BIM4ENERGY
ERASMUS+

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BIM digital competencies to evaluate and improve the energy efficiency of European buildings.

A digital way towards positive energy districts

11:30 – 11:30 Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

Speaker: UPCT

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RAMBOLL

Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

Summary :

- The building envelope.
- Common types of facades, walls and roofs
- Heat losses through the envelope
- Thermal properties of a wall
- Thermal properties of windows
- Thermal Envelope Code Requirements.
- Alternatives to improve the thermal envelope of existing buildings

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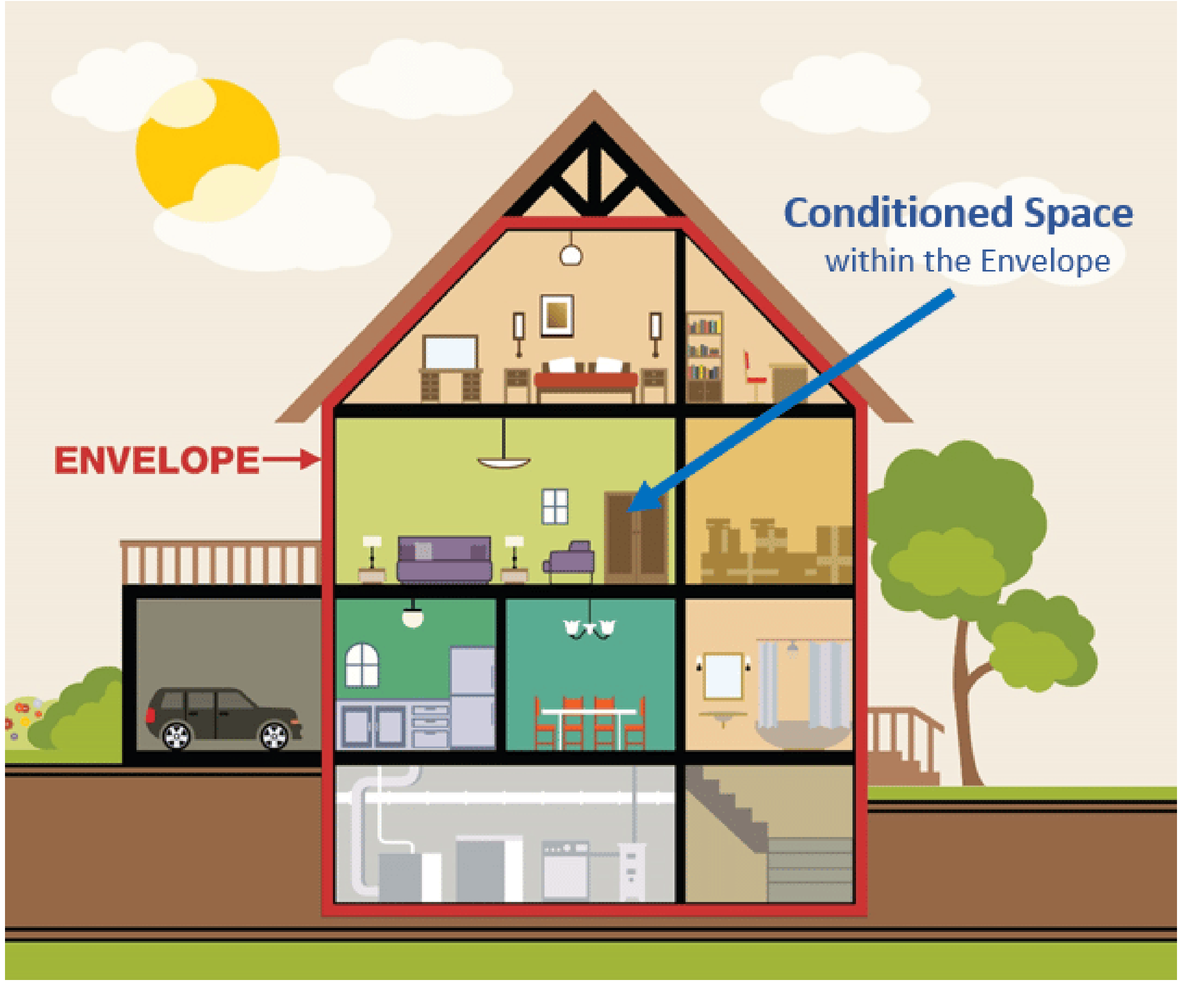
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- The building thermal envelope :



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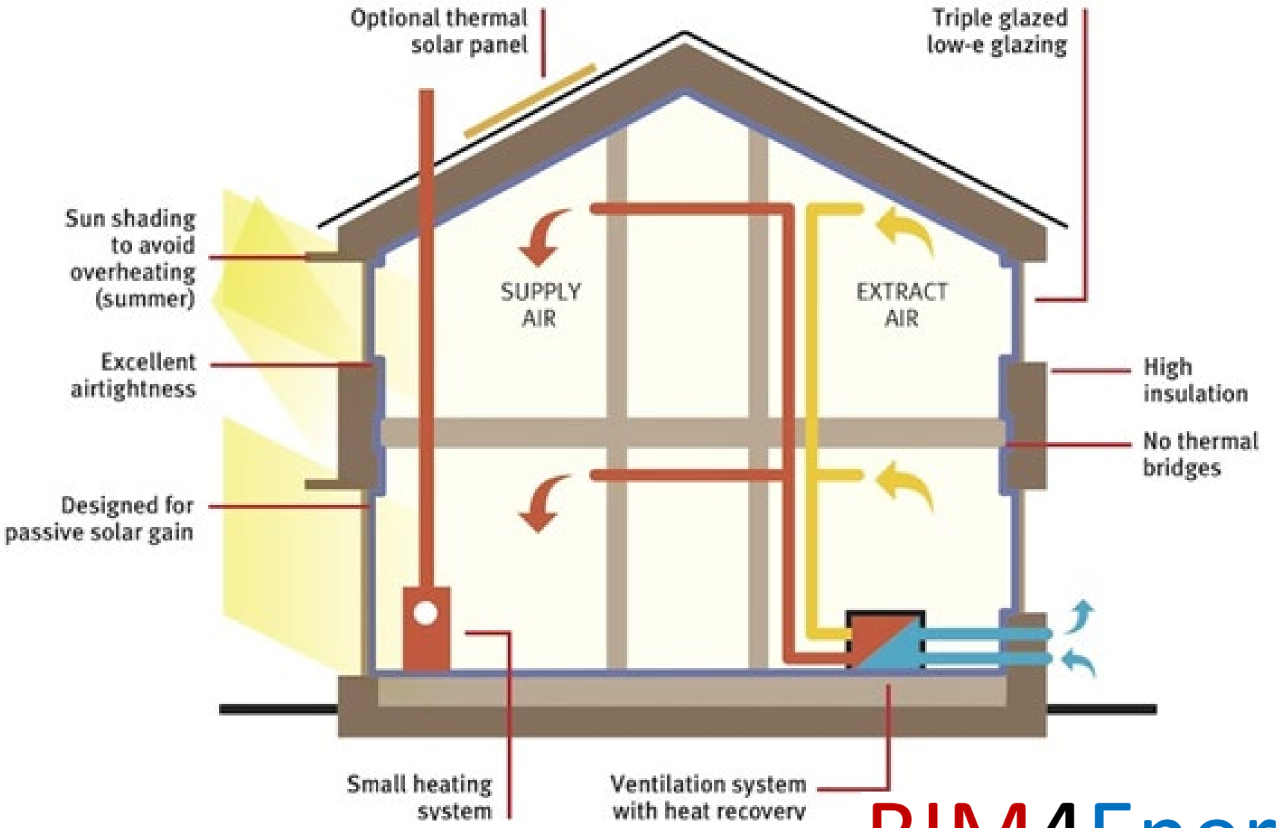
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- The building thermal envelope :

The term "**building thermal envelope" is defined as being "the basement walls, exterior walls, floor, roof and any other building elements that enclose conditioned spaces.**" This boundary also includes the boundary between conditioned space or provides a boundary between conditioned space and exempt or unconditioned space.



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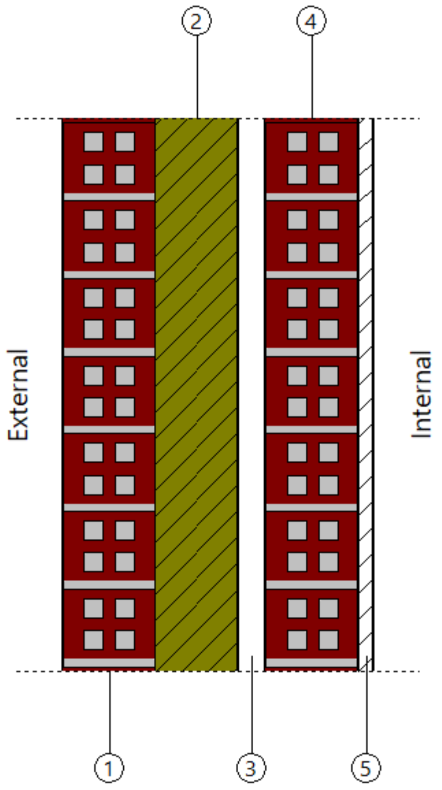
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Common types of facades, walls and roofs

Facade type I: Facade with double brick wall



Layers
1 - M01 - 100 mm brick: 10.16 cm
2 - I04 - 89 mm batt insulation: 8.94 cm
3 - F04 - Wall air space resistance: 3.00 cm
4 - M01 - 100 mm brick: 10.16 cm
5 - G01 - 16 mm gyp board: 1.59 cm
Total thickness: 33.85 cm
Thermal description
Heat transfer coefficient (U): 0.39 W/(m^2·K)
Thermal capacity: 51975.29 J/m^2·K

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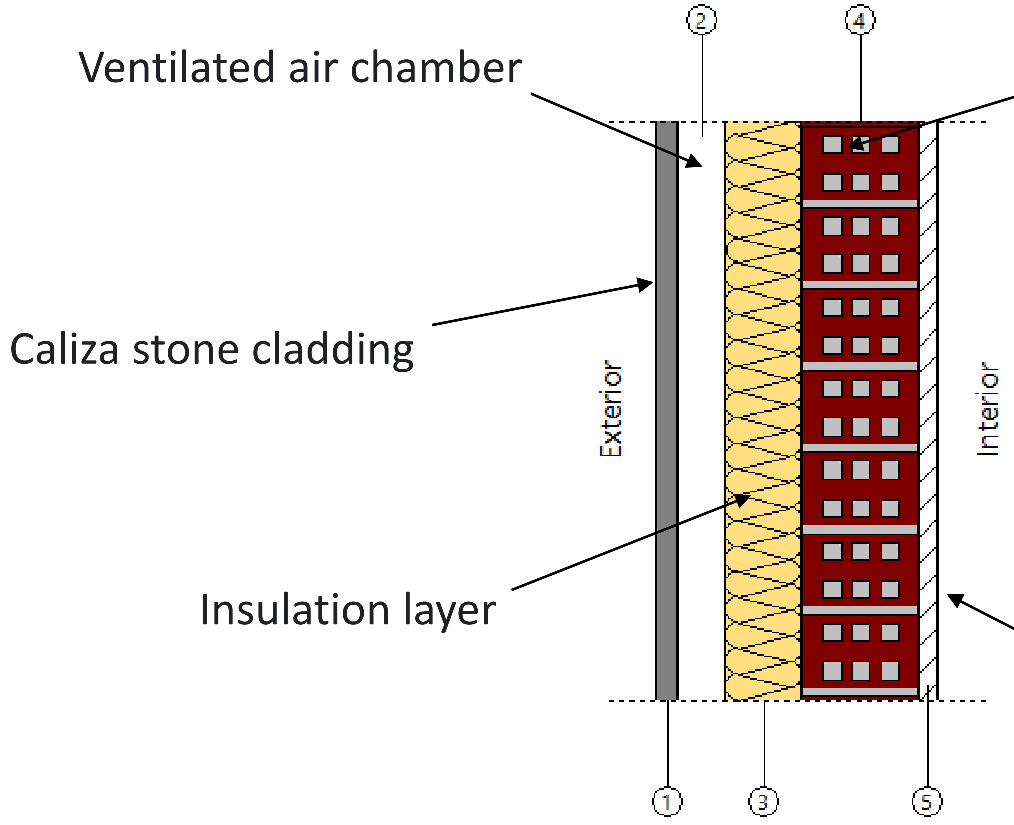
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Common types of facades, walls and roofs

Facade type II: Ventilated facade



Capas
1 - Caliza muy dura [2200 < d < 2590]: 2.00 cm
2 - Cámara de aire: 5.00 cm
3 - URSA TERRA Vento Plus P8792 80mm: 8.00 cm
4 - 1/2 pie LP métrico o catalán 40 mm< G < 60 mm: 12.00 cm
5 - Enlucido de yeso 1000 < d < 1300: 2.00 cm
Espesor total: 29.00 cm
Caracterización térmica
Transmitancia térmica (U): 0.33 W/(m²·K)
Capacidad térmica: 61992.71 J/m²·K

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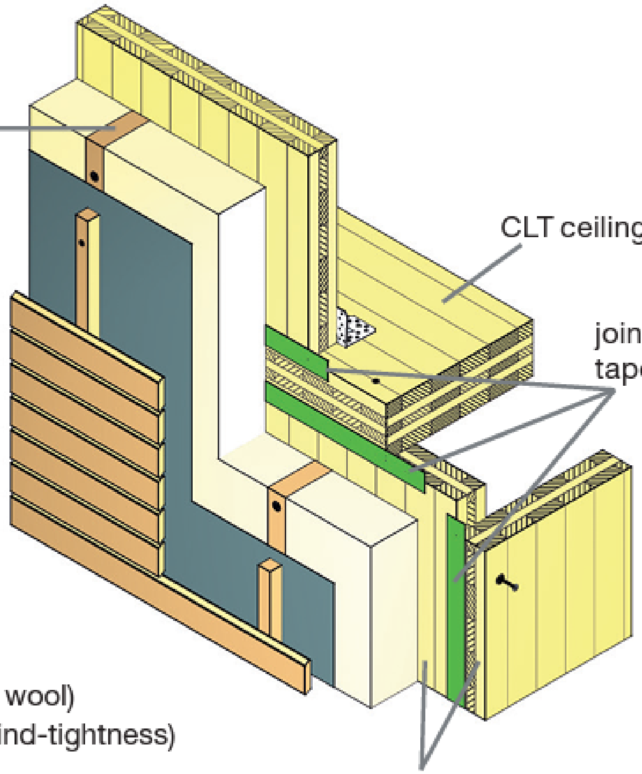
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Common types of facades, walls and roofs

Facade type III: Facade with timber wall



Structure:
- CLT wall board
- insulation (mineral wool)
- vertical seal (for wind-tightness)
- battens
- horizontal wall cladding

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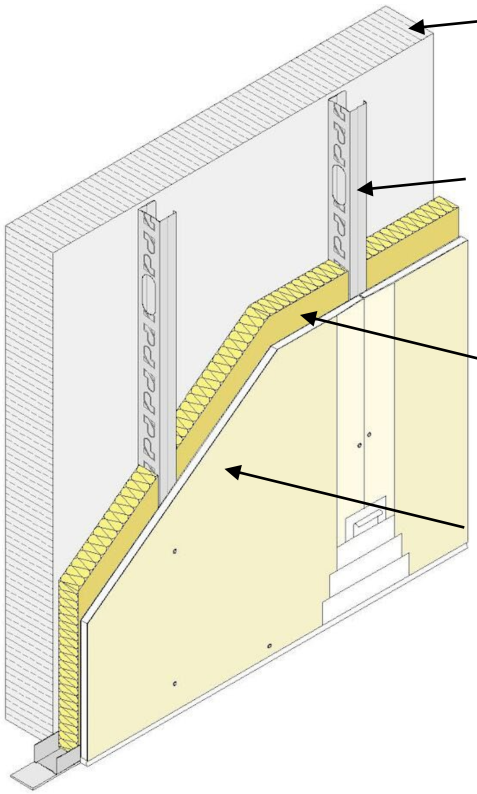
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Common types of facades, walls and roofs

Party wall: Wall with interior insulation and plasterboard covering



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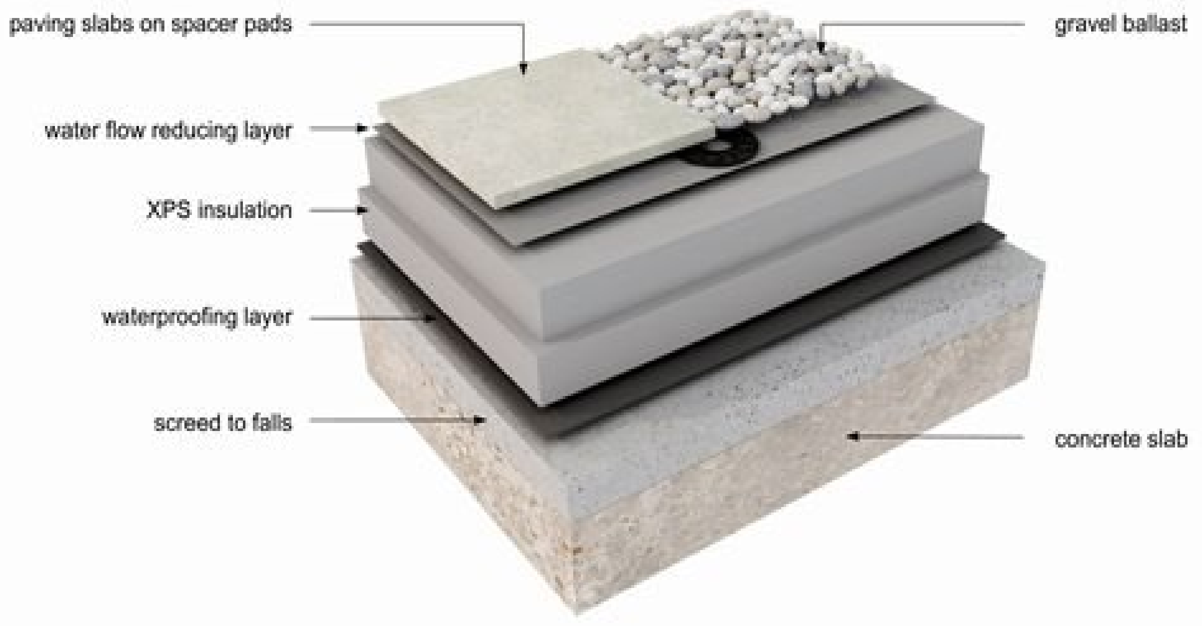
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Common types of facades, walls and roofs

Roof type I: Flat roof



Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

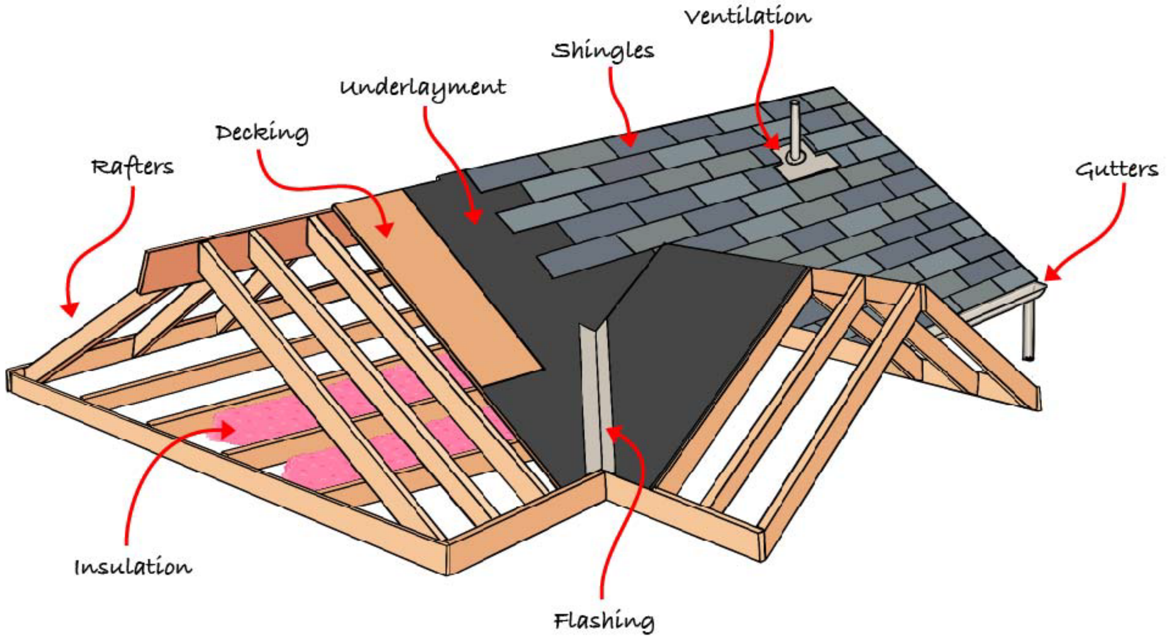
- Common types of facades, walls and roofs

Roof type II: Tiled roof with brick walls

Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Common types of facades, walls and roofs

Roof Type III: Tiled roof with timber structure



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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Heat losses through the envelope (heat transfer mechanisms):

The ability to hold indoor air temperature at the desired level is affected by all three methods of heat transfer:

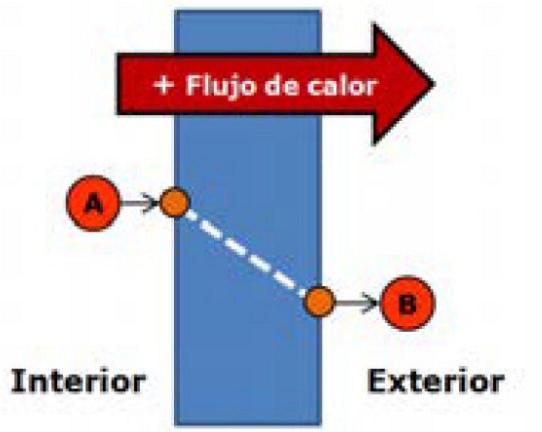
- Conduction
- Convection
- Radiation

Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Heat losses through the envelope (heat transfer mechanisms):

Conduction

- Requires that surfaces touch for solid-solid heat transfer.
- Because the different materials in an insulated assembly touch each other, conduction heat loss occurs through solid components of the building envelope.
- For example, heat flows by conduction from warm areas to the cooler areas of concrete slabs, window glass, walls, ceilings, and other solid materials.



Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Heat losses through the envelope (heat transfer mechanisms):

Convection

- Transferring heat from one place to another by molecular movement through fluids such as water or air.
- Heat loss by convection commonly results from exfiltration or air leakage.
- Convective heat loss occurs when warm air is forced out, usually from the building (exfiltration), by cold incoming air, usually in the lower part (infiltration).
- The rate of transfer is increased when the wind blows against the building or when the temperature difference between the inside and outside increases

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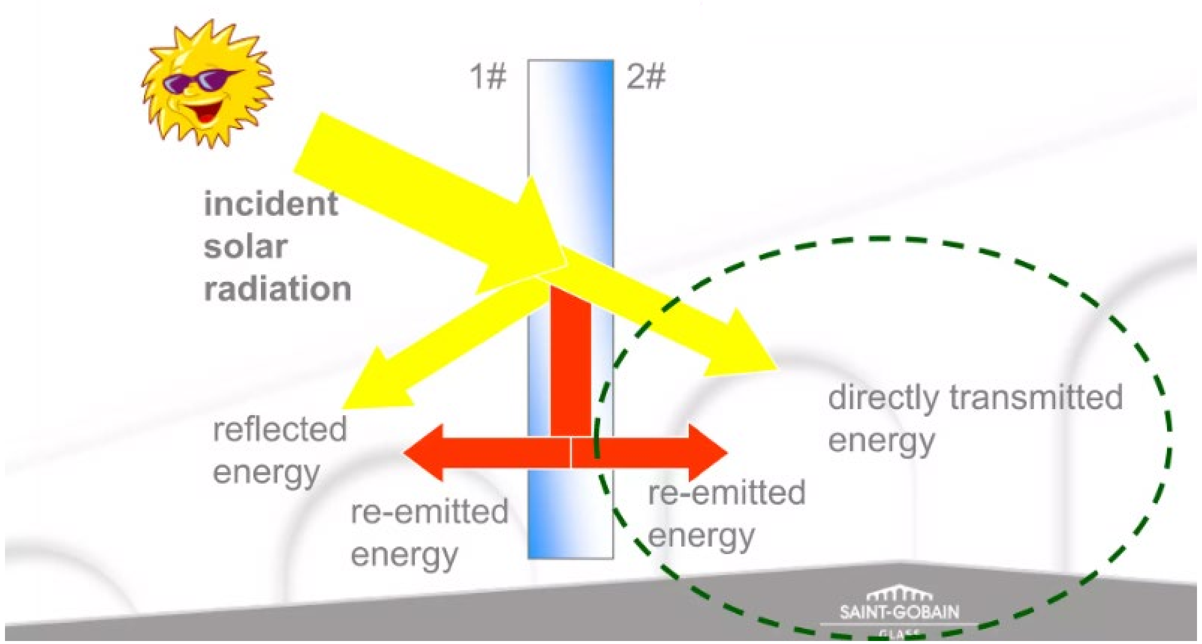
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Heat losses through the envelope (heat transfer mechanisms):



Radiation

- Radiation is the heat transfer by electromagnetic waves from a warmer to a cooler surface.
- The transfer of the sun's heat to a roof or the warmth of a standing near a glass furnace are examples of radiant heat transfer.

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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Heat losses through the envelope (heat transfer mechanisms):

The **thermal conductivity** of a material is a measure of its ability to conduct heat. It is commonly denoted by ***k*** , ***λ*** or ***κ*** and is measured in W/m·K.

This property is **independent of the thickness** of the material

Heat transfer occurs at a lower rate in materials of low thermal conductivity than in materials of high thermal conductivity.

No	Building Material	Density (kg/m3)	K (W/m.K)
1	Concrete	2.400	1,448
2	Aerated Concrete	960	0,303
3	Plastered Clay Brick	1.760	0,807
4	Exposed Clay Brick		1,154
5	Glass	2.512	1,053
6	Gypsum board	880	0,170
7	Steel	7.840	47,6
8	Granite	2.640	2,927
9	Marble/Ceramic/Terazzo	2.640	1,298

Source: SNI 03- 6389- 2000

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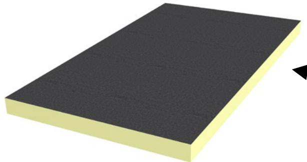
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Insulation products for buildings:

  - Mineral wool insulation (high bulk density range) λ = 0.038 W/m·K
  - Insulation board with a core of rigid polyurethane (PIR) λ = 0.022 W/m·K
  - Polyurethane thermal insulation spray foam λ = 0.02 - 0.03 W/m·K
  - Expanded polystyrene foam (EPS) λ = 0.035-0.037 W/m·K
  - Extruded Polystyrene or Styrofoam (XPS) panels λ = 0.024 W/m·K
  - Cellulose fibre insulation λ = 0.04 W/m·K
  - Cork-based thermal insulation panels λ = 0.037 – 0.040 W/m·K



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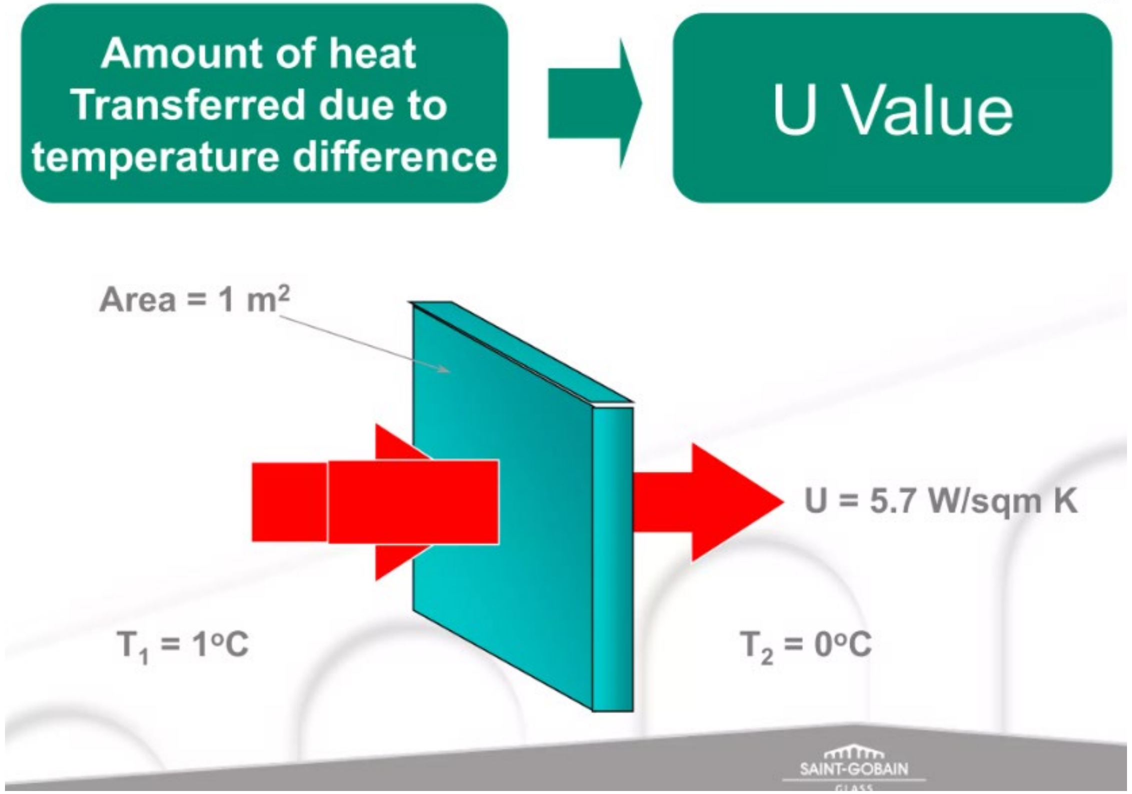
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a wall or a roof:

Conductance (or **thermal transmittance, or U-value**) of an element (wall or window)



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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a wall or a roof:

Conductance (or **thermal transmittance, or U-value**) of an element (wall or window)

How to calculate the **U-value** of a wall:

The thermal transmittance U ($W/m^2 \cdot K$) is given by the following expression:

$$U = \frac{1}{R_T} \qquad (1)$$

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R_T the total thermal resistance of the wall [$m^2 \cdot K/W$]:

$$R_T = R_{si} + R_1 + R_2 + \ldots + R_n + R_{se} \qquad (2)$$

R_1 , R_2 ...R_n the thermal resistances of each layer defined according to expression (3) [$m^2 \cdot K/W$];

R_{si} and R_{se} are the surface thermal resistances corresponding to indoor and outdoor air respectively, taken from Table 1 according to the position of the enclosure, direction of heat flow and its location in the building [$m^2 \cdot K/W$].

$$R = \frac{e}{\lambda} \qquad (3)$$

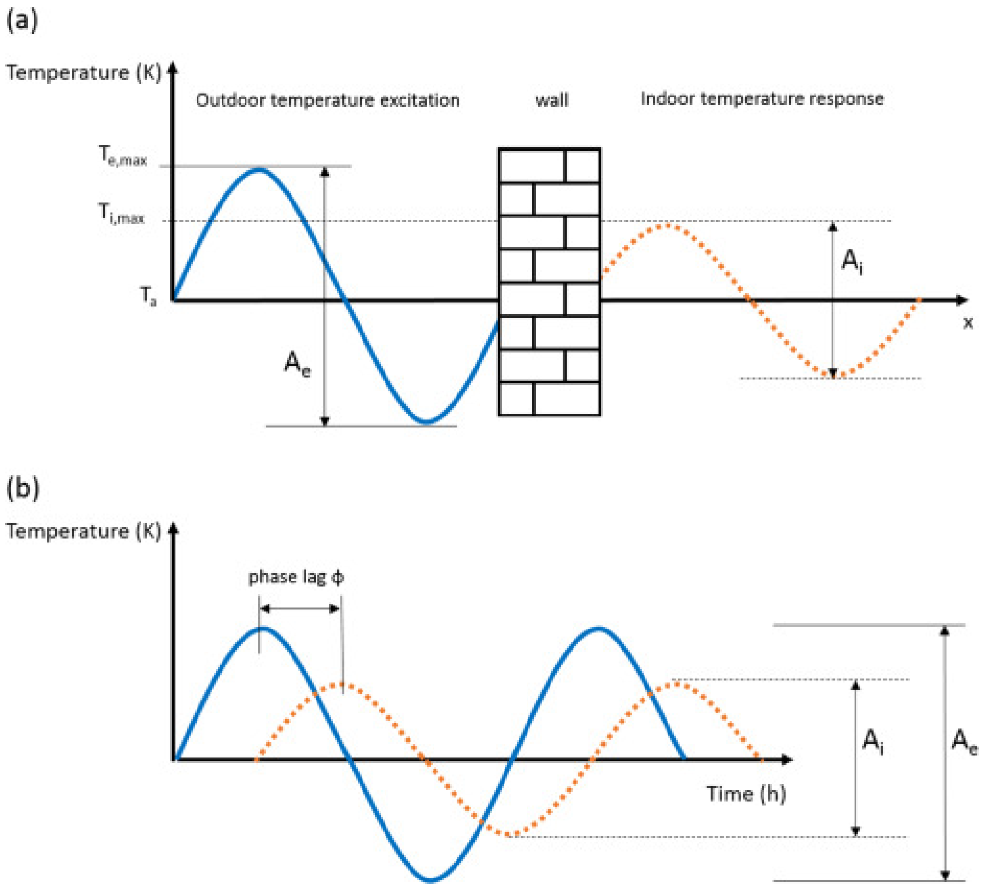
R thermal resistance of a layer; e thickness of the layer; λ conductivity of the layer material

Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a wall or a roof:

Thermal inertia

Thermal mass is a property of the mass of a building that enables it to store heat and provide inertia against temperature fluctuations.



Thermal Inertia: Capacity of a material to store heat and to delay its transmission

Thermal Inertia

$$P = \sqrt{C\ \lambda} = \sqrt{c\ \rho\lambda}$$

P: thermal Inertia, C: Volumetric heat capacity, c: specific heat, λ : thermal conductivity

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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

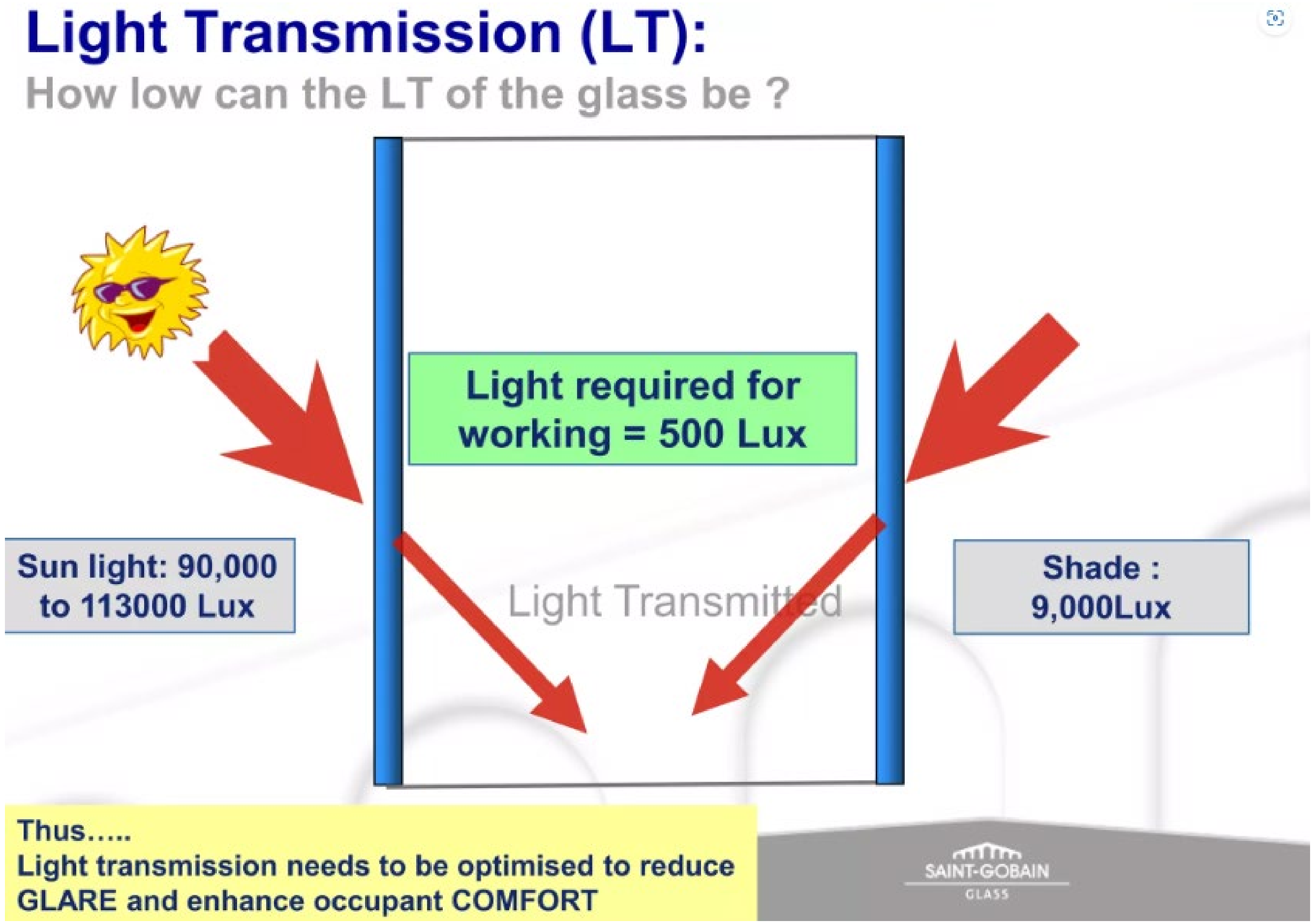
- Thermal properties of a **windows**:

Key Performance Factors

- Total Heat Gain / Heat Transmission
  - SHGC or SF : Solar Heat Gain Coefficient or Solar Factor
  - U Value
- Light Transmission: percentage of incident light transmitted

Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a **windows**:



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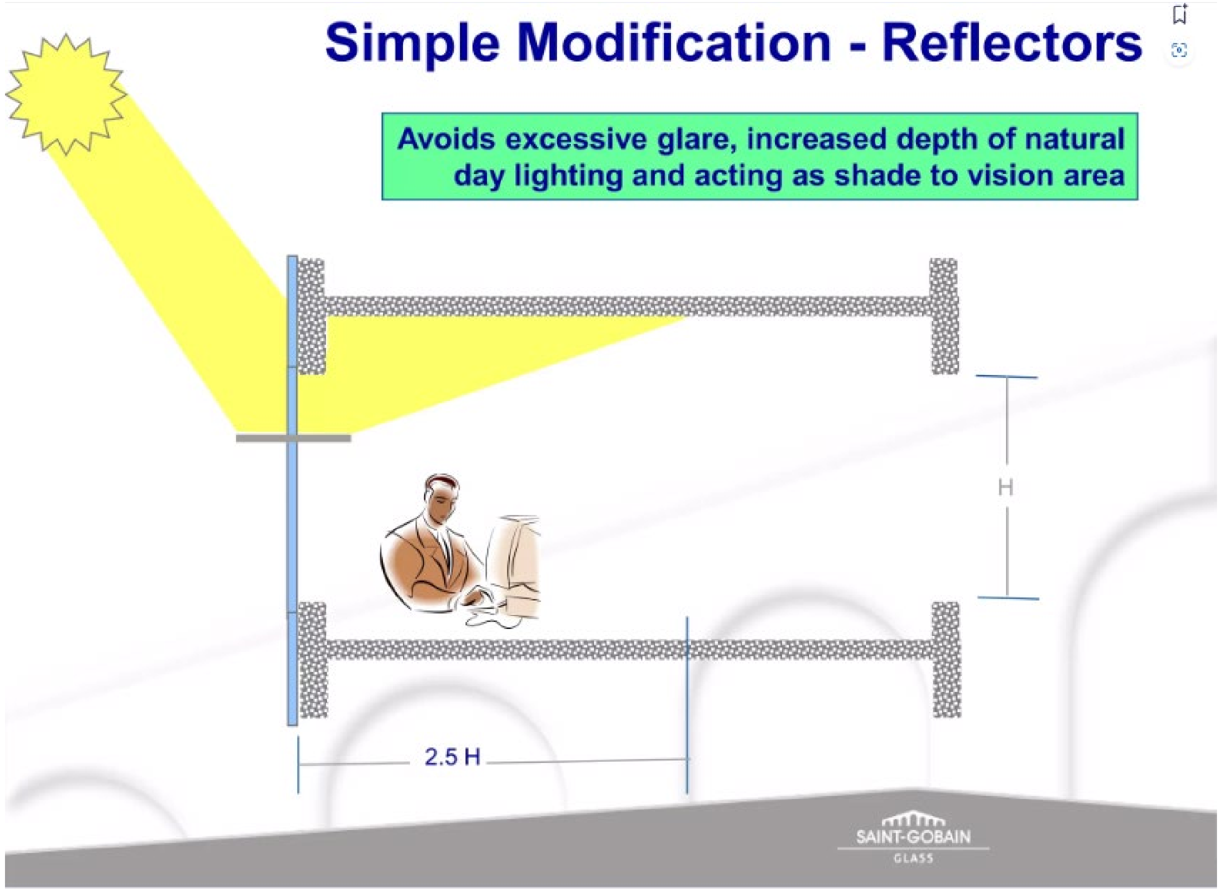

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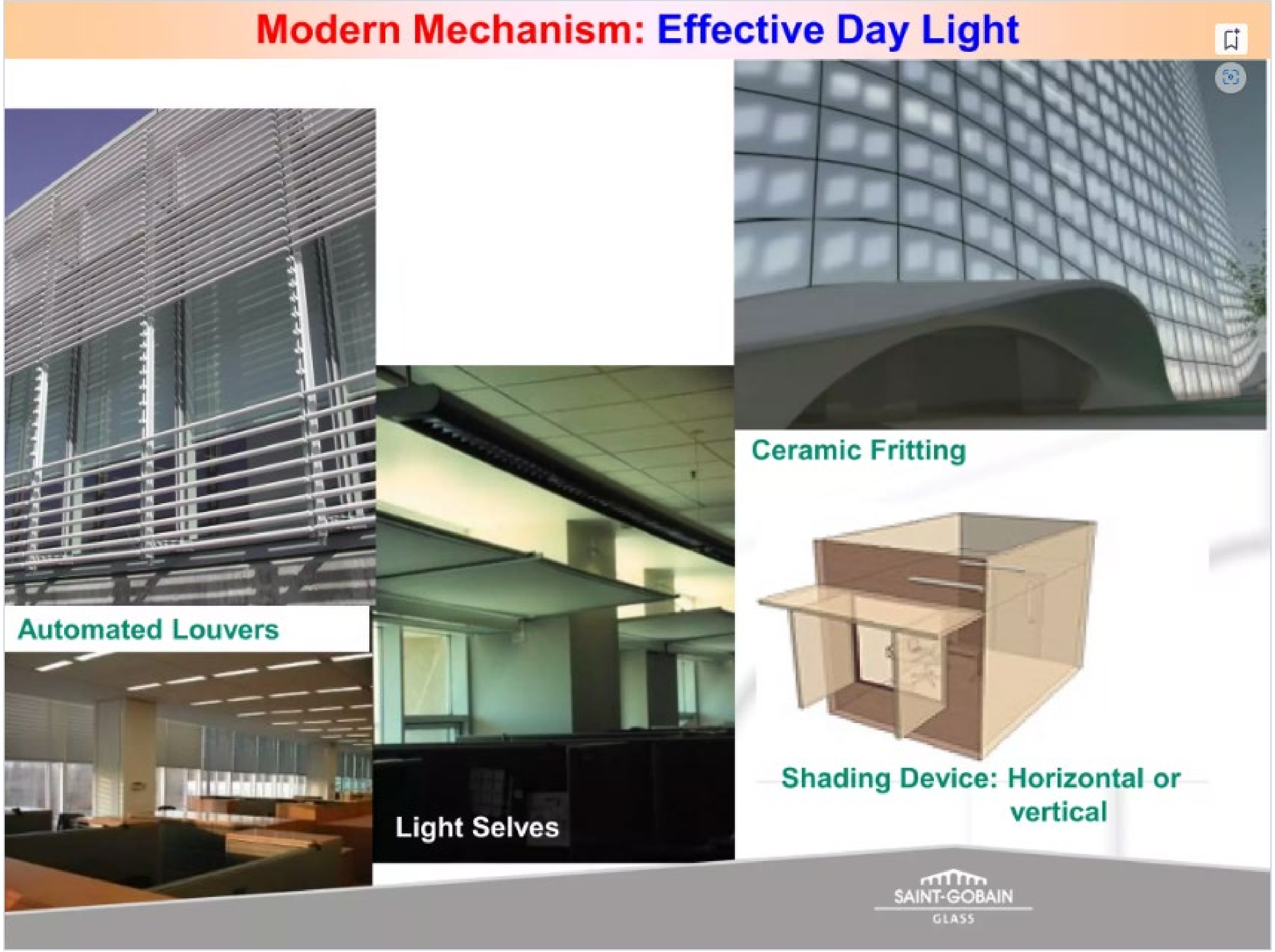

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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

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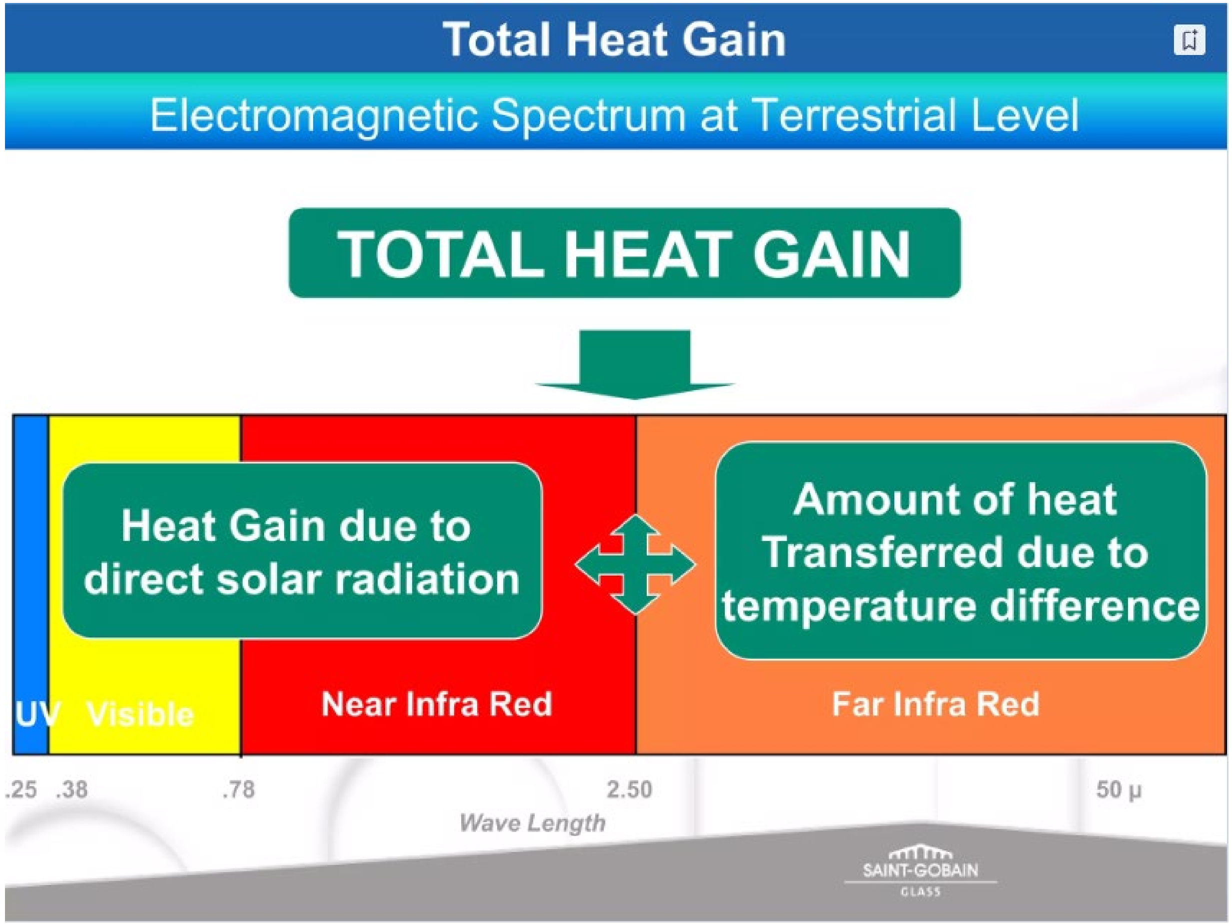

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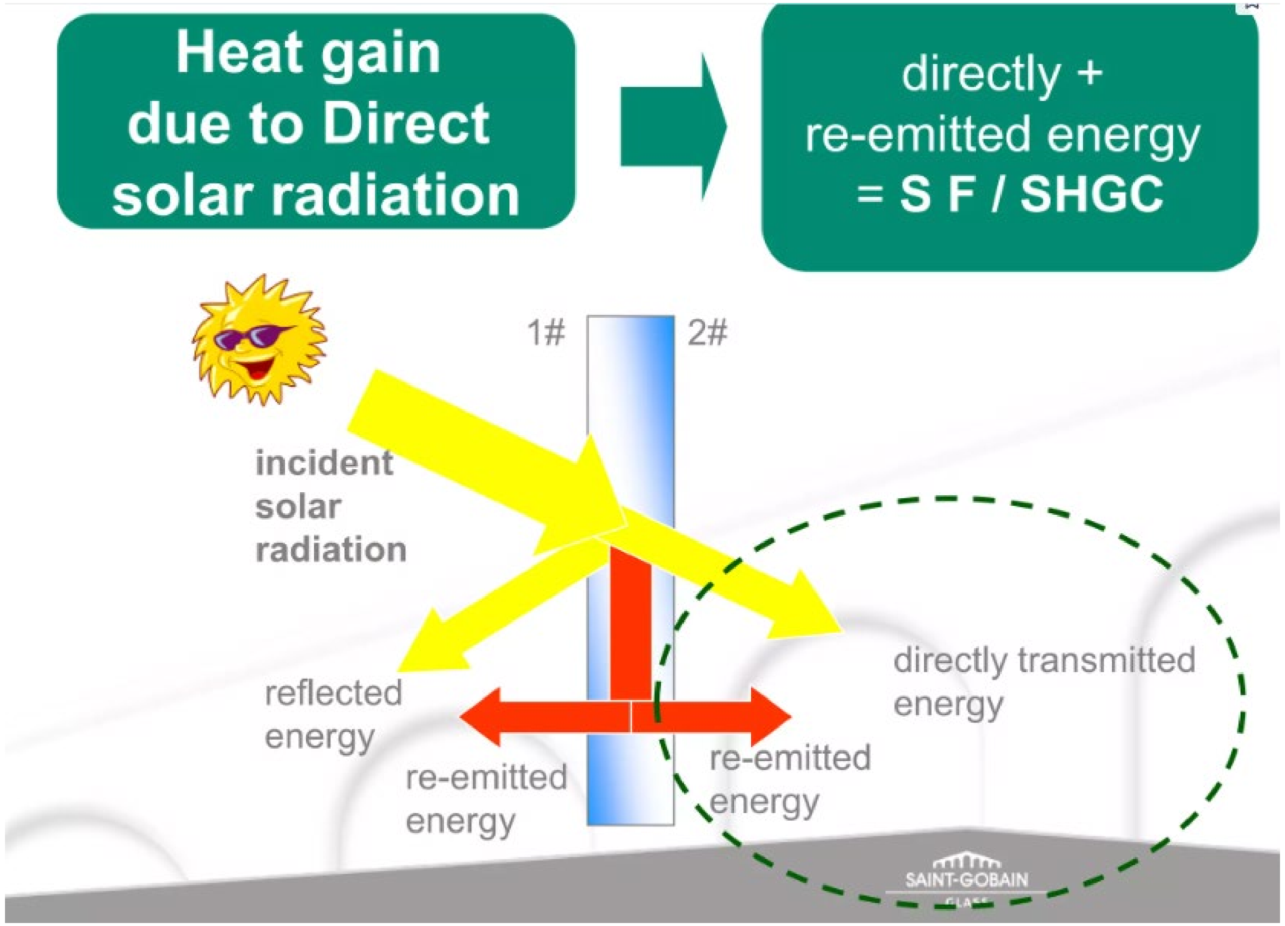
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a **windows**:



Solar Factor (SF) or Solar Heat gain coefficient (SHGC)

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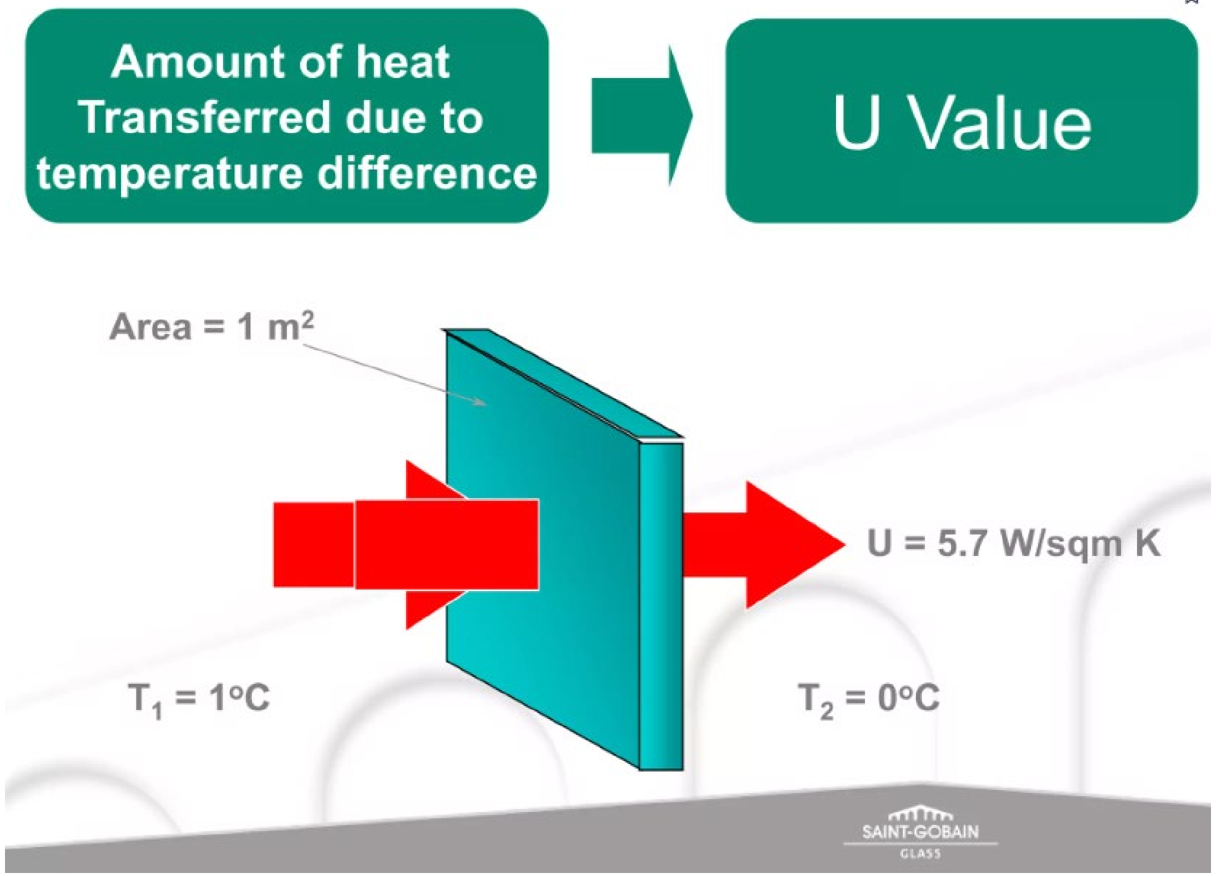
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a **windows**:



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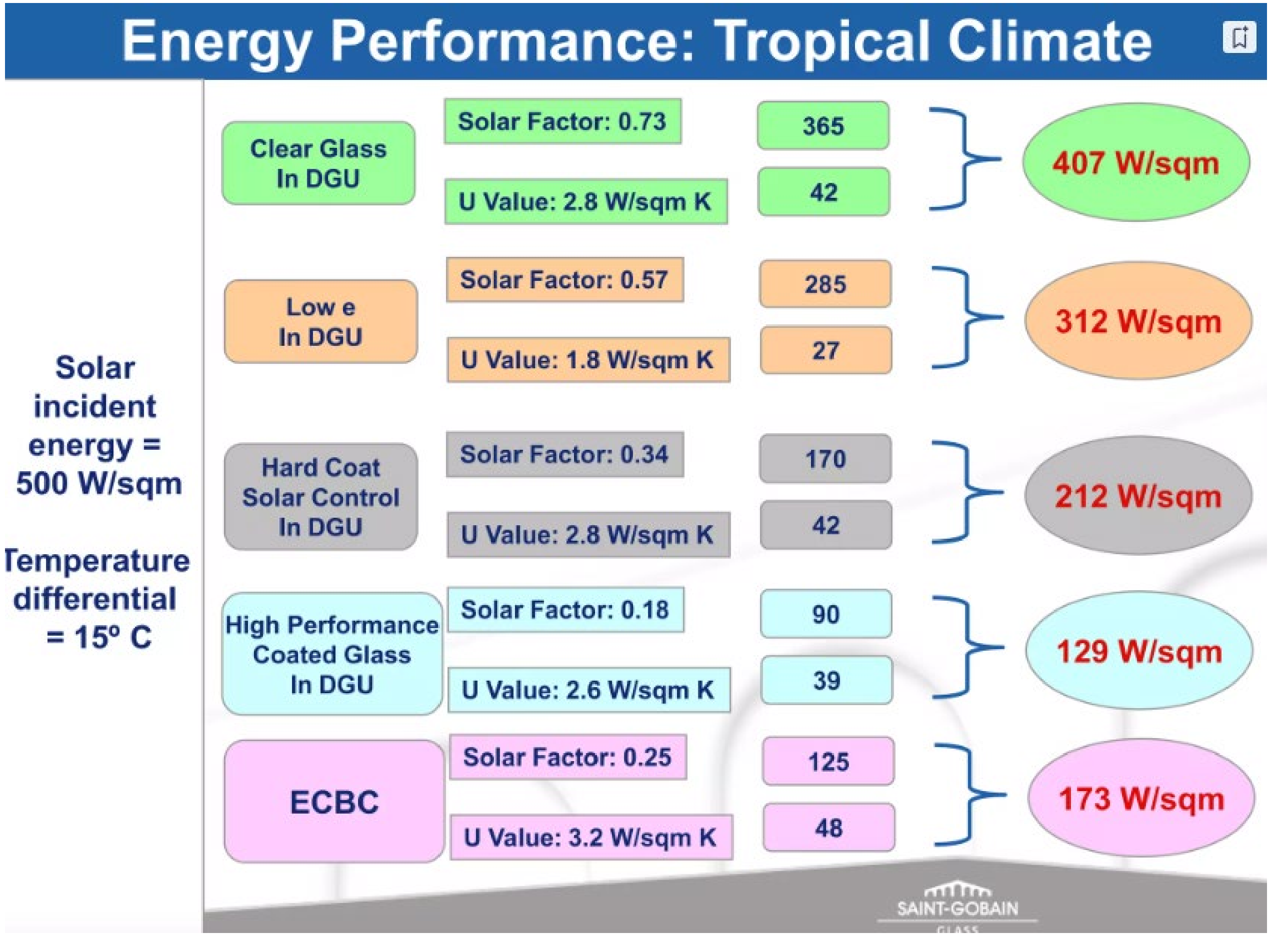
Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a **windows**:



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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal properties of a **windows**:

Walls, windows, shading and solar gains

- Wall should be designed to have insulation
- Window area should be limited to 10-30% of the wall area
- Windows should be highly efficient, particularly if more than 25% of the wall area (both thermal protection and solar protection)
- Shading with overhangs should be designed based on solar angles (i.e. typically overhangs are more effective on North and South walls)
- Shading with movable external shades can be highly effective for optimized daylighting and controlling solar gains.
  - Shutters
  - Movable blinds

Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal Envelope **Code Requirements**.

Spanish Technical Building Code

Buildings must have a thermal envelope that limits their primary energy needs according to the climatic zone, its use and its compactness.

In order to comply with this section, it is necessary to check five aspects:

1. Limitations in the global transmittance of the thermal envelope (K) and **transmittances** by elements (U_{lim})
2. **Solar Control** of the Thermal Envelope ($q_{SOL; Jul}$)
3. The **air permeability** of the thermal envelope (Q_{100} and n_{50})
4. **Limit imbalances between units of use** (U_{lim} interior partitions)
5. **Condensation control**.

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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal Envelope **Code Requirements**.

Spanish Technical Building Code

Cartagena: Zone B

Guideline table for new construction or interventions on the building as a whole:

Table a - Annex E   Thermal transmittance of the element as a guideline for compliance with K, U [W/m²K].

Element	Winter climate zone α	A	B	C	D	E
Walls and floors in contact with outside air (US, UM)	0,56	0,50	0,38	0,29	0,27	0,23
cm of insulation	4	5	7	9,5	10,5	12,5
Covers in contact with outside air (UC)	0,50	0,44	0,33	0,23	0,22	0,19
cm of insulation	5,5	6	8.5	13	13,5	16
Walls, floors and roofs in contact with non-habitable spaces or with the ground (UT) Partition walls or interior partitions belonging to the thermal envelope (UMD)	0,80	0,80	0,69	0,48	0,48	0,48
cm of insulation	2	2	3	5	5	5
Openings (frame, glass and, if applicable, louver box) (UH)* (UH)* (UH)* (UH)	2,7	2,7	2,0	2,0	1,6	1,5
glass composition and metallic carpentry, without roller shutter drawer	BE4/8/6 SinRPT	BE4/8/6 SinRPT	BE4/10/6 RPT	BE4/10/6 RPT	BE4/12Ar/ RPT	BE4/14Ar/6 RPT

Hip: Thermal conductivity of the insulation layer λ = 0.032 W/m·K

WALLS
Cement mortar
Perforated brick
Insulation (λ=0.032 W/m2)
Double hollow brick
Gypsum plaster

COVERS
Ceramic tile
Cement mortar
Insulation (λ=0.032 W/m2)
Lightweight aggregate concrete
Ceramic forging

Floor

Ceramic tile
Cement mortar
Insulation (λ=0.032 W/m2)
Reinforced concrete floor

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Properties and behaviour of the building thermal envelope. Alternatives to improve BEE

- Thermal Envelope **Code Requirements.**

Spanish Technical Building Code

Cartagena: Zone B

Table for interventions in existing buildings:

Table 3.1.1.a - HE1 Thermal transmittance limit values, U_{lim} [W/m²K].

Element	Winter climate zone α	A	B	C	D	E
Walls and floors in contact with outside air (US, UM)	0,80	0,70	0,56	0,49	0,41	0,37
cm of insulation	2.5	3	4	5	6.5	7
Covers in contact with outside air (UC)	0,55	0,50	0,44	0,40	0,35	0,33
cm of insulation	5	5.5	6.5	7	8	8.5
Walls, floors and roofs in contact with non-habitable spaces or with the ground (UT) Partition walls or interior partitions belonging to the thermal envelope (UMD)	0,90	0,80	0,75	0,70	0,65	0,59
cm of insulation	1.5	2	2.5	2.5	3	3.5
Openings (frame, glass and, if applicable, louver box) (UH)* (UH)* (UH)* (UH)	3,2	2,7	2,3	2,1	1,8	1,80
glass composition and metallic carpentry, without roller shutter drawer	4/16/6 SinRPT	BE4/8/6 SinRPT	BE4/8/6 RPT	BE4/10/6 RPT	BE4/20/6 RPT	BE4/20/6 RPT
Doors with semi-transparent surface equal to or less than 50%.	5,7					

*The window openings in *units of use* with commercial activity can increase the value of the HU by 50%.

Hip: Thermal conductivity of the insulation layer λ = 0.032 W/m·K

WALLS
Cement mortar
Perforated brick
Insulation (λ=0.032 W/m2)
Double hollow brick
Gypsum plaster

COVERS
Ceramic tile
Cement mortar
Insulation (λ=0.032 W/m2)
Lightweight aggregate concrete
Ceramic forging

Floors

Ceramic tile
Cement mortar
Insulation (λ=0.032 W/m2)
Reinforced concrete floor

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- Alternatives to improve the thermal envelope of existing buildings

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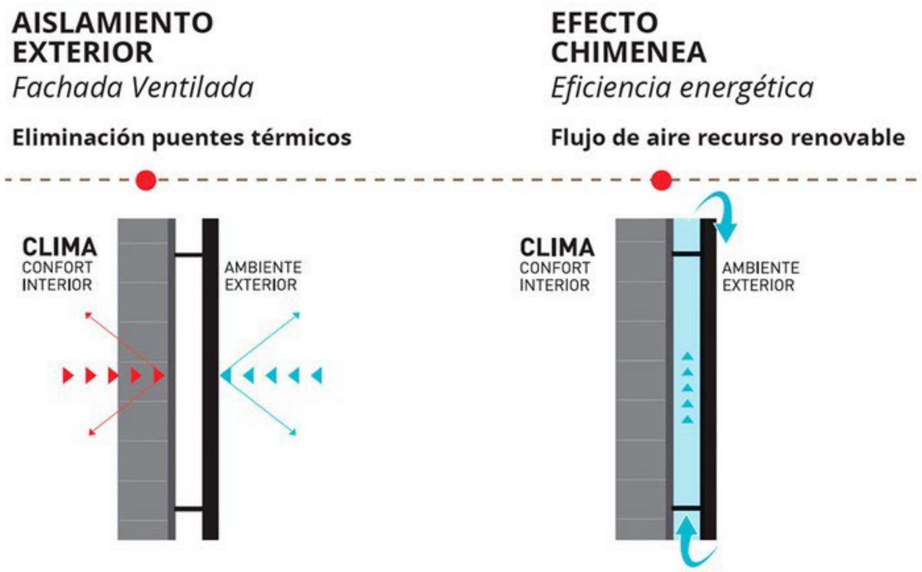
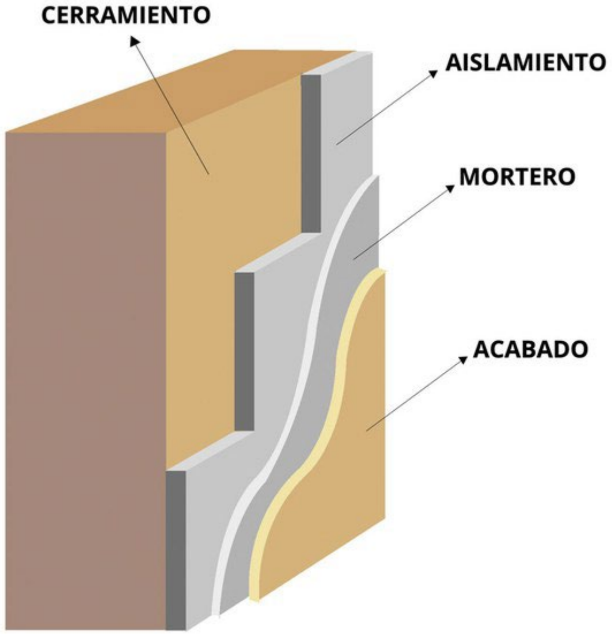
Exterior insulation: Ventilated facade or SATE





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Exterior insulation

https://youtu.be/xLuRVxfHZSE

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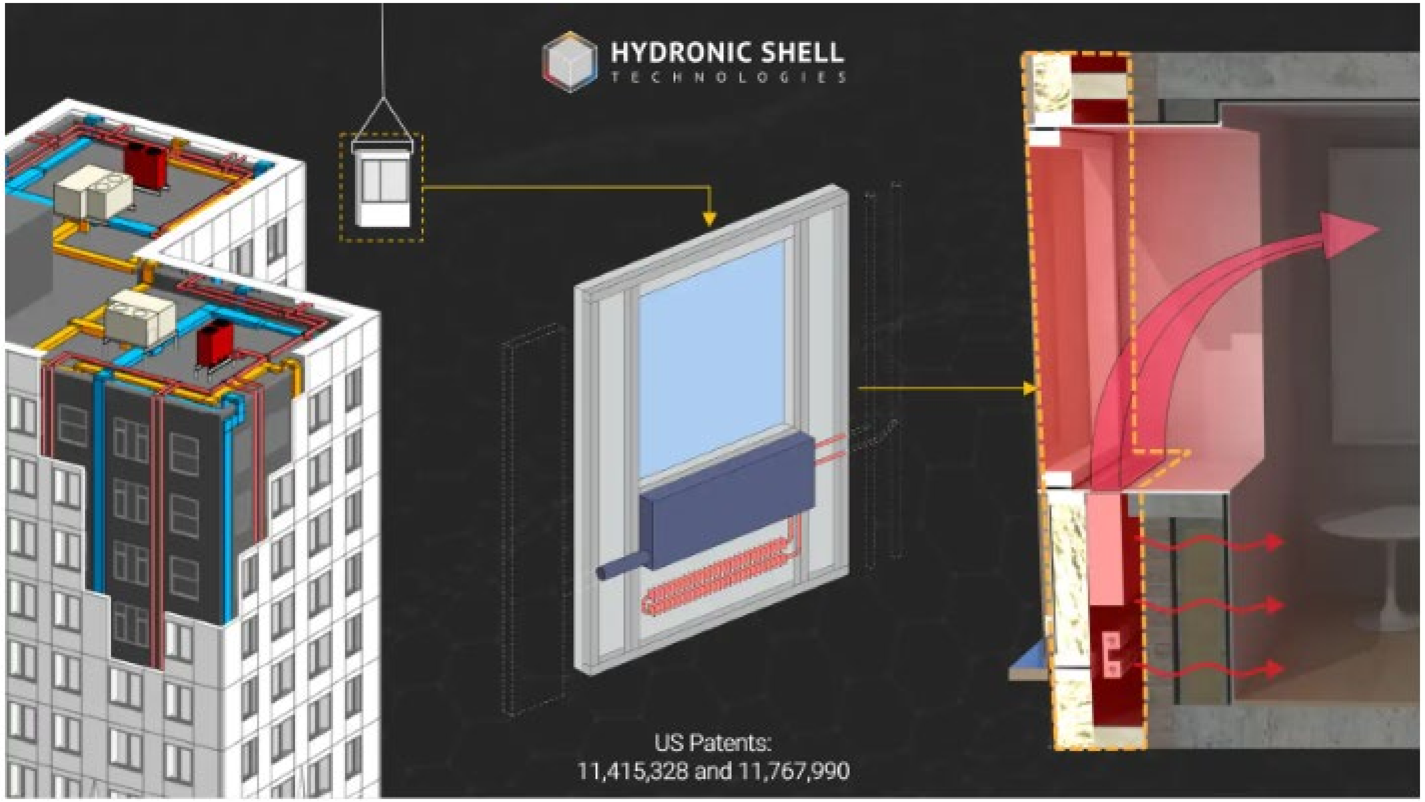
Exterior insulation



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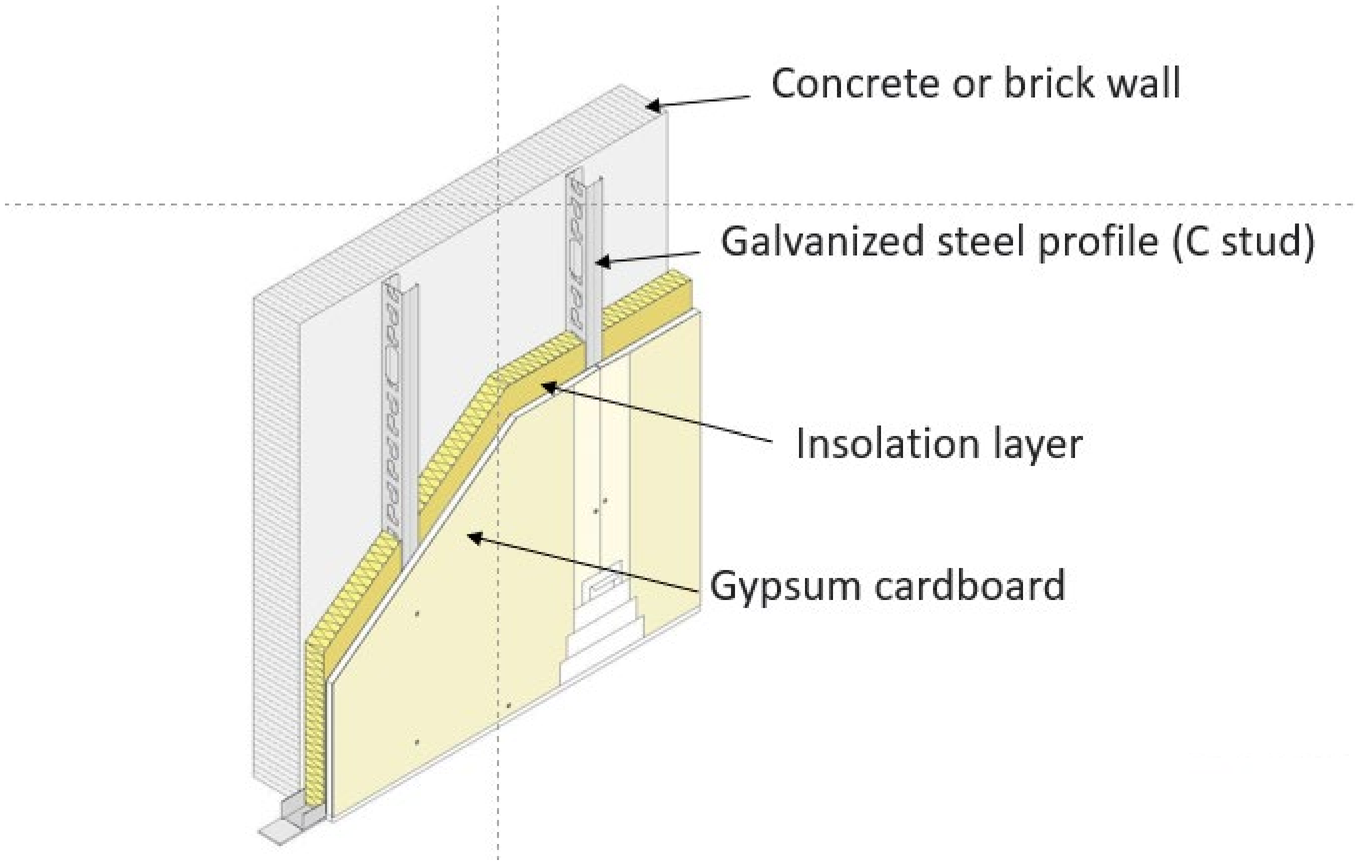
Interior insulation



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That's all

Thanks for your attention