Thermal Insulation Materials

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Chapter One
Introduction to the Insulation Materials

1.1 Introduction

There are many benefits of home insulation. Insulating will add the comfort to the building, create a healthier home environment, reduce the energy bills and have a positive environmental impact. Adding home insulation to an existing home will regulate the temperature, making the living environment more enjoyable, especially in places of extreme weather. With insulation the home will become more energy efficient. Insulation will keep the home cooler in the summer and warmer in the winter. This will reduce the amount of heating and cooling appliances that is needed to keep the house comfortable. Because of this, home insulation will reduce the energy bills and the costs of cooling and heating. Adding acoustic insulation will also enhance the sound control. Insulation creates a sound barrier, keeping unwanted sounds out and protecting the privacy by keeping the sounds inside from being audible outside.Insulating the home also creates a moisture barrier, keeping undesirable moisture out and offers much comfortable living environment inside. Insulating the electrical outlets and the corresponding components will protect home against any electrical shock. The benefit of home insulation is not related to the occupants inside the house only but it is also extended to keep the environment out of pollutants. The insulated building will contribute to use less energy for airconditioning.
This will reduce the carbon footprint, and also reduce the amount of chemicals released into the environment from air-conditioning units.

Therefore, insulation is a key element in the so-called "green home policy".

1.2 Insulation Materials

Insulation materials are made to maintain the building components and facilities as long as possible. There are many types of insulation materials according to the purpose and the structure.

1.3 Thermal Insulators

Thermal insulators are those materials that prevent or reduce various forms of heat transfer (conduction, convection and radiation). Insulator resists the heat transfer from out to in or in opposite direction whether the environment temperature is high or low. There are many advantages of thermal insulation that isolates the building from the heat and reduces the energy consumption as well as the costs of air-conditioning operation. Also, it makes the indoor temperature of the building stable and non-volatile.

To reduce the transmission of the heat, buildings must be isolated in order to protect it from heat loss in winter and heat gained in the summer. It is found that about 60% of heat losses directly through the ceilings and walls of the building and that about 15% through the glass and about 25% of the heat infiltrates through cracks, openings and doors. To make the thermal insulation of the building an economical process, the following factors should be chosen carefully:
- The amount of insulation material and thickness
- The cost of insulation material and labor costs for installation.
- The amount of energy saving and the reduction in greenhouse emissions.

1.4 *Location of thermal insulation*

It is used to choose a quality of insulation material that satisfies the balance between the economic saving and the energy saving. Buildings are divided in terms of thermal insulation location into two types, buildings in warm climates and buildings in cold climates. Most of the heat that is gained in hot climates come through the outer shell of the building due to high solar intensity and the temperature differences between indoor and outdoor environment. The heat gained from external sources is higher than that comes from the internal heat generated by the various activities. The increase in thermal insulation in the outer shell of the building will lead necessarily to reduce the amount of heat gained and this consequently leads to reduce the energy needed for cooling. TheU-value is a dominant factor to find the optimal thickness of the insulator in building. The amount of the total cost is equal to the total cost of insulating material plus the cost of energy saved in the building for a certain period. In cold climates, heat is transferred from inside to out, so the insulating layer should be located in the internal face of the surfaces in order to reduce the heat losses.

1.5 *Types of thermal insulators*

The thermal insulation refers to all isolators systems that reduce the heat transfer. Thermal insulation in buildings prevents the heat loss in winter and resists the heat from out in summer. It is looked to use best thermal insulation materials that reduces all types of heat transfer modes like conduction, convection and radiation. Glass wool is one of the most common thermal insulators as well as polyurethane, cork, polymers and many other materials.

Chapter Two
Thermal Insulation

2.1 Thermal Insulators

Those materials that prevent or reduce various modes of heat transfer (conduction, convection and radiation) from the outside to the inside or vice versa, whether the environment temperature is high or low.

2.2 The Advantages of Thermal Insulation

1. Reduce the amount of heat transmitted through the parts of the house.
2. Reduce the energy required for heating or cooling the house.
3. Make the internal temperature of the building stable, non-volatile.
4. Keep the temperature of the building elements stable thus long time life.
5. Reduce energy bills.
6. Reduce the burning of fuel in power plants.
7. Reduce the emission of greenhouse gases.

2.3 Classification of Thermal Insulators

A- According to the structure

1. Organic materials, such as cotton, wool, cork, rubber and cellulose.
2. Inorganic materials: such as glass, asbestos, rockwool, perlite, vermiculite and calcium silicate.
3. Metallics: such as aluminum foils and tin reflectors.

B- According to the Shape

- Rolls: vary in the degree of flexibility and the ability to bend or pressure. They could be fastened by nails like glass wool, rock wool, polyethylene and foil-ceramic rolls.
- Sheets: There are specific dimensions and thicknesses such as polyethylene layers, polystyrene, cork and cellulose.
- Liquid or gaseous fluids: poured or sprayed on to form the desired dielectric layer, such as polyurethane foam and epoxy.
- Grains: a powder or granules are usually placed in the spaces between the walls and it can also be mixed with some other materials. Examples of such materials granulated cork and polymers.

2.4 Commercial Insulators

The thermal insulation refers to all isolators systems and processes that reduce the heat exchange between inside and outside. Thermal insulation in buildings in hot climates is designed to prevent the entry of heat to the building. Thus, the using of thermal insulation materials reduces the heat transfer. The most important thermal insulators are glass wool, cork, polyurethane and other polymeric materials as well as evacuated panels. It should refer here that air is one of the best thermal insulators due to its low coefficient of thermal conductivity (0.025 W/m.K) and availability everywhere.

The most common insulators:

1. Cellulose: which is made from wood or recycled paper and is characterized by its susceptibility to water and dust absorption.

2. Cork: This is taken from cork tree. It could be made industrial from petroleum product which is called the Expanded Polystyrene (EPS). It is found in the form of panels and used as thermal and acoustic insulators.

3. Glass wool: are widely used to insulate buildings, as well as boilers and reservoirs.

4. Rock wool: This material is used to isolate the buildings and storages.

5. Polyurethane: usually uses as insulated panel or foam to fill the cracks.

6. Polystyrene cork: both types, EPS and XPS

7. Astrofoil (XPE) layers: consist of two aluminum foils and including air bubbles which are made of polyethylene materials. The aluminum layers reflect the solar radiations in the summer while the air bubbles reduce the heat transfer through the walls because of high air isolation. This material is a good insulator against the water and air leaks.

8. Polycarbonate panels: These sheets are lightweight panels, and are composed of several layers to be able to withstand the shocks with the presence of air cavities for the purposes of thermal insulation.

9. Reflective materials: such as aluminum panels, alu-cobond and reflective paints. These materials are used to reflect solar radiation on the exterior walls.

10. Fire retardant sheets: are wooden panels characterized by their ability to delay the fire growth in addition to the thermal insulation ability.

2.5 Phase Change Materials (PCM)

Those materials that consequently oscillating between liquid and solid phases, hence absorb or release heat depending on the surrounding temperature. Many substances that can act as phase change materials such as paraffin and salt hydrates. These materials could be used in moderate warm climate where the ambient air is hot at the daytime and cool nightly. In the warm daytime, this material absorbs the heat from indoor air and turns to be in the liquid state. In the cold night, the material releases the heat and turns to be in the solid state again. By repeating this process, the indoor air temperature remains stable without electricity.

National Gypsum has produced a phase change drywall with the following specifications:

- The phase change material is Micronal Paraffin
- Tiny spheres of paraffin (5-10 micrometers in diameter) are encapsulated in acrylic shells, and these are mixed with the gypsum in drywall.
- Melting temperature is 24 $_{o}$C and could be operated till 32 $_{o}$C
- Heat capacity is 125 W/m$_{2}$.

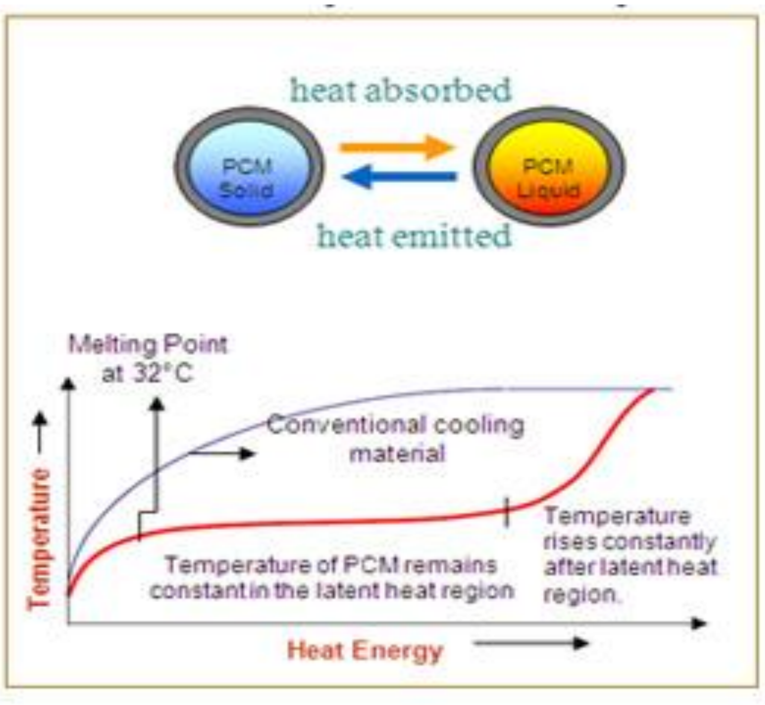


Fig. (2.2) PCM behavior

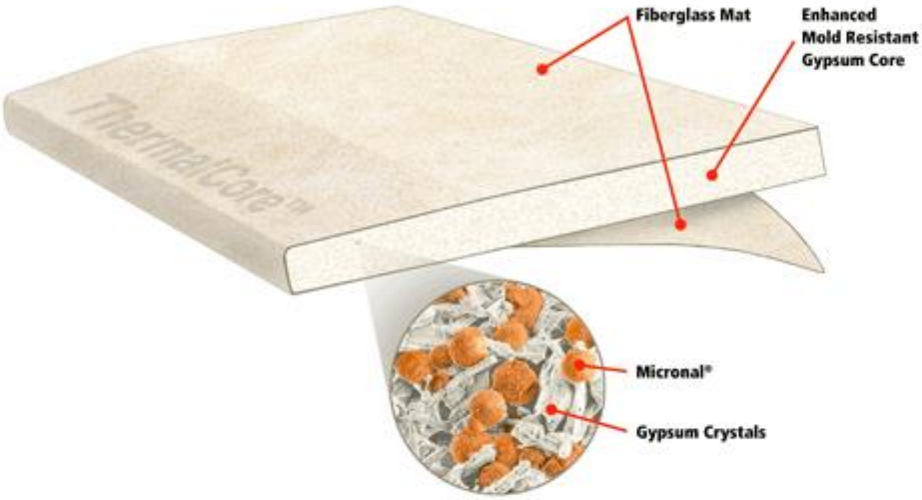


Fig. (2.3) Micronal paraffin

2.6 Thermal Properties of Insulator

Like the thermal conductivity coefficient, the less conductivity coefficient indicates the better resistance to heat transfer. The other thermal properties are:
reflectivity, absorptivity, heat capacity, density, coefficient of thermal expansion and the coefficient of thermal bridging.

Thermal conductivity: it is the property of a material to conduct heat. Heat transfer occurs at a higher rate across materials of high thermal conductivity than across materials of low thermal conductivity. Correspondingly, materials of high thermal conductivity are widely used in heat sink applications and materials of low thermal conductivity are used as thermal insulation. The thermal conductivity of a material varies with the temperature. The reciprocal of thermal conductivity called thermal resistivity. There are a number of ways to measure thermal conductivity of a material using the conductivity meter aperture. The unit of thermal conductivity is (W/m.K).

Table (2.1) Thermal conductivity for common insulators

Item	Material	Thermal Conductivity (W/m.K)
1	Astro-foil (XPE)	0.08
2	Asbestos	0.12
3	Asphalt	0.69
4	Alucobond	0.15
5	Acrylic	0.2
6	Aerogel	0.02
7	Bitumen	0.17
8	Calcium silicate	0.05
9	Cellulose	0.08
10	Coal	0.24
11	Cotton	0.04
12	Cork (EPS)	0.05
13	Ceramic fiber	0.08
14	Engine Oil	0.15
15	Epoxy	0.35
16	Glass Fiber	0.03
17	Glass Wool	0.04
18	PVC	0.2
19	Paraffin Wax	0.25
20	Plywood	0.13
21	Polycarbonate	0.19
22	Perlite	0.05
23	Polystyrene (XPS)	0.08
24	Polyurethane	0.02
25	Rubber	0.35
26	Vacuumed panel	0.007
27	Vermiculite	0.06
28	Wool	0.05

Table (2.2) Thermal conductivity for common construction materials

Item	Material	Thermal Conductivity (W/m.K)
1	Basalt	2.3
2	Block (Hollow) - 20 cm	0.5
3	Block (Hollow) – 15 cm	0.6
4	Block (Hollow) – 10 cm	0.7
5	Block (Solid)	0.9
6	Brick (Cavity)	0.4
7	Brick (Solid)	0.5
8	Concrete (Reinforced)	2
9	Concrete (Not Reinforced)	0.8
10	Cement plaster	1
11	Clay	1.2
12	Dry Wall – 10 cm	0.3
13	Granite	3
14	Gypsum	0.8
15	GRC	0.9
16	Glass	1
17	Limestone	1.5
18	Mica	0.7
19	Marble	2.2
20	Porcelain	1.5
21	Sandstone	1.5
22	Sandwich Panel – 10 cm	0.04
23	Sandwich Panel – 5 cm	0.05
24	Thermostone – 20 cm	0.3
25	Thermostone – 10 cm	0.4
26	Wood	0.15

Table (2.3) Thermal conductivity for common metals

Item	Material	Thermal Conductivity (W/m.K)
1	Aluminum (AL)	200
2	Bronze	110
3	Copper (Cu)	400
4	Iron (Fe)	80
5	Lead (Pb)	35
6	Silver (Ag)	450

Table (2.4) Thermal conductivity for common gases

Item	Material	Thermal Conductivity (W/m.K)
1	Air	0.025
2	Argon	0.015
3	Bromine	0.04
4	Carbon dioxide (CO_2)	0.014
5	Helium	0.15
6	Methane	0.03

Reflectivity: it is the ratio of reflected radiation from a surface to the total incident radiation. The factors affecting the amount of reflectivity are the color and the level of fine-tuning the surface. The following table shows values of reflectivity for some materials.

Table (2.5) Reflectivity for common materials

Material	Reflectivity (%)
Aluminum	80
Gypsum	70
Cork	45
Concrete	35
Plastic	20
Wood	17
Glass	10
Asphalt	3

Absorptivity: it is the ratio of absorbed radiation by the surface. The color of the surface affects the amount of absorption. The following table shows absorptivity values for some materials.

Table (2.6) Absorptivity for common colors

Color	Solar Absorptance
Green	0.47
Ochre	0.6
Dark Beige	0.7
Blue	0.7
Red	0.75
Brown	0.75
Dark Brown	0.83
Dark Colors	0.9
Black	0.95

Heat capacity: it is the ability of material to store the heat. The material with high heat capacity is called **thermal mass**

Density: it is the mass of matter in a certain volume. The unit is (kg/m3).

Thermal expansion coefficient: is the amount of change in the volume of material as a result of temperature change.

Coefficient of thermal bridge: which describes the amount of heat transfer in certain areas called thermal bridges. Thermal bridge is an area in the building envelope in which the highest heat transfer compared with neighboring areas, this causing the failure of building materials, the spread of moisture and mold growth. Examples of these areas:
- The joints between the ceiling and walls
- Link areas between windows and walls
- Piles and foundations

Table (2.7) Thermal properties of some materials

Item	Material	Specific Heat (J/kg.K)	Density (kg/m3)
1	Brick	850	1900
2	Concrete	900	2500
3	Granite	900	2750
4	Thermostone	750	890
5	Aluminum	900	2700
6	Iron	450	8000
7	Wood	1700	750
8	Rubber	1600	950
9	Marble	850	2800
10	Glass	600	2500
11	Water	4200	1000
12	Gypsum	1000	1500
13	EPS	1500	24
14	XPS	1900	32
15	Glass wool	700	24
16	Cellulose	1750	1200
17	Polyurethane	500	12

2.7 Other Features of Thermal Insulators

Mechanical: Such as durability, compression, tensile and shear stresses. Some insulators are characterized by strength and endurance than others. That makes sense to be used for supporting of the building beside to the goal of thermal insulation.

Moisture absorption: The presence of water or humid air in the insulator reduces the thermal insulation value of the material and it may destruct the material rapidly. The moisture is measured by the effect of moisture absorption and permeability.

Acoustical: Some insulating materials may be used as acoustic insulators as well as thermal insulators.

Safety: Some insulating materials could get hurt to human during storage, installation and usage. These may cause deformities in the human body, poisoning, infections or allergies in the skin and eyes, which requires importance of knowing the chemical composition of the material and ability to interact with the environment and constitute a mold, germs and insects. There are some physical properties should be considered like the ability of combustion and sublimation.

2.8 Modes of Heat Transfer

1. **Conduction:** it is heat transfer through the wall thickness from the hot face to the cold one. The thermal conductivity varies from a substance to another. For example, concrete and steel have high conductivity compared to an insulating material such as cork. The amount of heat transfer by conduction depends on the temperature difference between the surfaces of the wall, wall thickness, area of surfaces exposed to heat and coefficient of thermal conductivity of the material, as well as the lag time (period of accumulated heat).

2. **Convection:** it is the transfer of heat due to the ambient air nearby the wall. where, the air molecules move from hot zone to cold zone carrying the thermal
energy away and replaced by air molecules have cold temperature and less density. This process is known as convection current. Air movement helps to increase the heat transfer rate.

3. **Radiation:** it is the transfer of radiant heat that does not require necessarily a medium, like the heat of the sun to the earth. The radiant heat is transferred

from the source to the colder places. The reflective surfaces such as metal foils reflect thermal radiation and reduce heat absorption by the walls.

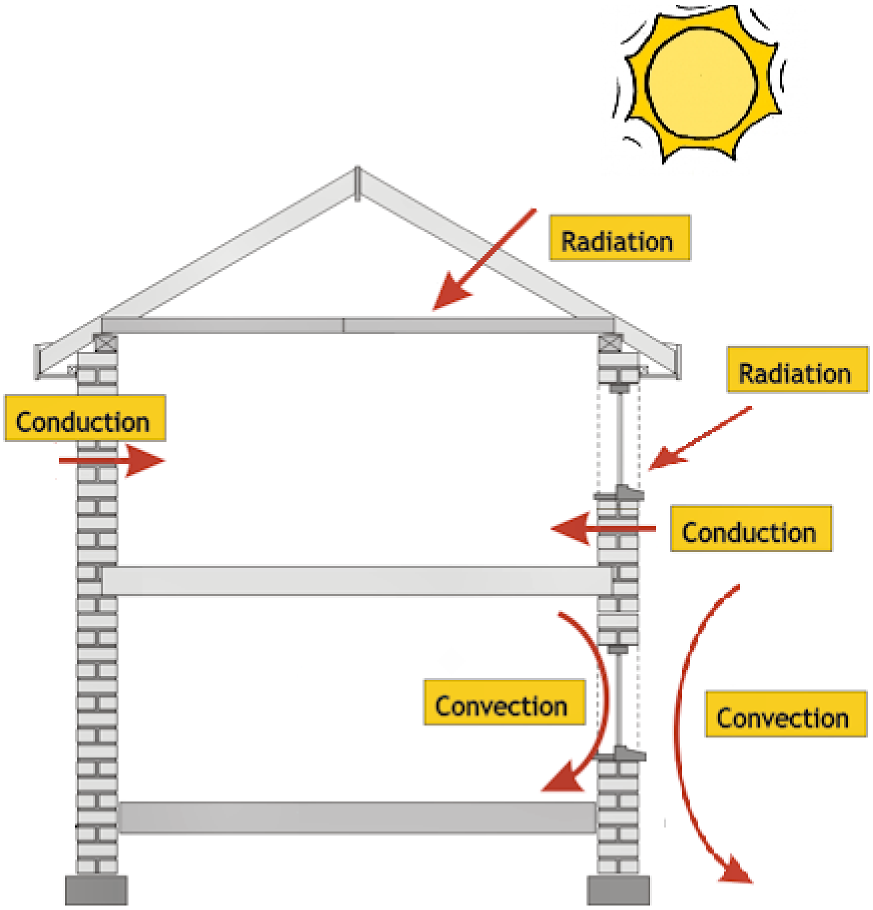


Fig. (2.4) Modes of heat transfer through the building

2.9 Thermal Insulation in Buildings

Buildings could be divided in terms of the acquisition method of heat into two types, which are buildings in hot climates and buildings in cold climates. In hot climates, most of the heat is gained from the outside through walls, ceilings and windows. The increase in thermal insulation in the outer shell of the building will lead necessarily to reduce the amount of heat gained and this consequently leads to reduce the energy needed for cooling. But in cold climates, heat is transferred from inside to out. Therefore, the insulating layers are placed inside.

It is found that the heat transfer through the house parts are as follows:

- About 60% of the heat is transmitted through the ceilings and walls of the building.
- About 15% of the heat is transmitted by the windows.
- About 25% of the heat is transferred through the vents and doors of the building.

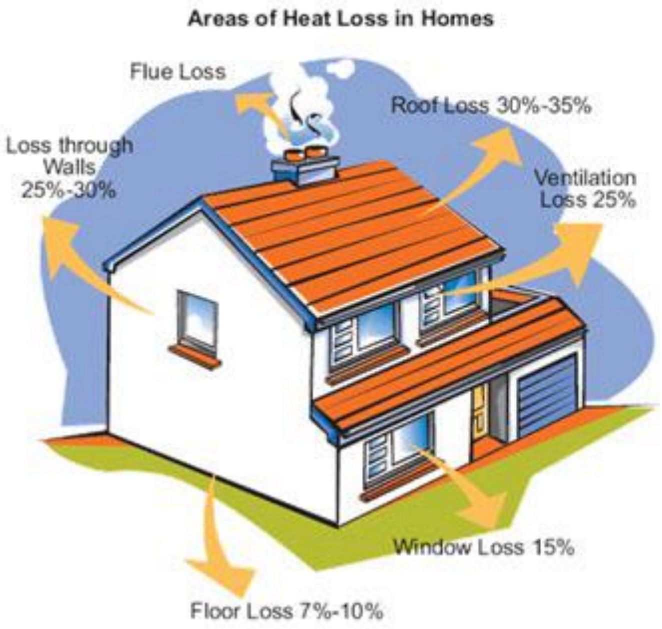


Fig. (2.5) Contribution of buildings elements in heat transfer

2.10 Thermal Insulation Expression

There are some concepts must be defined before entering to the design, such as:

Thermal resistance: it is the susceptibility of the material to resist the heat. Thermal resistance has inverse relation with the coefficient of thermal conductivity. To find out the total resistance of the wall or ceiling, the collection of resistors for all materials should be included as well as the convection resistance adjacent to the external and internal surfaces. Dealing with these resistors exactly like that used with electrical resistors, they are either parallel or series. Resistance also called R-Value. It is worth noting that the US R-Value is about six times the SI R-Value due to the different standards.

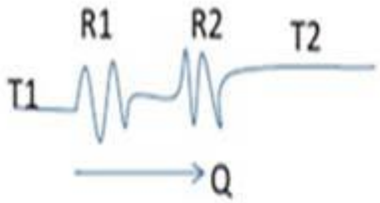
Using the resistance concept,

$$R_1 = \frac{x_1}{k_1}$$

$$R_2 = \frac{x_2}{k_2}$$

in case of convection resistance,

$$R_c = 1 / h$$



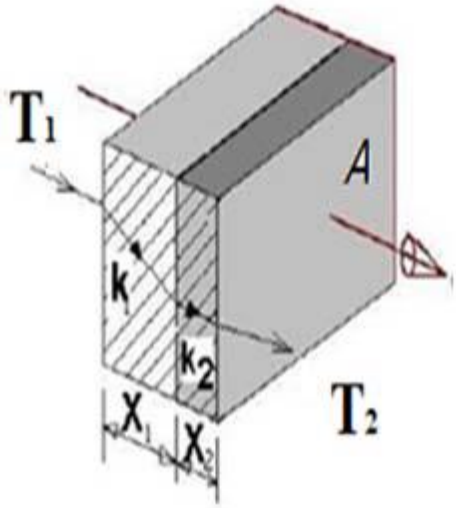


Fig. (2.6) Composite wall

Overall Heat Transfer Coefficient: it is a factor used to determine the optimum thickness of the insulation material in buildings. It is also called UValue. And it can be calculated from the following relationship:

$$U = \frac{1}{R_1 + R_2}$$

Then calculate the amount of heat transfer through the wall by the following relationship:

$$Q = U\ A\ (T_1 - T_2)$$

Where T is the temperature of the surface and A is the surface area
The unit of U-Value is ($W/m^2.K$). The U-Value of uninsulated wall is high up (1-5), while the U-Value of insulated wall is less than (1), while for super-insulation wall is less than (0.2). The world is moving to standardize the U-Value for residential buildings as minimum as possible toward satisfying the zero energy building.

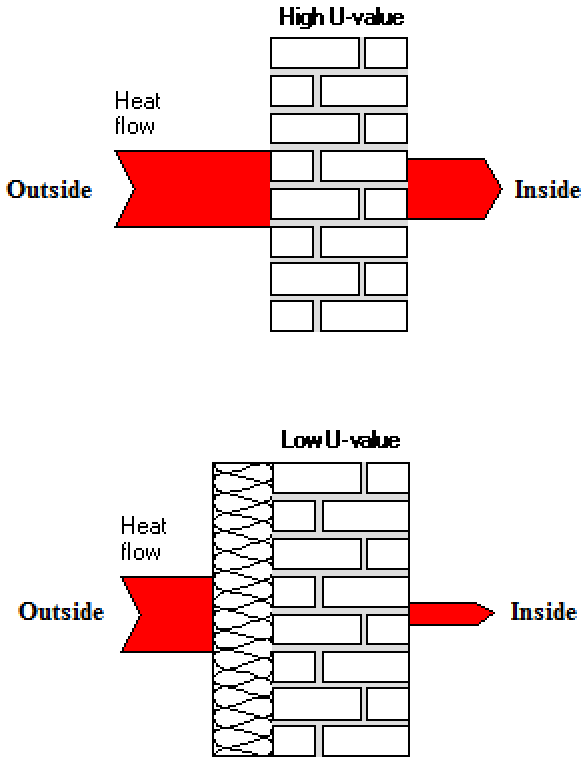


Fig (2.7) Effect of U-value in reducing the heat transfer

2.11 Engineering Calculations

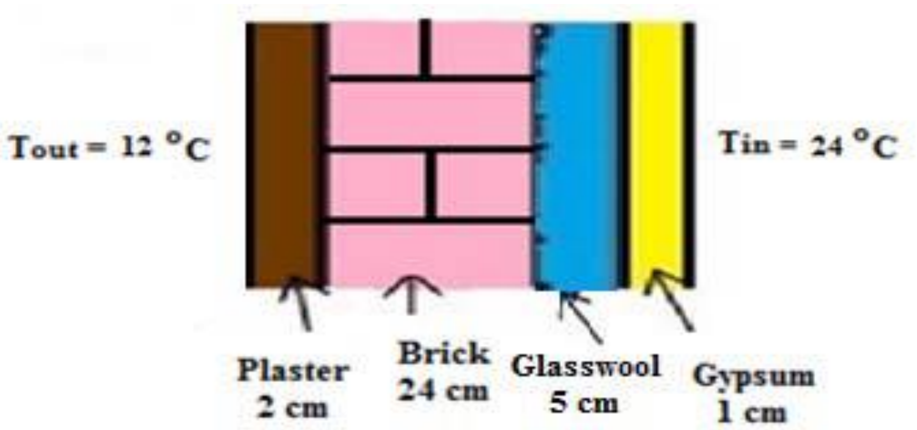
These are some examples to show the effect of thermal insulation in energy conservation.

Example (1): Heat losses through the wall in the winter

Calculate the reduction in the amount of heat transmitted through the wall shown in the figure due to the insulation. The area of the wall is 1 m^2 and the coefficients of convection heat transfer are:

- 10 $W/m^2.K$ for external surface
- 5 $W/m^2.K$ for internal surface

Note: Values of thermal conductivity of the materials are taken from the tables.



Solution:

- Before insulation

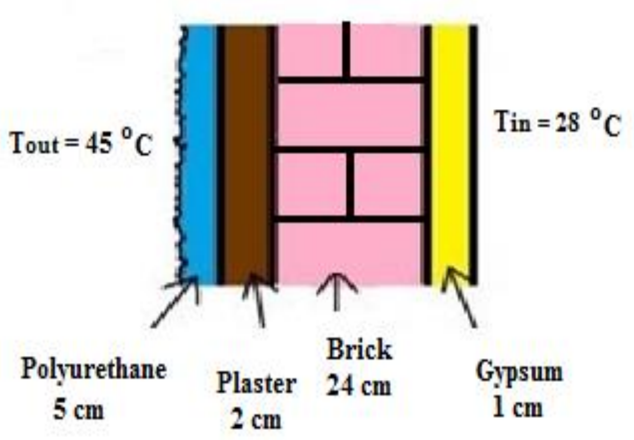
Plaster R1 = x1/k1 = 0.02/1 = 0.02
Brick R2 = x2/k2 = 0.24/0.5 = 0.48
Gypsum R3 = x3/k3 = 0.01/0.8 = 0.0125
External air Ro = 1/ho = 1/10 = 0.1
Internal air Ri = 1/hi = 1/5 = 0.2
Total resistance R = R1 + R2 + R3 + Ro + Ri = 0.8125
U = 1 / R = 1.23 $W/m^2.K$
Q = U A (Ti-To) = 1.23 * 1 * (24-12) = 14.8 W

- After insulation

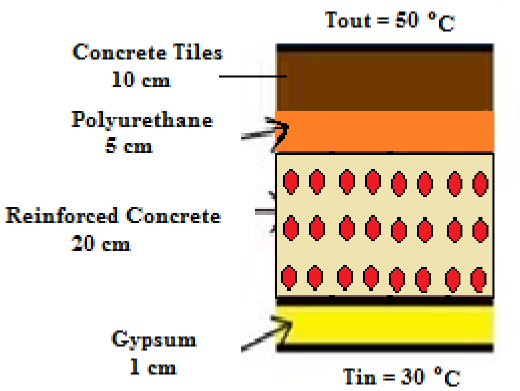
Glasswool Rg = xg/kg = 0.05/0.04 = 1.25
Total resistance R = R1 + R2 + R3 + Ro + Ri + Rg = 2.0625
U = 1 / R = 0.485 $W/m^2.K$
Q = U A (Ti-To) =0.485 * 1 * (24-12) = 5.8 W
So the reduction in the heat loss = (14.8 – 5.8)/14.8 = 0.608 = 61 %

Example (2): Calculation of the heat load in summer

Calculate the size of air-conditioning device (ton of refrigeration) required to cool a room of 6 m x 4m x 3m before and after the insulation. Note that the wall and the roof materials are shown in the figures below. Neglect the effect of radiation and convection heat transfer. Add 3000 W to the total load due to the heat gained through windows, ventilation, occupants and equipment.



Wall section



Roof section

$K_{plaster}=1$, $K_{brick}=0.5$, $K_{gypsum}=0.8$, $K_{polyurethane}=0.02$, $K_{RC}=2$, $K_{concrete\ tiles}=0.8$

Solution:

- **Before insulation**

- Walls

Plaster R1 = x1/k1 = 0.02/1 = 0.02

Brick R2 = x2/k2 = 0.24/0.5 = 0.48

Gypsum R3 = x3/k3 = 0.01/0.8 = 0.0125
Total resistance R = R1 + R2 + R3 = 0.5125
U = 1 / R = 1.95 W/m2.K
A = (6*3*2) + (4*3*2) = 60 m2
Q = U A (Ti-To) = 1.95 * 60 * (45-28) = 1990 W

- Roof

Concrete tiles R1 = x1/k1 = 0.1/0.8 = 0.125
Reinforced con. R2 = x2/k2 = 0.2/2 = 0.1
Gypsum R3 = x3/k3 = 0.01/0.8 = 0.0125
Total resistance R = R1 + R2 + R3 = 0.2375
U = 1 / R = 4.21 W/m2.K
A = 6*4 = 24 m2
Q = U A (Ti-To) = 4.21 * 24 * (50-30) = 2021 W
$Q_{total} = Q_{walls} + Q_{roof} + Q_{others}$ = 1990 + 2021 + 3000 = 7011 W
Load = Q_{total} / 3500 = 7011/ 3500 = 2 TR

▪ After insulation

- Walls

Polyurethane Rp = xp/kp = 0.05/0.02 = 2.5
Total resistance R = 0.5125 + 2.5 = 3.0125
U = 1 / R = 0.332 W/m2.K
Q = U A (Ti-To) = 0.332 * 60 * (45-28) = 338 W

- Roof

Polyurethane Rp = xp/kp = 0.05/0.02 = 2.5
Total resistance R = 0.2375 + 2.5 = 2.7375
U = 1 / R = 0.365 W/m2.K
Q = U A (Ti-To) = 0.365 * 24 * (50-30) = 175 W
$Q_{total} = Q_{walls} + Q_{roof} + Q_{others}$ = 338 + 175 + 3000 = 3513 W
Load = Q_{total} / 3500 = 3513/ 3500 = 1 TR

2.12 Electricity Demand Reduction

The use of insulation keeps the indoor temperature stable as well as reduces the thermal loads and thus the amount of electricity demand. It is usually account the electricity consumption in (kWh). In order to calculate the Annual Energy Demand (AED) use the following equation:

AED = Q_{total} * N / 100

Where N is the number of days under use
The amount of the annual consumption of electric power determines the building performance. The building performance factor could be calculated from the following relationship depending on the floor area:

BPF = AED / Floor Area

The building performance factor (BPF) is used to determine the type of building in terms of energy consumption, where high-energy building consumes more than (250 kWh/m2) per year while medium-energy building consumes an average between (100-200 kWh/m2) per year and low-energy building consumes less than (50 kWh/m2) per year.

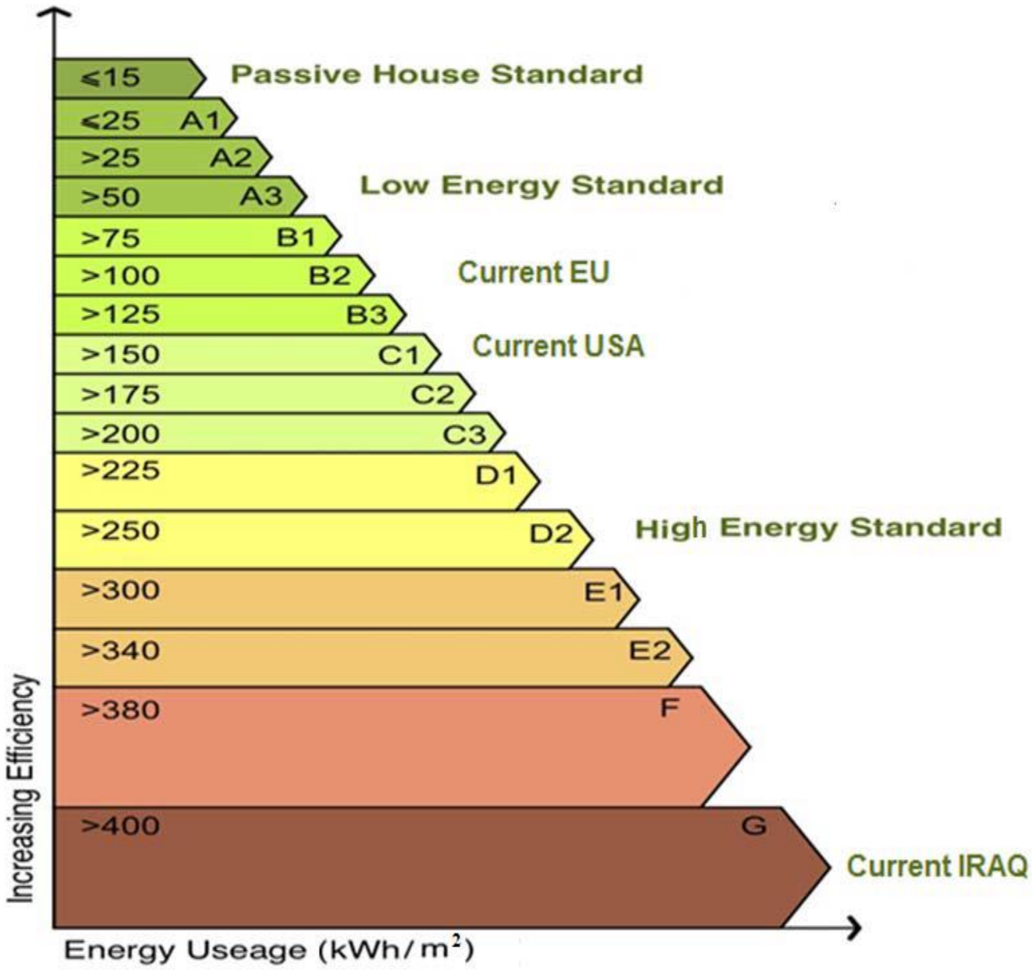


Fig (2.8) Energy classification standards

2.13 Reduce Oil Consumption

It is found that roughly about 3,000 liters of oil equivalent each year are burned to produce electricity for heating or cooling un insulated house. This could be saved up to 60% through the using of thermal insulation techniques. The approximate equation to determinate the relationship between energy demand and the annual oil consumption
In (liters / m2) of floor area is :

Oil Consumption = 1.5 * Exp (BPF /120)

2.14 Greenhouse Effect

Greenhouse gas is any compound gas in the atmosphere that is capable to absorb infrared and keeping the heat from escaping out of the atmosphere. Greenhouse gases are responsible of the phenomenon of global warming.

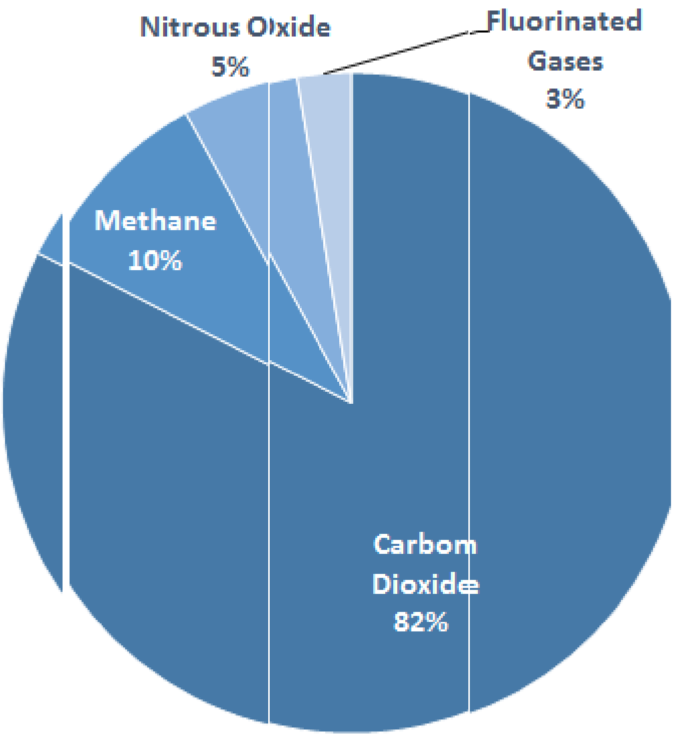


Fig (2.9) Greenhouse gases

The sector of residential building has the major impact on the increase of greenhouse gases and it is considered as the most damage to the climate. The traditional hose (non-insulated) causes the emission of more than 7,000 kilograms of carbon dioxide CO_2 in to the atmosphere each year. The approximate equation to determine the relationship between energy demand and the annual CO_2 emission in (kg /m2) of floor area is :

$$CO_2\ Emission = 3.5 * Exp\ (BPF /120)$$

Example (3): Extra calculations for oil consumption and CO_2 emission

A house of 10 m x 5 m x 3 m dimensions has insulated walls and ceiling, as shown in the figure. Neglect the effect of radiation and convection heat transfer. Add 4000 W due to the heat gained through other sources. Calculate:

1. Total heat transmitted through the building.
2. Annual electricity consumption in the building as a result of cooling (Suppose the use of air-conditioning for 120 days).
3. Efficiency of the building.
4. Oil consumption in power plant as a result of the annual consumption.
5. CO_2 emissions in power plant.

$K_{plaster}$=1, K_{EPS}=0.05, $K_{thermostone}$=0.3, K_{gypsum}=0.8

Solution:

1) Heat transfer

Plaster R1 = x1/k1 = 0.02/1 = 0.02
EPS R2 = x2/k2 = 0.04/0.05 = 0.8
Thermostone R3 = x3/k3 = 0.24/0.3 = 0.8
Gypsum R4 = x4/k4 = 0.02/0.8 = 0.025
Total resistance R = R1 + R2 + R3 + R4 = 1.645
U = 1 / R = 0.608 W/m^2.K
A = (10*3*2) + (5*3*2) + (10*5) = 140 m^2 total area of walls and roof
Q = U A (Ti-To) = 0.608 * 140 * (48-25) = 1957 W

2) Annual Electricity Demand

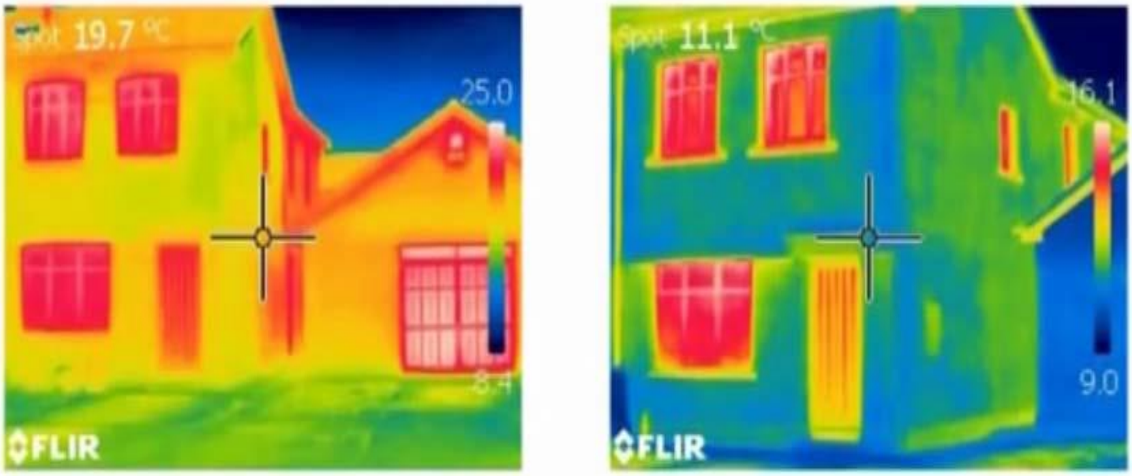
Q_{total} = 1957 + 4000 = 5957 W
AED = Q_{total} * N / 100 = 5957 * 120 / 100 = 7148 kWh
3) BPF = AED / Floor Area = 7148 / 50 = 143 kWh/m^2 medium energy house
4) Oil Consumption = 1.5 * Exp (BPF/120) = 1.5 * Exp (143/120) = 5 liters/m^2
5) CO_2 Emission = 3.5 * Exp (BPF/120) = 12 kg/m^2

2.15 Thermal Images

Thermal images could be captured using thermal cameras like: FLIR, FLUKE and MSA. A thermographic image is used to illustrate the difference between the well and poorly insulation levels. Heat loss through the wall is highlighted by several colors. The amount of radiation emitted increases with temperature, therefore warm objects appears in red color against blue colors for cool objects.

Example:

Thermal images of a building have been captured in the winter, as shown in the figure below. Explain your understanding



a. Before insulation **b. After insulation**

Answer: In image (a), where there is no insulation, heat is transferred easily through the walls and other building elements. Thus, the outer faces close to be red and yellow. On the other hand, in image (b) after insulation, heat is accumulated inside and the outer faces have the same ambient temperature, thus appeared in blue and green.

2.16 Economical Effect

The quality of the insulation materials are chosen to satisfy the requirements of good insulation and reduce energy consumption. To make the process more economical, thermal insulation of the building must be chosen carefully according to the following factors:

- The amount of insulation material and thickness.
- The cost of insulation material and labor costs, which will install it.
- The amount of energy that is saved to the building. Hence, the saved money.

The economical value of insulation equals to the cost of the insulators minus the cost of air-conditioning units that is saved for a certain period. It has found that super insulation of the building increases the cost of construction up to 20%, but this amount would be recovered as a result of lower electricity bills in a few years. Some countries encourage the low-energy homes by exempting the electricity bills. The costs of some insulators are shown in the table below.

Table (2.8) Average costs of some common insulators

Item	Insulation Material	Cost ($/m2) for each cm thickness
1	Alucobond	20
2	Asbestos	8
3	Asphalt	2
4	Cellulose	1.5
5	Cement	6
6	Clay	0.7
7	Coal	2
8	Cotton	3
9	Cork (EPS)	1.5
10	Glass Fiber	2.5
11	Glass Wool	2.5
12	Gypsum Plaster	3
13	Perlite	4
14	Polystyrene	3
15	Polyurethane	6
16	Rubber	2
17	Wood	15
18	Wool	8
19	Granite	18
20	GRC	10
21	Limestone	12
22	Sandstone	12
23	Marble	18
24	Basalt	12

2.17 Useful Applications

There are some tools used to obtain the contribution of thermal insulation to energy saving, fuel consumption and CO_2 emissions. The course included 2 computer-lab hours for the certain applications:

- **Iraqi Passive House Planning Package (IPPP):** It is a visual basic based design tool that is used to find complete energy balance of passive or active buildings in Iraq. The application is very responsible for the hot climate zone of Iraq. It includes the following features:

- Meteorological data (18 cities in Iraq)
- Properties library for different construction materials and insulations
- Cooling and heating load calculation for residential building
- Electricity power consumption
- Contribution of renewable energy

- Indoor air quality and ventilation system
- Passive house standards verification
- Oil consumption
- CO_2 emission
- Cost analysis

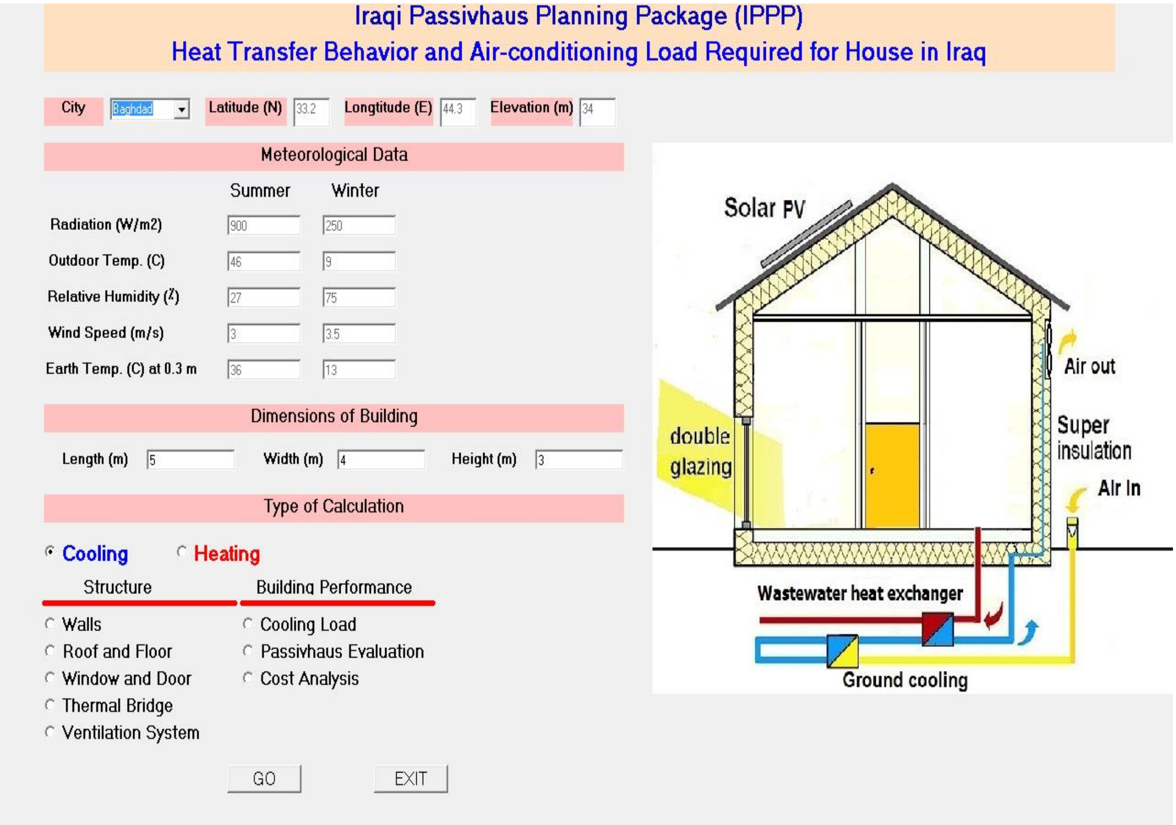


Fig. (2.10) Main form of Iraqi Passive House Planning Package

▪ **RETScreen:** is a clean energy management software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis. RETScreen 4 is an Excel-based clean energy project analysis software tool that helps to determine the technical and financial viability of potential clean energy projects. The application includes the following features:

- **Energy efficiency (EE)** models for residential, commercial & institutional buildings, & for industrial facilities & processes

- **Climate database** expanded to **4,700 ground-stations** & **NASA Satellite Dataset Integrated** within the software to cover populated areas across the entire surface of planet

- Renewable energy, cogeneration & EE models integrated into **one software file** & emerging technologies, such as wave & ocean current power added

- **Project database** providing users instant access to key data and information for hundreds of case studies & project templates

- **RETScreen file format (*.ret)** - a dramatically smaller file size (<25 KB instead of 10 MB) that is easily shared over the Internet & which allows the user to create custom databases for RETScreen

- Software & databases translated into **35 languages** that cover 2/3 of the world's population, and available at the click of the mouse

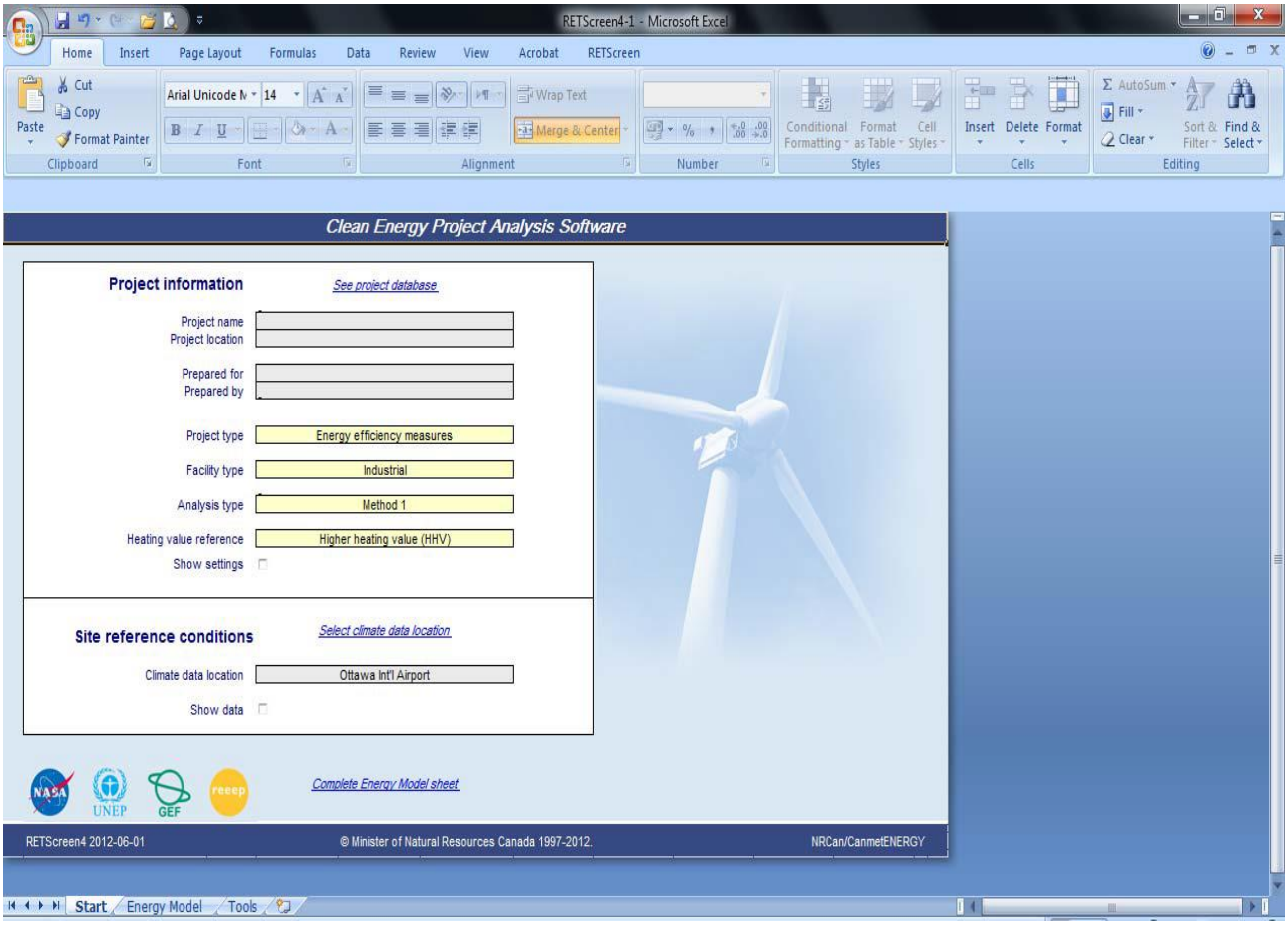


Fig. (2.11) Main form of RETScreen

- More information are available on the site: http://www.retscreen.net/

Contents :

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