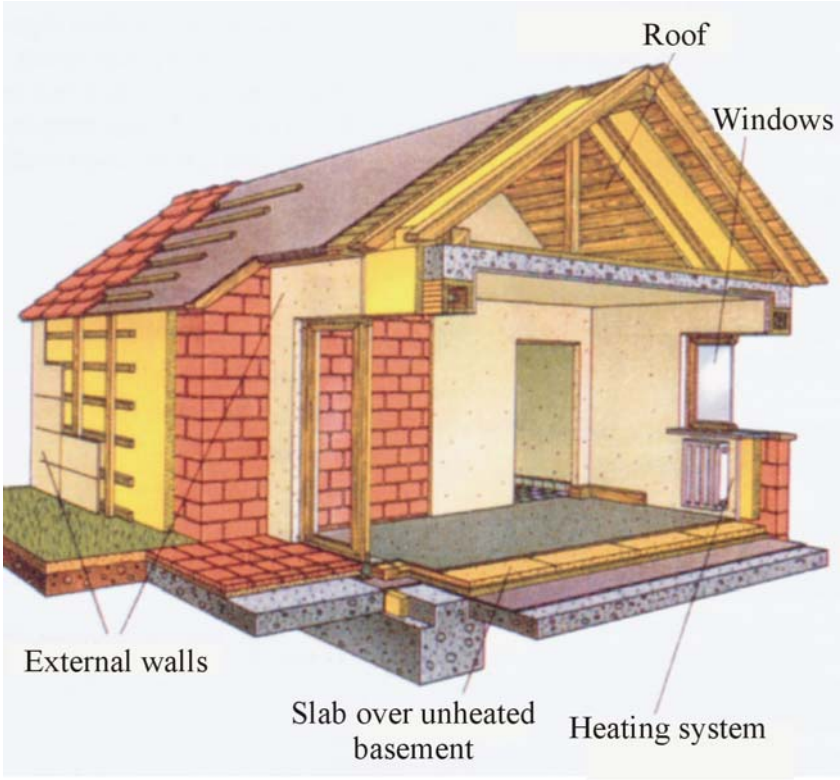
3. The elements of the buildings' envelope

3.1. Different types of buildings

The building's envelope and structure define to a large extend the thermal integrity of the building and its energy saving potential.



The elements of the building's envelope

Buildings in Bulgaria can be classified in four categories according their use: industrial, residential, public (incl. commercial) and traditional (houses built in the 18th –19th century or new houses in which have been used the same materials and contemporary structure system).

Industrial buildings

They are used for industrial purposes or warehouses. Their types of construction are:

Prefabricated constructions:

- **Metal structure and prefabricated concrete panels**. 85-95% of all industrial buildings are of this type of construction, but it is not longer in use due to its high cost.
- **Entirely metal construction**. Used for specific factory buildings as the big machine-building plants in Radomir and Russe. The span between columns ranges from 36 to 54m and big roof cranes can be used.

Reinforced concrete structure and brick masonry.

This type of construction has the lowest cost and is mainly carried out at the moment.

Residential buildings

Residential buildings in Bulgaria can be categorized in four groups according to their structures. These four groups and their distribution are as follow:

- half timbered structure 8%
- monolithic structure 53%
- reinforced concrete skeleton structure 18%
- prefabricated panel structure 21%

Traditional buildings (according the old Bulgarian architecture)

The main characteristics of these buildings are:

- stonework foundations and stonework walls for the first floor
- wooden structure for floors and roofs
- pitched roof covered with stone tiles.
- single glazed wooden windows

Public buildings

The main characteristics of these buildings are the same as these of residential buildings with reinforced concrete skeleton.

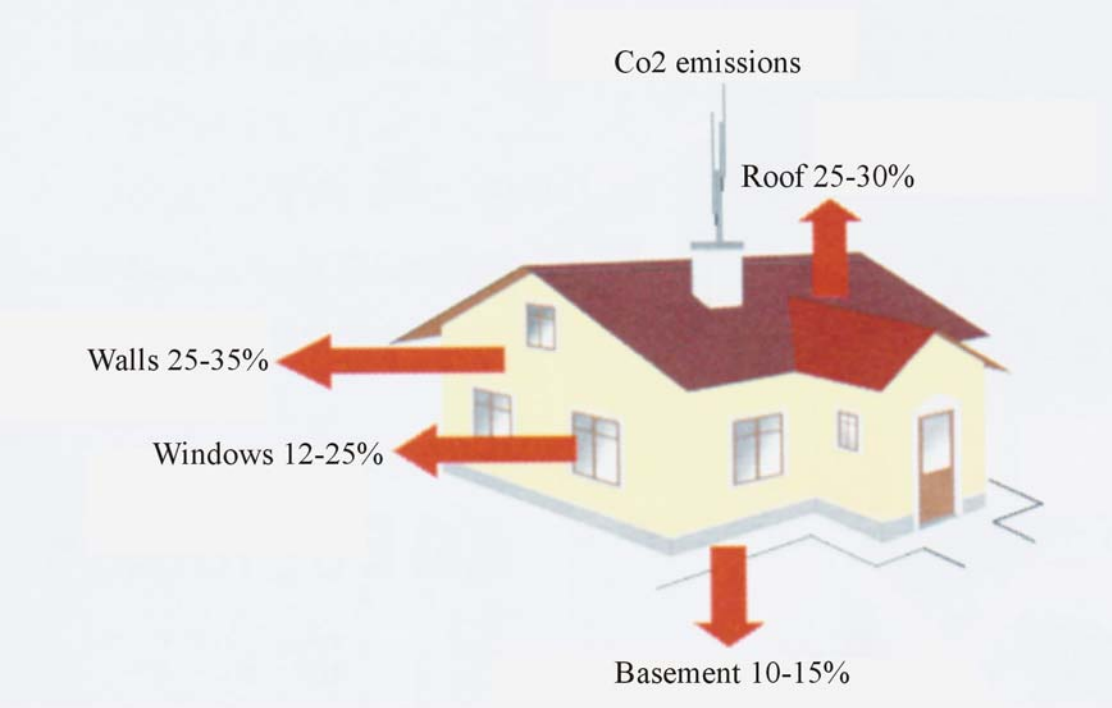
Due to specific requirements, large show-windows are common for these buildings.

3.2. External walls

External walls are one of the most important elements of the building's envelope. They have several functions: bearing, enclosing, insulating and shaping. They should suit several requirements:

- ***Static requirements*** such as strength, stability, stiffness, etc. Depending on the static characteristic, external walls are bearing and non-bearing;
- ***Structural-technical requirements*** connected with the methods of erection. External walls can be monolithically erected, mason and sectional depending of the methods of construction. They can be heavy, light or extra-light depending on the material;
- ***Structural-physical requirements*** such as thermal insulation, sound insulation, water-resistance, waterproofing, heat conductivity, etc.;
- ***Aesthetic requirements*** connected with the texture, the relief, the colour, the shape of the façade and the situation of the windows;
- ***Exploitation requirements*** for an easier maintenance and low cost repairs.

As external walls can be the cause for 25 to 35% of the heat losses through a building's envelope, we will examine the structural-physical requirements.



Thermal losses of a single-family house

The main problem with external walls is their thermal insulation and the connected with it phenomena: heat conductivity, heat absorption capacity, sweat condensation and several others. All these factors determine the thermal-technical characteristic of the building.

The main factor is the thermal protection of the premises, which should ensure constant favourable conditions (internal climate) regardless of the variable external atmospheric conditions. These conditions can be achieved through the heating and the ventilation of the premises and through a suitable structure of the enclosing elements, which should obstruct the exchange of heat between the premises and the external environment.

Usually, building materials have low thermal insulation qualities (except the wood). Because of this, external walls have thermal insulating layers that can be:

- ***Air insulating*** layer placed between the structural layers of the wall. Several air layers are more effective than one air layer, with a thickness equal to the sum of the several layers' thickness;
- ***Separate insulating layer*** placed between the structural elements of the wall. This layer can be from all kinds of plates, blocks, mattresses, etc. made of different materials;
- ***Insulating fillings***, where the insulating material fills in cavities of the structure elements of the walls.

- These insulating methods can be combined. The choice of insulating methods and materials depend on the type of construction of the building and the wall.

Another aspect of the insulating characteristics of external walls is their heat absorption capacity that depends on the mass and the relative heat absorption of the wall's materials. As much massive is a wall as much heat it absorbs before to let heat pass through it. But during the evening, when it is cooler, mass wall radiate heat in the premises. The main problem connected with massive external walls is the over-heating. This problem can be solved by means of shading elements or screens, this can be terraces, loggias, eaves, grilles, etc.

Another problem is the sweat condensation. When water's vapour reaches a cold surface, it condenses. The probability of condense depends on the type and the disposition of the external wall's layers. The probability of condense is especially high when effective thermal insulation is placed on the side of the premises. In this cases the external layers of the wall are highly cooled, because of the thermal insulation and there is a high probability of condense. To avoid the appearance of condense the following measures can be undertaken:

- Avoid the penetration of humidity in the wall's structure through a suitable vapour insulation on the premises' side or through such a thermal insulation on the external side, which ensure a temperature in the wall higher than the condensation temperature;
- Lead water vapour got into the wall through ventilation canals and openings or through vapour-permeable layers on the external side.

It very suitable to put vapour proofing barriers in the elements of the building envelope, which will avoid the penetration of water vapour in them. Vapour insulating material can be asphaltic felt or plastering, synthetic sheet, folio, paint, etc.

3.3. Roofs

As 25 to 30% of the heat losses of a house can be through the roof, it is very important to insulate them in a suitable way.

The covering layers of roofs have several functions:

- Protection of the building against rainfall, snowfall, hailstorm, atmospheric humidity and condense of internal humidity in the roof;
- Protection of the roof against other factors – cold, heat, overheating, wind, noise;
- Fire protection.

To fulfil these tasks, the roof covering should have at least the following ***structural-physical qualities:***

- ***Waterproofing insulation***: waterproofing, low water absorption, cold resistance, possibility for a freely water drainage;

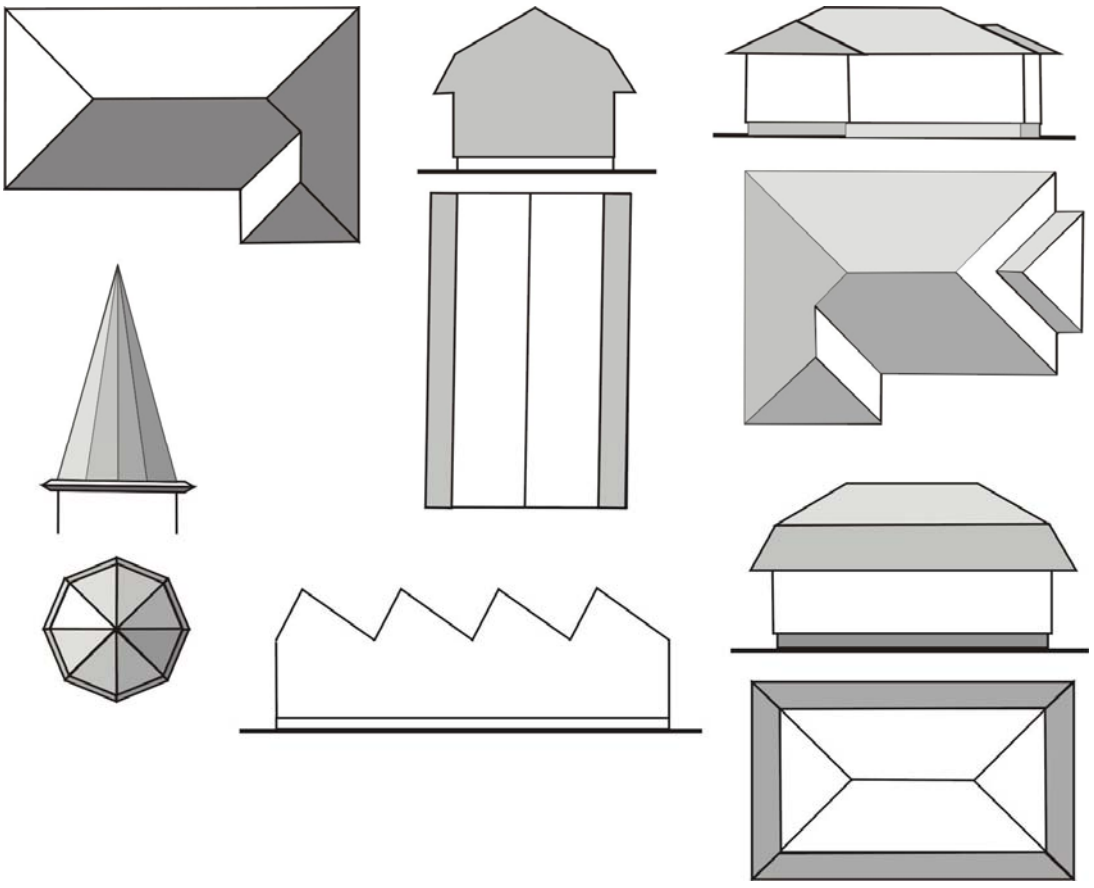
- ***Thermal insulation***: protection against cold and heat, against overheating due to solar radiation, reverberation of solar radiation, measures against condense;
- ***Wind stability***: assurance against damages from strong (tornado) wind as detaching from the base, raising and blowing away parts of the covering, etc.;
- ***Sound insulation***: protection against air noise of inhabitable parts of the roof structure, and against percussion noise from rain, hailstorm, strong winds for all roofs.

Roof covering should have also several ***structural-technical qualities***:

- Solidity, safety and durability, including for the fasten elements of the covering;
- Easy and convenient technology of execution;
- Low cost;
- High fireproofing degree;
- Low maintenance costs;
- Good external appearance.

There are two main types of roofs:

- ***Pitched roofs***: they can have different shapes:



Different types of pitched roofs

- ***Flat roofs*** with inclination less than 10-12%.

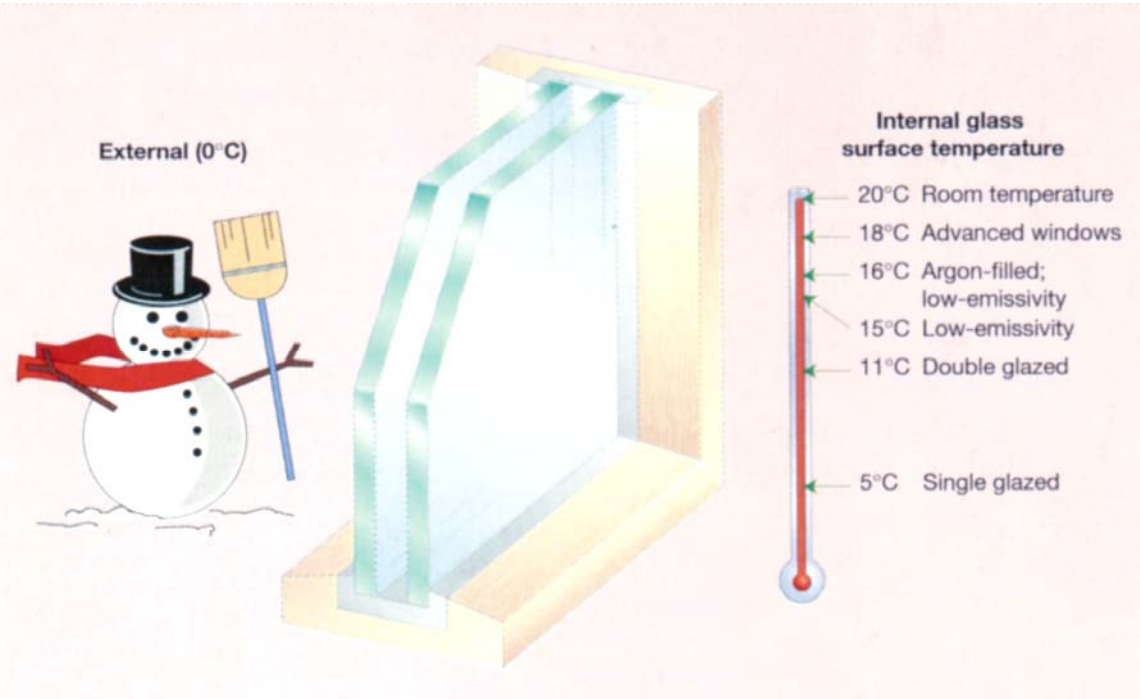
Roofs can be regarded as inhabitable (when there are tenantable premises under the roof covering) and unutilized (when the space under the roof covering is not foreseen for utilization).

Another categorization of roofs is heated roofs and cold roofs.

- ***Heated roofs***: these are roofs where the space under the roof structure is heated (they are often inhabitable roofs). To avoid the water vapour condensation a vapour barrier is required for this type of roofs;
- ***Cold roofs***: the roof structure is over unheated space (they are usually unutilized roofs). This space should be ventilated, as humidity from the building should be lead out of the roof. In case of pitched, roof the ventilation can be ensured by openings near the eaves (for air entrance) and near the ridge (for air exit). In case of flat roof, the ventilation is ensured through openings in the wall between the last slab over heated space and the roof slab. In both cases thermal insulation is installed over the last slab over heated space.

3.4. Windows

Windows and external doors are very important elements of the building envelope in regard to the thermal integrity of the building. Their thermal insulating qualities depends on three main elements: glazing, frame, and specification and installation.



- **Glazing**

Improving the thermal performance raises the surface temperature of the inner pane of glass and improves the occupant comfort

Most of the new windows and balcony doors are double-glazed but it should be taken into consideration that higher thermal performance glazing out-performs standard double glazing in a number of areas:

- Heat loss and fuel bills are significantly reduced.
- Warmer internal surfaces reduce cold downdraughts and improve the comfort.
- This type of window has an even lower risk of condensation.
- In some cases the heating system may be reduced.

The thermal performance of glazing depends on the glass and the air gaps.

- **Glass**

There is a wide range of laminated glasses with excellent thermal performances. For example the low-emissivity glass has a microscopically thin metal coating applied to one glazing surface. As the coating does not affect visible radiation it is transparent to the eye (early low-e glass had a tint). However, longer wavelength radiation – heat that is radiated from surfaces in a room – is not transmitted through the coating, but reflected back into the building, so reducing heat loss.

- **Cavity width**

Increasing the width of the cavity between the panes of glass will reduce the conductive losses and improve performance. The optimum cavity is approximately 16-20 mm but cavities of 12 mm are a good compromise where the choice of window frame limits the size of the glazing unit.

- **Gas filling**

In a gas-filled unit the air in the glazing unit is purged and replaced with an inert gas. Inert gases have a low thermal conductivity than air so they help to suppress convection within the unit, reducing heat loss and possibility to condense. The quantity of the inert gas in the unit must not decrease under 75-80% in order to the gas-filled unit can isolate with full value. At well-executed gas-filled units the outflow is about 1% annually.

The following table gives the characteristics of the gases used for filling of gas-filled units.

Gas	Density kg/m³	Thermal conductivity W/mK	Specific thermal capacity J/kgK
Air	1,232	2,496x10 ⊠²	1,008x10³
Argon	1,699	1,684x10 ⊠²	0,519x10³
SF6	6,360	1,275x10 ⊠²	0,614x10³
Krypton	3,560	0,900x10 ⊠²	0,245x10³

- **Triple glazing**

Triple glazing has the effect of allowing a larger insulating air gap while preventing the convective losses that can occur in an equivalent single air space. When used without coating and inert gases, triple glazing is comparable to double glazing with low-e, but the addition of coatings and inert gases will improve the performance beyond that achievable by double glazing.

- **Advanced glazing**

Very high performance glazing with coefficient of heat transmission 0,8 W/m²K (centre of panes) can be created using three or four panes of glass with different combinations of coatings and gas-fills. Thin films of coated polymers suspended between outer and inner panes can be used instead of glass. In some designs one pan of glass is installed in a separate sub-frame.

➢ **Frame and materials**

The choice of timber, PVC or aluminium frame depends of factors such as aesthetics and maintenance. All are suitable for use with double glazing systems. However, when specifying aluminium units, care should be taken to avoid thermal bridge problems.

The frame must be strong enough to support the weight of the glazing unit.

Windows and balcony doors frames should be designed with integral draughtstripping. Ideally, two separate draughtstrips should be installed.

Correct specification and installation of hardware (hinges, locks, etc) is also important for ensuring compression of draughtstrips.

In appendix 2 are given the evaluation values of the coefficient of heat transmission for glazing and frames of windows and balcony doors.

3.5. Basements

As low insulated slabs over basements or ground can account for 10% to 15% of the heat losses of a house, it is necessary to foresee a thermal insulation on the first slab under heated space. If the basement is heated, thermal insulation should be installed on the slab over ground. If the basement is not heated, thermal insulation should be installed on the first slab over the basement. It is better to install the thermal insulation on the upper side of the slab, but if there is no such a possibility, this can be done on the lower side of the slab.

According the Bulgarian Norms for design of building's thermal insulation, the coefficient of heat transmission Umax for floors over unheated basements is 0,50 and this coefficient for floors that are directly on the ground depends on the whole area A of the floor according the following table:

N°	Total area of the floor A	Coefficient of heat transmission U
1	<100	2,15
2	500	1,26
3	1000	1,00
4	1500	0,87
5	2000	0,79
6	2500	0,74
7	3000	0,69
8	5000	0,58
9	>8000	0,50

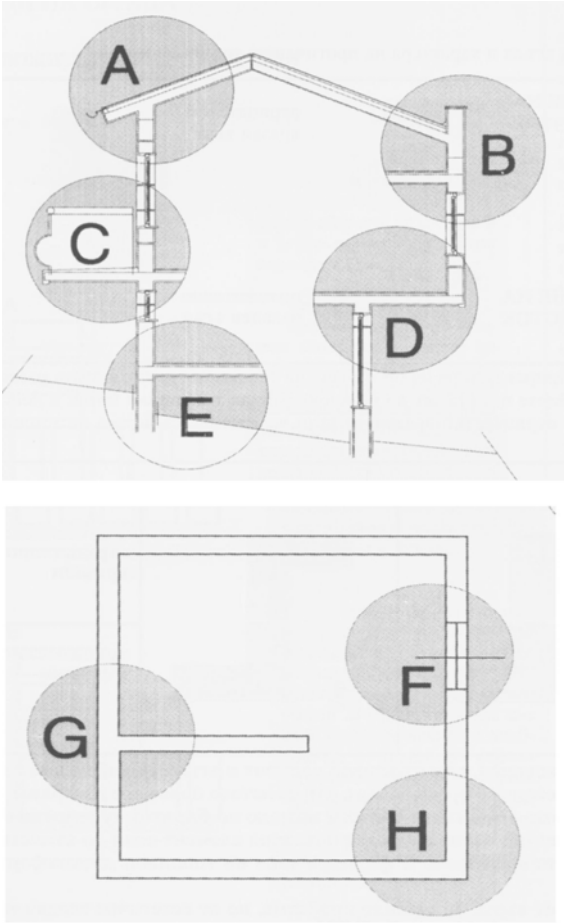
3.6. Thermal bridges

Thermal bridges are the places in the construction structure which thermal resistance is lower than this of the neighbouring structural elements.

As the heat is diffusing not only from inside to outside and vice versa, but in all directions following the principle of the lowest resistance, some connections between the enclosing elements are in fact thermal bridges. Such elements are columns, beams, lintels, walls, metal structural elements, etc. In these zones during the winter, when the temperatures differences outside-inside are higher, the thermal flux in direction inside to outside increases and the difference between the temperatures of internal side and the external air layer augments.

With regard to the energy efficiency, important are the situation of the thermal bridge toward the heat source and its place in the building structure.

The heat absorbing surfaces should be larger than the heat radiating surfaces for each thermal bridge.



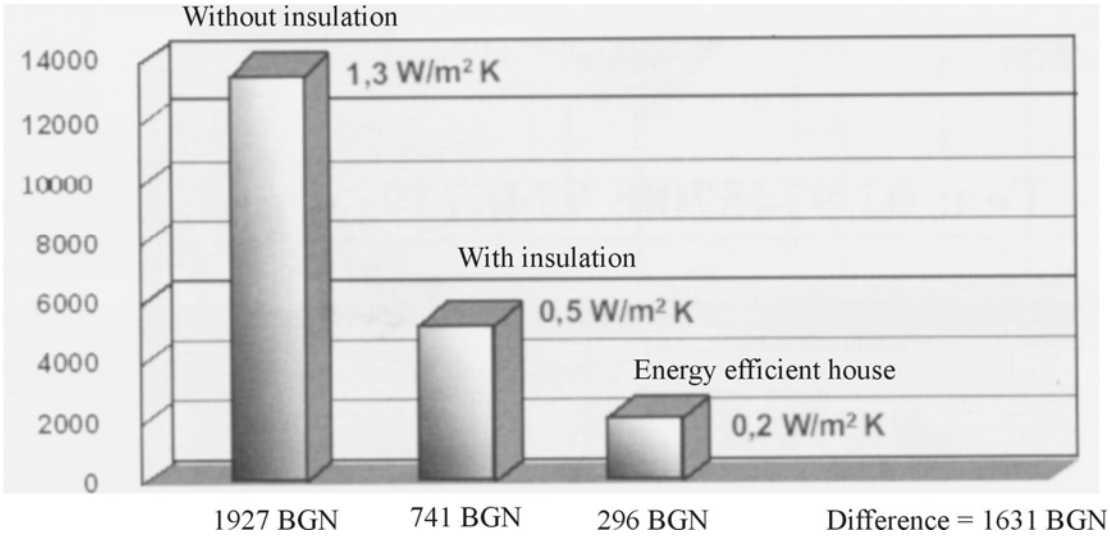
Typical thermal bridges in a building

A Eaves
B Cornices
C Balconies and loggias
D Jetties
E Slab over unheated basement
F Windows and balcony doors
G Cross concrete walls, columns, external concrete walls and beams
H Corners of the building

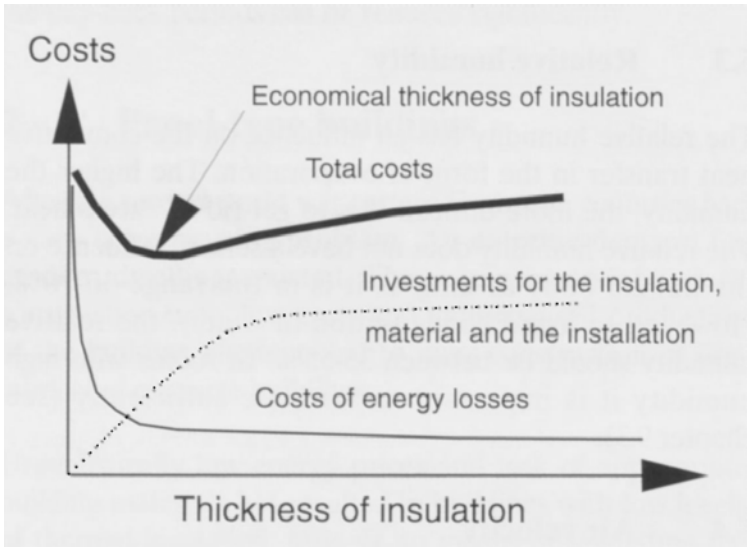
3.7. Economic thickness of insulation

A good thermal insulation can not only improve the thermal comfort in a building, but also it can improve its energy efficiency and respectively cost maintenance can be reduced. It is established that in Bulgaria an energy efficient dwelling with an area of 130m² can save more than 1600 BGN per year (1BLN = 0,51129Euro BLN = Bulgarian Leva).

Energy consumption for 130m² dwelling area / year



The economic thickness is understood as the thickness giving the largest energy savings for the lowest investment cost. This figure depends on the climate and the thermal characteristics of the material (energy consumption), the costs of the material, the cost of installation and the energy price (energy savings). The total costs for installation of insulation is not linear (as it is shown on the following figure), because the cost of the installation is a fixed cost per m² surface and the cost of the material depends on the thickness of the insulation. Therefore the first cm of insulation is relatively more expensive than the next cm.



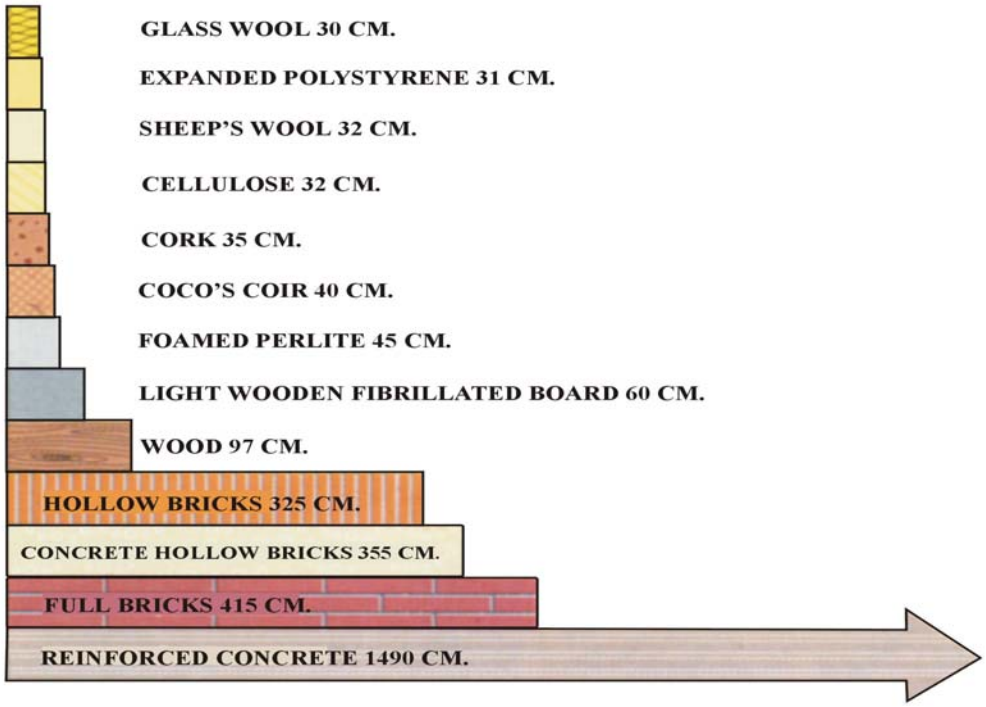
The energy losses depend on the thickness of the insulation material and the climate. This figure is also not linear. The difference in the extra savings will be smaller and smaller per extra cm of insulation. The economic thickness of insulation is where the sum of the costs for energy losses and the costs for investment for the insulation is lowest. With the current world market prices for energy the economic thickness of insulation for a normal wall in Europe is 8-12cm.

Experience from the past shown that energy prices are subject to rapid changes and are very unstable. The prices are influenced by political decisions and although the trend at the moment is towards a reduction in the energy prices, it is economically sensible to choose a larger thickness than the current economic thickness.

3.8. Insulation materials

The ability to hold air is the most important characteristic for a good insulation material since air has a very low thermal conductivity. Many different types of insulation materials exist, but for all materials it is important to fulfill the criteria listed below.

- **Low heat conductivity**
- **Operating temperature flexibility**
- **Optimal distribution of heat within the material**
- **Optimal density**
- **Low fire and explosion hazard**
- **Good physical properties, strong enough not to be damaged during handling**
- **High resistance to water and vapour penetration**
- **Good durability, the material should not shrink or deteriorate under the influence of weather or insects**
- **Chemical resistance**
- **No hazard to health**



To get the same thermal insulating effect, different thickness is required for the different materials

Following are the characteristics of some of the most common insulation materials:

- ***Gas concrete*** is from the group of autoclaved cellular concrete. It is a natural product made from sand, cement, lime and alumimium dust. The porosity of its structure is a result of a gas releasing chemical reaction between the aluminium and the other components. This material has a low density: 450 to 650 kg/m³, it is fire resistant and has good compressive strength of 2,5 to 7,5 Mpa. The elements of gas concrete are easy to work and are suitable for a wide range of purposes: external and internal walls, bearing and non-bearing walls, decoration elements, etc. In the following tables are given the main characteristics of walls erected with gas concrete blocks.

Walls of gas concrete blocks YTONG with thin joint 1 to 3mm													
Symbol	Measure	Class of strength MPa	Density kg/m³	Coefficient of heat conductivity λ W/mK	Thickness of the wall in mm without plasters								
					50	75	100	125	150	175	200	250	300
Coefficient of heat transmission U	W/m²K	2.5	500	0.17	2.16	1.64	1.32	1.10	0.95	0.83	0.74	0.61	0.52
		3.5	600	0.20	2.38	1.82	1.49	1.25	1.05	0.95	0.85	0.71	0.60

Walls of gas concrete blocks YTONG with ordinary joint and grout 10mm													
Symbol	Measure	Class of strength MPa	Density kg/m³	Coefficient of heat conductivity λ W/mK	Thickness of the wall in mm without plasters								
					50	75	100	125	150	175	200	250	300
Coefficient of heat transmission U	W/m²K	2.5	500	0.17	2.50	1.96	1.61	1.35	1.18	1.03	0.93	0.76	0.65
		3.5	600	0.20	2.63	2.08	1.72	1.45	1.25	1.11	1.00	0.83	0.70

Walls of gas concrete blocks YTONG with ordinary joint and light grout 10mm													
Symbol	Measure	Class of strength MPa	Density kg/m³	Coefficient of heat conductivity λ W/mK	Thickness of the wall in mm without plasters								
					50	75	100	125	150	175	200	250	300
Coefficient of heat transmission U	W/m²K	2.5	500	0.17	2.08	1.56	1.25	1.05	0.90	0.80	0.70	0.58	0.49
		3.5	600	0.20	2.33	1.79	1.43	1.20	1.04	0.92	0.82	0.67	0.57

- ***Stone wool*** is a natural material formed through volcanic activity. It was discovered when scientists visited Hawaii at the beginning of the 20th century. Nowadays it is produced from diabase rock and briquettes with stone wool remnants and other recyclable materials that are molten at 1500ºC. By applying a centrifugal process, the liquid stone mass is spun and solidifies in the air as fibres

to which small amount of binder and water-repellent oil are added. After hardening and moulding, a strong, versatile insulation material is obtained.

The unique properties of stone wool make it highly suitable for many applications:

- Thermal insulation
- Acoustic ceilings
- Façade panels
- Reinforcement fibres
- Noise and vibration control.

Products of stone wool are available as rolls, semi-rigid and rigid boards. Following are the main characteristics of stone wool products manufactured by ROCKWOOL, Denmark.

	Bulk density	Coefficient of thermal conductivity W/mK	Thickness mm	Recommended for thermal insulation of:
Rolls (Rollbatts)	30 kg/m³	0.036	50, 70, 100	Attics, internal walls, floors
Semi-rigid boards (Flexi-Batts)	34 kg/m³	0.035	50, 75, 100, 125, 150	Internal walls, attics, roof structures
Rigid boards (Venti-Batts)	Rigid layer 90 kg/m³ Soft layer 45 kg/m³	0.035	75, 100, 125, 150, 175, 200	Ventilated façade structure
Rigid boards (Façade Slab)	6.5 kg/m² 9.4 kg/m² 11.6 kg/m² 14.0 kg/m²	0.035	50 80 100 125	External insulation
Rigid boards (Hardrock)	7.1 kg/m² 11.0 kg/m² 13.0 kg/m² 14.0 kg/m² 19.0 kg/m²	0.036	50 85 100 120 180	Upper layer of multi-layer insulation or under water proofing insulation
Rigid boards (Lamella Roof)	100 kg/m³	0.037	50, 92, 126, 144, 166, 193	Roofs
Rigid boards (Underlay Roof Slab)	110 kg/m³	0.035	35, 40, 50, 90, 100	First insulating layer on roofs
Rigid boards (TF-Board)	175 kg/m³	0.039	20, 25, 40	Roofs covered with metal sheets
Rigid boards (Concrete Element Slab)	70 kg/m³	0.036	50, 75, 100	Sandwich concrete panels
Rigid boards (Floor-to-Ground Slab)	6.2 kg/m² 11.3 kg/m²	0.035	50 100	Ground floors

- ***Glass wool*** is produced from sand, fluxing agents and recycled products that are molten at 1100°C. By applying a centrifugal process, the liquid stone mass is spun and solidifies in the air as fibres to which small amount of binder is added, after that the wool blanket is polymerized and calendered. Before packing the products are tightly compressed. The unique properties of glass wool make it highly suitable for many applications:

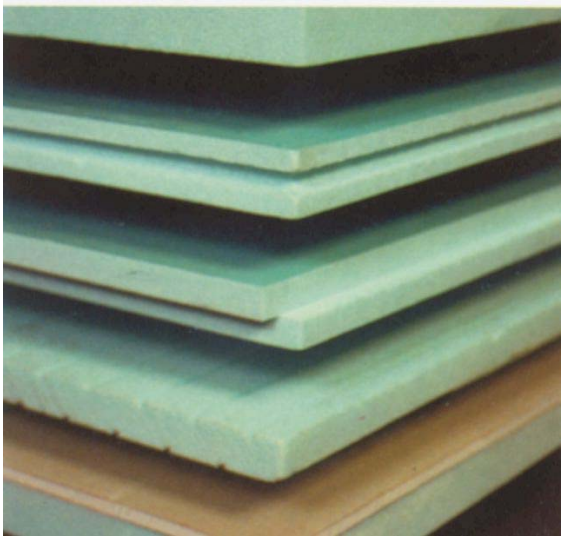
  - Thermal insulation
  - Acoustic ceilings
  - Façade panels
  - Reinforcement fibres
  - Noise and vibration control.

  Products of glass wool are available as rolls, semi-rigid and rigid boards. Following are the main characteristics of glass wool products:

	Bulk density	Coefficient of thermal conductivity W/mK
Rolls	30-60 kg/m³	0.038-0.040
Semi-rigid boards	80-100 kg/m³	0.036-0.038
Rigid boards	120-150 kg/m³	0.036-0.037

- ***Extruded polystyrene*** is an organic insulating material from the group of foamed plastics. This material has a comparatively low water-absorption capacity (0,15 – 0,30%), a coefficient of thermal conductivity of 0.025 – 0.029 W/mK and a compressive strength of 0.25 – 0.40 Mpa for 10% deformation. This material is combustible and must therefore be covered on all sides with fire resistant materials. This material is available in slabs and blocks in different sizes. It is suitable for insulation of internal and external walls, roofs, beams, columns, and floors with normal and heavy loading.

- ***Expanded polystyrene*** is an organic insulating material from the group of foamed plastics. This material has a water-absorption capacity of 1,5 – 2,5%, a coefficient of thermal conductivity of 0.032 – 0.037 W/mK and a compressive strength of 0.1 – 0.20 Mpa for 10% deformation. This material is combustible and must therefore be covered on all sides with fire resistant materials. This material is available in slabs and blocks in different sizes. It is suitable for insulation of internal and external walls, roofs, beams, columns, and floors with normal and heavy loading.



- ***Polyurethane foam*** is available in sheets, slabs, blocks, prefabricated panels and laminated sheets. This material has low moisture permeability, low density and a good resistance to oil and chemicals. CFC's are normally used as a foam blowing agent. When exposed to the atmosphere, air steadily diffuses inwards through the cells. This results in a decrease of the thermal resistance of the insulation material and a release of CFC's into the atmosphere. Polystyrene and polyurethane foam should only be used if there are no other alternatives. In addition, the energy needed for its production is significantly higher than for other insulation materials.

- ***Expanded perlite*** is notable for its high quality. It has a low loose density 80 – 100 kg/ m³, a thermal conductivity of 0,03 – 0,04 W/mK and a homogeneous granulometry.

  Expanded perlite is used mainly for the preparation of thermal insulating perlite concrete. This mixture is used for floors' thermal insulation. Another use of the expanded perlite is for thermal insulating plaster. This plaster is prepared on the basis of expanded perlite, cement, lime or gypsum.

  THERMOFIX is a new ecological thermal insulating material based on the material perlite. It represents a dry mixture for plastering. It is not only a very good thermal and acoustic insulating material, but it is also fire resistant and easy to apply, it is suitable for a wide range of buildings.

Specialists from the building sector have looked for new materials and technologies in order to improve the energy efficiency of buildings. These researches have two main goals:

- To improve the longevity of traditional thermal insulating building materials (foamed polystyrene, glass and mineral wool etc.) and to make easier their installation.

- To improve the efficiency of traditional thermal insulating building materials through the use of additional thermal insulating plastering or paint.

Most of these technologies and materials are available on the market.

POLYNOR, the Nederlands, produce medium size prefabricated elements for construction of external walls of residential and commercial buildings. The elements are based on:

-facing and/or load bearing material: fired clay bricks, concrete blocks, calcium silicate blocks

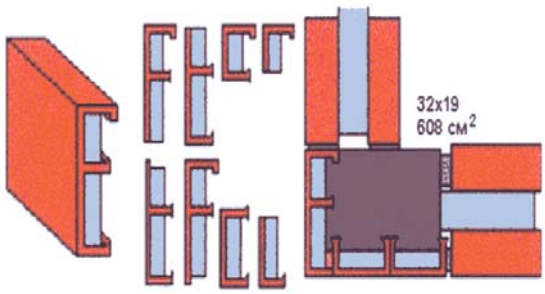
-thermal insulation: PU rigid polyurethane foam, XPS extruded polystyrene foam or EPS expanded polystyrene foam

This technology saves up to 70% of time required for wall construction and insulation and ensures continuous thermal insulation without thermal bridges as well as substantial reduction of the possibility of mistakes while applying the thermal insulation.

Following are the characteristics of three types of elements.

POLYNOR – T elements: represent an element that is a combination of two hollow ceramic bricks with thermal insulation.

Bricks (thick. cm.)	9	9	12	12
Insulation (cm.)	5	8	5	8
Coefficient of heat transmission (W/m²C)	0.48	0.35	0.46	0.33
Weight of 1 elem. (kg.)	10	10	14	14
N° of elements (m²)	15	15	15	15
Thickness of wall (cm)	23	26	29	32

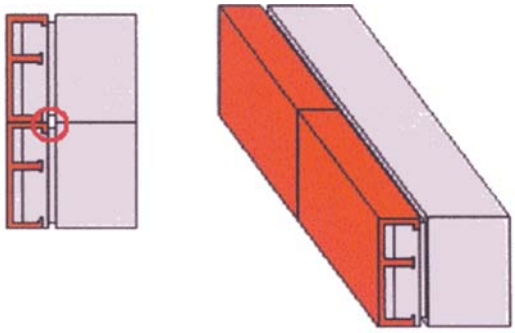


POLYNOR – B elements: combination of ceramic and thermal insulation for insulation of concrete elements of buildings (slabs, beams, columns, jetties) or for insulation of ground floor and attic slabs.

Insulation (cm.)	2	3	4	5
Coefficient of heat transmission (W/m²C)	1.89	1.20	0.98	0.75
Weight of 1 elem. (kg.)	4	4	4	4
N° of elements (m²)	13	13	13	13

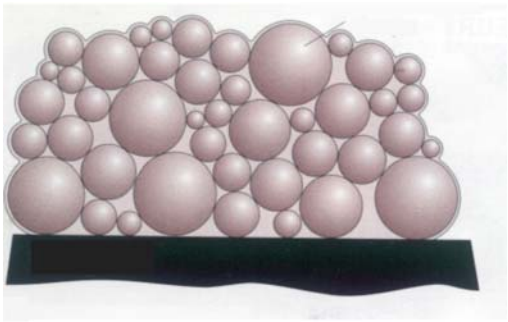
POLYNOR – Y elements: combination of ceramic, thermal insulation and gas concrete type YTONG in one element for erection of external walls.

YTONG (thick. cm.)	15	25
Insulation (cm.)	4	2
Coefficient of heat transmission (W/m²C)	0.48	0.45
Price (BGN/ m²)	36	42
Weight of 1 elem. (kg.)	19	26
N° of elements (m²)	6.6	6.6
Thickness of wall (cm)	20.5	28.5



The above mentioned characteristics are for elements with insulation of expanded polystyrene.

The product ***"THERMO-SHIELD",*** USA, is an energy efficient coating for use as additional insulation. Its thermal insulating qualities are due to the micro-ceramic vacuum capsules, which represent 40-60% of the dry substance. The product has an unique heat reflecting capacity (86%) and lows heat conductivity.The product is suitable for a wide range of purposes.



The advantages of the product are:

- additional thermal insulation equal in value of 3cm. foamed polystyrene at a standard thickness of the insulating coat of 0.3mm.
- easy to apply with brush or applicator roll
- good waterproofing qualities
- no need of supplementary decorative coat
- no problems with insulation of surfaces with sophisticated shapes
- protection against UV light
- good acoustic insulation
- longevity