NEARLY ZERO ENERGY BUILDING CONSTRUCTIONS

Dynamic insulation systems

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Date: Augest 2021

Module 2, chapter 6

Co-funded by the
Erasmus+ Programme
of the European Union

Aim and scope

- Investigate the different structures of buildings thermal insulation.
- Introduce the background and concept of conventional and dynamic (active) insulation.
- Efforts directed to achieve the Nearly Zero Energy Building (NZEB).
- Mathematical models, experimental studies, and numerical simulations done by the literature.

INTRODUCTION

Dynamic insulation as an approach for nzeb

The two critical factors for an energy-efficient building sector are the energy supply from sustainable sources all over the year and the efficient utilisation of the produced energy with minimal losses

The building sector accounts for about 40% of energy consumption worldwide

Building insulation systems can be divided into two categories: conventional and dynamic insulation

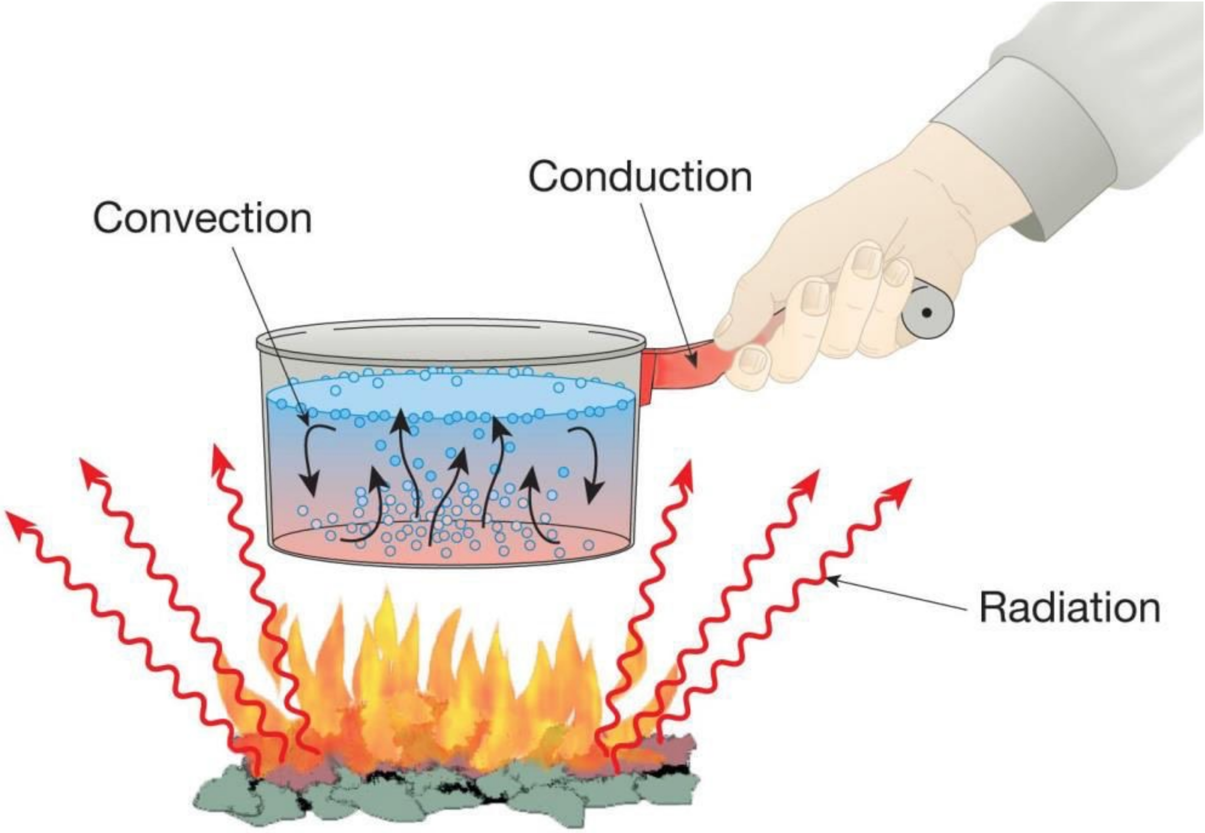
Energy consumption in Europe is increasing at a 1.5 percent yearly pace due to economic growth, the expansion of the building sector, and the development of building services, particularly HVAC systems

DYNAMIC INSULATION AS AN APPROACH FOR NZEB

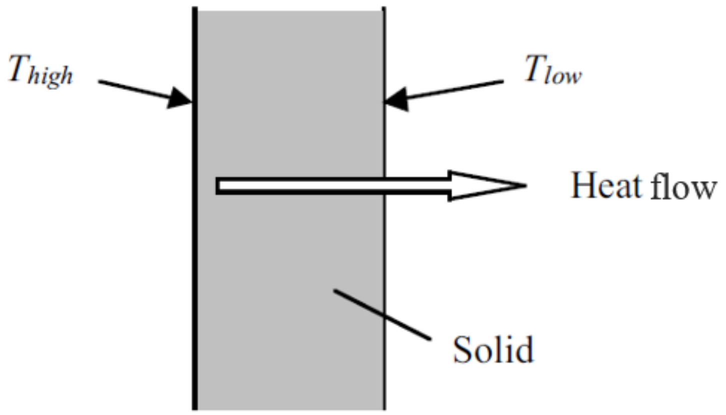
The European union demonstrated its dedication to resolving the issue by introducing the "2020 by 2020" initiative, which plans to reduce energy emissions by 20% and increase the renewable energy share by 20% in 2020 compared to 1990 levels

Heat transfer in buildings

There three primary modes for the heat transfer in buildings; Conduction, Convection, and Radiation.



CONDUCTION HEAT TRANSFER



The first is conduction, which is defined as heat transmission through intervening matter that does not involve motion of the substance

In conduction, energy is transferred within and through the body itself, unlike the other heat transfer modes

Convection heat transfer

Free convection : Occurs due to the fluid temperature difference, leading to a difference in density, resulting in a buoyancy force.

Forced convection: An artificially induced convection transfer occurs when a fluid is forced to flow over a surface by an external source such as a fan or pump.

Radiation heat transfer

1

In radiation heat transfer, energy can be transmitted through space without the existence of a substance.

2

Radiation is fundamental for sweltering temperature bodies like the sun, were electromagnetic radiation transfers energy.

3

Nevertheless, all existing bodies emit energy in photons that go in a random direction and have a random phase and frequency.

Background of Thermal Insulation

Thermal insulation of building envelopes plays a significant role in energy saving by creating an additional layer with high thermal resistance between the interior and external environment.

The main focus was finding the highest possible thermal resistance materials with the lowest costs.

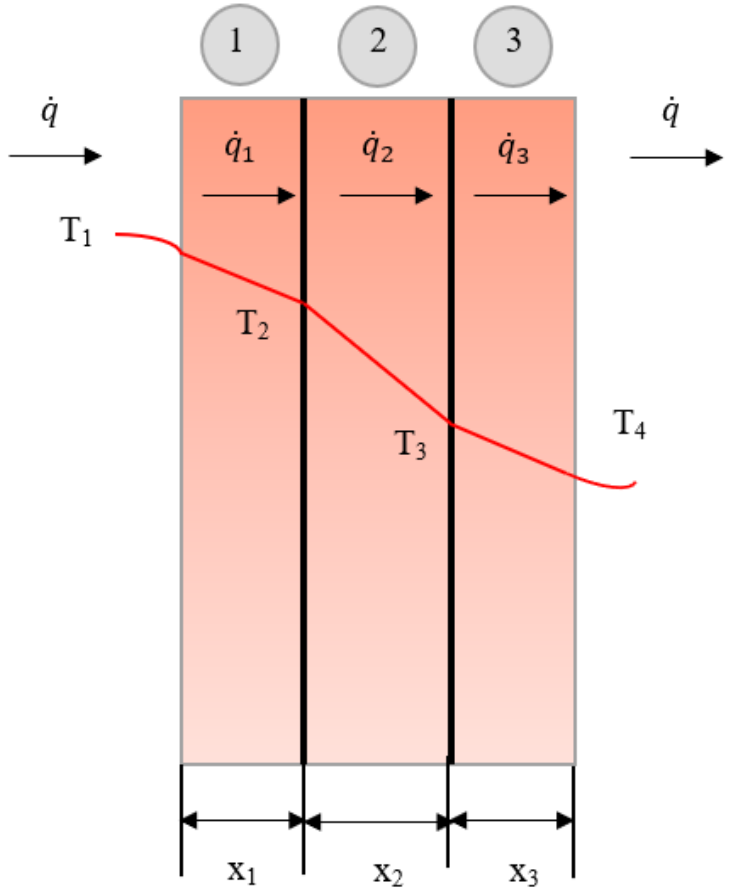
Dynamic insulation can be achieved by having a running fluid added to the insulation layer, which can capture the heat loss throughout the building envelope.

Thermal insulation in residential buildings

- Conserve energy by reducing heat loss rates or heat gain rates for pipes, ducts, equipment and building structures
- Control the surface temperature of building structures and equipment for both comfort and personal protection
- Prevent moisture condensation on building structures surfaces
- Reduce temperature fluctuations within the conditioned space for personal comfort
- Provide fire protection
- Reduce noise and vibration levels
- Reduce growth of mould

Heat transfer through composite layers wall

Over the years, the building services engineers presented several novel solutions to reduce buildings energy consumption by tunning the heat transfer through the building envelope.



Heat transfer through composite layers wall

Within the layers of composite walls , the heat transfer mode is conduction is the dominant as the hotter molecule energy is being transferred to the cooler molecule.

Building walls are usually built with several layers, as shown in Figure 6.3 shows the schematic diagram for the heat transfer in a three-layer wall.

It was observed by Fourier that conduction heat flux , in a given direction, is directly proportional to the temperature difference ΔT, in the direction of heat flow and inversely proportional to the distance Δx, in the same direction.

The thermal resistance for each inside and outside air layer depends on the wall geometry, the airflow velocity, heat flow direction, and type of convection heat transfer.

Building thermal insulation

Using static insulation materials would decrease the heat losses from the building facades due to the temperature difference between inside and outside

In contrast, another solution is dynamic insulation with variable thermal resistance

Dynamic insulation = Conventional insulation + Dynamic heat exchange within the building envelope

CONVENTIONAL thermal insulation

Several static insulation materials are available nowadays, ranging from traditional/conventional to high-performance thermal insulation, with the latter exhibiting much lower thermal conductivity values

Building's insulating capacity depends on many factors, including its thermal inertia, moisture-absorbing capacity, and airtightness and not only the type and thickness of insulating material

In winter, as an example, having a static higher insulation level will assist in reducing heat losses from buildings, but it will also limit heat flow across the wall when this is potentially valuable

CONVENTIONAL thermal insulation

The traditional way of thinking is that the higher constant R-value for the envelope always lowers energy consumption and running energy costs.

	Material	Thermal Conductivity
Conventional	Cellulose Cork	40-50 W/(m.K)
	Mineral Wool Expanded Polystyrene (EPS) Extruded Polystyrene (XPS)	30-40 W/(m.K)
	Polyurethane (PUR)	20-30 W/(m.K)
State-of-the-art (High-performance)	Aerogels	13-14 W/(m.K)
	Vacuum Insulation Panels (VIP)	3-4 W/(m.K)
	Vacuum Insulation Materials (VIM) Gas Insulation Materials (GIM) Nano Insulation Materials (NIM)	< 4 W/(m.K)

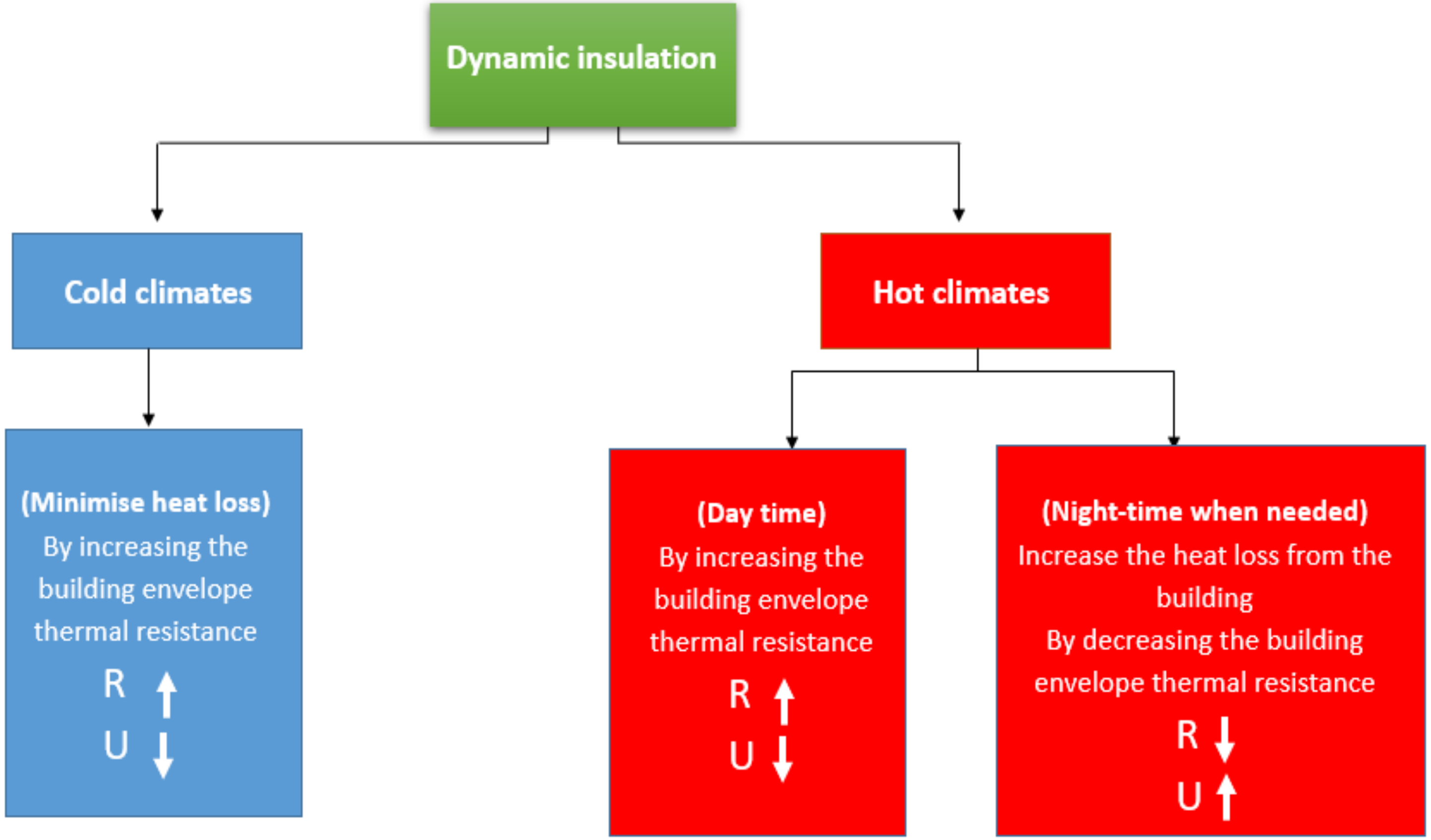
Dynamic insulation

Consists of two types:

Proflux heat exchanger, the airflow and heat flux are moving in the same directions

Contraflux heat exchanger, airflow and heat flux are moving in opposite directions

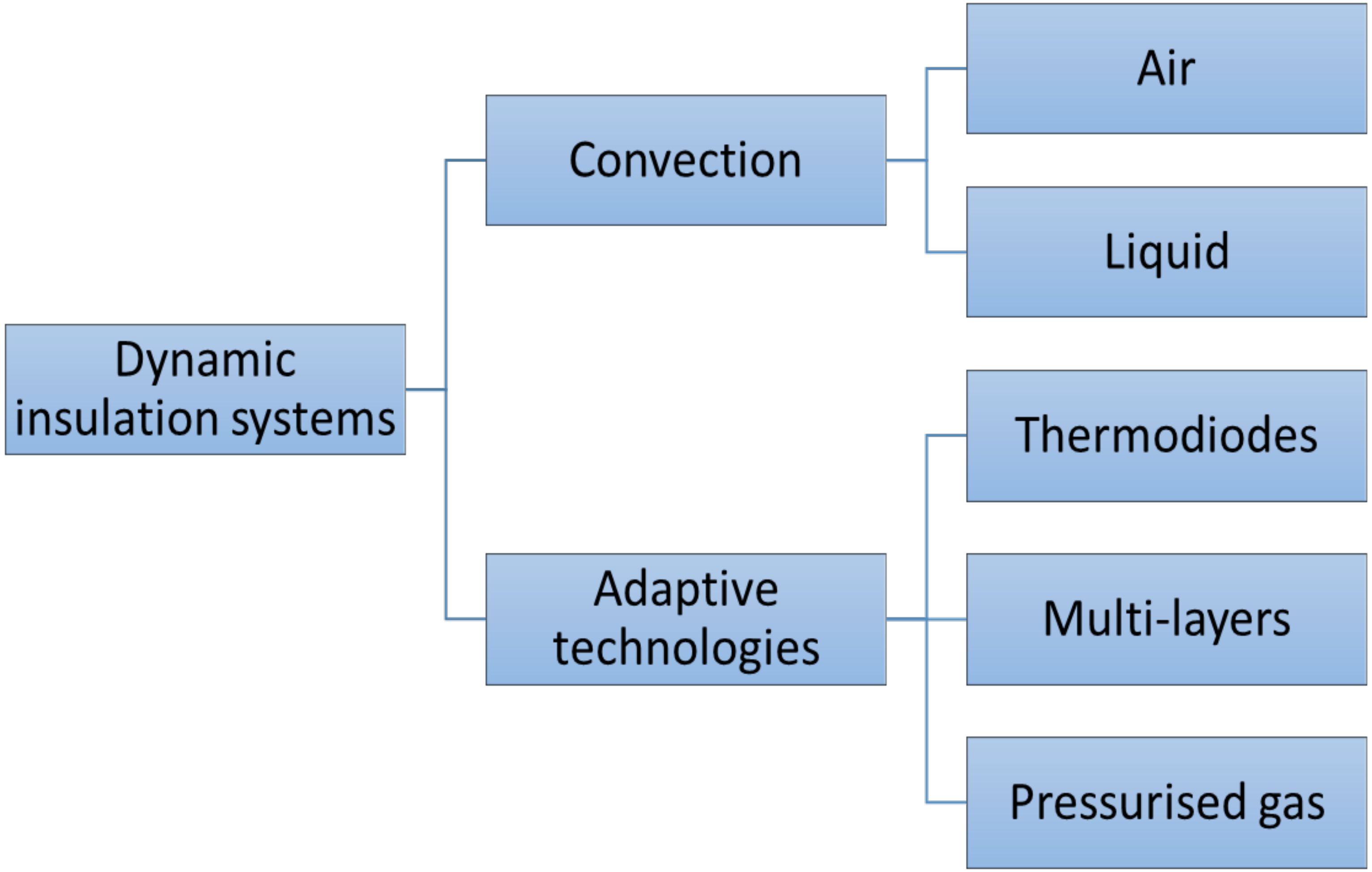
Possible dynamic insulation strategies based on climate and purpose of usage



Dynamic insulation advantages

- The system can act as a heat exchanger, i.e. the indoor ventilation can be either pre-heated in winter and pre-cooled in summer
- DI can work as a filter that can capture particulate matter with a diameter less than 0.5μm and larger than 5μm , providing better indoor air quality
- The dynamic insulation limits the passage of water vapour to the interior environment when in contra-flux mode, lowering the danger of interstitial condensation and mould formation
- As the heat loss through the building structure would be much less using the DI, it would provide a better solution instead of using the conventional building envelope

Available Applications



Dynamic insulation by convection

- Dynamic insulation basic principle is by having a running fluid added to the static insulation layer.
- Therefore, it aims to minimise the building envelope heat losses by allowing effective preheating of the ventilation air and capturing the heat loss through the envelope.
- For simplicity, in this section, DI is being handled based on the winter season so that the heat loss will be from inside to outside.

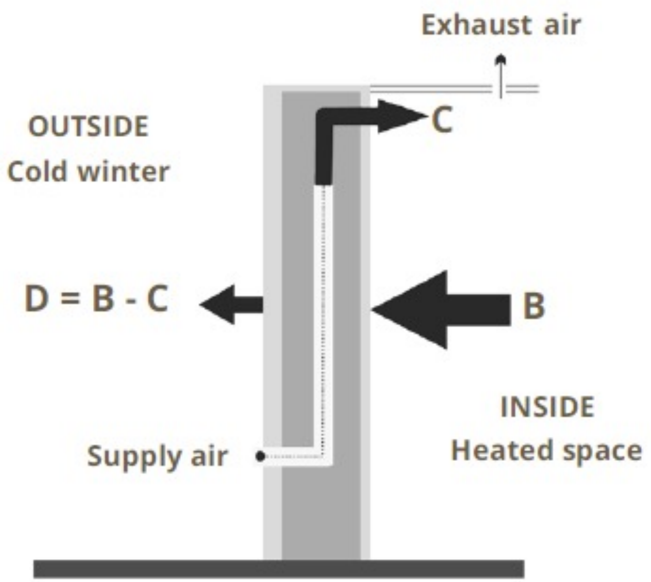
Dynamic insulation using air

Consists of two main types:

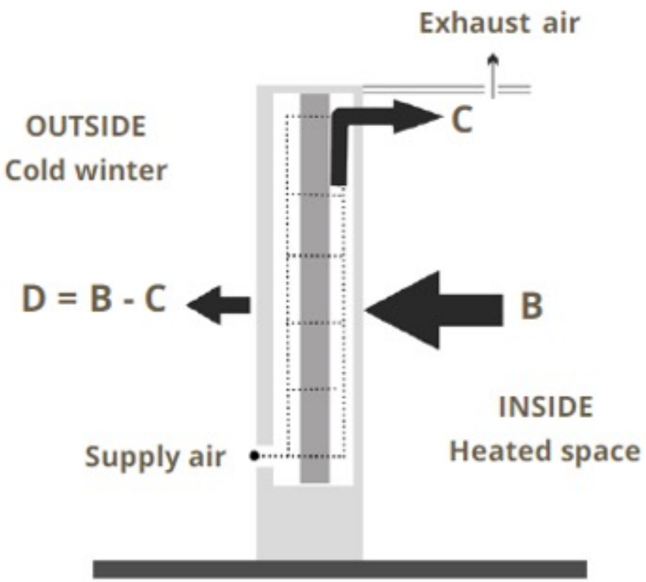
Cavities in the wall to circulate air (Parietodynamic wall).

Using breathing walls which is an air-permeable wall design that allows air to pass through (Permeodynamic wall).

Dynamic insulation using air

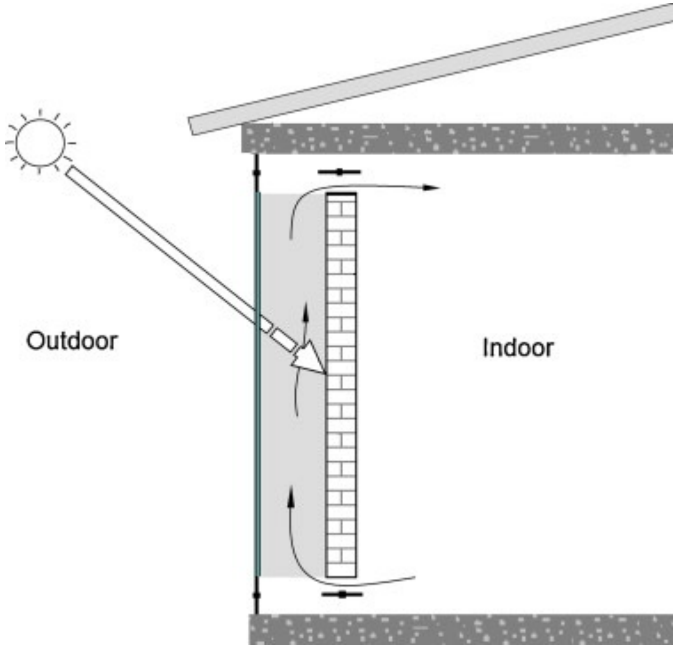


(a)

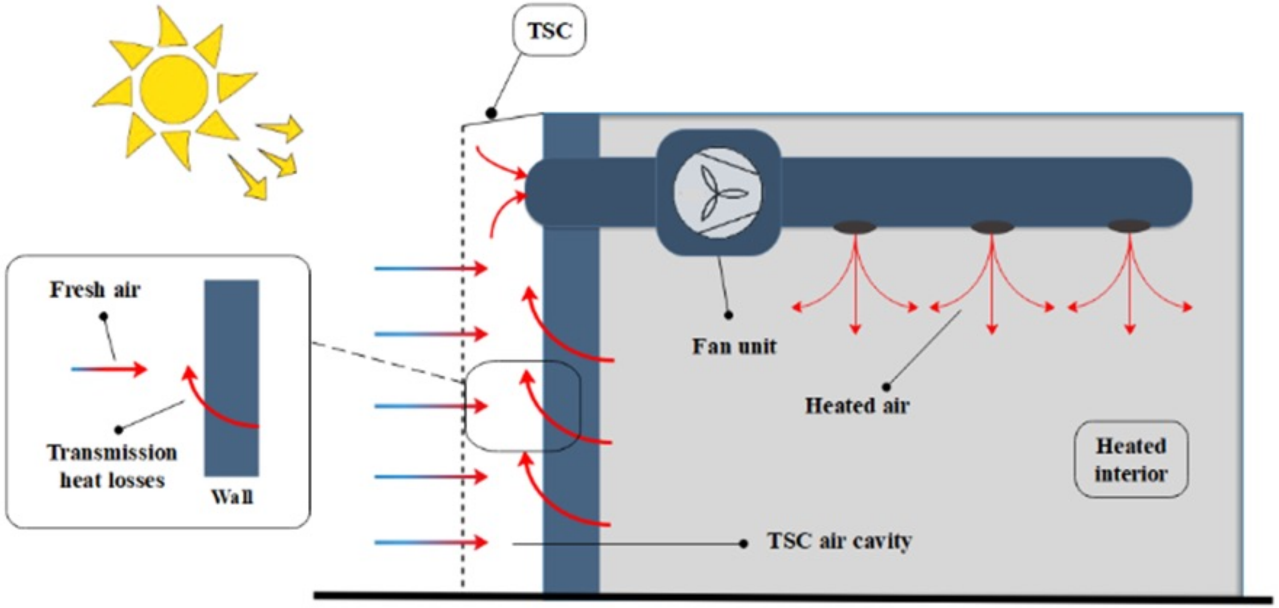


(b)

Applications using air dynamic insulation



Trombe wall

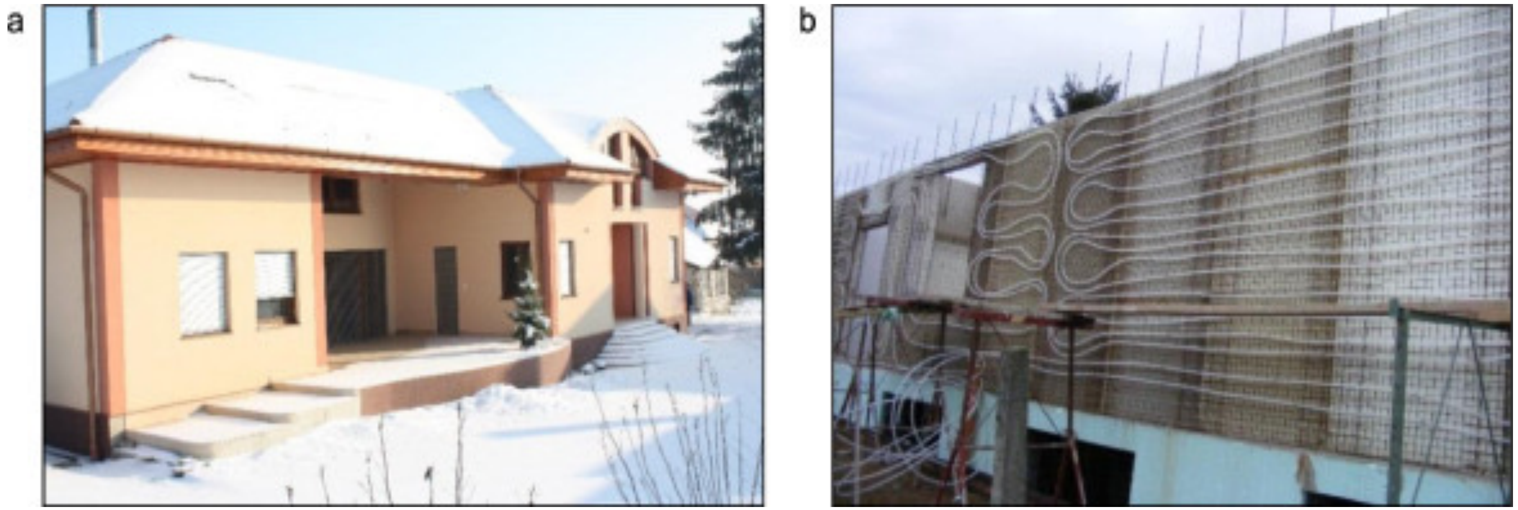


Transpired solar collector (TSC)

Dynamic insulation using liquid

- The second fluid system of dynamic insulation is performed using liquids such as water or refrigerant.
- For this type, a system of pipes is placed inside the structure of an external building envelope in which heating and cooling medium circulate depending on the required application.
- This thermal barrier has improved thermal comfort in summer and winter, and it has reduced the heat losses by 63% compared to the conventional static insulation materials.
- A water-based Thermo active wall barrier was mounted in the wall construction, where the system pipes provide an active thermal barrier for heat transfer between the outer and the heated space.

Dynamic insulation using liquid



The research was experimentally investigated a family-house in Nyíregyháza, Hungary.

Dynamic insulation adaptive insulation technologies

Despite the advantages of using dynamic convection insulation by air or liquid, the method has several challenges.

These challenges are related to the system design's complexity and the mechanical components required for fluid circulation.

Therefore, there are other approaches researchers did to integrate the technology in buildings facades.

Using thermodiodes

The first method uses a bidirectional thermodiode that can transfer heat in one direction and provide insulation in the other direction.

Varga; Chun and other researchers studied different design variations of the bidirectional thermodiode under cooling and heating season conditions.

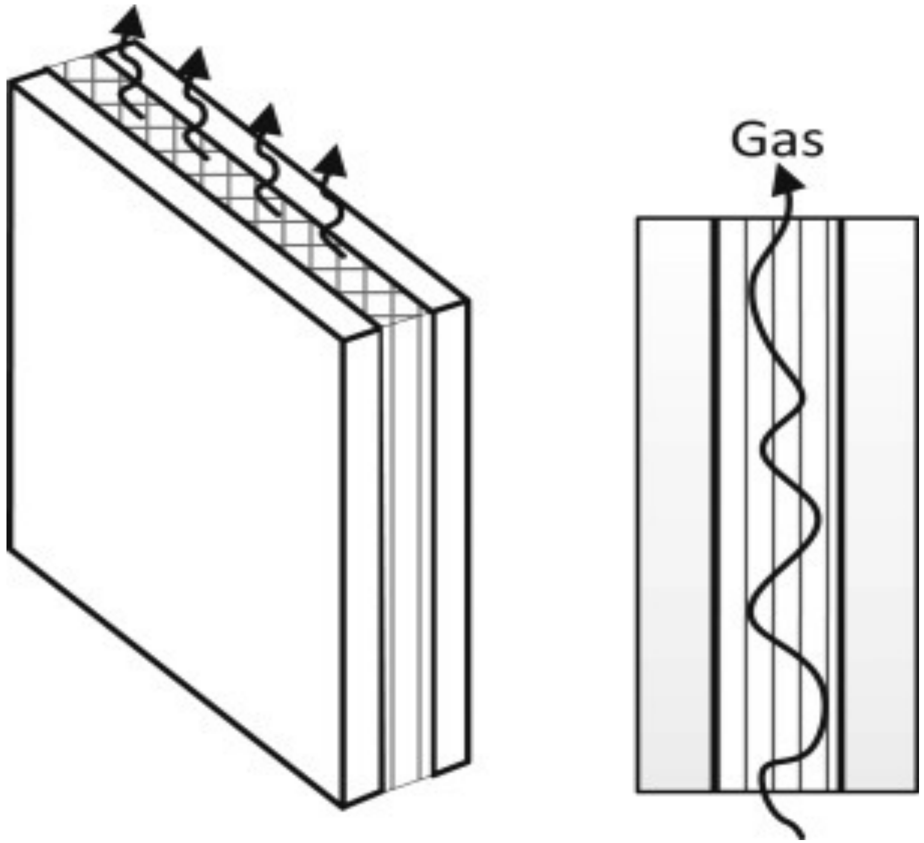
Using multilayers

Another mechanism is to use multilayered insulation, which allows switching between high and low R-values.

Kimber; Park and others proposed the new multifunctional insulation, where different aspects focused on both the insulating and conductive configurations.

The insulation media can be adjusted through control strategies based on indoor-outdoor temperature differences daily, weekly, or seasonally.

Using multilayers



Using pressurised gas

Several approaches to design a variable resistance (dynamic U-value) using gas pressure were implemented.

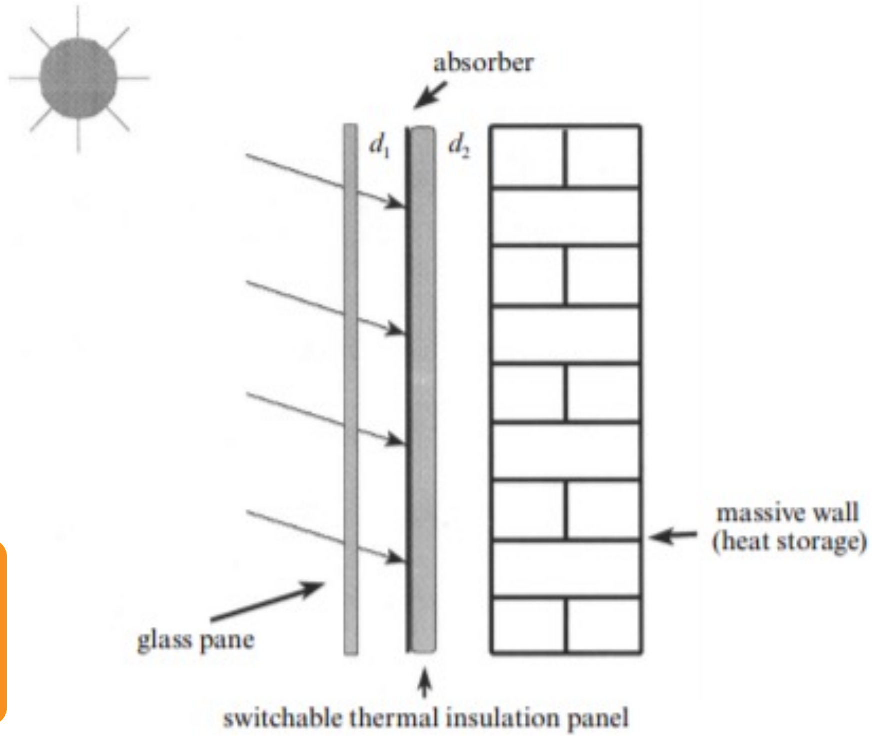
Benson et al. introduced a concept for vacuum insulation of variable conductance

The system's thermal resistance difference was accomplished by electronically adjusting the temperature of a small metal hydride attached to the vacuum envelope.

By regulating the air pressure, Berge et al. developed a method for modulating the air's thermal conductivity in the nanoporous fumed silica structure of a vacuum insulation panel and aerogel blanket

The findings showed a variation in the thermal conductivity of around three times for a fumed silica and less than two times for an aerogel blanket when the pressure ranged from 1 to 100 kPa

Using pressurised gas



Horn et al. have introduced a switchable thermal insulation using pressurised gas.

The method uses metal hydride to adjust the Hydrogen gas pressure inside the panel and thus change the heat conductivity by approximately half.

Thank you for your attention!

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