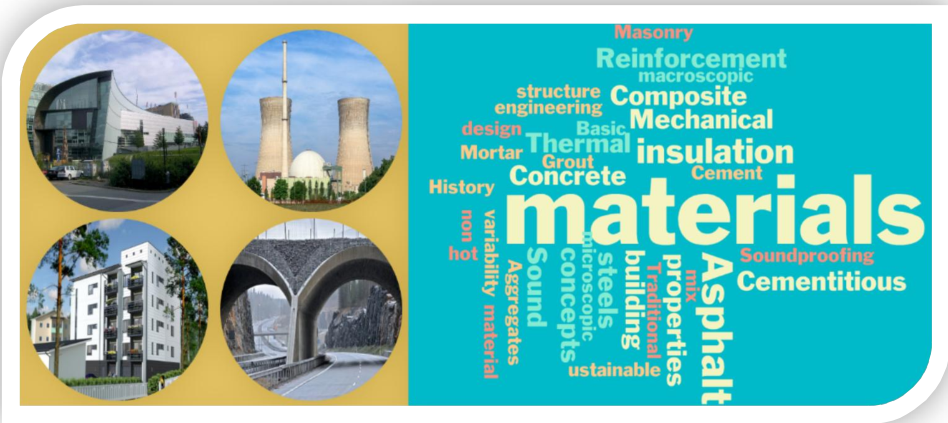

Lecture 8. Thermal insulation for buildings

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Thermal insulation is an important technology to reduce energy consumption in buildings by preventing heat gain/loss through the building envelope. Thermal insulation is a construction material with low thermal conductivity, often less than 0.1W/mK. These materials have no other purpose than to save energy and protect and provide comfort to occupants. Of the many forms, shapes and applications of thermal insulation, this lecture focuses on industrial insulation products that are commonly used for building envelopes– i.e., floor, walls and roof.

8.1 Methods of heat transfer [1]

Heat transfer (or heat) is thermal energy in transit due to a spatial temperature difference. Whenever a temperature difference exists in a medium or between media, heat transfer must occur.

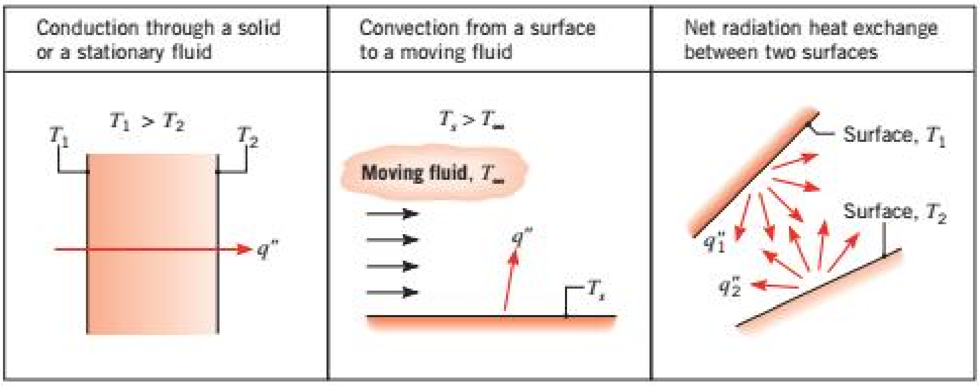


Figure 1. Conduction, convection, and radiation heat transfer modes (1).

As shown in Figure 1, different types of heat transfer processes are:

- Conduction: A diffusive process wherein molecules transmit their kinetic energy to other molecules by colliding with them. The temperature gradient exists in a stationary medium, which may be a solid or a fluid. Conduction heat transfer is the flowing of heat energy from a high-temperature object to a lower-temperature object.
- Convection: A process associated with the motion of the medium. When a hot material flows into a cold material, it will heat the region - and vice versa. The term refers to heat transfer that will occur between a surface and a moving fluid when they are at different temperatures. Convection is the primary way that heat moves through gases and liquids.
- Radiation: All surfaces of finite temperature emit energy in the form of electromagnetic waves. Hence, in the absence of an intervening medium, there is net heat transfer by radiation between two surfaces at different temperatures.

[1] Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt (2011) Fundamentals of Heat and Mass Transfer, 7th Edition

8.2 Building insulation performance

One of the most important and cost-effective energy saving materials in building construction is the insulation. Insulation keeps buildings warm in winter and cool in summer.

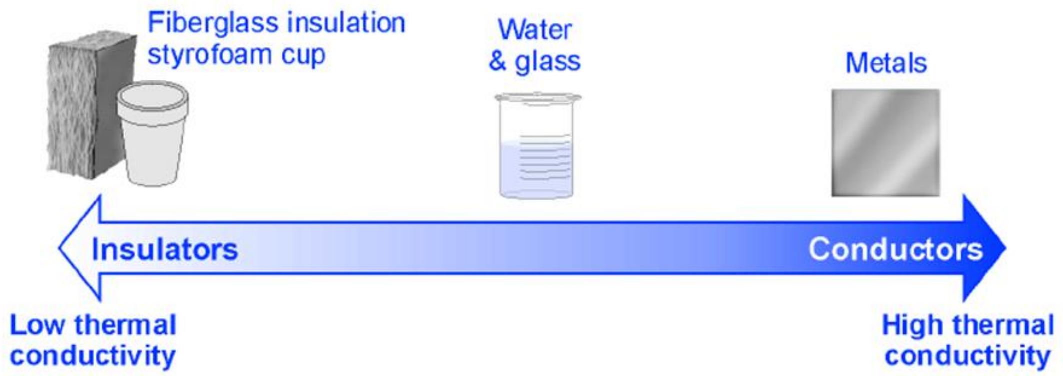
8.2.1 Thermal conductivity – l (Lambda) value [2]

Thermal conductivity, often referred to as the 'K' or 'λ' (lambda) value, is a constant for any given material, and is measured in W/mK (watts per kelvin meter). The higher the λ value, the better the thermal conductivity. Good insulators will have as low a value as possible. Steel and concrete have very high thermal conductivity and therefore very low thermal resistance. This makes them poor insulators.

The λ value for any material will become higher with an increase in temperature. Although the temperature increase will need to be significant for this to occur, and the temperature variants in most buildings are generally within the tolerances that would render any change in the lambda value negligible.

Based on equation (2), the thermal conductivity is assumed to be independent of temperature.

$$\lambda = q \times \frac{L}{A(T_1 - T_2)} \qquad \left[\frac{W}{m \cdot K}\right] \tag{1}$$



Material	Air	Fiberglass insulation	Wool insulation	Wood	Liquid water	Glass	Brick	Concrete, stone	Steel	Aluminum	Copper	Diamond
W/m·K	0.024	0.04	0.04	0.12	0.58	1.05	1.4	1.7	43	205	401	1000

Figure 2. The thermal conductivity of common materials - describes how well the material conducts heat [3]

[2] Designing Buildings Wiki - Thermal insulation for buildings. Online at: http://www.designingbuildings.co.uk/wiki/Thermal_insulation_for_buildings
[3] Thermal Conductivity of some common Materials and Gases. Online at: http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

8.2.2 Thermal resistance – R - value

Thermal resistance, referred to as the 'R' value of a material, is a product of thermal conductivity and thickness. The R-value is calculated from the thickness of the material divided by its thermal conductivity and expressed in the units m^2K/W (square metre kelvins per watt). The greater the material thickness, the greater the thermal resistance.

- The R-value of a substance is its direct measure of its resistance to transferring energy or heat
- Basically the higher the value the better it is at resisting energy transfer, so the easier it is to maintain a difference in temperatures across it for a longer time.
- Usually the R value is given for a certain type and thickness of material as installed (often known as the 'added R value'); i.e. a low density glass wool batt would need to be 130mm installed to achieve an R of 2.5, but only 100mm thick of medium density.

$$R = \frac{d}{\lambda} \tag{2}$$

Where R = is known as the thermal resistance of the wall, $[m^2 \cdot K/W]$
d = the thickness of the wall, [m]
l = coefficient of thermal conductivity $[W/m \cdot K]$, the lower the value, the better the insulating capacity of the product (for a given thickness).

8.2.3 Coefficient of heat transmission - U-Value:

- In construction terms, while a U-value may be calculated and attributed to a single thickness of any material, it is more usual to calculate it as a product resulting from the assembly of different materials in any given form of construction.
- U-value is a measure of the transmission of heat through a pre-determined area of the building fabric — this being $1m^2$. The unit measurements are therefore W/m^2K (watts per square metre kelvin) and describe the heat transfer, in watts, through a square metre of a building element (such as a wall, floor or roof).
- U-value is used to calculate the heat transfer, or loss, through the building fabric. For example, if a wall had a U-value of $1W/m^2K$ — with a temperature differential of 10°, there would be a heat loss of 10 watts for every square metre of wall area.
- The U-value for a construction is defined as the ratio between the density of heat flow rate q, W/m^2, through the construction and the temperature difference between the ambient temperatures on both sides

$$U = \frac{q}{(T_i - T_e)} \tag{3}$$

Where q = heat flow rate
T_i = the internal temperature

T_e = the external temperature

- For a construction with n layers the U-Values are calculated as the reciprocal of the sum of R values (1/total sum of R values):

$$U = \frac{1}{R_{si} + \sum_{j=1}^{n} R_j + R_{se}} \tag{4}$$

Where R_{si} = thermal resistance of the internal surface of the wall
R_{si} = thermal resistance of the external surface of the wall
R_j = thermal resistance of the (j) layer of the wall

8.2.4 Steady state heat flow

Steady state means that the temperatures of the system do not vary with time. Heat transfer processes can be quantified in terms of appropriate rate equations. These equations may be used to compute the amount of energy being transferred per unit time. For heat conduction, the rate equation is known as Fourier's law. For the one-dimensional plane wall shown in Figure 3, having a temperature distribution T(x), the rate equation is expressed as:

$$\frac{dq}{dt} = -\lambda A \times \frac{dT}{dx} \tag{5}$$

Where q = quantity of heat in time (t)
A = area perpendicular to the flow, (for on-dimensional heat flow A = 1 m^2)
λ (Lambda value) = coefficient of thermal conductivity
(the negative sign because $T_2 < T_1$).
dT/dx = the temperature gradient.

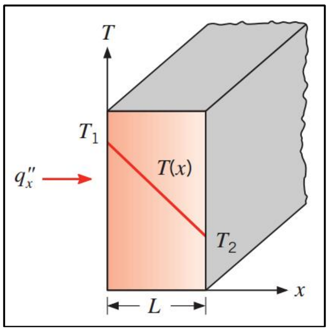


Figure 3. One-dimensional heat transfer by conduction (diffusion of energy)

For steady state one-dimensional heat flow, the conductive equation can be written as:

$$q = -\lambda \times \frac{T_2 - T_1}{L} = -\frac{\lambda}{L} \times (T_2 - T_1) \tag{6}$$

Where q = density of heat flow rate, W/m^2
L = length of heat flow path

T_1 and T_2 = temperature at either end of the flow path

8.2.5 Steady state heat flow and temperature distribution in a multilayer wall

The concept of a thermal resistance circuit allows ready analysis of problems such as a composite slab (composite planar heat transfer surface). In the composite slab shown in Figure 4, the heat flux is constant through the construction wall, i.e. $q_1 = q_2 = q_3 = \cdots = q_n$. The resistances are in series and sum to $R = R_1 + R_2 + \cdots + R_{n-1}$.

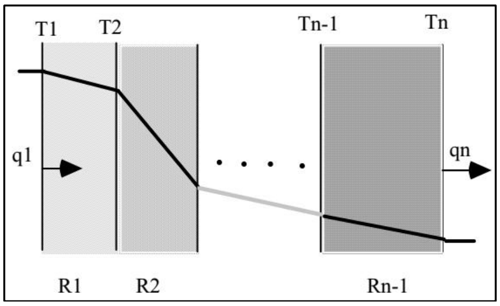


Figure 4. Heat transfer across a composite slab (series thermal resistance).

$$q = \frac{(T_1 - T_2)}{R_1} = \frac{(T_2 - T_3)}{R_2} = \cdots\cdots = \frac{(T_{n-1} - T_n)}{R_{n-1}} \tag{7}$$

$$(T_1 - T_2) = q \cdot R_1, \cdots\cdots\cdots (T_k - T_{k+1}) = q \cdot R_k \tag{8}$$

$$(T_1 - T_n) = \sum_{k=1}^{n-1} (T_k - T_{k+1}) = \sum_{k=1}^{n-1} (qR_k) = q \sum_{k=1}^{n-1} R_k \tag{9}$$

$$R_{tot} = \sum_{k=1}^{n-1} R_k \tag{10}$$

$$q = \frac{T_1 - T_n}{R_{tot}} \tag{11}$$

8.2.6 Location of insulation

Generally insulation is installed between the framing members in the home. Walls, ceilings, floors around the perimeter, basements, attics and even interior rooms of the home. The potential locations of insulation are shown in Figure 5: ([4])

1) In unfinished attic spaces, between and over the floor joists to seal off living spaces below. If the air distribution is in the attic space, then consider insulating the rafters to move the distribution into the conditioned space. (1A) attic access door
2) In finished attic rooms with or without dormer, (2A) between the studs of "knee" walls, (2B) between the studs and rafters of exterior walls and roof, (2C) and ceilings with cold spaces above. (2D) Extend insulation into joist space to reduce air flows.
3) All exterior walls, including (3A) walls between living spaces and unheated garages, shed roofs, or storage areas; (3B) foundation walls above ground level; (3C) foundation walls in heated basements, full wall either interior or exterior.
4) Floors above cold spaces, such as vented crawl spaces and unheated garages. Also (4A) any portion of the floor in a room that is cantilevered beyond the exterior wall below; (4B) slab floors built directly on the ground; (4C) as an alternative to floor insulation, foundation walls of unvented crawl spaces. (4D) Extend insulation into joist space to reduce air flows.
5) Band joists.
6) Replacement or storm windows and caulk and seal around all windows and doors.

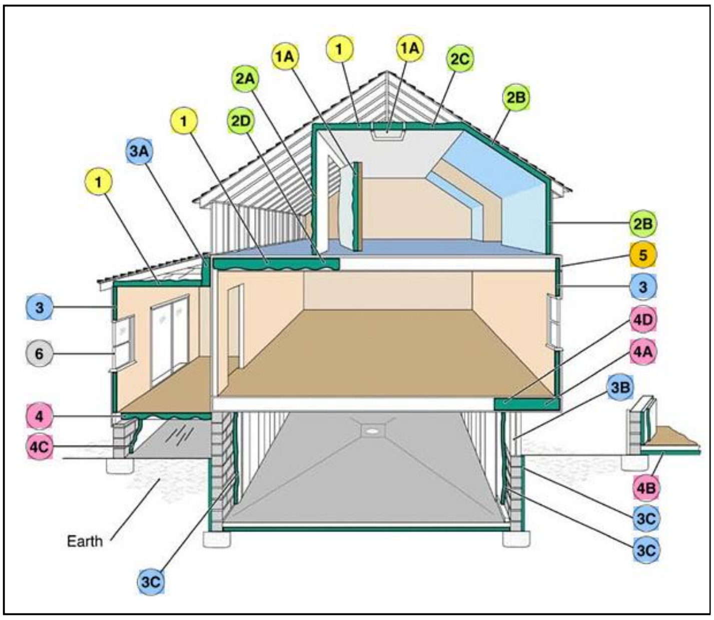


Figure 5. Examples of building insulation locations.

[4] U.S. Department of Energy's (DOE), Energy saver - Where to insulate in a home. Online at: http://energy.gov/energysaver/where-insulate-home

8.3 Construction insulation materials [5]

Thermal insulation is the reduction of heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact.

- Reducing the amount of energy used from fossil fuels is the most important factor in promoting sustainability.
- Insulation has the greatest potential for reducing CO_2 emissions.
- Energy conserved through insulation use far outweighs the energy used in its manufacture. Only when a building achieves a 'LowHeat' standard does insulation's embodied carbon (see below) become significant

8.3.1 Common building thermal insulation materials

Many types of building thermal insulation are available which fall under the following basic materials and composites:

- Inorganic materials:
  - Fibrous materials such as glass, rock, and slag wool.
  - Cellular materials such as calcium silicate, bonded perlite, vermiculite, and ceramic products.
- Organic materials:
  - Fibrous materials such as cellulose, cotton, wood, pulp, cane, or synthetic fibers.
  - Cellular materials such as cork, foamed rubber, polystyrene, polyethylene, polyurethane, polyisocyanurate and other polymers
- Metallic or metallized reflective membranes. These must face an air-filled, gas-filled, or evacuated space to be effective.

8.3.1.1 Inorganic Materials

Glass mineral wool

Made from molten glass, usually with 20% to 30% recycled industrial waste and post-consumer content. The material is formed from fibres of glass arranged using a binder into a texture similar to wool. The process traps many small pockets of air between the glass, and these small air pockets result in high thermal insulation properties. The density of the material can be varied through pressure and binder content.

[5] Insulation materials and their thermal properties. Available online at: http://www.greenspec.co.uk/building-design/insulation-materials-thermal-properties/

Figure 6. Glass mineral wool insulation

- The glass mineral wool has a long fibres
- great absorbance of sound energy
- incombustible material, incombustibility class A1
- maximum working temperature 230°C
- fire resistance and melting temperature, about 700°C
- high elasticity of the material and high tensile strength
- resistant to mechanical damage during handling

Table 1. Properties of the glass mineral wool insulation.

Property	Glass mineral wool Insulation
Thermal conductivity, λ [W/m.K]	0.035
Thermal resistance at 100mm [K·m^2/W]	2.85
Specific Heat Capacity [J/(kg.K)]	1030
Density [kg/m^3]	20
Thermal diffusivity [m^2/s]	0.0000016
Embodied energy [MJ/kg]	26
Vapour permeable	Yes

Stone mineral wool

Stone mineral wool is a furnace product of molten rock at a temperature of about 1600 °C, through which a stream of air or steam is blown. More advanced production techniques are based on spinning molten rock in high-speed spinning heads somewhat like the process used to produce candy floss. The final product is a mass of fine, intertwined fibres with a typical diameter of 2 to 6 micrometres. Mineral wool may contain a binder, often a Ter-polymer, and an oil to reduce dusting.

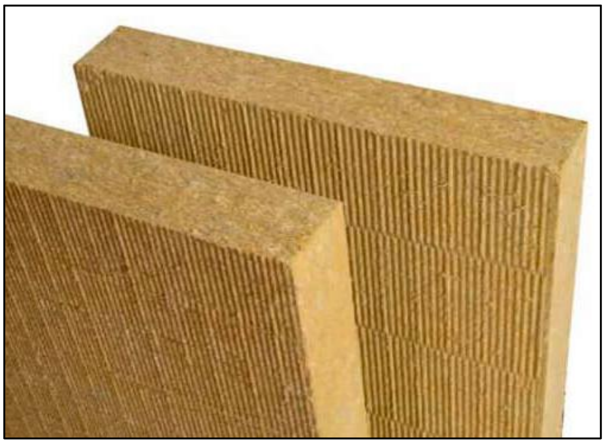


Figure 7. Stone mineral wool insulation.

- Stone mineral wool is made of volcanically originated stone- dolomite, diabase and basalt
- Stone mineral wool has short fibres
- great absorbance of sound energy
- incombustible material, incombustibility class A1
- maximum working temperature 750°C
- high melting temperature, over 1000°C
- low tensile strength
- very resistant to mechanical damage during handling

Table 2. Properties of the glass mineral wool insulation.

Property	Glass mineral wool Insulation
Thermal conductivity, λ [W/m.K]	0.032 to 0.044
Thermal resistance at 100mm [K·m^2/W]	2.70 to 2.85
Specific Heat Capacity [J/(kg.K)]	n/a
Density [kg/m^3]	n/a
Thermal diffusivity [m^2/s]	n/a
Embodied energy [MJ/kg]	n/a
Vapour permeable	Yes

Production process of mineral wool insulation

Glass and stone wool insulation are fibre-based products that deliver outstanding thermal performance. Both are made from plentiful, locally-sourced, renewable natural resources – sand and basalt rock are the basic raw materials of mineral wool.

- Raw materials: The raw materials are measured and sent to a melting furnace.
  - For stone wool à rock or recycled material plus energy
  - For glass wool à the raw materials are sand, limestone and soda ash, as well as recycled off-cuts from the production process.

- Furnace:
  - o The raw materials are melted in a furnace at very high temperatures, typically between 1,300°C to 1,500°C.
- Spinning
  - o The droplets of melt exiting the furnace are spun into fibres. Droplets fall onto rapidly rotating flywheels or the mixture is drawn through tiny holes in rapidly rotating spinners. This process shapes it into fibres.
- Binding
  - o Small quantities of binding agents are added to the fibres. The structure and density of the product will be adapted according to its final usage.
- Curing
  - o The mineral wool is then hardened in a curing oven at around 200°C.
- Cutting
  - o The mineral wool is cut to the required size and shape, for example into rolls, batts, boards or it can be customised for use with other products. Off-cuts and other mineral wool scraps are recycled back into the production process, which further reduces inputs and energy requirements.
- Packaging
  - Due to its impressive elasticity, mineral wool can be compressed during packaging to reduce its volume. This makes it cheaper and easier to handle and results in lower carbon emissions due to transportation.

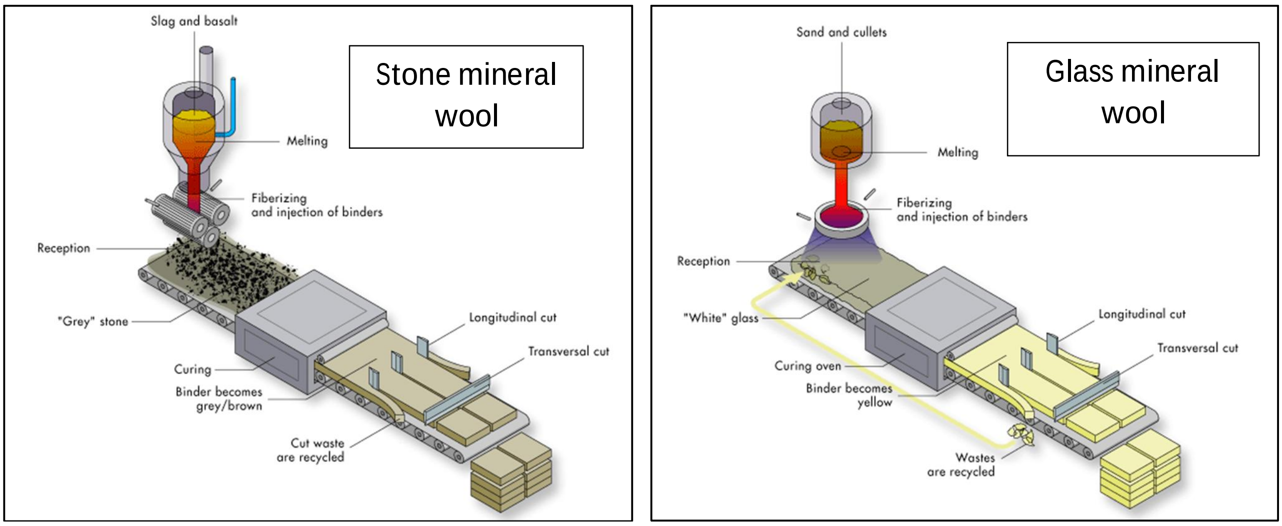


Figure 8. Production process of the mineral wool insulation [(6)].

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[6] http://www.eurima.org/about-mineral-wool/production-process.html

8.3.1.2 Organic materials

Expanded polystyrene (EPS) [7]

Polystyrene is a synthetic aromatic polymer made from the monomer styrene. Polystyrene can be solid or foamed. Expanded polystyrene (EPS) is a rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. Polystyrene foams are produced using blowing agents that form bubbles and expand the foam. Although it is a closed-cell foam, expanded polystyrene is not entirely waterproof or vapour proof. Discarded polystyrene does not biodegrade for hundreds of years and is resistant to photolysis.

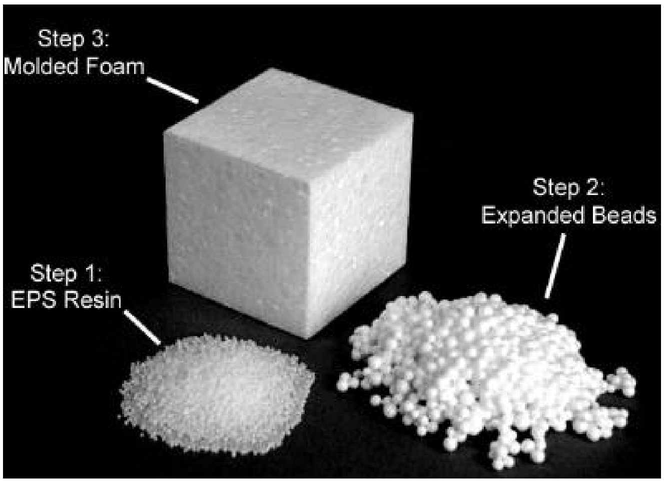

Figure 9. Expanded polystyrene (EPS)

Table 3. Properties of the Expanded Polystyrene (EPS).

Property	Glass mineral wool Insulation
Thermal conductivity, λ [W/m.K]	0.034 to 0.038
Thermal resistance at 100mm [K·m^2/W]	3.52
Specific Heat Capacity [J/(kg.K)]	1300
Density [kg/m^3]	15 to 30
Thermal diffusivity [m^2/s]	n/a
Embodied energy [MJ/kg]	88.60
Vapour permeable	No

Manufacturing Process

As shown in Figure 10, the conversion of expandable polystyrene to expanded polystyrene is carried out in three stages.

[7] Expanded Polystyrene (EPS) and the Environment. Online at: http://www.eps.co.uk/pdfs/eps_and_the_environment.pdf

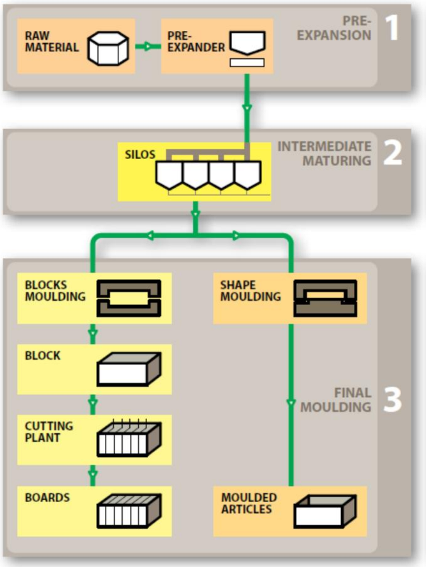

Figure 10. Manufacturing process of the Expanded Polystyrene (EPS).

1st stage - Pre-expansion

- The raw material is heated in special machines called pre-expanders with steam at temperatures of between 80-100°C.
- The density of the material falls from some 630kg/m^3 to values of between 10 and 35kg/m^3.
- During this process of pre-expansion the raw material's compact beads turn into cellular plastic beads with small closed cells that hold air in their interior.

2nd stage - Intermediate Maturing and Stabilisation

- On cooling, the recently expanded particles from a vacuum in their interior and this must be compensated for by air diffusion.
- This process is carried out during the material's intermediate maturing in aerated silos.
- The beads are dried at the same time.
- This is how the beads achieve greater mechanical elasticity and improve expansion capacity — very important in the following transformation stage.

3rd stage - Expansion and Final Moulding

- During this stage, the stabilised pre-expanded beads are transported to moulds where they are again subjected to steam so that the beads bind together.
- In this way moulded shapes or large blocks are obtained (that are later sectioned to the required shape like boards, panels, cylinders etc).

Extruded polystyrene (XPS)

XPS (extruded polystyrene) is also plastic foam based on polystyrene that is formed by adding gas during extrusion not by expanding beads containing gas; which is how EPS is formed. Extruded polystyrene foam (XPS) consists of closed cells, offers improved surface roughness and higher stiffness and reduced thermal conductivity. It is slightly denser and therefore slightly stronger than EPS.

Water vapour diffusion resistance (μ) of XPS is very low - making it suitable for application in wetter environments.

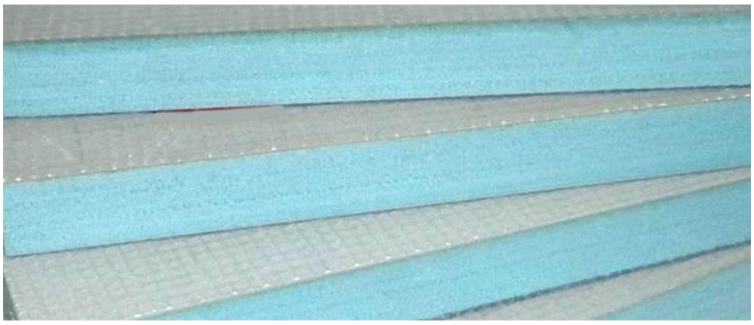

Figure 11. Extruded Polystyrene (XPS)

Table 4. Properties of the Extruded Polystyrene (XPS).

Property	Glass mineral wool Insulation
Thermal conductivity, λ [W/m.K]	0.033 to 0.035
Thermal resistance at 100mm [K·m^2/W]	3.0
Specific Heat Capacity [J/(kg.K)]	N/a
Density [kg/m^3]	20 to 40
Thermal diffusivity [m^2/s]	n/a
Embodied energy [MJ/kg]	88.60
Vapour permeable	No

Wood fibre

Industrially produced wood fibre insulation was introduced around twenty years ago after engineers from the timber producing areas of Europe devised new ways of transforming timber waste from thinning and factories into insulation boarding.

Figure 12. Wood fibre insulation

Wood fibre insulation can be designed to deliver a range of functions:

- Flexible insulation à Application: Friction mounted between studs / rafters
- Weather resistant insulation for sheathing and sarking à Application: Walls and roof
- Renderable insulation for walls à Application: External walls

- Load-bearing & water resistant insulation for below floor screeds à Application: Below floor screeds (also roof and walls)

Table 5. Properties of the wood fiber insulation.

Property	Rigid (available in: boards, semi-rigid boards)	Flexible (available in: batts)
Thermal conductivity, λ [W/m.K]	0.038	0.038
Thermal resistance at 100mm [K·m^2/W]	2.5	2.6
Specific Heat Capacity [J/(kg.K)]	2100	2100
Density [kg/m^3]	160	50
Thermal diffusivity [m^2/s]	n/a	n/a
Embodied energy [MJ/kg]	n/a	n/a
Vapour permeable	Yes	Yes

Cellulose insulation [8]

Figure 13. Cellulose Insulation.

Cellulose insulation is a material made from recycled newspaper. The paper is shredded and inorganic salts, such as boric acid, are added for resistance to fire, mould, insects and vermin. The insulation is installed either blown or damp-sprayed depending on application.

The three principal methods of installing cellulose insulation in buildings are:

- Loose Fill - consists of either manually pouring in place, or pneumatically blowing in place, cellulose insulation into wall or ceiling cavities.
- Spray-On - involves pneumatic application of cellulose materials that are impregnated with adhesives material to the exposed interior horizontal and vertical surfaces of walls and ceilings.
- Boardstock - involves cellulosic materials that are compressed and formed into rigid boards or panels. The panels may be manufactured with or without surface coatings, facings, or decorative finishes.

Table 6. Properties of the cellulose insulation.

[8] Special Building Material: Cellulose Insulation. Available online at: http://www.noao.edu/safety/itt_hartford_risk_management_resources/cellulose_insulation.pdf

Property	Cellulose Insulation
Thermal conductivity, λ [W/m.K]	0.035 in lofts; 0.038 - 0.040 in walls
Thermal resistance at 100mm [K·m^2/W]	2.632
Specific Heat Capacity [J/(kg.K)]	2020
Density [kg/m^3]	27 to 65
Thermal diffusivity [m^2/s]	n/a
Embodied energy [MJ/kg]	0.45
Vapour permeable	Yes

Sheep's Wool

Wool insulation is made from sheep wool fibres that are either mechanically held together or bonded using between 5% and 15% recycled polyester adhesive to form insulating batts and rolls. The wool used to manufacture insulation is the wool discarded as waste by other industries due to its colour or grade.

Figure 14. Sheep's wool insulation

Table 7. Properties of the sheep's wool insulation.

Property	Cellulose Insulation
Thermal conductivity, λ [W/m.K]	0.038
Thermal resistance at 100mm [K·m^2/W]	2.63
Specific Heat Capacity [J/(kg.K)]	1800
Density [kg/m^3]	23
Thermal diffusivity [m^2/s]	n/a
Embodied energy [MJ/kg]	6
Vapour permeable	Yes

Hemp Fibres

Hemp fibres are produced from hemp straw of the hemp plant. Hemp grows up to a height of nearly 4 metres within a period of 100-120 days. Because the plants shade the soil, no chemical protection or toxic additives are required for hemp cultivation. The product is composed of, usually, 85% hemp fibre with the balance made up of polyester binding and 3-5% soda added for fire proofing.

Figure 15. Hemp fibres.

- Hemp is a natural raw material with extremely high thermal resistance
- It has an ability to absorb and release moisture without effecting thermal performance
- Hemp is compatible with diffusion open construction and has effective acoustic properties

Table 8. Properties of the hemp fibre insulation.

Property	Hemp Fibre Insulation
Thermal conductivity, λ [W/m.K]	0.039 to 0.040
Thermal resistance at 100mm [K·m^2/W]	2.5
Specific Heat Capacity [J/(kg.K)]	1800 to 2300
Density [kg/m^3]	25 to 38
Thermal diffusivity [m^2/s]	n/a
Embodied energy [MJ/kg]	10
Vapour permeable	Yes

8.3.2 Selection criteria for building thermal insulation [9]

Many parameters should be considered when selecting thermal insulation, including durability, cost, compressive strength, water vapor absorption and transmission, fire resistance, ease of application, and thermal conductivity. However, the thermal resistance of insulation materials is the most important property that is of interest when considering thermal performance and energy conservation issues. The factors that impact the choice of insulating materials can be summarized as follows:

1. Thermal performance
   - Thermal resistance:

        - High R-value insulation material (e.g., fiberglass, rock wool, polystyrene, polyethylene, polyurethane, etc.).
        - Material thickness vs. thermal resistance.
        - Material density vs. thermal resistance.
        - Operating temperature range vs. thermal resistance.
    - Thermal bridging
        - Continuity of thermal insulation around walls/roof.
        - No/minimum framing.
    - Thermal storage
        - Thermal storage benefits from massive walls (e.g., concrete, adobe).
        - Time lag capabilities.
2. Cost
    - Extra cost of insulation (cost per R-value).
    - Extra cost of quality materials and workmanship.
    - Impact on labor cost.
    - Impact on air-conditioning equipment size and initial cost.
    - Impact on energy/operating cost.
3. Ease of construction
    - Impact on workmanship requirements.
    - Impact on ease/speed of construction.
    - Impact on ease of operation, maintenance and replacement.
4. Building codes requirements (safety and health issues)
    - Fire resistance capabilities.
    - Health hazards (toxic or irritating fumes).
    - Structural stability (load bearing vs. non load bearing, compressive strength).
    - Odor and skin/eye irritation.
5. Durability
    - R-value change over time (e.g., foams filled with gases heavier than air that diffuse over time).
    - Water and moisture effects (absorption and permeability).
    - Dimensional stability (thermal expansion and contraction).
    - Settling over time.
    - Strength (compressive, flexural, and tensile).
    - Chemicals and other corroding agents.
    - Biological agents (dry rot and fungal growths).
6. Acoustical performance
    - Sound absorption.
    - Sound insulation.
7. Air tightness
    - Vapor/infiltration barrier.

- Wall/roof construction quality.
- Sealed penetrations.
- No cracks.
- Good weather stripping.

8. Environmental impact
9. Availability

8.3.3 Benefits of using thermal insulation (9)

There are many benefits for using thermal insulation in buildings, which can be summarized as follows:

1. A matter of principle: Using thermal insulation in buildings helps in reducing the reliance on mechanical/electrical systems to operate buildings comfortably and, therefore, conserves energy and the associated natural resources.
2. Economic benefits: An energy cost is an operating cost, and great energy savings can be achieved by using thermal insulation with little capital expenditure (only about 5% of the building construction cost). This does not only reduce operating cost, but also reduces HVAC equipment initial cost due to reduced equipment size required.
3. Environmental benefits: The use of thermal insulation not only saves energy operating cost, but also results in environmental benefits as reliance upon mechanical means with the associated emitted pollutants are reduced.
4. Customer satisfaction and national good: Increased use of thermal insulation in buildings will result in energy savings which will lead to:
    - Making energy available to others.
    - Decreased customer costs.
    - Fewer interruptions of energy services (better service).
    - Reduction in the cost of installing new power generating plants required in meeting increased demands of electricity.
    - An extension of the life of finite energy resources.
    - Conservation of resources for future generations.
5. Thermally comfortable buildings: The use of thermal insulation in buildings does not only reduce the reliance upon mechanical air-conditioning systems, but also extends the periods of indoor thermal comfort especially in between seasons.
6. Reduced noise levels: The use of thermal insulation can reduce disturbing noise from neighboring spaces or from outside. This will enhance the acoustical comfort of insulated buildings.

[9] Mohammad S. Al-Homoud, (2005). Performance characteristics and practical applications of common building thermal insulation materials. Building and Environment 40 (2005) 353–366

7. Building structural integrity: High temperature changes may cause undesirable thermal movements, which could damage building structure and contents. Keeping buildings with minimum temperature fluctuations helps in preserving the integrity of building structures and contents. This can be achieved through the use of proper thermal insulation, which also helps in increasing the lifetime of building structures.
8. Vapor condensation prevention: Proper design and installation of thermal insulation helps in preventing vapor condensation on building surfaces. However, care must be given to avoid adverse effects of damaging building structure, which can result from improper insulation material installation and/or poor design. Vapor barriers are usually used to prevent moisture penetration into low-temperature insulation.
9. Fire protection: If the suitable insulation material is selected and properly installed, it can help in retarding heat and preventing flame immigration into building in case of fire.