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WOOD IN CIRCLE

# Building Thermal Balance

***Simplified procedure***


Assoc. Prof. Dr Giuseppina Ciulla
University of Palermo


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# Sustainable Building

What does Sustainable Building mean?

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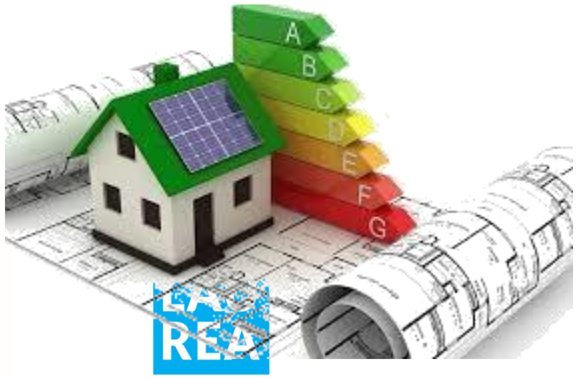
# The Building Sector

About **40%** of European energy consumption is related to the **Building sector** and the most part is linked to satisfy the **Heating and cooling Energy demand**

Buildings energy consumption **has become a relevant international issue** and several policy measures for energy saving are under discussion in many countries

**The estimation of energy demand is a complex task; nevertheless, it is important to assess the contribution of all the activities that take place within buildings in terms of energy consumptions**


**Studying the factors that affect the energy performance of a buildings and the energy characteristics of building constructions is essential to perform a careful analysis of heating energy demand**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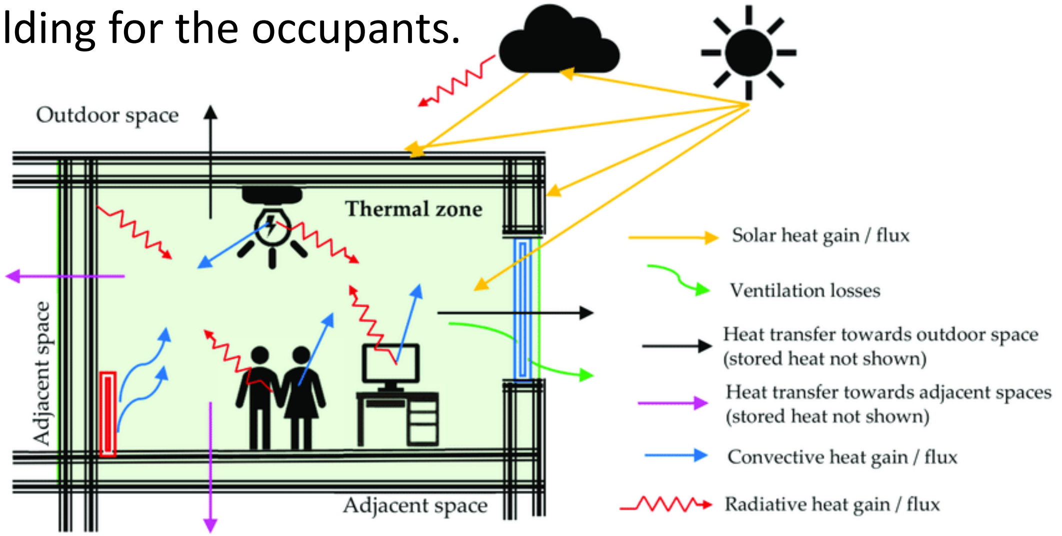
## Building Thermal Balance

When a building is designed, the engineer must evaluate all the exchanges that the building thermodynamic system exchanges with the surrounding environment.

The goal is to create a comfortable building for the occupants.

*The building is not an object in its own right, but part of an interactive and dynamic system that considers the natural (earth, water, wind, sun, vegetation) and social (identity and belonging to places) and technical (materials, geometry) elements , position ..)*

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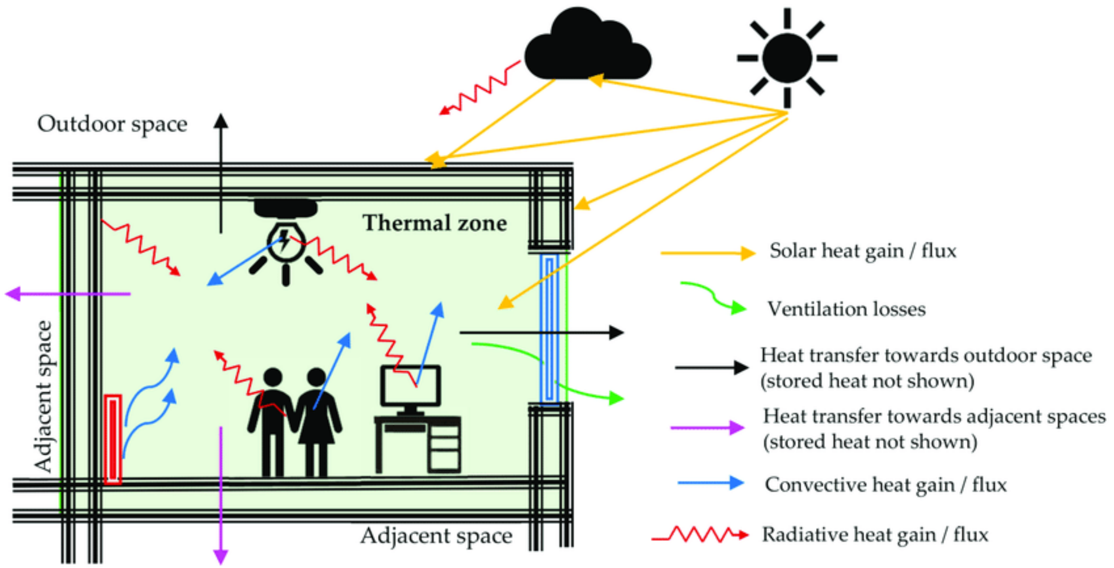
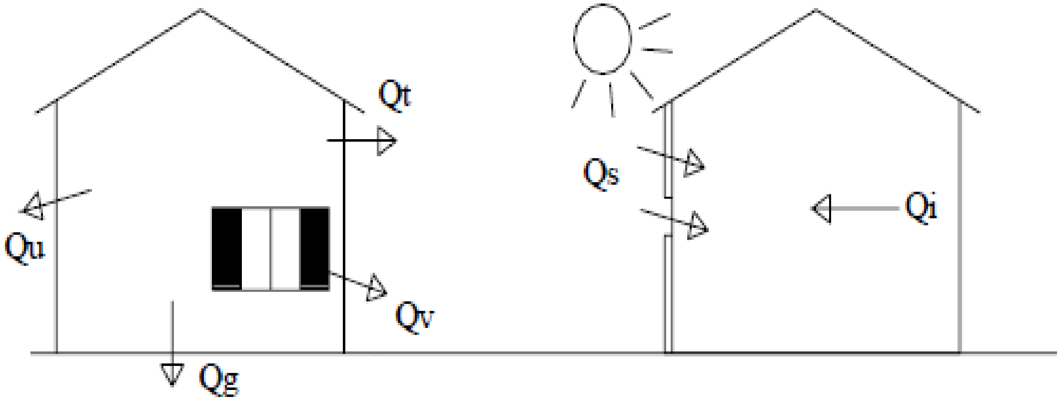
# Heating Thermal Balance

LOSSES

GAINS




NEEDS

$$Q = UA\,(T_{indoor} - T_{outdoor})$$

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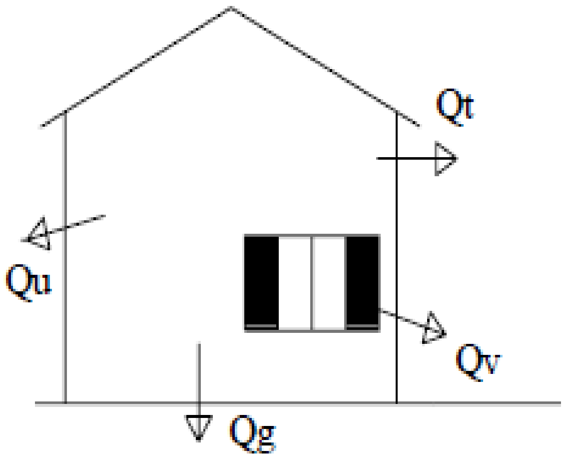
## Heating Thermal Balance




### All Transmission Losses

$$Q_L = Q_T + Q_V + Q_g + Q_U = (H_T + H_V) \quad [MJ]$$

$Q_T$ = heat losses through the opaque and glass building surface
$Q_V$= Ventilation losses from the windows or door
$Q_g$ = heat losses from the building to the ground
$Q_U$= heat losses to unheated confined spaces

**Heat Losses**
**Transmission losses** are those amounts of heat, which flow through the building envelope from inside to outside by conduction or heat transfer, respectively.
**Ventilation losses** are caused by exchange of warm indoor air with colder outdoor air. The user independent air exchange is through joints by infiltration or exfiltration, respectively. In addition, room air can be exchanged through open windows or by a mechanical ventilation system. Ventilation is indispensable, up to a certain extend, to assure the hygienically necessary air exchange rate.

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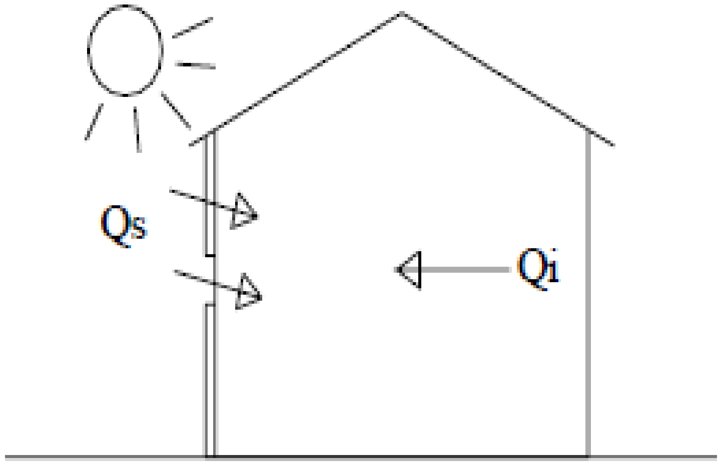
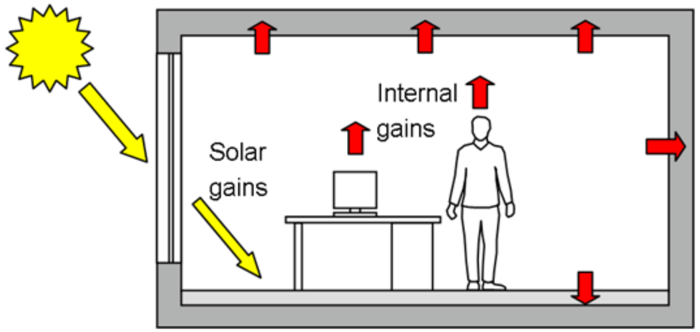
## Heating Thermal Balance




## All Heat Gains

$$Q_G = Q_i + Q_S \quad [MJ]$$




**Heat Gains**

**Solar gains $Q_S$** are irradiations of solar energy through windows and other transparent or translucent constructional elements. Also added to the solar gains, is that part of the solar heating of the opaque building envelope, from which the indoor area benefits.

**Internal gains Qi** are heat outputs from persons, appliances, computers and other electric devices, as well as from illumination.

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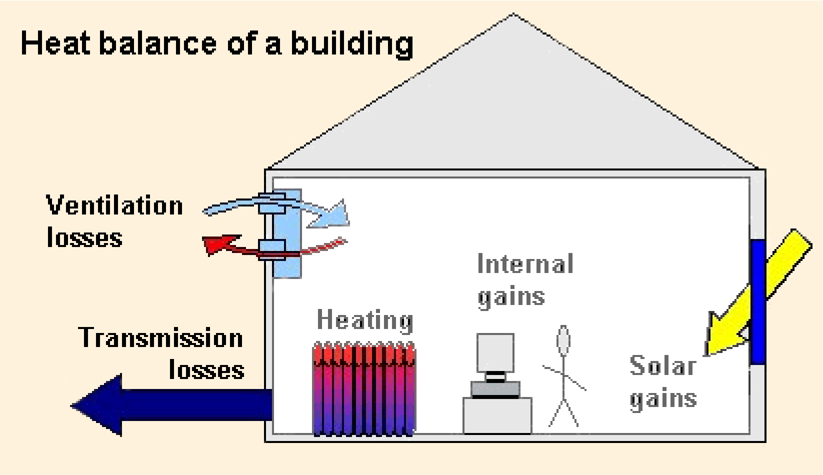
## Heating Thermal Energy Demand $Q_H$

… is exactly that amount of heat, which is necessary to maintain the desired room temperature by compensating the excess of losses compared to the gains.




*Utilization factor*

$$Q_H = Q_L - \eta_f \, Q_G$$

*Heat Losses* *Thermal gains*

**Utilization factor**
is a parameter that has the function of compensating for the additional losses that occur when the thermal gains are greater than the losses, i.e. the thermal energy accumulated by the building masses

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## Energy performance index for winter air conditioning

The **Primary Energy** for winter air conditioning can be obtained as:

$$PE = \frac{(Q_H / A_{flo})}{\eta_{gl}}$$

Where:

$Q_H$ = Heating Thermal Energy Demand , expressed in kWh;

$A_{flo}$ = the useful surface (floor) expressed in $m^2$;

$\eta_{gl}$ = global seasonal efficiency of the plant-system

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## QH = Heating Thermal Energy Demand

$$Q_H = Q_L - \eta_f \; Q_G$$

*Heat Losses*

$$0{,}024 \; HDD \; (H_T + H_V)$$

transmission and ventilation losses

DEGREE DAYS
A **degree day** is a measure of heating or cooling. (Heating Degree-days or Cooling degree days)
Each city based on height above sea level is represented by a number that represents a sum as a function of the differences in temperatures between inside and outside, the higher this number, the more rigid the climate and the longer the winter.
**The values are tabulated in appropriate technical standards and indicates also the HEATING PERIOD**

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# Heating Degree Days

**A heating degree day (HDD)** is a measurement designed to quantify the demand for energy needed to heat a building. It is the number of degrees that a day's average temperature is below 65º Fahrenheit (18º Celsius), which is the temperature below which buildings need to be heated.

**Each city has a specific HDD value:**

**Palermo** (South Italy): HDD=751 °C/day, **Heating Period:** from 1° December to 31° March

**Belluno** (North Italy): HDD 3043 °C/day; **Heating Period: all year**

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## QH = Heating Thermal Energy Demand

$$Q_H = Q_L - \eta_f \; Q_G$$

*Heat Losses*

*Thermal gains*

$$0{,}024 \; HDD \; (H_T + H_V)$$

transmission and ventilation losses

$$(Q_S + Q_I)$$

Internal and solar gains

DEGREE DAYS
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## QH = Heating Thermal Energy Demand

$$Q_H = 0{,}024\ HDD\ (H_T + H_v) - \eta_f\ (Q_s + Q_i)$$

**0,024:**
is a correction coefficient for the measurement units

**ηgl:**
is the utilization coefficient (dimensionless) equal to 0.95;

$$0{,}024 = \frac{24}{1000}$$

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# Simplied Procedure

Determination of all parameters

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# $H_T$ Overall transmission coefficient

$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

Where is it:

**Si= disperding surfaces** that enclose the gross heated volume. Surfaces facing other rooms heated to the same temperature [m$^2$] are not considered;

**Ui = thermal transmittance** of the structure [W/m$^2$K]

**btr, i = correction factor** of the heat exchange towards non-conditioned environments or towards the ground (dimensionless)

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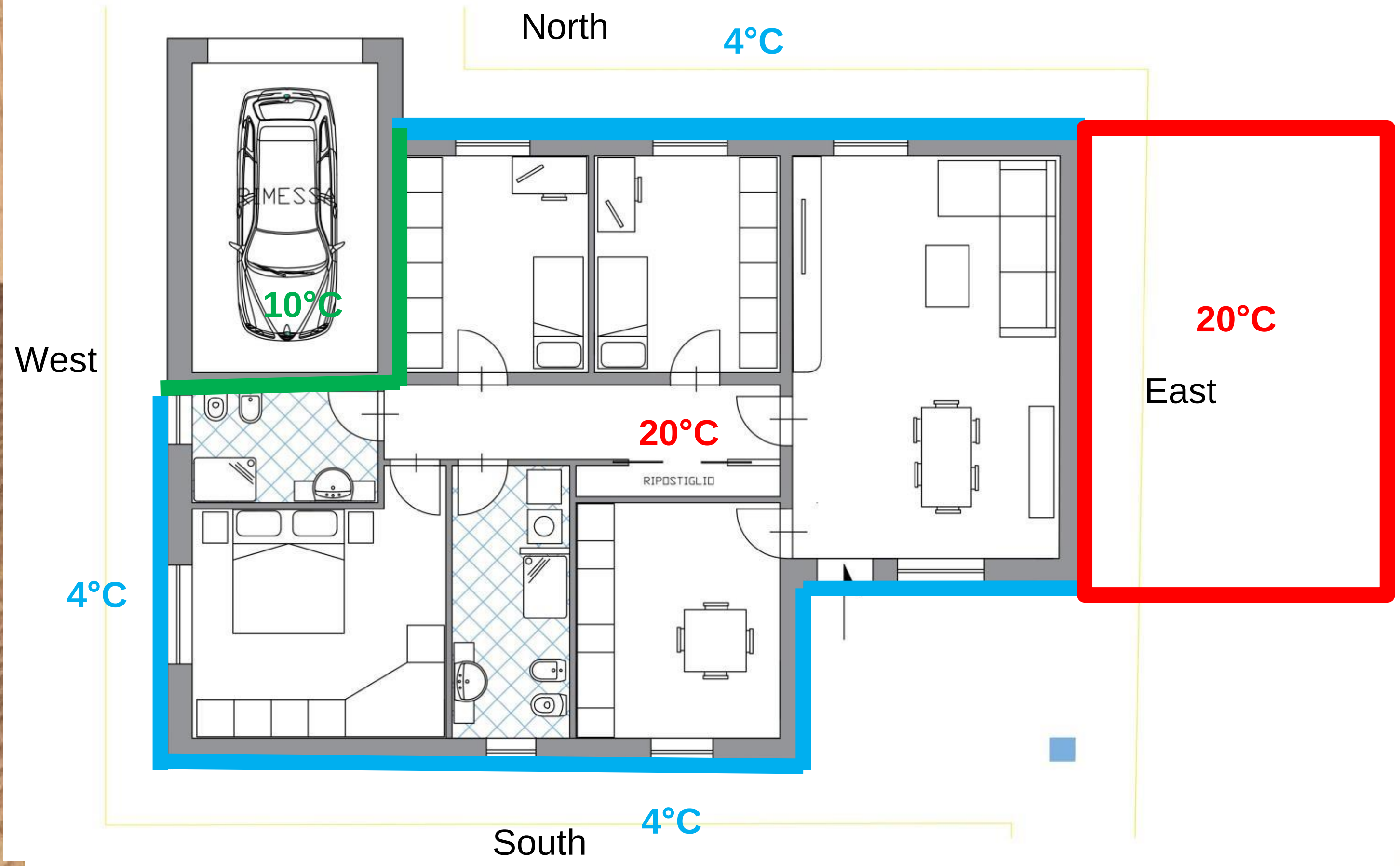
$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

City: Palermo
HDD= 751
Heating period:
from 1° December to 31° March

## Example




If we calculate the temperature difference for all walls with different conditions, we have:

$(T_{indoor} - T_{ext}) = (20\text{-}4) = 16°C$

$(T_{indoor} - T_{Indoor}) = (20\text{-}20) = 0°C$

$(T_{indoor} - T_{garage}) = (20\text{-}10) = 10°C$

$(T_{indoor} - T_{ground}) = (20\text{-}5) = 15°C$

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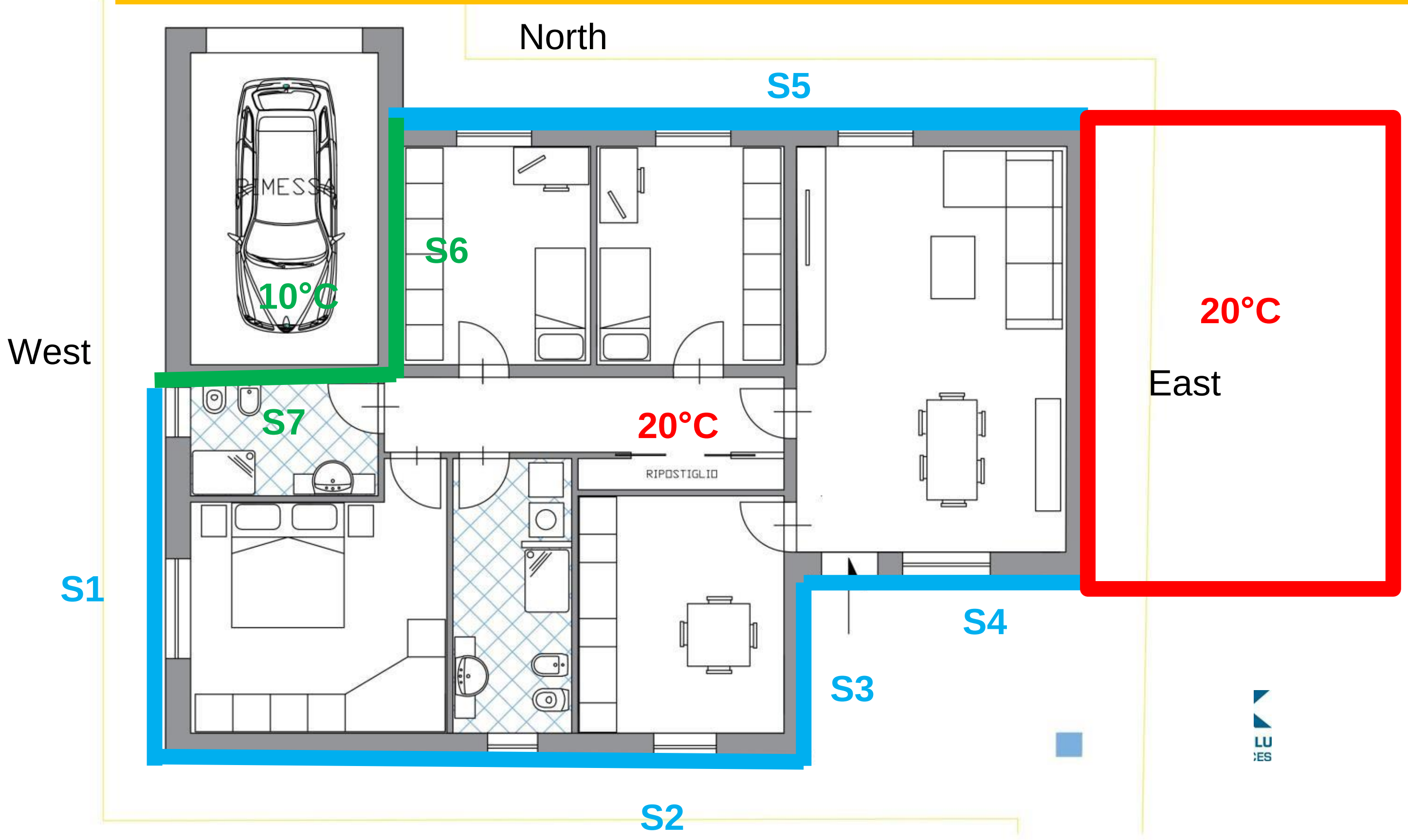
$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

## Si= Dispersing surfaces

Dispersing surfaces are defined as all surfaces in which I have a difference of temperature between the two environments that it divides and therefore I have a flow of heat.In this case the dispersing surfaces are the square meters of blue and green surfaces.




$Si = S1+S2+S3+S4+S5+S6+S7+ S_{ground}$

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$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

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## U= Thermal Trasmittance

It is a physical quantity that measures the amount of thermal power exchanged by a material or body per unit of surface area and unit of difference of temperature. It defines the tendency of an element to exchange energy, that is the inverse of the insulating capacity of a body. It is measured in W /(m$^2$K).

$$U = \frac{1}{R_{tot}} = \frac{1}{\frac{1}{h_i} + \sum_i \frac{s_i}{\lambda_i} + \frac{1}{h_e}} \left[\frac{W}{m^2K}\right]$$

**The transmittance is the inverse of the total thermal resistance**

- hi is an internal adductive coefficient which depends on whether the internal surface is vertical, horizontal or inclined
- he is an external adductive coefficient which depends on whether the external surface is vertical, horizontal or inclineds
- s is the thickness of the single materiall
- l is the thermal conductivity of the material

All walls, roof, floor and windows are characterized by a transmittance

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$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

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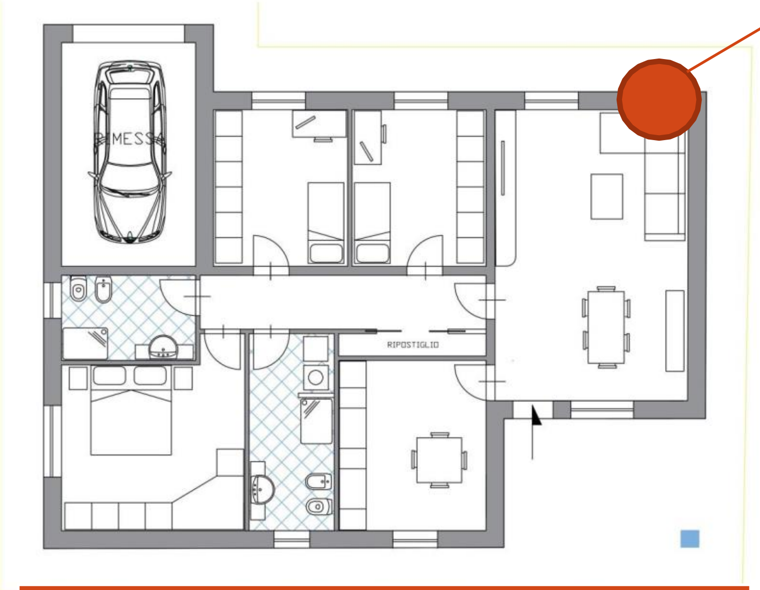
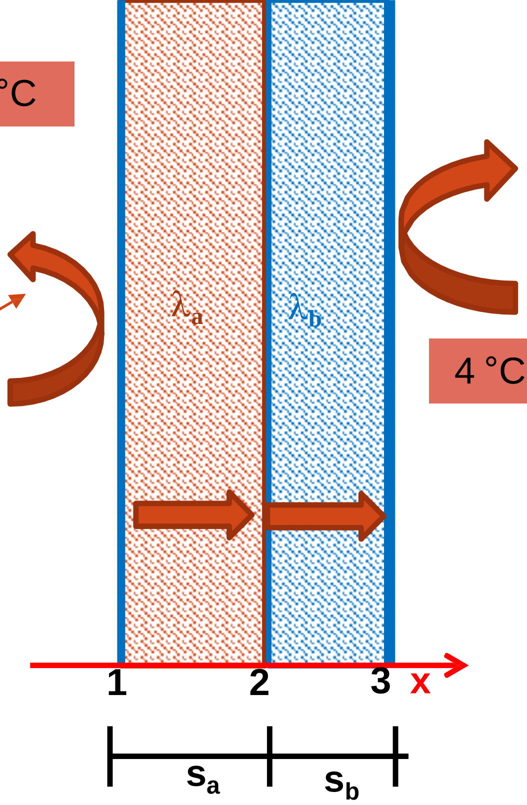
## Uwall= Wall Trasmittance




20°C




4 °C

Sa= 12 cm of brick
Sb= 3 cm of plaster

Conductivity
la = 0,36 W/mK
lb = 0,07 W/mK

Each material is characterized by a conductivity, an intensive property of a material that indicates its ability to conduct heat.

From experience we know that if I put an iron rod and a plastic rod on a flame, the iron will heat up faster.
This is because iron has a higher conductivity

| Adductive Coefficient [W/m²K] | | | |
|---|---|---|---|
| | Horizontal surface ascending flow | Vertical surface | Horizontal surface downward flow |
| hi | 10 | 8 | 6 |
| he | 25 | 23 | 25 |

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$$H_T = \sum_1^n S_i \cdot U_i \cdot b_{tr,i}$$

## U= Thermal Trasmittance

$$U = \frac{1}{R_{tot}} = \frac{1}{\frac{1}{h_i} + \sum_i \frac{s_i}{\lambda_i} + \frac{1}{h_e}} \left[\frac{W}{m^2K}\right] = \frac{1}{\frac{1}{8} + \frac{sa}{l\ a} + \frac{sb}{l\ b} + \frac{1}{23}} = \frac{1}{\frac{1}{8} + \frac{0,12}{0,35} + \frac{0,03}{0,07} + \frac{1}{23}} =$$

For vertical Wall is equal to 8 W/mK

For vertical Wall is equal to 23 W/mK

U wall = 1,064 W/m²K

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$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

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# btr, i correction factor

| Condition | btr value |
|---|---|
| floor in contact with the ground | 0,45 |
| wall in contact with the ground | 0,45 |
| floor on ventilated crawl space | 0,8 |

| Condition | btr value |
|---|---|
| room with an external wall 0.4 | 0,4 |
| environment without external doors and windows and with at least two external walls 0.5 | 0,5 |
| environment with external doors and windows and with at least two external walls 0,6 | 0,6 |
| room with three external walls 0,8 | 0,8 |
| basement or basement without windows or external doors 0.5 | 0,5 |
| basement or basement with external windows or doors 0.8 | 0,8 |
| attic with high ventilation rate without felt or planking 1.0 | 1 |
| attic with non-insulated roof of another type 0.9 | 0,9 |
| attic with insulated roof 0.7 | 0,7 |
| freely ventilated internal circulation areas0.4 | 0,4 |

It is a correction coefficient that changes according to the condition that exists in the environment in contact with the home

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$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

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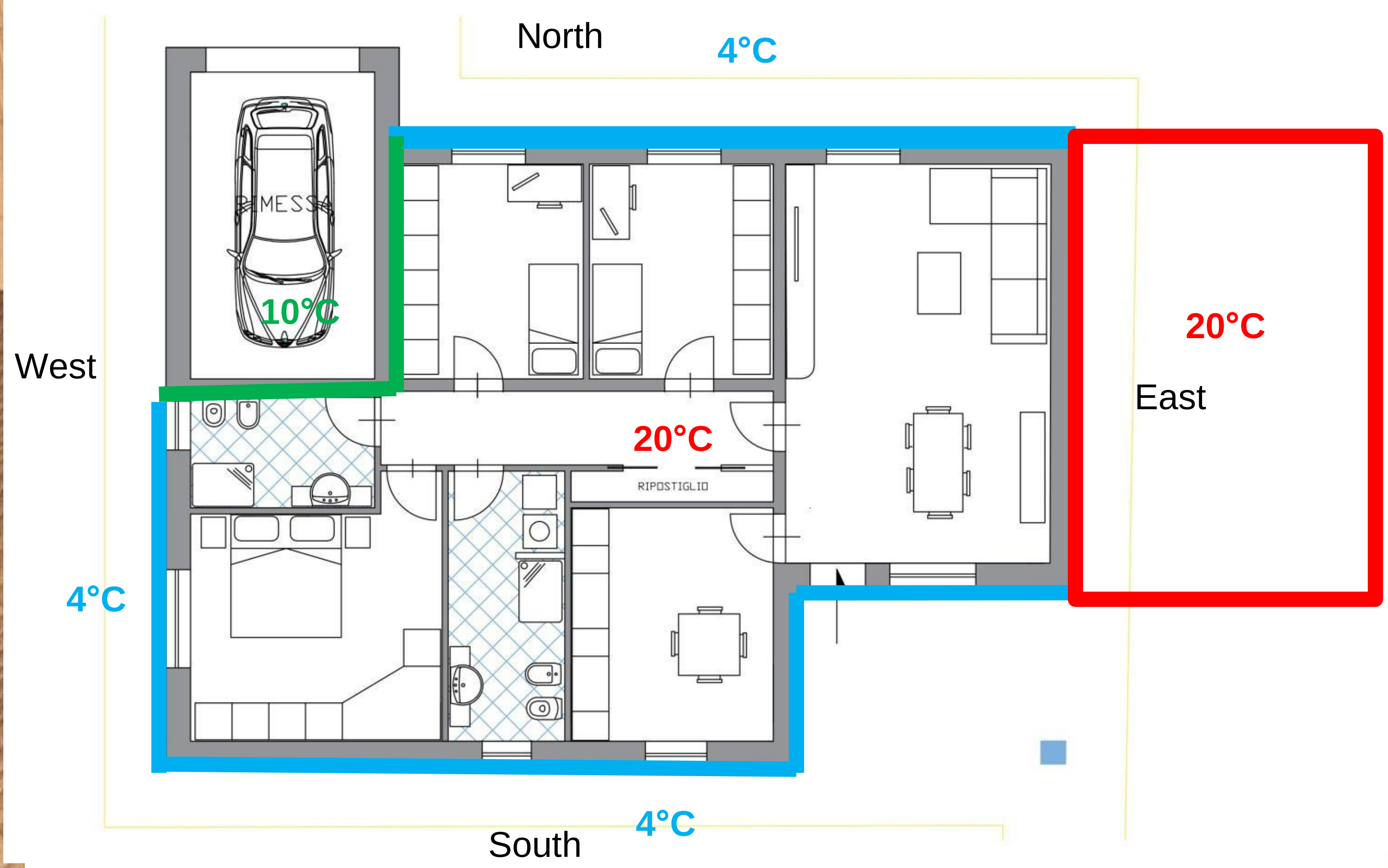
## Example




1. It Is consider a coefficient btr=1 for all external wall
2. It Is consider a coefficient btr=0 for all internal wall
3. It Is consider a coefficient btr between 0 and 1, for all other conditions. The value of which depends on the condition of the neighboring environment (see the Table)

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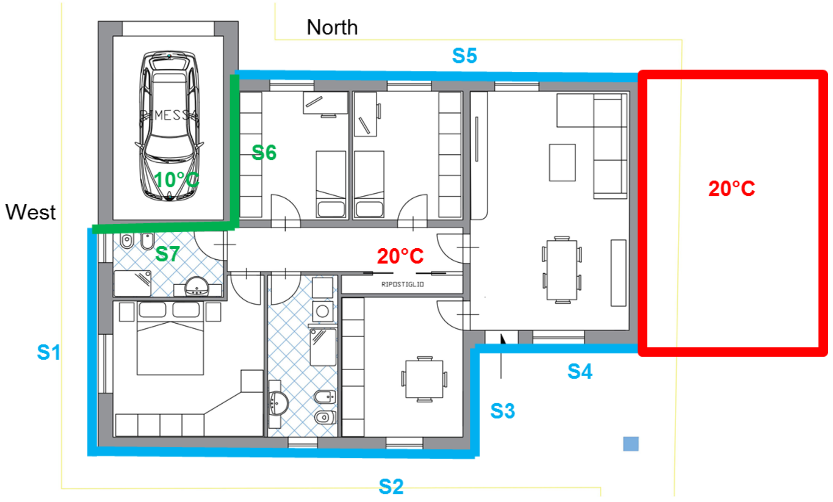
# $H_T$ Overall transmission coefficient




$$H_T = \sum_{1}^{n} S_i \cdot U_i \cdot b_{tr,i}$$

$=S_1xU_{wall}x1+ S_2xU_{wall}x1+ S_3xU_{wall}x1+ S_4xU_{wall}x1+ S_5xU_{wall}x1+ S_6xU_{wall}x0,6+ S_7xU_{wall}x0,6+ S_{ground}x\ U_{ground}\ x\ 0,45$

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# Hv
# Overall ventilation coefficient

$$H_V = 0.34 \cdot n \cdot V_{net}$$

Where:

- n = number of air changes; and residential building is equal to 0.3 vol / h;
- Vnet = net volume of the air-conditioned environment assumed equal to 70% of the gross volume

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$$Q_H = 0{,}024\ HDD\ (H_T + H_v) - \eta_f\ (Q_s + Q_i)$$

All the parameters of the first part of the equation have been defined

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$$Q_H = 0{,}024\ HDD\ (H_T + H_v) - \eta_f\ (Q_s + Q_i)$$

The second part of the equation involves the determination of internal gains

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# Qs
# Solar gains

$$Q_S = 0.2 \sum_{esposizione} I_{sol,i} \cdot S_{serr,i}$$

Where
-0.2 = reduction coefficient which takes into account the solar factor of the transparent elements and average shadings;

- Isol, i = total seasonal irradiance (in the heating period) in the vertical plane, for each exposure
- Sserr,j= total surface of a single window or transparent component

***The value is calculated as the sum of the monthly mean irradiance values on the vertical plane****, extended to the months of the heating season.*
*The duration of the calculation season is determined according to the climatic zone dependent on degree days of the city*

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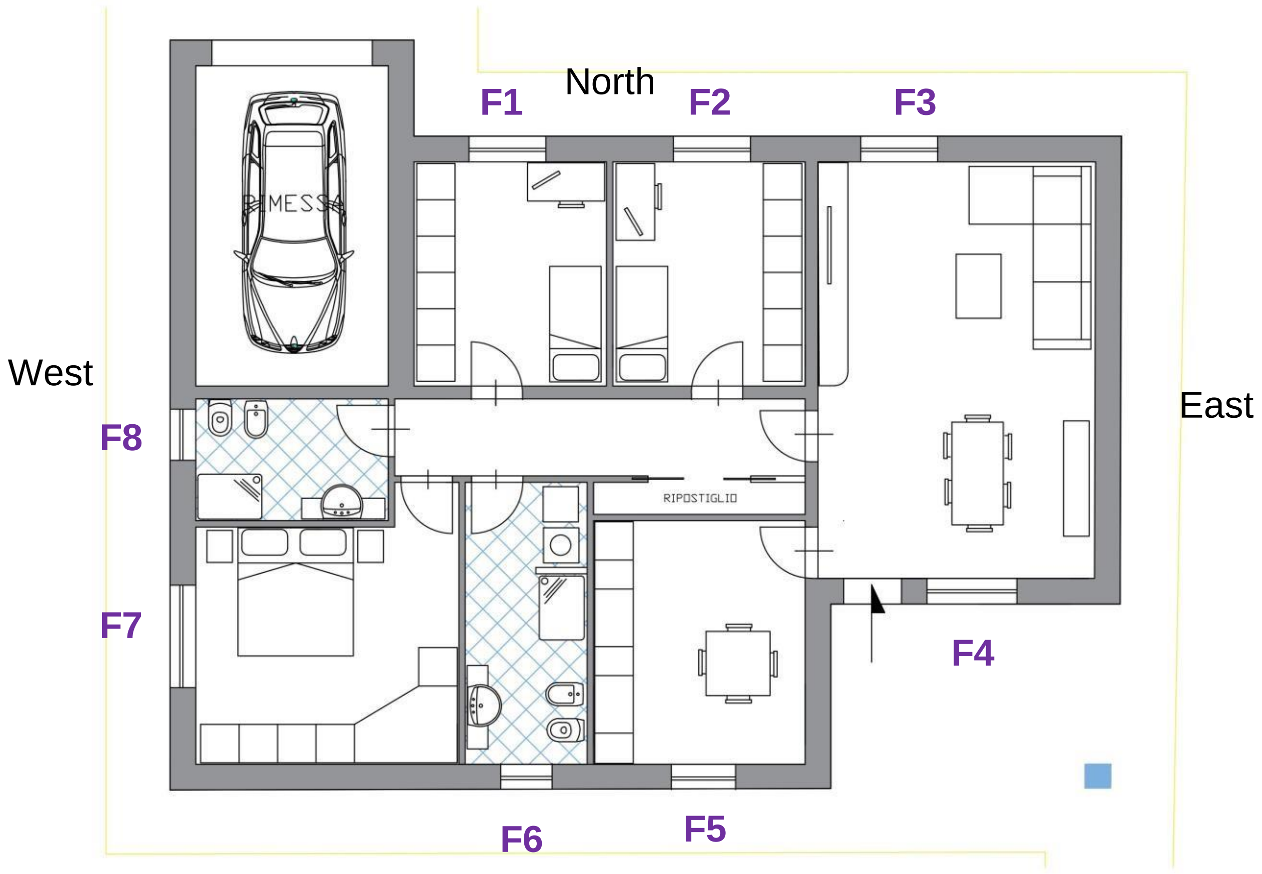
$$Q_S = 0.2 \sum_{esposizione} I_{sol,i} \cdot S_{serr,i}$$

City: Palermo
HDD= 751
Heating period:
from 1° December to 31° March

Only for the heating period and for exposures where there are windows, it is necessary to collect the data of the total solar radiation




data provided by technical standards

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# Qi
# internal gains

$$Q_i = \frac{(\Phi_i \cdot A \cdot h)}{1000}$$

Heating period:
from 1° December to 31° March are equal to 121 days

h= 121x24 hours= 2904 hours

Where is it:

-Φi = internal gains in residential building, assumed conventional value equal to 4 W / m2;

- h = number of hours in the heating season – is function of the climate (Degree days)
- Ai: internal superface of the floor

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All parameters of the Heating Thermal Energy Demand equation have been determined

$$Q_H = 0{,}024\ HDD\ (H_T + H_v) - \eta_f\ (Q_s + Q_i)$$

$$PE = \frac{(Q_H / A_{flo})}{\eta_{gl}}$$

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# ηg Global seasonal efficiency

$$\eta_{gl} = \eta_e \cdot \eta_r \cdot \eta_d \cdot \eta_g$$

ηe = emission efficiency, it depends on the type of emitting system chosen (radiators, fan coils, air vents); this value is tabulated

ηrg = regulation efficiency, depends on the regulation system (thermostat, climatic probe, etc); this value is tabulated

ηd = distribution efficiency, it depends on how the pipe has been distributed and what type of insulation the pipe has; this value is tabulated

ηg = generation efficiency, it depends on the heat generator (gas boiler, biomass boiler, electric split, etc) this value is sought in the technical sheet of the chosen generator

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# Thank you

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