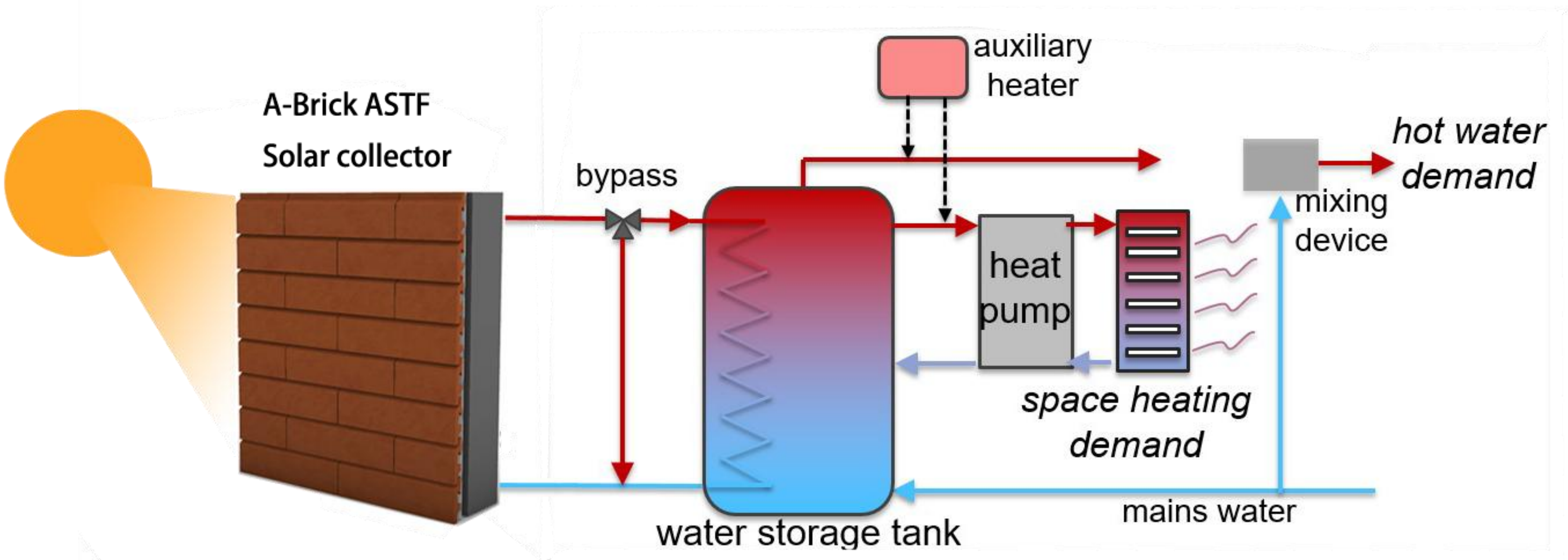


Summer cooling mode

Releasing heat

Solar assisted heat pump

1. ASTF serves as additional heat source, enhance heat pump **COP**.
2. Only heating mode for **domestic hot water** and **space heating**



Chapter 3 Experiments & software simulation

*"How is the **thermal performance** of A-Brick ASTF?"*

Laboratory experiment instruments and setup

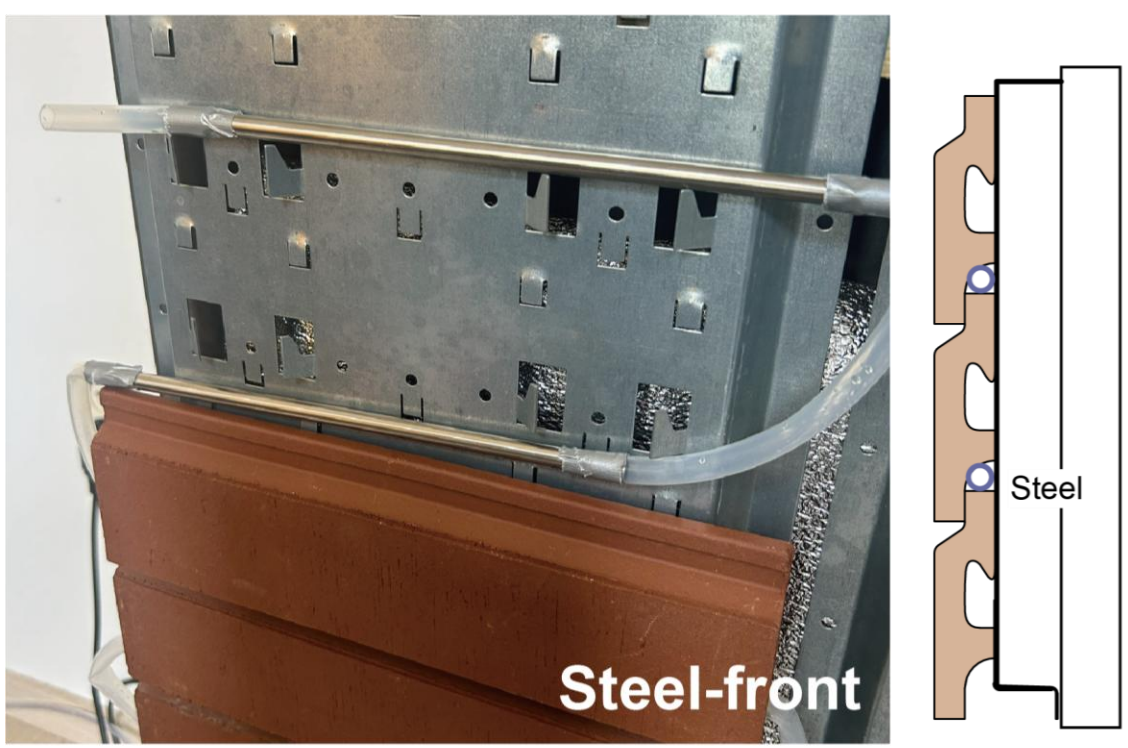
Indoor experiment setup

Experiment instruments

Different experiment configurations

Front-mounted PVC pipe

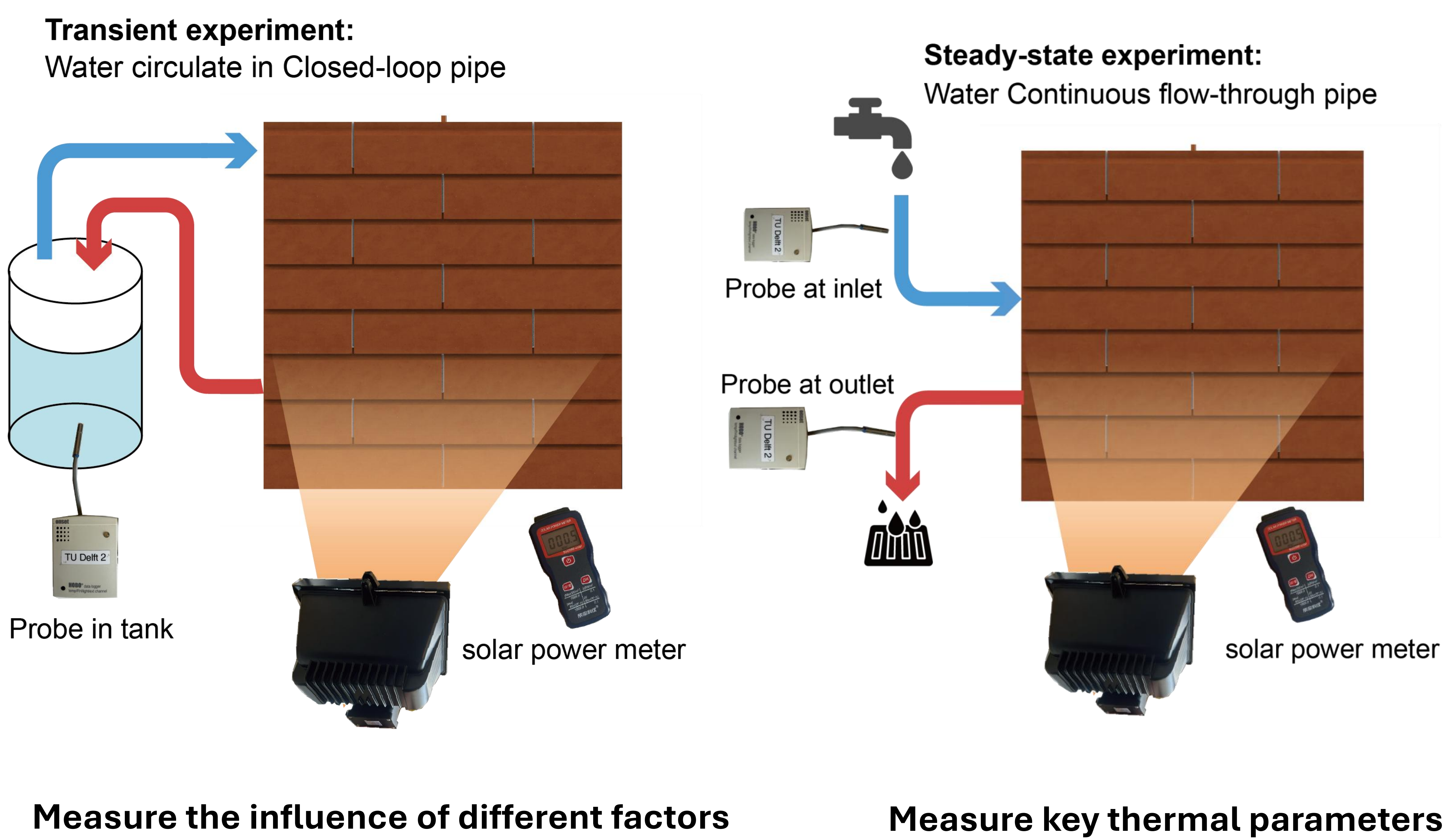
Back-mounted Copper pipe



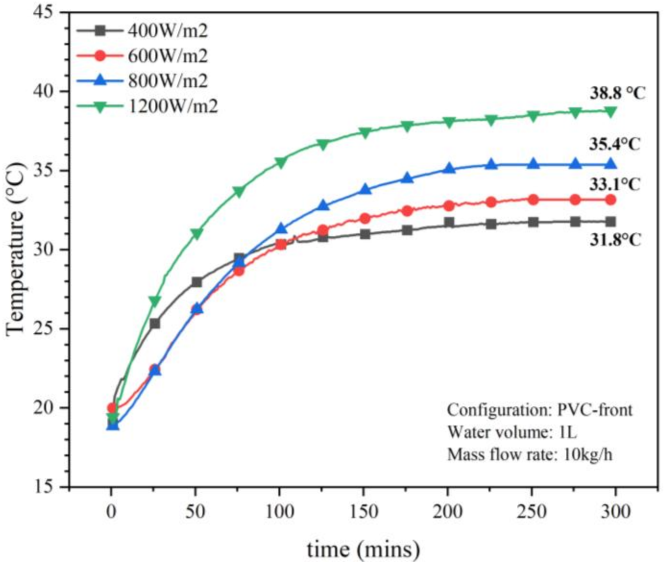
Front-mounted Steel pipe

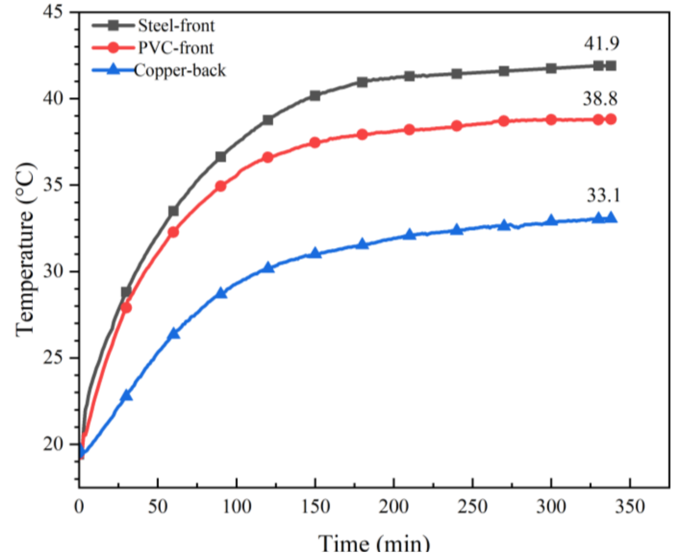
Back-mounted Steel pipe

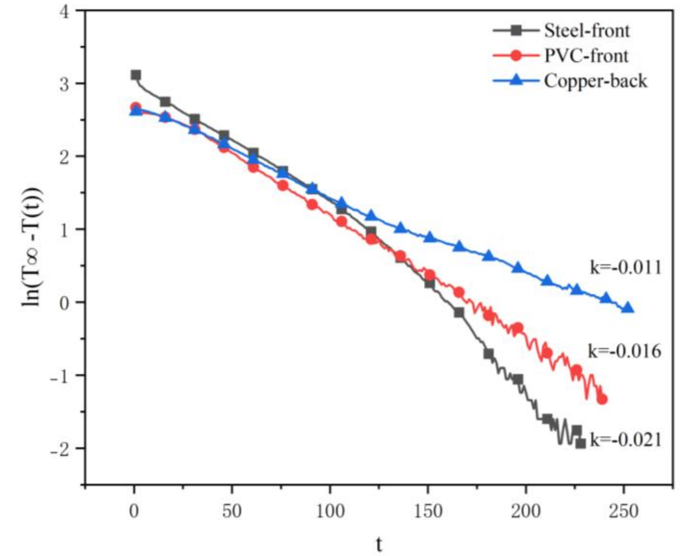
Two experiment methods

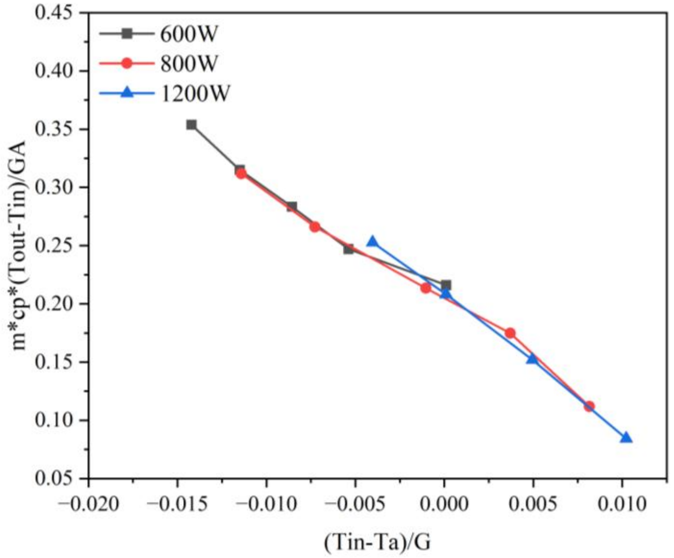


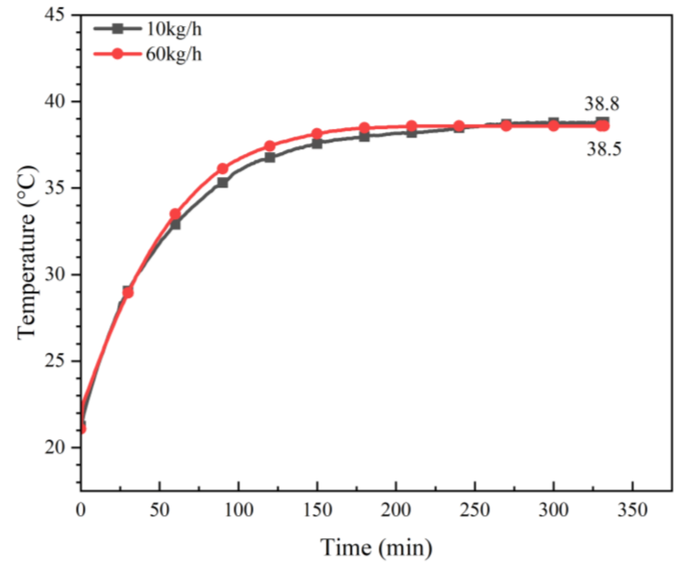
Experiment results

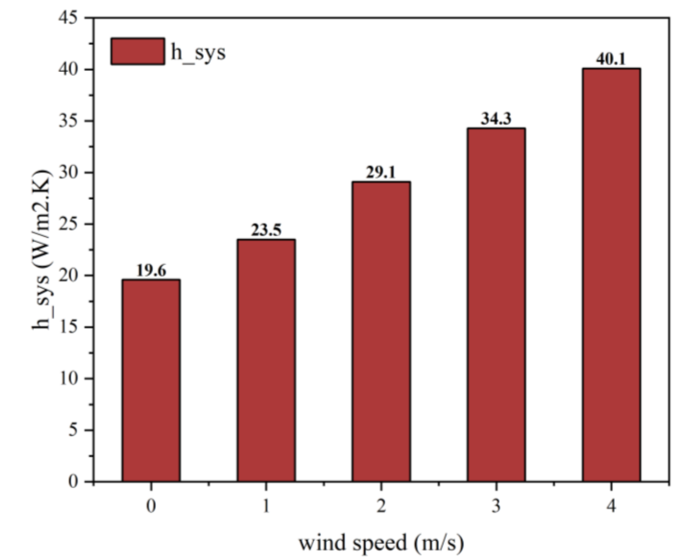


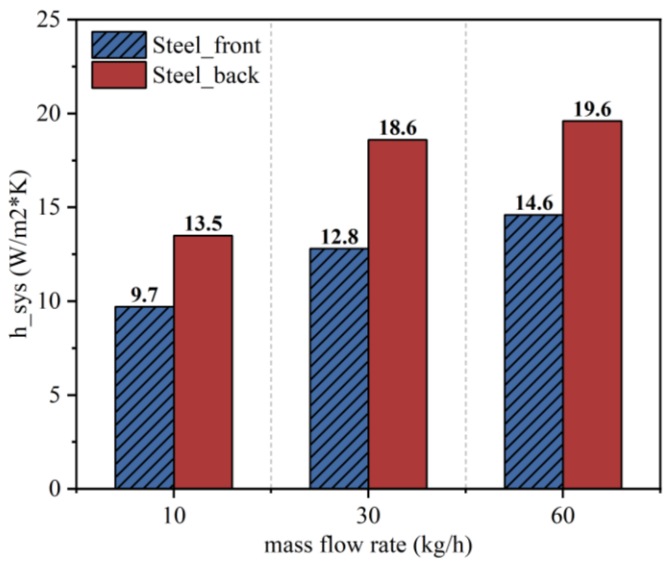


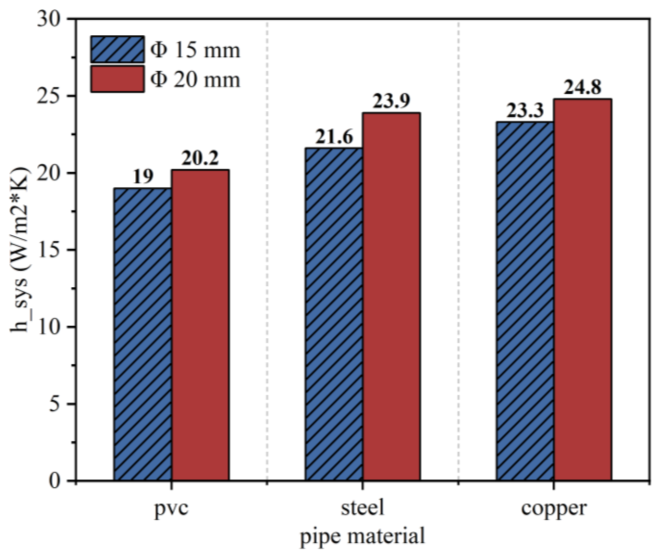


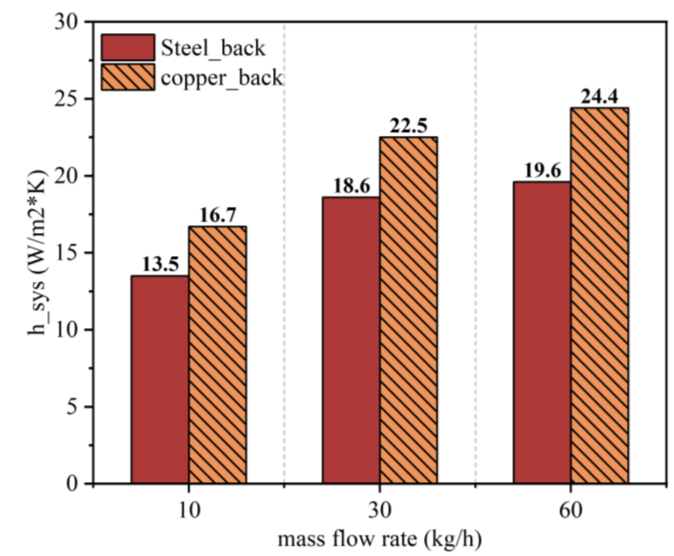












ANSYS CFD simulation

Objective:
Simulate $\mathbf{h}_{\mathbf{sys}}$ under heat pump working conditions

Water flow rate: >1000L/h
Fluid temperature: -20°C - 50 °C

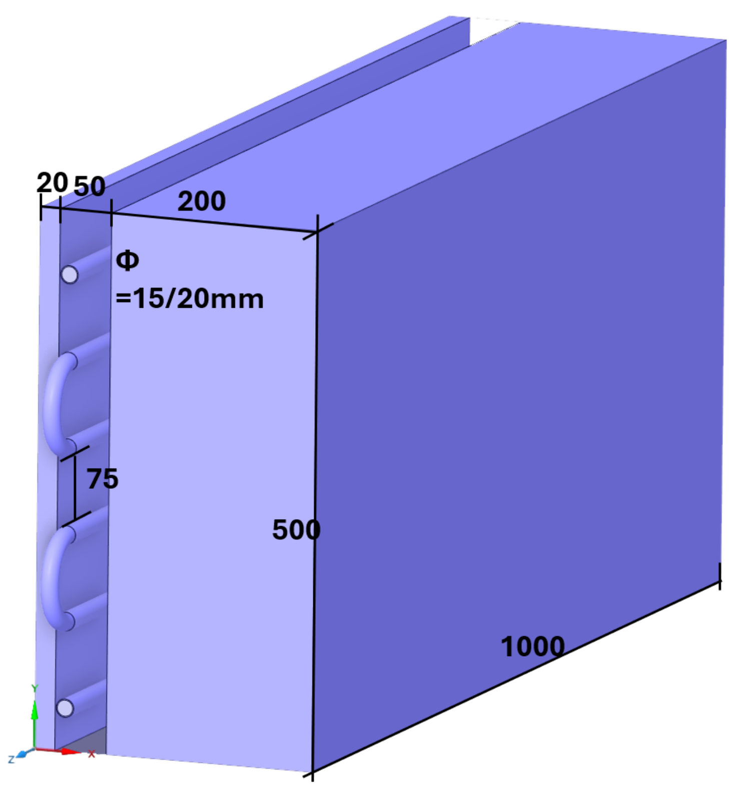


Figure : Simplified model for ANSYS simulation

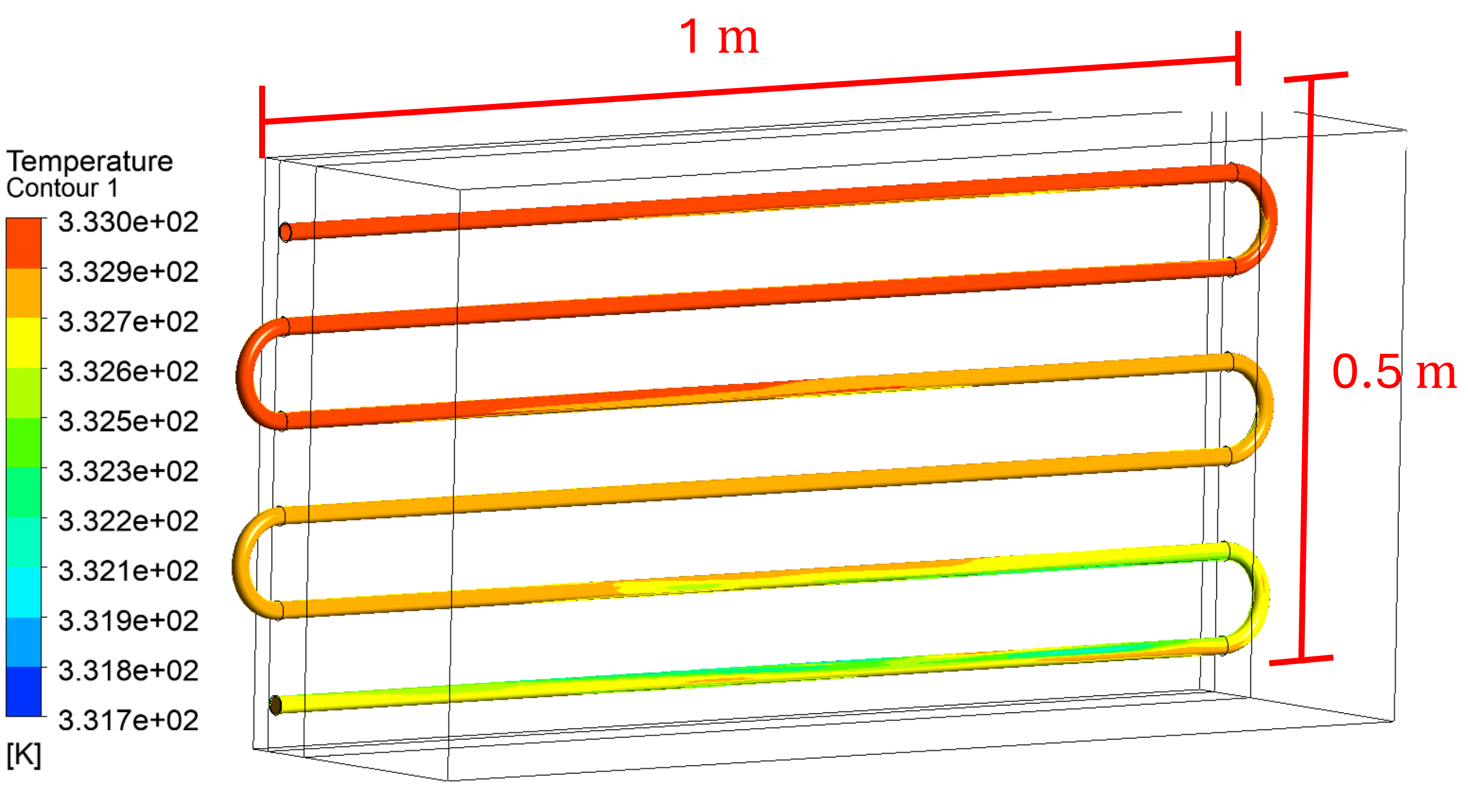


Figure :Water temperature profile in cooling mode

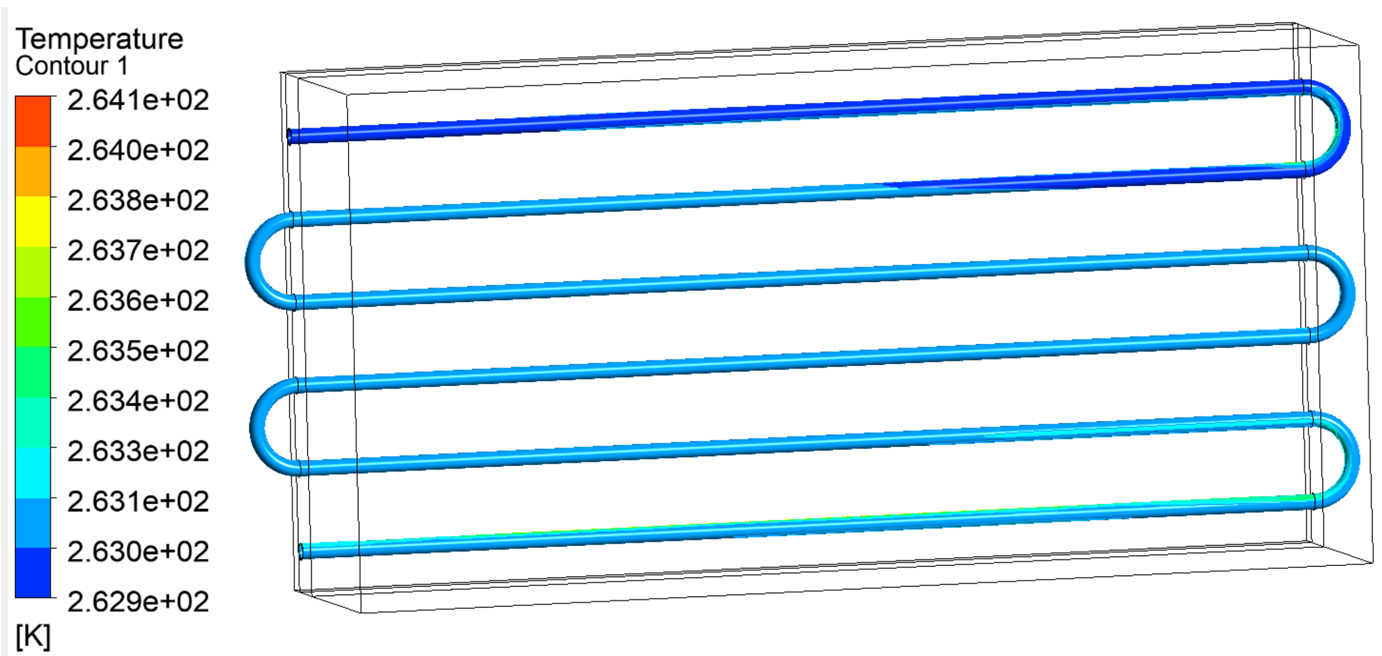
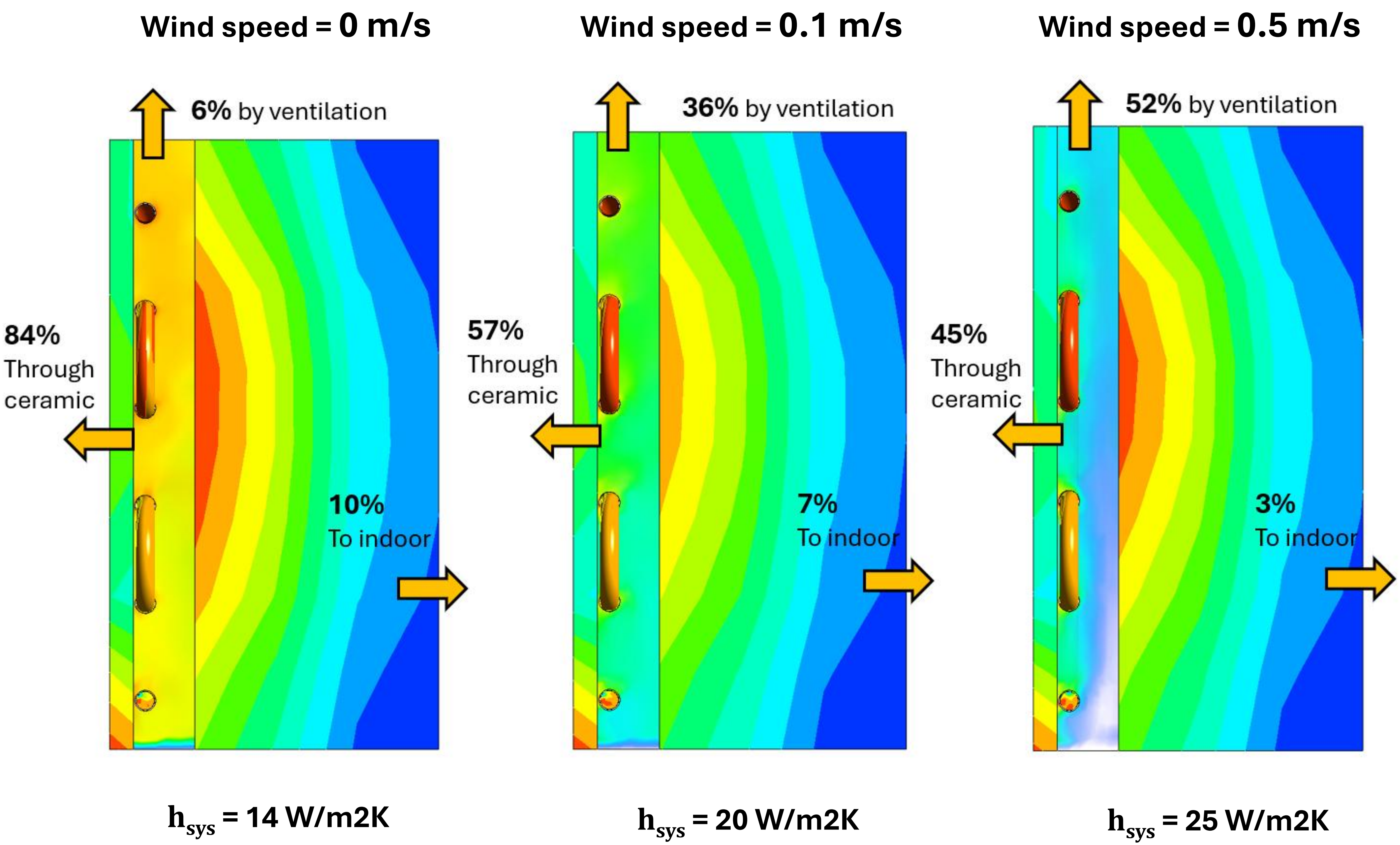


Figure : Water temperature profile in heating mode

Software simulation



Results

Thermal properties of A-Brick ASTF heat collector

A-Brick ASTF

Metal-plate ASTF

Glazed solar collector

	A-Brick ASTF	Unglazed metal-plate ASTF	Glazed Flat-plate collector
Water temperature	T_{∞} = 30-40°C	T_{∞} = 45-55°C	T_{∞} =60°C-80°C
Collector Efficiency	η = 20%	η = 45%	η = 60%
Heat removal factor	F_R = 0.25	F_R = 0.50	F_R = 0.80
Heat loss coefficient	h_L = 41 W/ m2K	h_L = 25 W/ m2K	h_L = 5 W/ m2K

Thermal properties of A-Brick ASTF heat exchanger

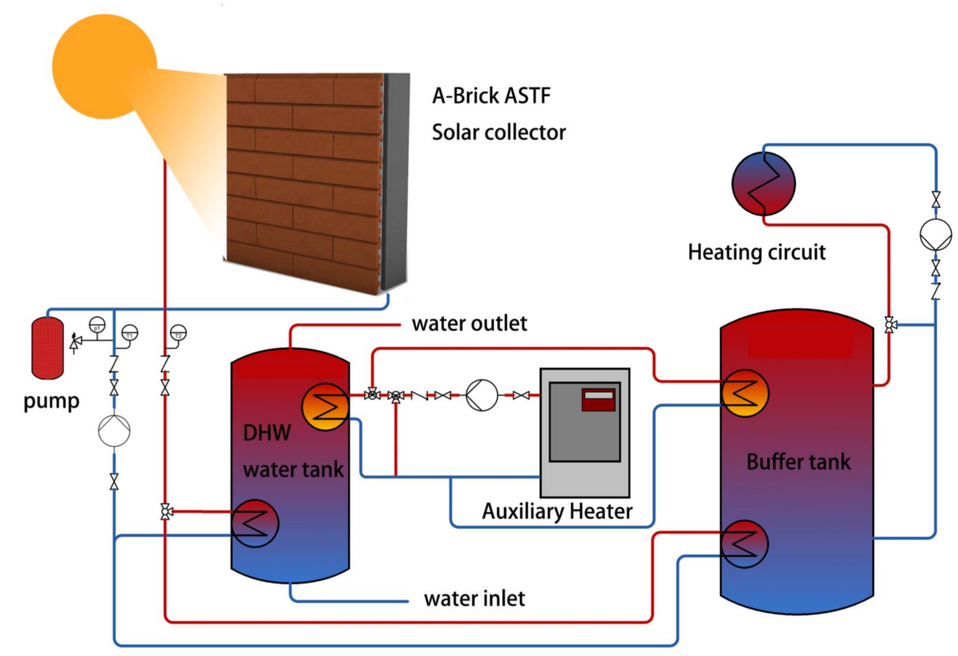
A-Brick ASTF

h_{sys} = **14-25** W/ m^2 K (façade surface)

Outdoor fan unit

h_{sys} = **25-50** W/ m^2 K (metal fin surface)

Results of DHW preheating



For a single-family house (**200L per day**):

Average ASTF thermal power: $\dot{Q} = \mathbf{78W/m^2}$

Annual output: $Q = \mathbf{313\ kWh}$

Required ASTF surface：

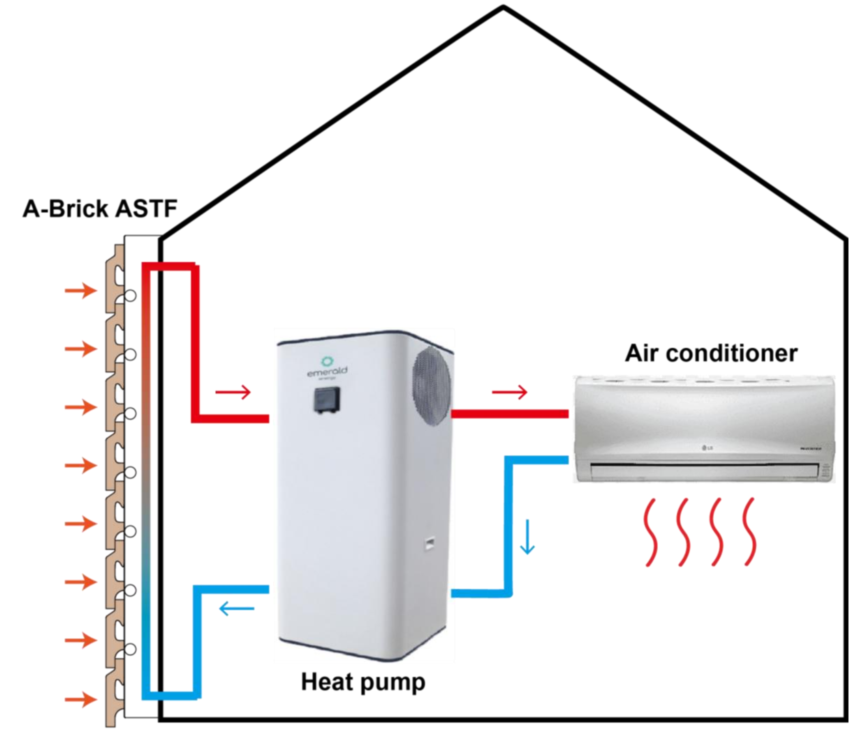
$$A = \mathbf{10.8m^2}$$

Results of heat pump

For a 150m2 single-family house (**6kW heat pump**)

Heat pump Seasonal COP: **4.2**

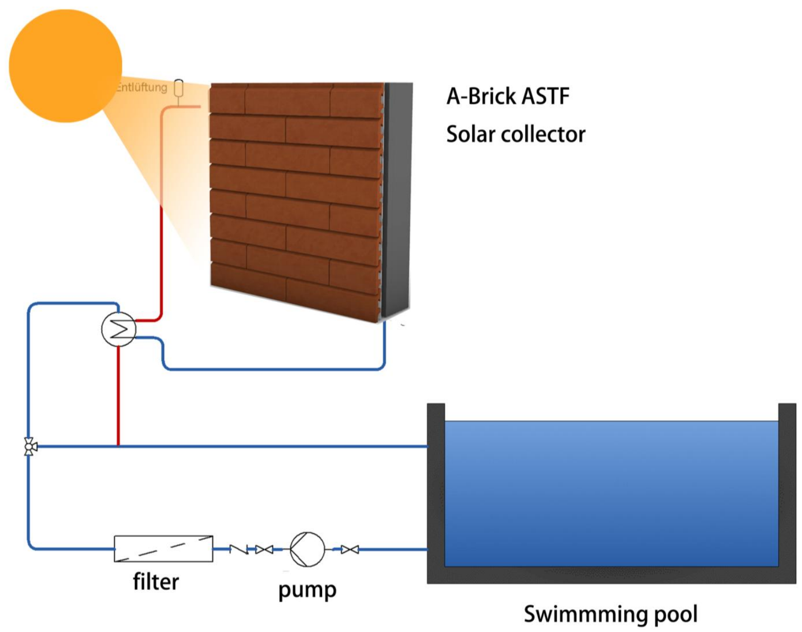
1kWh electricity ➡ 4.2 kWh heat



Required ASTF surface：

$$A = \mathbf{22.8m^2}$$

Results of swimming pool heating



For a **30m2** family swimming pool:

Average ASTF thermal power: $\dot{Q} = \mathbf{52W}/\boldsymbol{m^2}$

×4

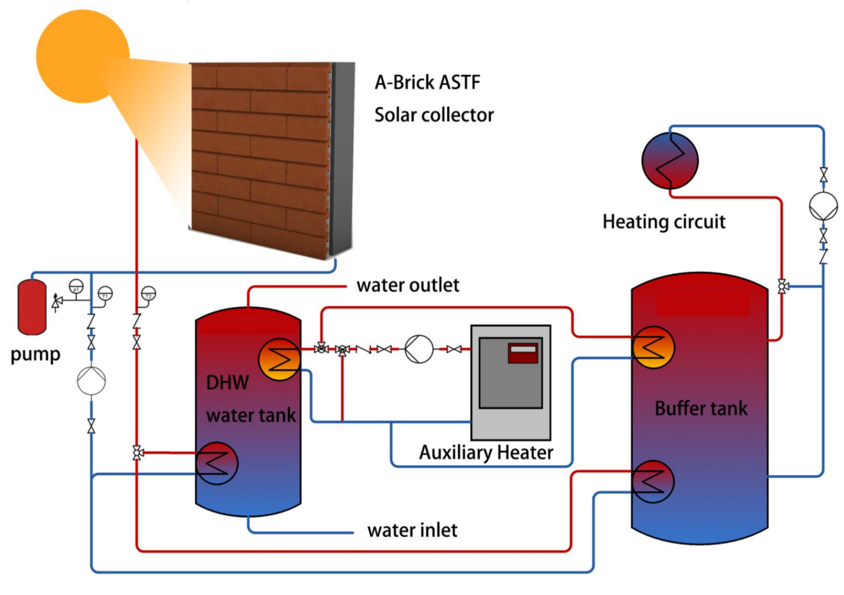
Required ASTF surface：

$A = \mathbf{75}\ \boldsymbol{m^2}$

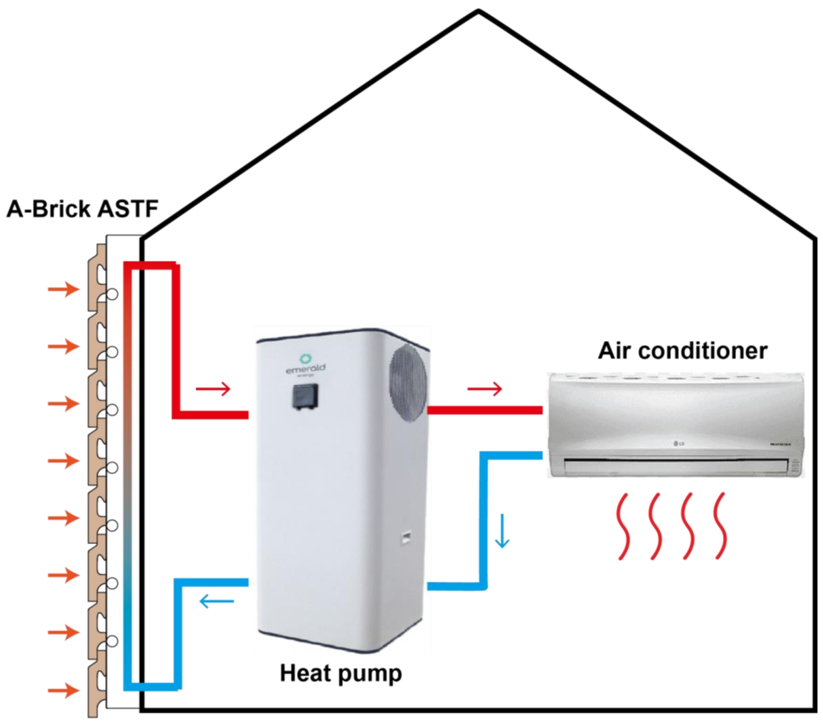
Conclusion

Recommended systems

Recommended

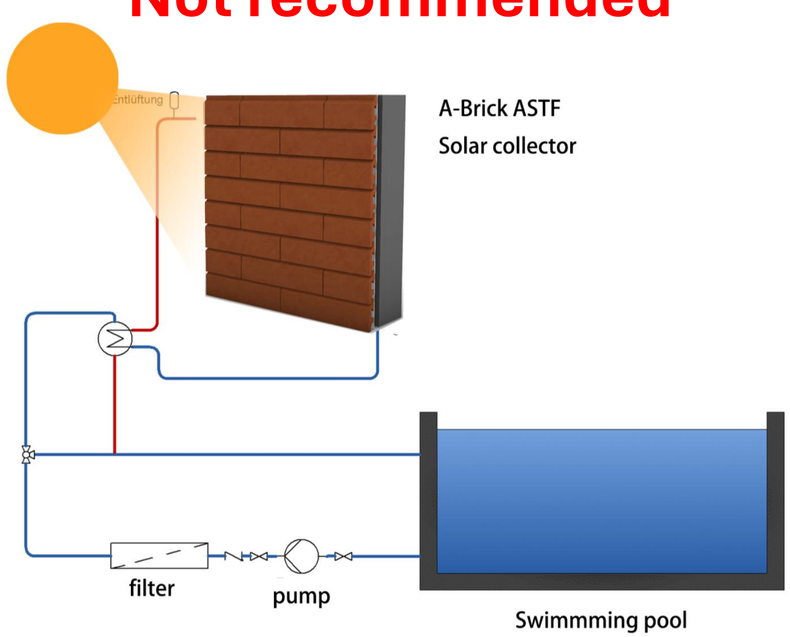


DHW preheating



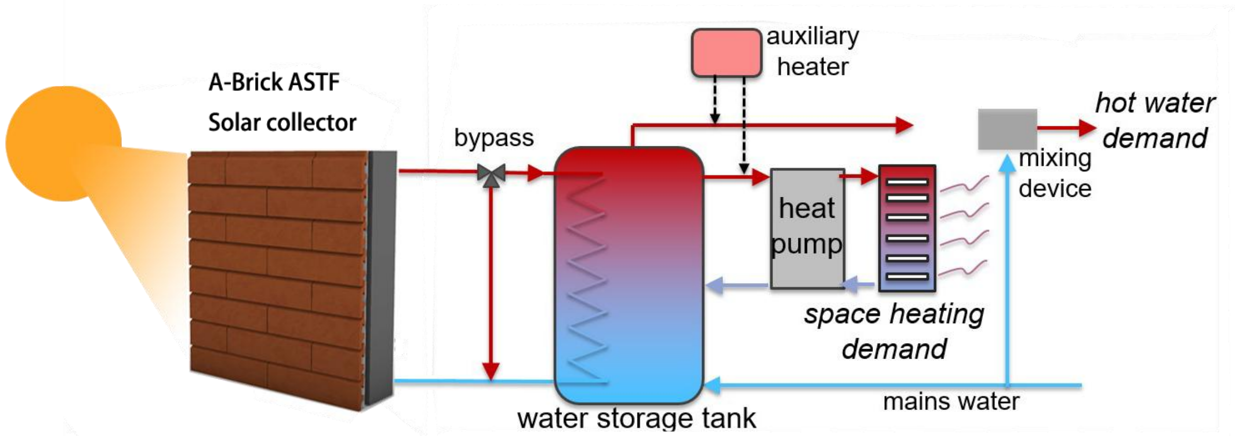
Air source heat pump

Not recommended



Swimming pool heating

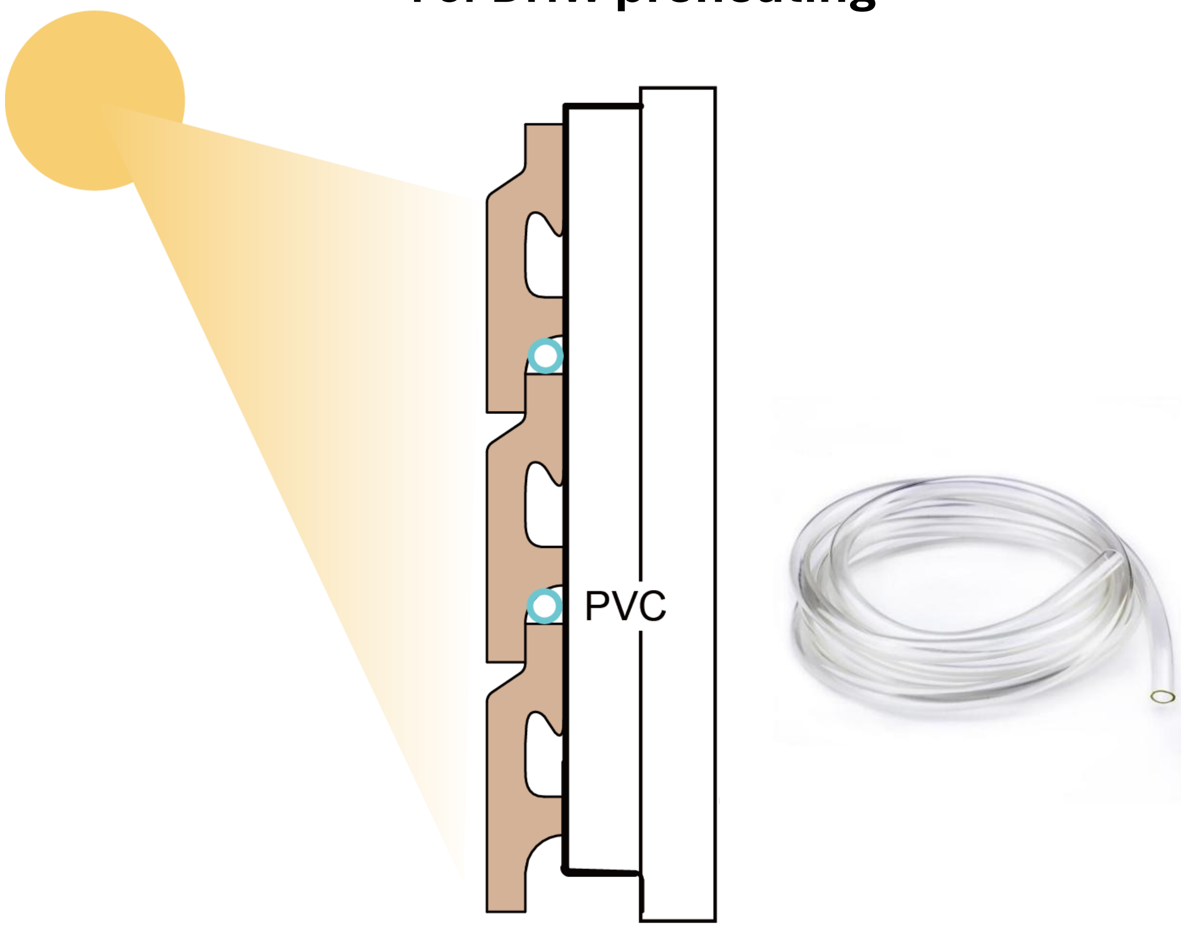
Need to be tested



Solar assisted heat pump

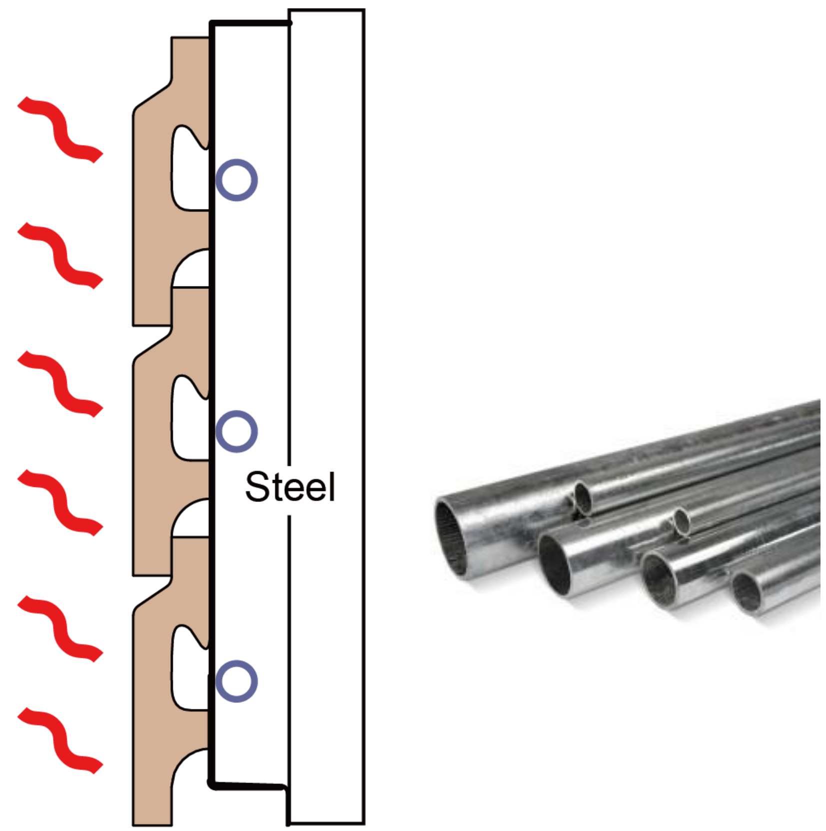
Configuration suggestion

For DHW preheating



Front-mounted PVC pipe

For Air source heat pump



Back-mounted steel pipe

1. **Pipe Position**: **Large impact**

Front-mounted: Better solar heat absorption

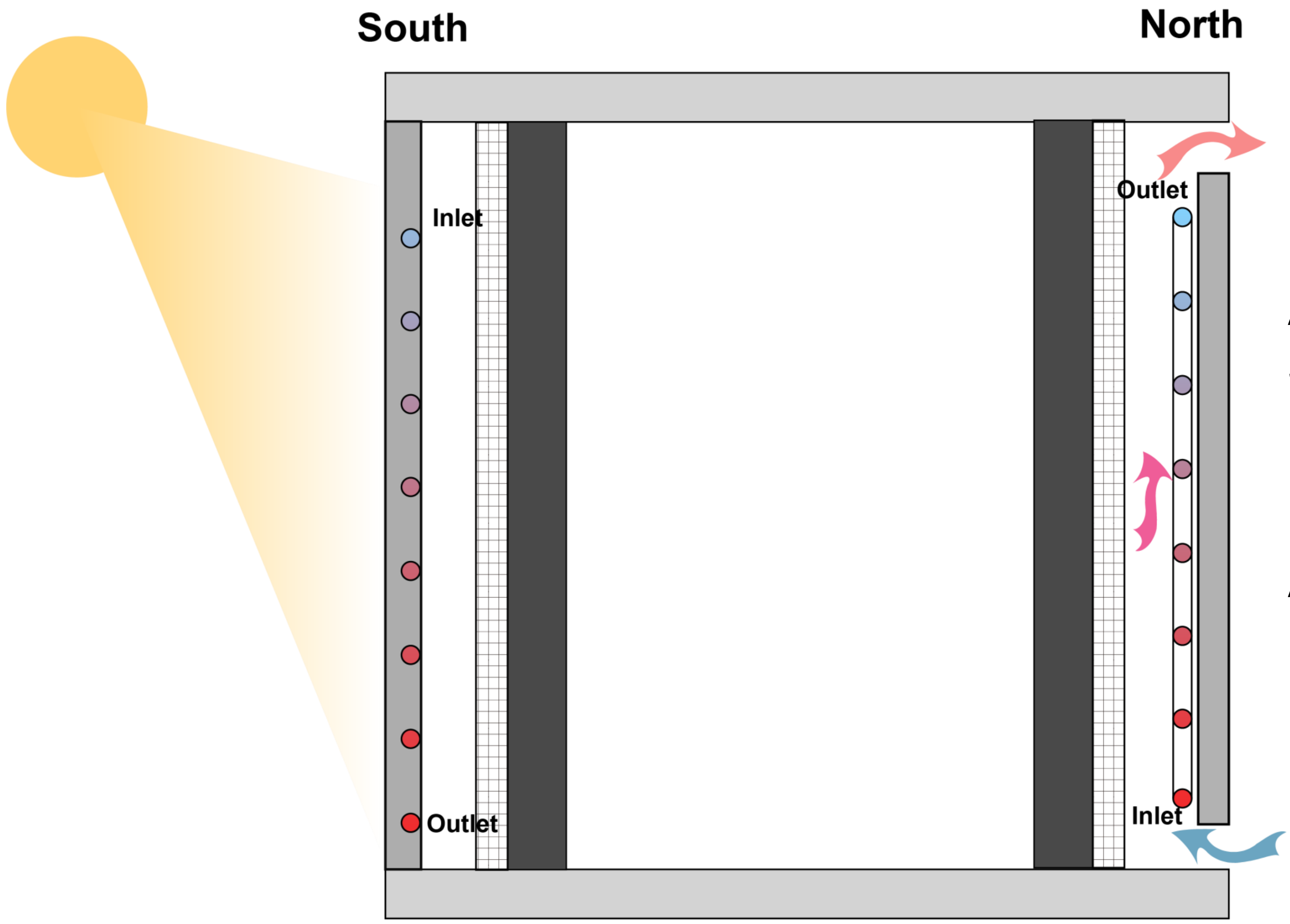
Back-mounted: Better heat exchange efficiency

2. **Pipe Material**: **Small impact**

PVC pipe: Soft, Easy for installation in front

Steel pipe: Robust, cheap

Influence of orientation and ventilation



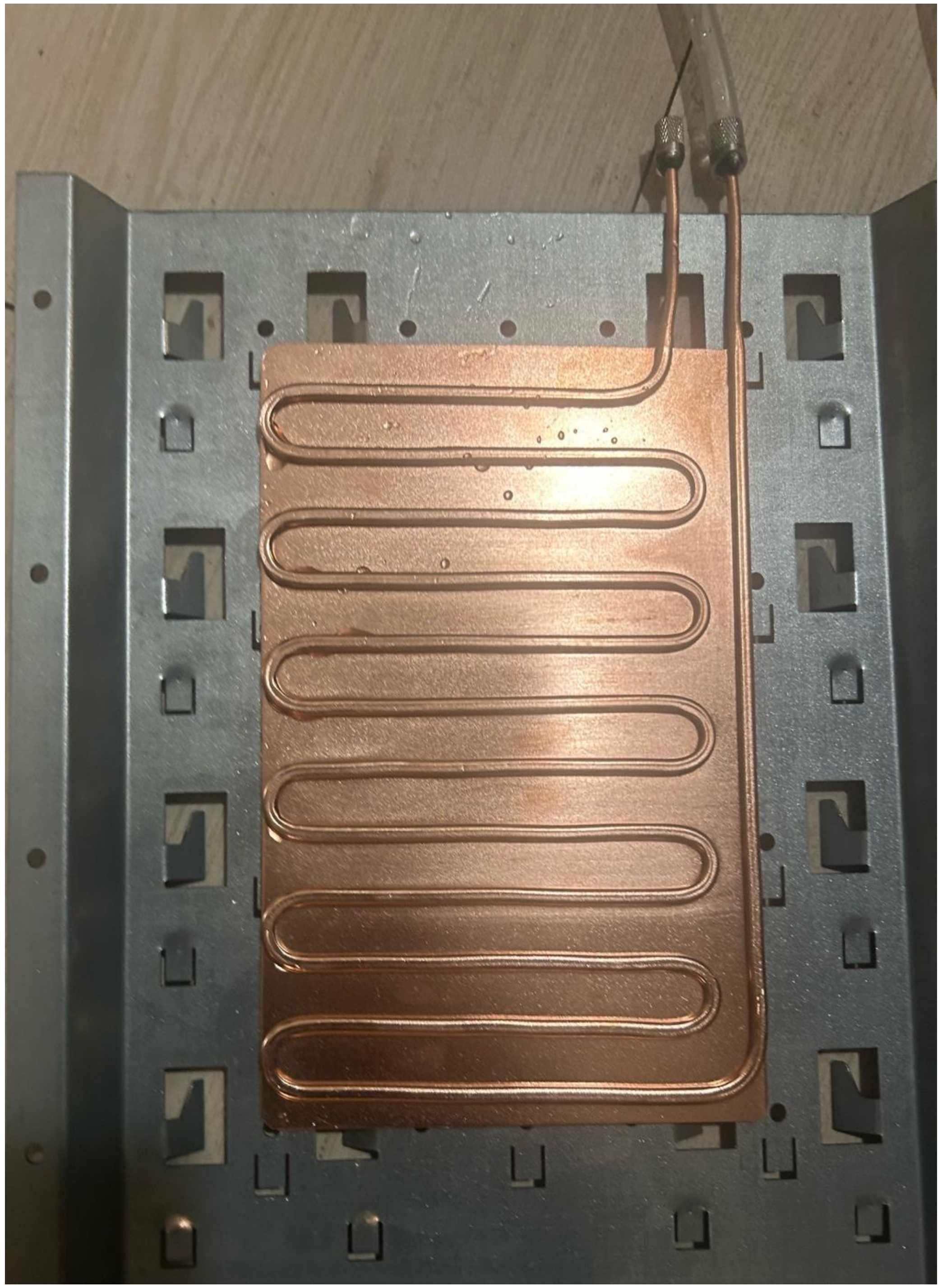
Absorb heat in winter,
Sunlight is not important

Release heat in summer,
Avoid sunlight

DHW preheating:
South façade, reduce ventilation

DHW preheating:
North façade, enhance ventilation

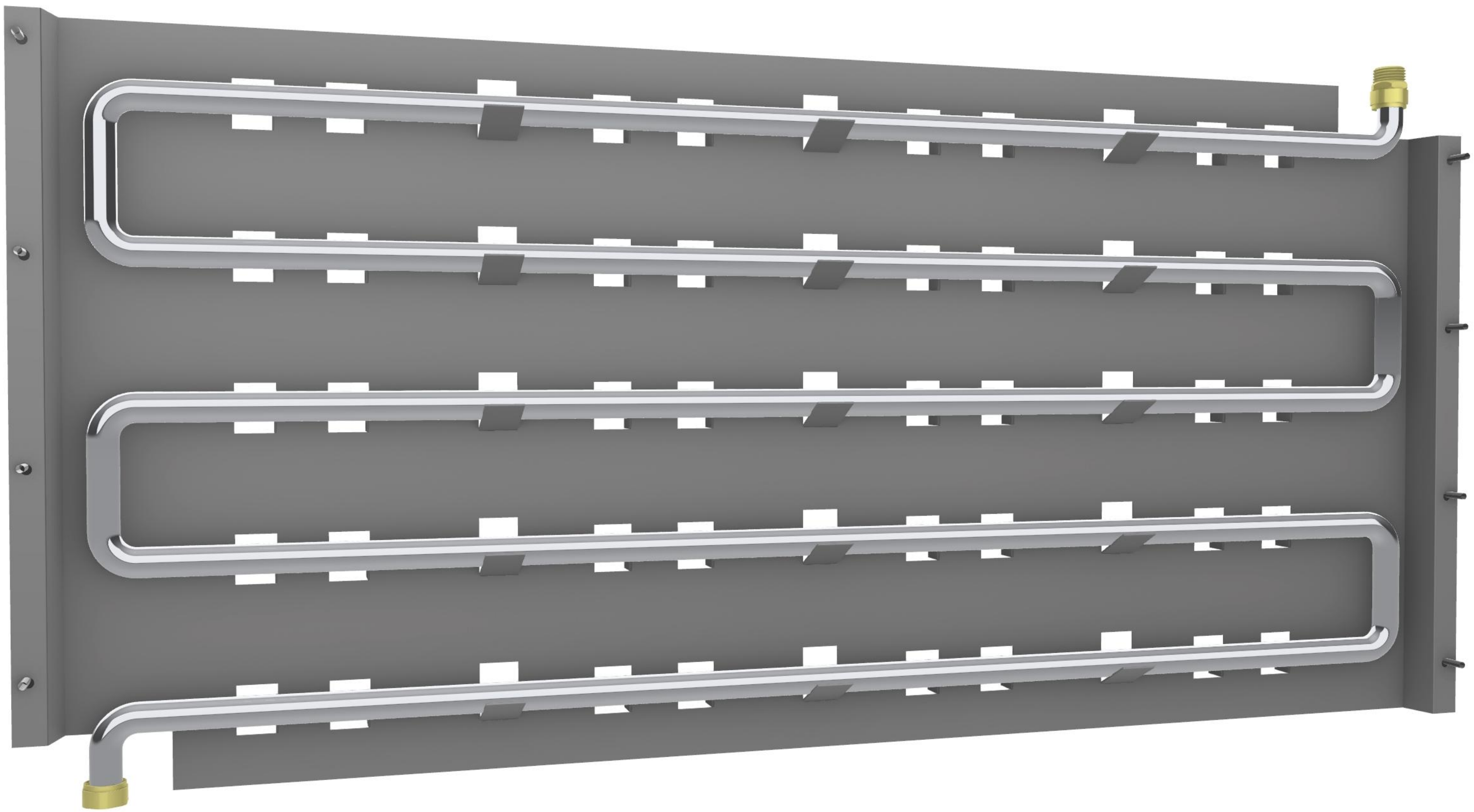
10% of improvement



30% of improvement

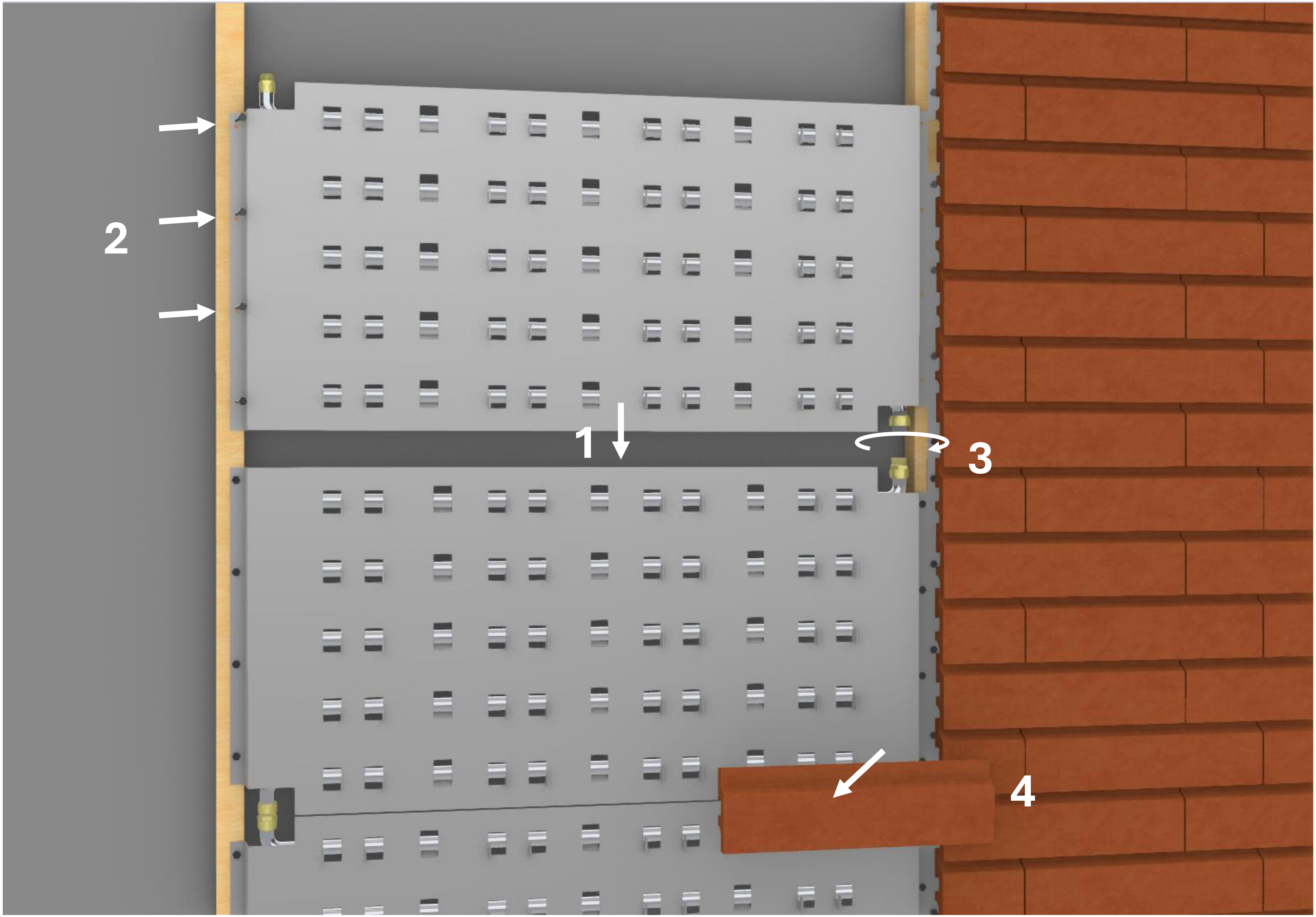
Chapter 3 Technical design

Back-mounted water pipe



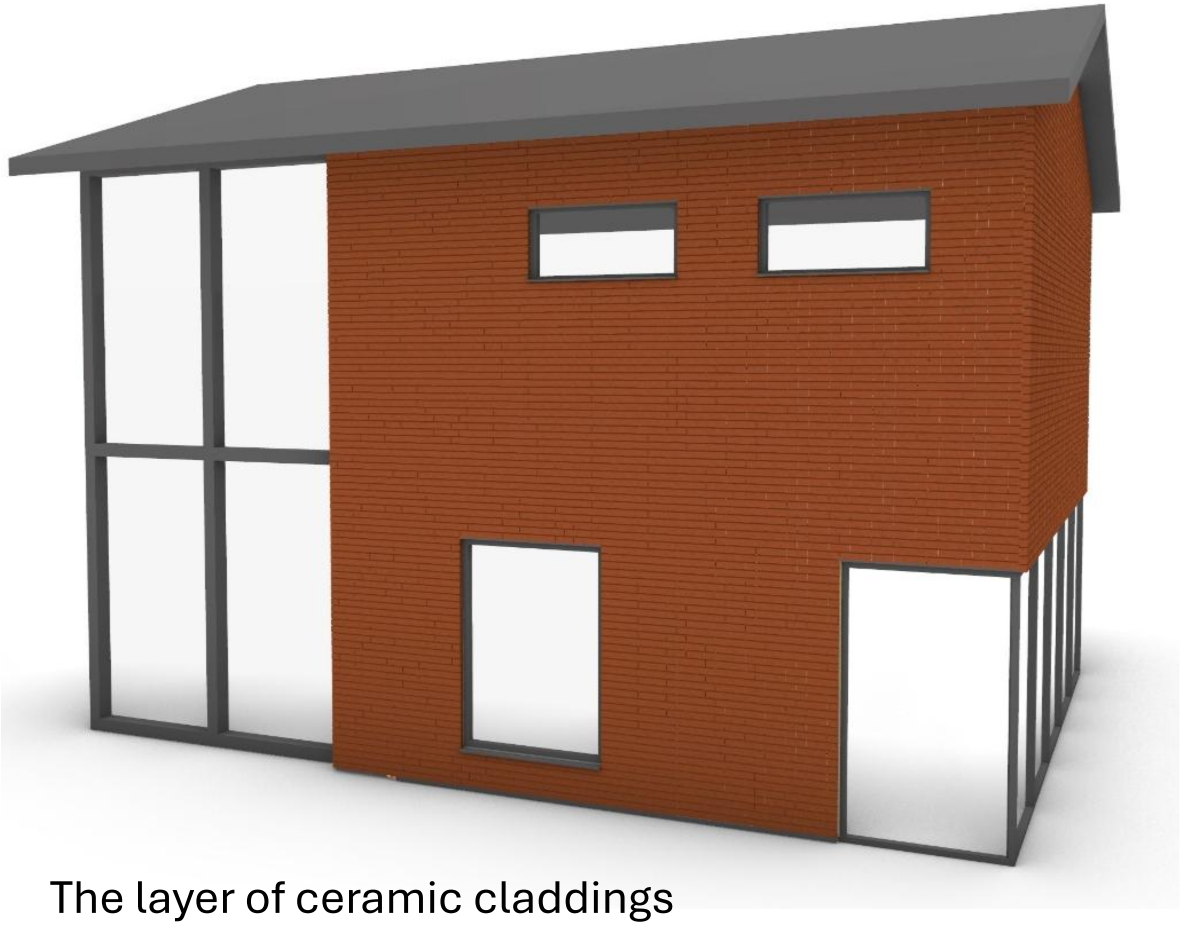
Cutting and bending metal cassette to form braces.
Cutting metal cassette at diagonal corner to allow for pipe connections

Assembly sequence

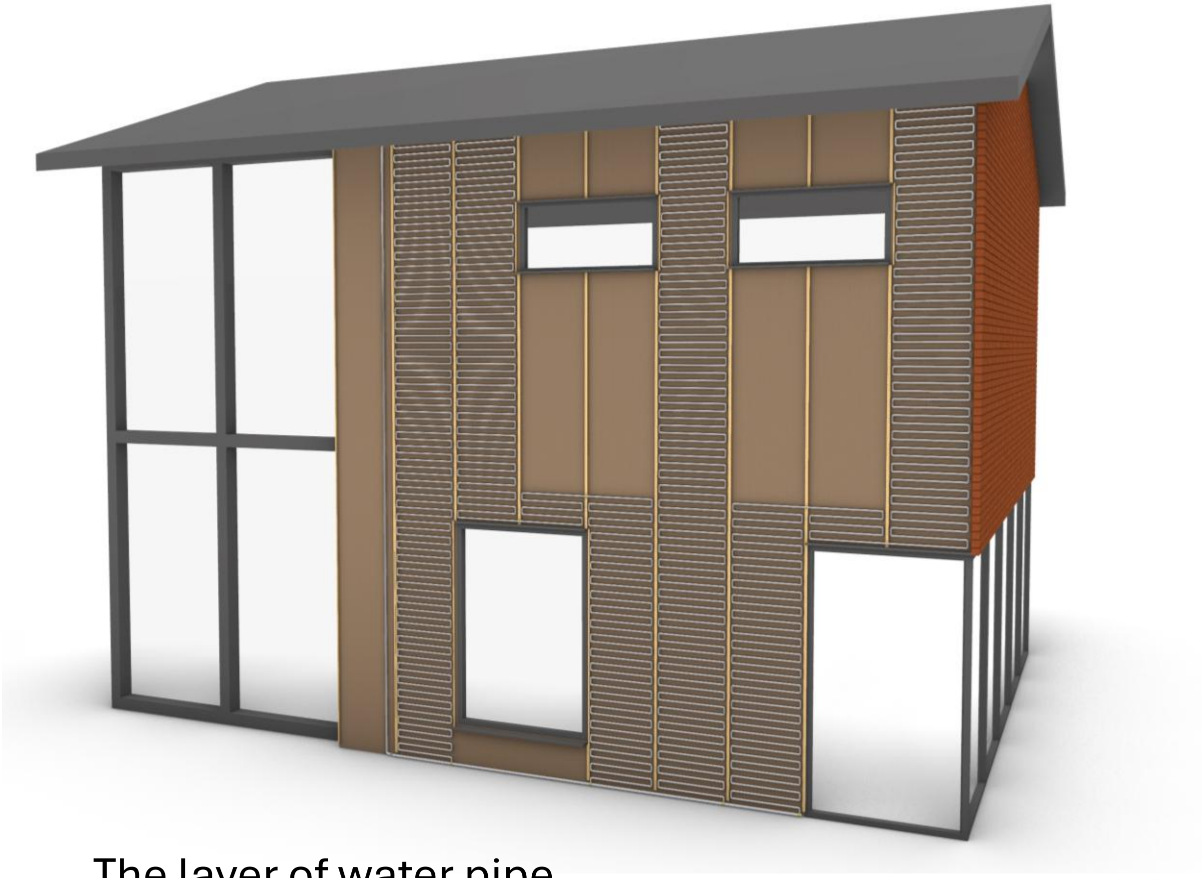


Assembly on building

A real case model is created in Rhino to show the connection details

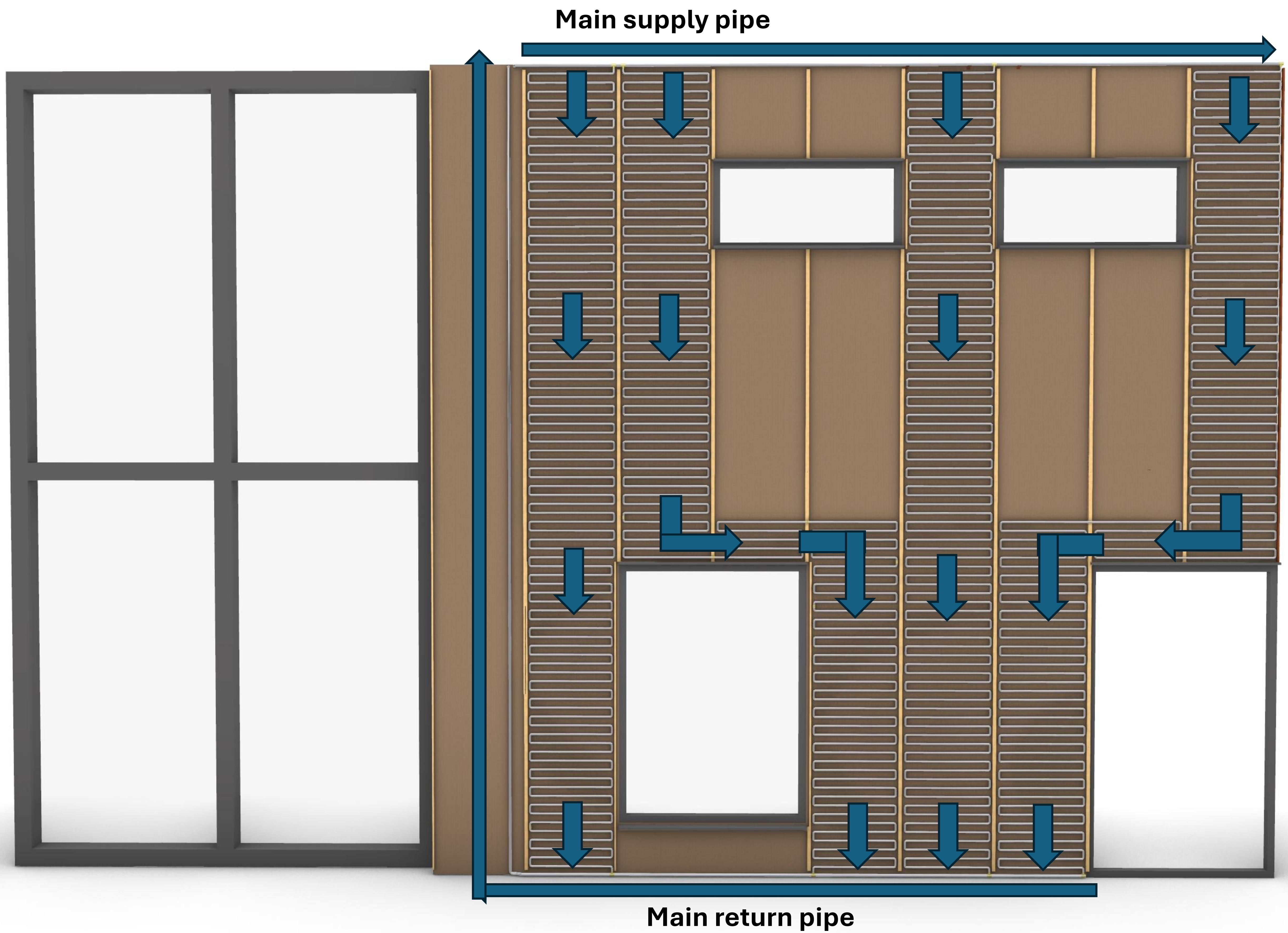


The layer of ceramic claddings



The layer of water pipe

The layer of metal cassette



Main supply pipe
Main return pipe

Details at window

Details at top

Details at bottom

Passive dwelling

Load:	**ASTF:**	**Pipe:**
6kW	22.8 ㎡	Φ12mm × 4

Old house

Load:	**ASTF:**	**Pipe:**
15kW	57.1 ㎡	Φ15mm × 5

multi-family dwelling

Load:	**ASTF:**	**Pipe:**
25kW	95 ㎡	Φ20mm × 5

Apartment (For each flat)

Load:	**ASTF:**	**Pipe:**
2kW	8 ㎡	Φ15mm × 1

Future research

Improvement: How to modify product to improve efficiency?

Maintenance: How to deal with leakage or blockage?

Liability: Who's responsible? Façade or Heat pump company?

Economic assessment : Is the product worth for investment?