GRINSCO

LECTURE NOTES UNIT 1

GRINSCO
GREEN INSULATION SKILLS FOR CONSTRUCTION WORKERS

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1. The “envelope”

The use of the term "envelope" is relatively new and emerged as a further development of the concept of enclosure, which characterises the outer envelopes (horizontal, vertical, opaque, transparent, etc.) as separate entities. The building envelope, the term for the entire external closure system, is divided into different functional layers and materials.

The growing interest in environmental issues has led to the building envelope no longer being considered merely as a separating element between the inside and the outside, but as a dynamic interface that is in constant and active interaction with external climate factors (green building projects). The efficiency of the building envelope stems from its ability to respond flexibly to the variability of environmental conditions, minimising heat loss in winter and limiting the temperature rise in summer, leading to an improvement in living comfort and environmental quality.

The building envelope is likened to a third skin: a sequence of the three skins that characterise human life, which performs a protective function by opposing those influences that are otherwise responsible for irreversible damage to the human organism, ensuring well-being and health. The skin tissue that covers our body and our clothing is in fact comparable to the envelope of the home, which is not understood as a "closure", a separation between inside and outside, but as a boundary of transformation capable of regulating the internal environmental conditions vis-à-vis the external ones.

2. Introduction -Materials that insulate

If you insulate your house well, you save on heating costs and, along with your energy consumption, you also reduce carbon dioxide emissions, which are mainly responsible for global warming. The use of suitable heat-insulating materials not only reduces heat loss from the building in winter, it can also prevent overheating in summer and thus significantly improve the comfort of the indoor climate throughout the year.

Not all insulation materials are the same physical properties.

There is a wide range of insulating materials available, depending on the application as well as on economic, ecological and health criteria. The right choice and application is a prerequisite for perfect hygienic conditions and to avoid moisture damage to the building.

In general, all common insulation materials have their justification and are suitable for different applications depending on the material, commercial form, resilience, moisture and fire protection behaviour, thermal conductivity, ageing resistance, pest resistance and other properties. For example, insulation boards are particularly suitable for exterior walls, as above-rafter insulation in the roof or for insulating the basement ceiling. Flexible mats, insulation wedges or blow-in flakes are suitable for angled constructions, and fillers are used to fill cavities or to compensate for uneven floors.

Source: freepic-wirestock

In addition to mineral (rock and glass wool, foam glass, calcium silicate boards, perlite, etc.) and plastic-based materials (expanded and extruded polystyrene, polyurethane), there is a wide range of products made from renewable raw materials such as wood fibre, cellulose, cork, hemp, flax or sheep's wool. Decisive for the choice, however, are the sometimes-considerable price differences.

Ecological assessment

To assess the ecological impact of different insulation materials, the energy required for raw material extraction, product manufacture, transport and installation must be taken into account. Estimating the service life and deconstruction is sometimes more difficult. However, for every common insulation material, the savings are many times higher than the energy used.

This educational text is not intended to determine what is ecological and what is not, but to provide the reader with the necessary technical information to make the right decision together with the building user and to find the best solution, considering all sustainability aspects.

Source: freepic-wirestock

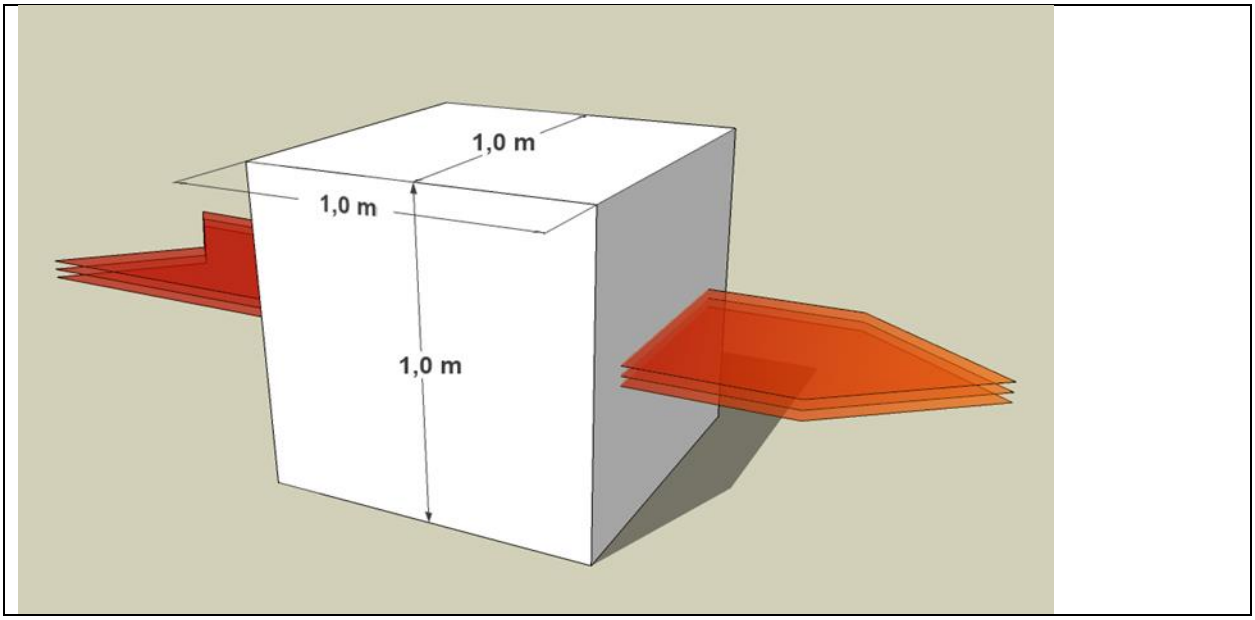
3. GENERAL PARAMETERS

3.1. Thermal conductivity

When choosing insulation, one of the main parameters to consider is the thermal conductivity λ (lambda), which is measured in W/mK. To be defined as such, an insulating material must have a thermal conductivity of less than 0.1 W/mK, according to the German DIN 4108 standard, and equal to or less than 0.045 W/mK in common use.

This parameter measures the ability of a material to conduct heat and depends only on the nature of the material and not its shape. A low conductivity value characterises insulating materials with higher performance. Thermal conductivity plays a key role in the design of low-energy houses: materials with low thermal conductivity ensure the thermal insulation of the building, allowing for lower energy consumption and, if laid properly, maintaining a comfortable interior temperature.

This educational text is not intended to determine what is ecological and what is not, but to provide the reader with the necessary technical information to make the right decision together with the building user and to find the best solution, considering all sustainability aspects.



Source: Agenzia CasaClima

Thermal Conductivity indicates the amount of heat that passes in unit time through 1m² of material with thickness of 1m in the presence of a temperature difference on opposite sides of 1°C (or Kelvin). It measures the ability of a material to transmit heat and depends on its nature.

3.2. Density

Insulation materials are generally light and, therefore, have, with a few exceptions, little mechanical strength. In general, the higher the mass, the more stress-resistant the material is. In the field of insulation, this requirement is particularly important if the material is used in walkable structures, where it may be subject to cracking and breaking if it does not have adequate mechanical strength properties.

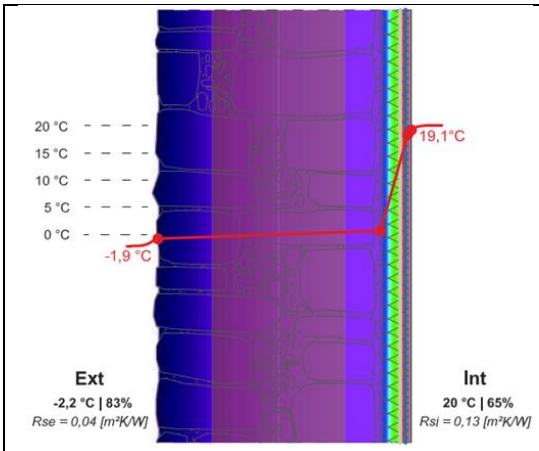
Density or density, as we shall see later, plays a decisive role in summer thermal protection.

Source: freepic-60k risorse

A stone wall has a very high mass because the density of the stone is very high, but poor insulating properties.

3.3. Vapour diffusion resistance factor

The vapour diffusion resistance coefficient is the parameter indicating how much more resistant a material is to vapour diffusion than an even layer of air. The higher the dimensionless value μ (mu) of the material, the greater its resistance to water vapour passing through. This parameter becomes very important for assessing the breathability of a stratigraphy, especially when the insulating material is arranged in a cavity or on the inside, where, depending on the materials used, there may be a greater risk of interstitial condensation.



As we can see from the images shown, when a layer of thermal insulation is applied, the line describing the temperature trend within the stratigraphy assumes its maximum slope within the insulation layer. Therefore, when thermal insulation is applied on the warm side of the masonry, this causes the critical temperatures for the formation of surface and interstitial condensation to be created right at the interface between the existing wall and thermal insulation.

3.4. Fire Behaviour

Among the essential requirements that construction products must fulfil is safety in the event of fire. In European legislation, a distinction is made between two parameters: reaction to fire - standard EN 13501-1 and fire resistance - standard EN 13501-2. Both parameters define a performance level and form part of the passive safety of the building. products according to their flammability. They are grouped in descending order from A1, A2, B, C, D, E to F, which identifies products that have not yet been classified. Floors, linear insulation and electrical cables are further differentiated by the letters FL, L, CA, respectively. The European standard also takes into account two further parameters such as smoke emission with subclasses s1, s2, s3 and dripping with subclasses d0, d1, d2.

3.5. Fire resistance

Fire resistance is a parameter that typically refers to structures and buildings and allows the evaluation of their behavior during a fire by analyzing their ability to retain certain mechanical characteristics for a certain period. The acronyms defining the fire resistance characteristics are of the REI 60, REI 120 and so on, where the letters stand for:

- R = structural stability: ability to retain mechanical resilience under the action of fire;
- E = tightness: ability to not allow flames, vapours or hot gases to pass through or produce on the non-exposed side;
- I = insulation: ability to reduce heat transmission. The numbers instead (10, 15, 20, 30, 45, 60, 90, 120, 180, 240 and 360)

express the time in minutes during which fire resistance must be guaranteed.

In the case of load-bearing masonry, the main reference values will be REI, in the case of non-load-bearing closures, as in the case of infills, EI values will be analysed.

3.6. Specific Heat and Mass Heat Capacity

The specific heat, a characteristic property of each material, expresses how much heat must be supplied to one kilogram of the material to raise or lower its temperature by one degree. The specific heat is determined experimentally for each material.

The heat capacity of a material, on the other hand, represents the heat required to cause the temperature of the material to vary by one degree. Unlike specific heat, which only depends on the type of material it is made of, heat capacity is proportional to the amount of matter (C = m*c, where m is the mass and c the specific heat per unit mass and C the heat capacity). It is a particularly important parameter in assessing the summer comfort of a room, as it describes the ability of a stratigraphy (wall, roof, etc.) to accumulate heat, which will only later be released to the environment to a lesser extent.

3.7. Acoustic insulation

In addition to thermal properties, insulation materials may be able to reduce airborne sound from outside through ducts, windows and other air passages. Sound can also come from adjacent rooms and is transmitted airborne, but mainly through the vibration of rigid structures. Noise from neighbours' footsteps or vibrations from technological installations fall into this category.

To counteract airborne noise, fibrous or porous insulation materials are generally inserted in the wall cavities to increase soundproofing capacity.

The combination of these two solutions will make rooms noise-proof, guaranteeing excellent acoustic comfort, if the components are correctly designed and installed.

3.8. Hygroscopicity

This is the property of a material to absorb and retain water vapour within its structure. Hygroscopic materials (properly called 'active' materials) allow for optimal indoor moisture management as they are able to dampen moisture peaks by absorbing it into their structure. The prolonged presence of water in insulation materials damages their structure and reduces their insulating capacity. It is therefore preferable to provide non-hygroscopic materials in areas where there is a risk of water infiltration, in contact with the ground or on a flat roof.

3.9. Winter thermal protection

A good building envelope is one that allows maximum reduction of heat transmission from the heated interior to the colder exterior in winter. When choosing an insulating material, limited to its winter prestations, it is essential to evaluate it with respect to its declared thermal conductivity λd. The useful value for establishing the actual insulating capacity of an insulating panel of a defined thickness is actually not λd, but the resulting thermal resistance R. It expresses the insulating capacity of a material of a given thickness. To quickly calculate the R-value of an insulation board, divide the thickness of the insulation material by its thermal conductivity.

$R\ [m^2K/W] = \text{thickness}\ [m] / \lambda\ [W/mK]$

3.10. Summer thermal protection

Like in the winter, a good building envelope in summer is one that is able to protect against overheating in summer, i.e. the heat that tends to move from the outside to the inside of the building. The thermal conductivity λ is no longer a sufficient parameter for assessing the summer performance of insulating materials, so the material's ability to absorb heat must also be taken into account. The values to be taken into account in this case are specific heat and density. With the same thermal conductivity, an insulating material with a higher specific heat and density will be much more effective in protecting against heat, as it will be able to accumulate more heat. This will delay the entry of heat into rooms (phase shift) and reduce its intensity (attenuation factor). Layers with a high thermal phase shift allow,

especially in summer, that the external heat peak does not penetrate the interior of the house immediately but is delayed. This aspect is particularly important in the insulation of lightweight structures such as timber frame structures.

3.11. Technical rules

Insulation materials are covered by the European Union's rules for the marketing of construction products.

Since 1 July 2013, EU Regulation No. 305/2011 has been in force, laying down harmonised conditions for the marketing of construction products. As of this date, in order to be placed on the market, construction products falling within the scope of a harmonised standard or, in the absence thereof, conforming to a European Technical Assessment, must bear a declaration of performance and CE marking.

The CE marking is the manufacturer's declaration of conformity of a product to a harmonised European technical standard and compliance with the established essential safety requirements. CE marking a product means declaring performance values, for which a systematic control of the production process (from raw materials to the finished product) is necessary.

An important innovation was the introduction of a new document called DoP (Declaration of Performance).

By drawing up a Declaration of Performance, according to a harmonised standard (EN) or a European Technical Assessment (ETA) issued by a Technical Assessment Body, the manufacturer assumes responsibility for the conformity of the product.

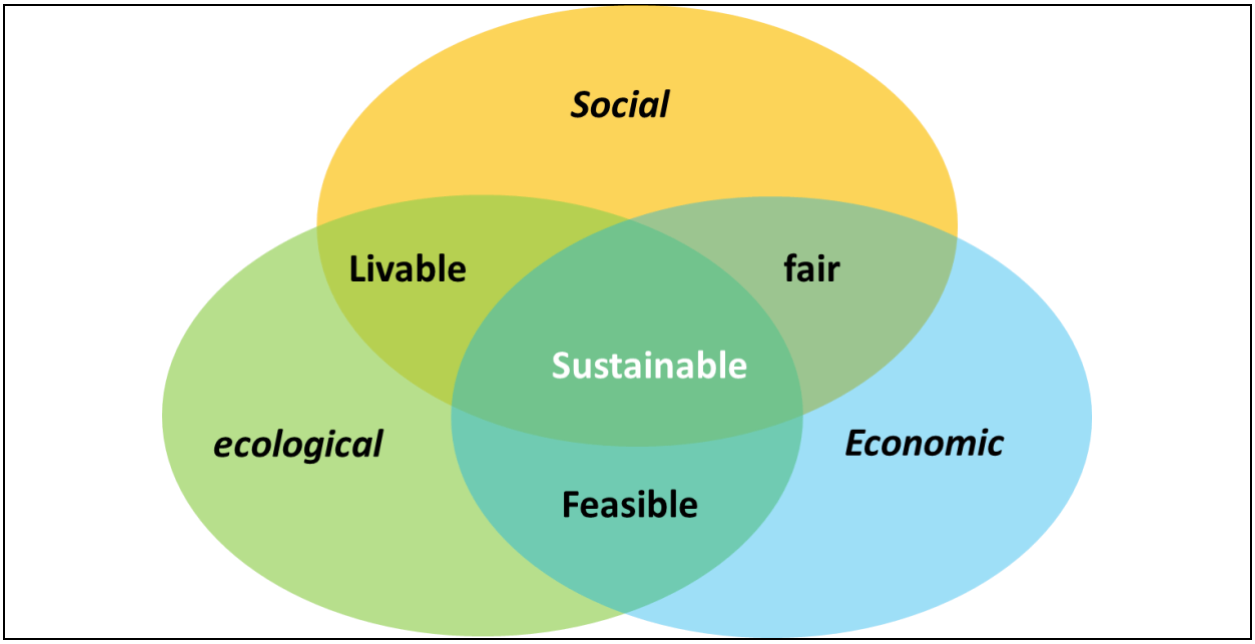
All building insulation materials that have a harmonized standard must be CE-marked. Please note that insulation that is not CE-marked must still be thermally characterized as required by national legislation concerning energy savings in buildings.

4. ENVIRONMENTAL ASSESSMENT

4.1. Environmental assessment

All building materials consume resources from the environment and can release pollutants into the atmosphere. When choosing an insulation material, the environmental aspects should always be considered in addition to the properties and economic aspects. Some insulators can be critical about the characteristics of the raw materials used during the transformation process or the impact of transport. For natural insulation materials, it is important to know which substances have been used to prevent deterioration, as this may make recycling or composting problematic. For those of mineral origin, on the other hand, the most critical environmental aspects concern the high energy expenditure for the raw material processes.

The world of insulation material production is increasingly attentive not only to methods and criteria for assessing the environmental quality of products and manufactured goods, but also to procedures for certifying their requirements. In recent years, both at international and European level, labels and product declarations have started to become more widespread. Although on a voluntary basis, these instruments aim to communicate the environmental characteristics and performance of a product to the market. The recipients of these messages, depending on the products analysed, can be either simple consumers or professionals who offer these products to their customers.



Dimensions of sustainability

4.2. LCA

The methodology supporting environmental labelling is the LCA (Life Cycle Assessment,) regulated by the ISO 14040 standard. The procedure, designed to help quantify, interpret and assess the environmental impacts of a specific product or service, can be applied to the entire life cycle of the product, from extraction, raw material processing, manufacturing, transport, distribution, use, reuse, recycling and final disposal.

4.3. EPD

On an international level, the nations most active in sustainability issues, particularly those in Europe, have recognised the EPD (Environmental Product Declaration) environmental label, defined by ISO 14025 and EN 15804, as a valid tool for communicating and disseminating certified environmental information on the sustainability of manufactured products.

The EPD provides quantitative data on the environmental profile of a product, not expressing a rating scale on its performance, nor a permissible threshold value. However, EPD certification requires adherence to precise rules for assessment and a certain format for reporting data in order to facilitate comparison between different products. It is to be hoped that in the coming years more and more companies will decide to adopt EPDs as a tool for declaring the environmental performance of their products: this will allow greater transparency and facilitate choices by consumers, who are now increasingly attentive to the environmental impact of the products they use.

Example of EPD

4.4. How to recognise green products and services

In order to be able to recognise generally which goods are able to fulfil the environmental criteria of Green Procurement, it is necessary to have sufficient information on their life cycle.

The necessary information can be obtained through various certification tools, which must be based on objective and transparent criteria and must be assigned by an independent third party, such as:

Environmental Labels (ISO Type I, ISO 14024); Environmental Self-Declarations (ISO Type II, ISO 14021,); Environmental Product Declarations (ISO Type III, ISO 14025);

Mandatory Marks and Labelling; Environmental Management System Certifications.

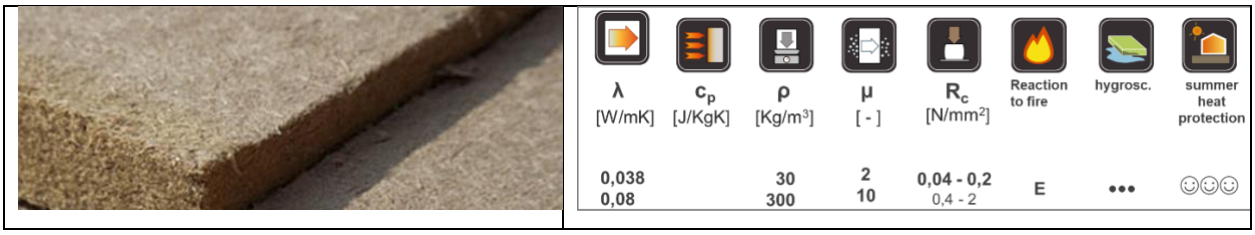
Examples of Environmental Labels

5. INSULATION MATERIALS

5.1. WOOF FIBRE WF

Raw material and production process Wood fibre is derived from production waste from wood processing, forest thinning or trees planted in controlled forests. Insulation panels can be produced using the traditional wet method or the innovative dry method. To improve the water repellency of the wood fibre, substances such as latex or natural resins can be added.

Usage. Wood fibre panels can be used for the insulation of sloping roofs (between and above rafters, on the extrados or intrados of the supporting structure) and cold floors, by laying the panels on the extrados or intrados of the supporting structure. Wood fibre can also be used for acoustic insulation between building units. Panels are used on walls for external insulation (external insulation and ventilated façades), insulation inside timber frame structures or for internal insulation.



woodfibre

5.2. CORK

Raw material and production process Cork is derived from cork oaks, the bark of which, after peeling, is treated and ground to obtain a granular material, which can have various applications in construction. To make the panels, the granulate is placed in autoclaves at high temperatures: the dissolution of suberin (a natural resin present in cork) thus enables agglomerated cork blocks to be obtained. The blocks are then cooled and cut into slabs of various thicknesses.

Use. Cork panels can be used for the insulation of sloping roofs at the extrados of the load-bearing structure. Flexible panels are generally thin and can be used for impact sound insulation between building units. The granulate can be used as dry underlay or for blowing in wall cavities. On the wall, they are used for external insulation (external insulation and ventilated facades).

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,036 0,06	1560 1800	100 220	2 10	0,1 - 0,25 1– 2,5	B2	•	☺☺☺

cork

5.3. CELLULOSE FIBRE

Raw material and production process Cellulose is derived from recycled newsprint which, after being shredded, is treated with boron salts to improve its fire behaviour. The flakes obtained in this way can be used as an insulator by insulating in a cavity. Panels can also be made from the flakes by adding a small percentage of synthetic binders.

Usage. Cellulose can be used for the insulation of roofs, intermediate floors and cold floors by means of insulating or laying panels inside the structure. It can also be used for the insulation of cavity walls within timber frame structures.

5.4. HEMP FIBRE

Raw material and production process. Hemp fibre comes from the stem of the hemp plant, reduced to fibre and occasionally enriched with boron salts to improve its fire behaviour, and polyester fibres to improve its strength and flexibility. Hemp fibres are obtained by maceration of the plant followed by artificial drying of the fibres, which causes them to bond with the added artificial fibres.

Usage. Hemp fibre is mainly used in cavities within timber frame structures or in drywall structures (plasterboard walls and counterwalls). Due to its soundproofing properties, it can be used for soundproofing intermediate floors. The insufflating of hemp fibres is very rare.

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,04 0,05	1500 2200	20 190	1 2	n.d.	E		☺☺☺

5.5. MINERAL WOOL

Raw material and production process Stone wool is derived from basalt rock and production waste that is melted at very high temperatures and processed into fibres. The addition of resins and binders allows the fibres to adhere, which, once cooled, harden and form panels of varying density depending on the amount of fibres used.

Usage. Stone wool is used for external wall insulation (cladding insulation and ventilated façades), external roof insulation and insulation of cold floors. It is also used inside lightweight wooden structures and, due to its soundproofing properties, is often used in partition structures between building units or as an impact insulation mat.

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,033 0,054	800 1030	20 200	1 2	0,015 - 0,08 0,15 – 0,8	A1		☺☺

5.6. Glass Wool

Raw material and production process. Glass wool has a production process very similar to that of rock wool but differs in raw material consisting mainly of silica sands and recycled glass. As with rock wool, the addition of resins and binders allows the fibers to adhere which, when cooled, harden and form panels of varying densities depending on the number of fibers used

Usage. Glass wool can be used for the external insulation of walls (insulation coat and ventilated facade), for the external insulation of roofs and for the insulation of cold floors. It can also be used inside drywall structures.

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,032 0,053	840 1030	10 70	1 2	n.d.	A1-A2		☺

5.7. Calcium silicate mineral foam CS

Raw material and production process. Calcium silicate is produced from calcium and silicon oxide with the addition of 3-10% cellulose in water. The mixture is placed in molds and then treated with water vapor in an autoclave at high pressure.

Usage. Calcium silicate is used for wall insulation from the outside or inside. The panels can also be applied indoors for insulation of floors and roofs. They are often used for thermal bridge mitigation due in part to their hygroscopicity and chemical properties, which allows the material to absorb large amounts of moisture, reducing the risks of mold formation.

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,06 0,095	1000	115 300	30 20	0,5 – 1,5 5- 15	A1 - A2		☺☺

EXPANDED CALCIUM SILICATE HYDRATES.

Raw material and production process. Calcium silicate hydrates are derived from the mixture of quartz sand, water and aluminum paste. The latter, when reacting, creates hydrogen

gas, which in turn expands and creates alveoli in the slurry. It hardens by steam autoclave process (about 5-12 hours at 190 °C).

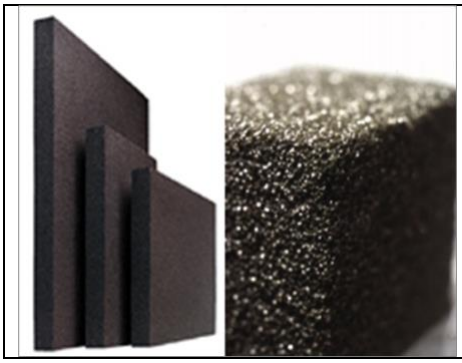
Usage. Silicate hydrate panels are mainly used for exterior insulation coatings of walls with masonry or brick structure

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,04 0,06	1000	100 300	2 6	0,35 3,5	A2	---	☺☺☺

5.8. Cellular glass - CG

Raw material and production process. Cellular glass is derived from glass powder, including recycled glass, which, when additivated with carbon and brought to a high temperature, expands in volume, creating a honeycomb structure. Blocks are thus obtained which, after undergoing gradual cooling, are cut into sheets of various sizes and thicknesses.

Usage. The material can be effectively used in all cases where waterproofing and load resistance are required, such as exterior insulation of structures against the ground, exterior insulation of foundation slab, flat roofing and green roofs.



λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,04 0,065	800 1000	100 200	∞	0,2 - 1,7 2- 17	A1		

5.9. EXPANDED CELLULAR GLASS GRANULATE

Raw material and production process. Cellular glass granulate is derived from recycled glass that, after being reduced to powder, is mixed with water and other additives, broken down into granules, and placed in high-temperature furnaces. The result is an expanded granulate that is subjected to further crushing to obtain different particle sizes.

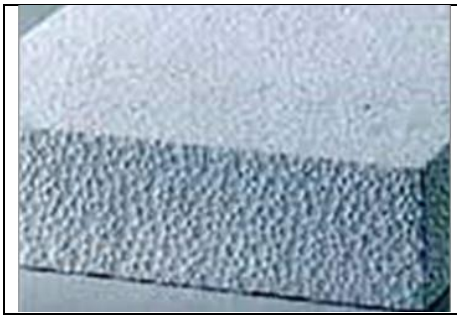
Use. The material can be effectively used for insulating structures against the ground (walls and floors). For applications under foundation slab, the granules after being laid must be compacted and mechanically beaten. Used as subfoundation drainage increases the mechanical properties of the soil .

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,065 0,093	800 1000	140 530	1 8	0,12 - 0,5 1,2 -5	A1	•	☺☺

5.10. EXPANDED POLYSTYRENE - EPS

Raw material and production process. EPS is derived from the polymerization of styrene, a mixture of benzene and ethylene. The beads, obtained by combining the polymer with additives, including one that gives it self-extinguishing properties, are subsequently expanded with water vapor by incorporating air into their structure. The next stage of sintering consists of casting the beads into the shape of the article. In the case of blocks, this is followed by cutting into slabs after a period of curing.

Usage. EPS can be used for the external insulation of walls (insulation coat), of cold floors, and of inclined and flat roofs with masonry and brickwork structure.



λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,032 0,056	1250 1500	10 50	20 100	0,06 - 0,2 0,6- 2	E		☺

5.11. EXPANDED POLYSTYRENE WITH GRAPHITE- EPS

Raw material and production process. EPS is derived from the polymerization of styrene. The beads are obtained by combining polystyrene with additives, including graphite, which gives it greater insulating capacity, and poly-FR, a polymer that ensures its self-extinguishing properties. The beads are expanded with water vapor by incorporating air into their structure and are subsequently welded into the shape of the manufactured product by the sintering process. In the case of blocks, this is followed by cutting into slabs after a curing period.

Usage. EPS can be used for the external insulation of walls (insulation coat), of the floors and roofs.

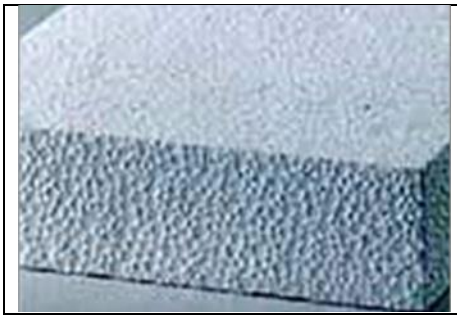
λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,032 0,056	1250 1500	10 50	20 100	0,06 - 0,2 0,6- 2	E		☺

5.12. BIO-DERIVED EXPANDED POLYSTYRENE - EPS BMB

Raw material and production process. Biomass Balance (BMB) is the certified process by which up to 100 percent of the primary fossil sources required for styrene production are replaced by sustainable renewable sources, namely biomass.

From the saving of primary fossil sources follows a reduction in the carbon footprint of the panels. The resulting raw material is processed in exactly the same way as standard raw material, resulting in panels and insulation products with thermal and mechanical performance identical to panels from fossil sources.

Usage. EPS can be used for the external insulation of walls (coat insulation), of floors and of roofs.

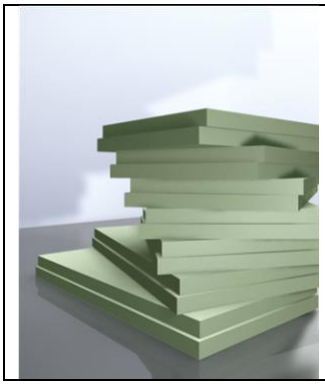


λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,032 0,056	1250 1500	10 50	20 100	0,06 - 0,2 0,6- 2	E		☺

5.13. EXTRUDED POLYSTYRENE FOAM - XPS

Raw material and production process. XPS (extruded polystyrene foam) is derived, like EPS, from styrene. The production process is very similar but differs in the extrusion stage in which the granular material is mixed with additives. This makes the structure of the material homogeneous. Once extruded, the material is subjected to cutting operations and processed into panels.

Usage. Because of its compressive strength properties, XPS can be used for the insulation of structures against the ground (walls and floors), cold floors, and flat or sloping roofs with masonry and brick structure. Because of its water-resistant properties, it is frequently used as a baseboard in exterior perimeter wall insulation.



λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,03 0,04	1300 1700	25 65	70 200	0,15 - 0,7 1,5- 7	E	–	☺☺

5.14. RIGID POLYURETHANE FOAM - PUR/PIR

Raw material and production process. Polyurethane is an insulating material of synthetic origin derived from the reaction of various polymeric compounds. By partially modifying the raw materials, PIR is obtained, with better fire resistance and reaction characteristics.

Usage. Polyurethane can be used for the insulation of cold floors, flat or sloping walls and roofs with a masonry or brick structure. In cavity or non-exposed walls, spray application can be used.

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,024 0,035	1400 1500	25 100	30 200	0,1 - 0,5 1-5	B	•	☺☺

5.15. POLYETHYLENE FOAM - PNT

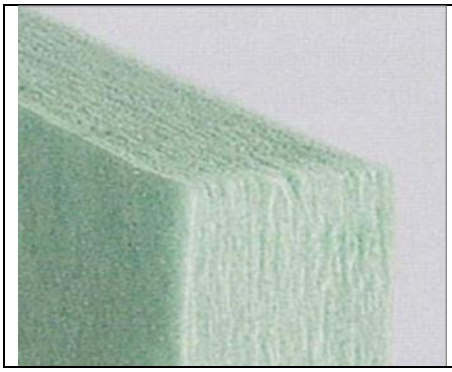
Raw material and production process. Cross-linked expanded polyethylene is obtained by a process of expanding the raw material by injection of expanding gas.

Usage. Polyethylene foam can be used for acoustic insulation of attics and for insulating plant piping.

5.16. POLYESTER FIBERS - PET

Raw material and production process. Polyester fiber is mainly derived from recycled plastic from bottles and thermobinders mixed together to achieve the desired weight. Then the thermobonding fibers are melted with hot air (180 °C) and then cooled. Other materials can be laminated during the process without the use of adhesives.

Usage. Polyester fiber is used within lightweight drywall structures. Due to its acoustic properties, it can be used for the insulation of partition structures between building units.



λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,035 0,045	1200 1250	15 50	1 3	n.d.	B	•	☺

5.17. PHENOLIC RESIN FOAM - PF

Raw material and production process. Phenolic resins are a family of polymers obtained by reaction between phenol and formaldehyde. They are generally thermosetting materials, meaning they cannot be further melted after molding because they possess a cross-linked structure. They are rigid expanded foams with open or closed cells and have varying thermal conductivity depending on density. Water vapor permeability also depends on the density and the manufacturing process, but is still quite high.

Usage. Rigid panels are generally used for the insulation of flat roofs under exposed or weighted synthetic coverings and under cold-applied bituminous coverings. Phenolic resins are used for the insulation of pitched roofs, but also for wall and/or floor insulation and applied as an overlay system and generally in all applications where high fire resistance is required.

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,024 0,035	1400 1500	25 100	30 200	0,1 - 0,5 1-5	B	•	☺☺

5.18. EXPANDED CLAY GRANULATE

Raw material and production process. The material is produced from cured clay (aluminum silicate hydrate) fired at 1200-1300 °C in rotary kilns. At this temperature, the clay granules shed their moisture and expand. Chemically inert, expanded clay is a long-lasting stable material, resistant to insects and biodegradation, with good mechanical and frost resistance. Expanded clay has low thermal insulating power, low hygroscopic, but highly breathable.

Usage. Used as a cavity filler, inert for plasters and in lightened mixtures for floors.

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,085 0,13	920 1100	200 500	2 8	0,10 - 0,3 1-3	A1	•	☺☺

5.19. EXPANDED PERLITE - EPB

Raw material and production process. The material is produced from siliceous rock of volcanic origin. Reduced to powder, it is exposed to thermal shock (1000 °C) to evaporate the water contained in the mineral. This causes the glass walls to expand and the granule to increase in volume by up to 20 times its initial volume.

Usage. It is commercially available in the form of granules and is used as aggregates in the composition of mortars, light lime- struments and plasters. Expanded perlite is offered as lightweight granular insulation for unfilled cavity insulation for example as cavity insulation, insulation between load-bearing beams or ceiling insulation . In panels, it is ideal for use in roofing as a waterproofing support, but also for interior insulation

λ [W/mK]	c_p [J/KgK]	ρ [Kg/m³]	μ [-]	R_c [N/mm²] [Kg/cm²]	Reaction to fire	hygrosc.	summer heat protection
0,045 0,07	840 1200	30 490	1 8	0,15 - 0,30 1,5 – 3,0	A1	•	☺☺

5.20. AEROGEL

Raw material and production process. The material is composed of 98% air and 2% silicon and is produced by dehydration of a colloidal silica gel. Aerogel is a solid state gel-like substance in which the liquid component is replaced with gas. It is impalpable and very volatile. Aerogel panels and felts used in construction are a compound consisting of a matrix, usually of polyester fibers, impregnated with aerogel.

Usage. The predominant use of aerogel is for interior insulation of cold floors, roofing and perimeter walls. Aerogel can be laminated to plasterboard sheets and used for plating existing structures. The price of this product is generally high.

5.21. VACUUM INSULATION PANEL - VIP

Raw material and manufacturing process. Vacuum insulating panels (VIPs) generally consist of a core and a coating. The core is a porous silica compound to which an opacifier is added, to minimize the passage of thermal radiation, and cellulose fibers, to improve the mechanical stability of the panel. During the coating stage, the product is placed under vacuum and sealed. The coating soli- tly consists of an aluminum film. Each panel is equipped with a sensor for verification of no puncture.

Usage. VIP panels are particularly suitable in all situations where excellent insulation and reduced thicknesses are required. They can be used for the insulation of perimeter walls, cold floors and roofs, having, however, the utmost care in the installation since, if perforated, the panels lose part of their thermal insulation characteristics. They cannot be cut or adapted on the construction site. The price of this product is generally high

5.22. THERMORFLECTIVE MATERIALS

Raw material and manufacturing process. Heat-reflective materials are composed of very thin layers of reflective and insulating materials. The former consist of very thin metallized films that re-radiate heat back to the source, the latter of materials such as felt, wadding, and bubble polyethylene, which form very thin layers that can trap still air and thus hinder heat transmission by conduction. The overall thickness of these products is usually between 1 and 3 cm. For proper operation, they must be put in place between two sealed air chambers of varying thicknesses between 15 mm and 40 mm depending on the uses.

Usage. They find use mainly in renovations. The thermophysical properties of the material depend on the design of the system installation.

	Note: When we speak of "heat-reflective" or simply "reflective" material, we do not actually mean a specific insulating material, but a system consisting of several elements. It is usually composed of one or more reflective surfaces with low emissivity given by the thermal reflective mat, which must border one or more air chambers. This means that the insulating performance of the entire system is mainly given by the performance of the air spaces, which, to be effective, must be of optimal size, be sealed, and be free of air motions.

6. FAQS

1) Which materials are called insulating materials?

Only materials with a thermal conductivity of less than or equal to 0.1 W/mK are called insulating materials. This property is due to the material.

2) What origin can insulation materials have.

The insulation materials can come from animal (wool), mineral (e.g. rock wool), vegetable (wood fibre), synthetic-fossil and recycled sources.

3) What are the physical properties of insulation materials?

As insulating materials, these materials have a very low conductivity, so they are rather negligible in terms of thermal resistance, which depends on the layer thickness. Thus, the distinguishing properties are the specific heat capacity, moisture resistance and fire behaviour.

4) Which insulation materials have the best fire performance?

Mineral insulation materials are among the insulation materials that have the best fire protection behaviour.

5) What does the CE marking mean?

The CE marking is a declaration by the manufacturer that a product conforms to a harmonised European technical standard. All insulation materials must be CE marked in order to be traded in the free European area.

6) What construction typologies can an insulation material be found in?

Insulation materials can be manufactured as rigid or flexible panels, loose fill or foam. Therefore the product properties and the processing guidelines can be very different and have to be applied specifically.

7) What are the advantages of using wood fibre panels?

Compared to other insulation materials, wood fibre boards have a high thermal capacity, which is advantageous for summer heat protection against overheating.

8) What is the advantage of using hemp fibre boards?

Hemp has a very similar behaviour to wood fibre board, whereby the energy input of the product is lower.

9) What is the advantage of using calcium silicate boards?

Calcium silicate boards are very hygroscopic, which means it can absorb a lot of moisture and is very alkaline and therefore not susceptible to mould. Therefore, it is used for interior insulation.

10) What is the advantage of using foam glass?

Foam glass is a vapour-proof insulation material and is used where moisture must not penetrate under any circumstances. E.g. for the insulation of green roofs.

11) What is the advantage of using cellulose?

Cellulose is mainly used as a filling material for blowing in cavities in new buildings, but also in the renovation of double-shell masonry.

12) What is the advantage of using cork?

Cork is the only vegetable insulation material that has a structure that does not consist of fibres. Therefore, in contrast to wood fibre and other fibrous materials, it is moisture-resistant and has very good properties for thermal insulation in summer.

13) What are the advantages of using sheep's wool?

The sheep's wool used in the construction sector is actually a waste product that cannot be used in the textiles industry or where large quantities are produced. The insulation material is also suitable as acoustic insulation for increased sound insulation.

14) Which building components should be considered for insulation?

All heat-emitting components of the building envelope are relevant for energy consumption. The orientation of the building components is not important because the energy gains from solar radiation on the non-transparent building components are not relevant.

15) What are the main components of an ETICS?

The system is composed of an adhesive, insulation board, reinforcement mesh, base coat and final coat (finishing coat). The paint is not part of the ETICS, but is relevant when choosing the colour because it affects the surface temperature and can cause cracks in the exterior plaster.

16) What are the insulation solutions for a wooden roof construction?

The insulation can be placed between the rafters (internal insulation) or on top of the rafters (external insulation). It is important that the moisture behaviour is checked and the air sealing layer is placed on the so-called warm side of the stream part.

17) What is a Blower Door Test?

To check the airtightness of a building or a dwelling, a so-called "Blower Door Test" is carried out. This is necessary to check whether warm and humid air can penetrate into the building component or between two different building components (e.g. window and wall) and cause condensation. This not only leads to considerable heat loss, but can also cause damage to the building component.

18) What are thermal bridges?

Thermal bridges represent a thermal disturbance of the heat flow in a building. This "disturbance" occurs because the geometry of the building component changes (e.g. a corner of a house) or if different materials, which have a different thermal conductivity, have been constructively joined together (e.g. a concrete balcony on a masonry wall, improperly installed dowels in an ETICS). Thermal bridges can cause a temperature drop on the inside of the building component, where condensation and mould can then occur. If insulation materials are installed incorrectly, thermal bridges can occur, which can cause mould growth.

19) Why can interior insulation cause structural damage?

If exterior insulation is not applicable for technical reasons or architectural preservation, interior insulation can be a solution to improve the energy efficiency of the building. Placing the insulation on the warm inside causes a drop in temperature in the building component. This drop can cause moisture penetration of the building component, or if driving rain reaches the building component, it cannot dry

out. Therefore, proof of condensation formation must be provided in relation to the application of interior insulation.

20) What are the dimensions of sustainability?

All human actions must be ecologically, economically and socially compatible if they are to be defined as sustainable. Thus, when choosing insulation materials or generally increasing the energy efficiency of buildings, not only the economic aspect but also the ecological aspect is important.

21) What is the best way to classify insulation materials in terms of sustainability?

In terms of sustainability, the method of renewal, i.e. whether the insulation material comes from renewable raw materials, can be a subdivision. However, there is also the possibility to classify the insulation materials according to the proportion of recycled material. Since there are very different reference points, it is basically difficult to find a technical classification that treats all insulation materials equally.

22) Why is the building sector one of the most resource and energy consuming sectors?

In the past, very few building materials were available because transport was difficult. They also had to be durable and easy to maintain. In addition, comfort requirements were very low because only a few rooms were heated or air-conditioned.

Today, there is a myriad of materials, some of which have low durability, and the building is heated and conditioned in almost all rooms. These high comfort requirements have led to a lot of energy and resources being spent on constructing and maintaining buildings.

23) How can the indicators of a life cycle be described?

For the whole life cycle of the building material, input characteristics (consumption of energy, water, raw materials) and output characteristics (pollutant emissions, CO2 emissions, waste) are defined in the system. These characteristics (indicators) are considered in detail for the entire cycle and presented numerically. As an example, the so-called CO2 footprint is the CO2 emission of a product (per kg of product) calculated over the entire life cycle.

24) What is an EPD?

An EPD is a manufacturer's product declaration that reflects the characteristics described in the international standard. According to the standard, at least the life cycle "cradle to gate" must be described.

25) What are environmental certifications?

An environmental certification is an inspection of certain environmentally relevant characteristics of a product by a neutral inspection body. Such certification also specifies minimum requirements, which can also exclude certain products. According to ISO 14024.

7. Multiple choice questions

1. Which part of the building loses the most heat energy?

   a. Windows ☐
   b. Exterior walls ☒
   c. Roof ☐
   d. Cellar ☐

2. What is the term for the inherent movement of water vapour through building and insulation materials:

   a. Water transformation ☐
   b. Water adhesion ☐
   c. Water vapour diffusion ☒
   d. Water vapour cohesion ☐

3. How does water change when it cools below freezing point?
   a. does not change its volume ☐
   b. contracts ☐
   c. expands ☒

4. In the process of diffusion:
   a. Air flows through a wall ☐
   b. there is a difference in air pressure on both sides of a wall ☐
   c. it is a balancing process ☒

5. To avoid harmful condensation in a wall, the insulation material should be placed where possible?
   a. outside ☒
   b. inside ☐
   c. in the middle ☐

6. In which unit is the diffusion μ given?

a. W/mK ☐
b. None, because it compares vapour diffusion in relation to an air layer ☒
c. g/m³ ☐

7. In which unit is the thermal conductivity □ (Lambda) stated?

a. μ ☐
b. N ☐
c. W/mK ☒
d. g/m³ ☐

8. Which insulation material has the better fire protection behavior?

a) Wood fibre board ☐
b) Hemp fibreboard ☐
c) Cork ☒

9. Which insulation material has better vapour diffusion properties (lower μ value)?

a) Cellular glass ☐
b) Cork ☐
c) Hemp ☒
d) EPS ☐

10. Which insulation material has the better specific heat capacity (high cp value) ?

a) Glass wool ☐
b) EPS ☐
c) Wood fibre board ☒
d) Mineral wool ☐

12. Which natural insulation material can be considered for blowing into the masonry?
    a. Glass wool ☐
    b. Cellulose ☒
    c. Mineral wool ☐

13. Which natural insulation material can be considered for blowing into the masonry?
    a. Glass wool ☐
    b. Cellulose ☒
    c. Mineral wool ☐

14. Which natural insulating material can also be used as an admixture in insulating plaster (plaster with insulating material)?
    a. Wood fibre ☐
    b. Cork ☒
    c. Perlite ☒

15. Which of the components listed below is not part of an ETICS?
    a. Fabric angle ☐
    b. Paint ☒
    c. Dowel ☐
    d. Flush-mounted ☐

16. What labelling must an ETICS have in order to be placed on the market in Europe?
    a. Eco-label ☐
    b. Manufacturer's marking ☐
    c. CE marking ☒
    d. European Technical Marking ☐

17. What is the function of the vapor membrane?
    a. To improve the thermal resistance of the component ☐
    b. To improve the sound insulation of the component ☐
    c. To ensure the airtightness of the building component ☒

18. What problems can occur if the insulation material is applied from the inside?
    a. The thermal resistance of the component is reduced ☐

b. Moisture can develop in the component ☒
c. The temperature on the surface of the inner wall decreases ☐

19. What is the g-value of an insulating glass?
a. It is the value of the thermal resistance of the glass ☐
b. It is the proportion of the total sunlight that passes through the glass, ☒
c. It is the proportion of visible sunlight that passes through the glass, ☐

20. What problems can occur if the insulation material is applied from the inside?
a. The thermal resistance of the component is reduced ☐
b. Moisture can develop in the component ☒
c. The temperature on the surface of the inner wall decreases ☐

21. What is an EPD?
a. A declaration of performance of the building physical properties of the material ☐
b. An environmental certificate from an independent auditing body ☐
c. An ecological product declaration from the manufacturer ☒

22. Which dimension of sustainability is not assessed in the EPD?
a. The ecological ☐
b. The social ☒
c. There will be ☐

23. What is environmental certification?

a. An environmental certificate from an independent auditing body ☒
b. An ecological product declaration from the manufacturer ☐
c. A declaration of performance of the building physical properties of the material ☐

24. What is PEFC /FESC environmental certification?

a. An environmental certificate for sustainable forest management ☒
b. An environmental certificate for the carbon footprint for wood products ☐
c. An environmental certificate for low pollutant emissions ☐

25. Is the valuation unit always identical in the EPD?

a. No, it must always be checked exactly the valuation unit (kg, m3 or other unit per material) ☒
b. Yes, the valuation unit is always the same for insulation materials ☐