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Building Energy Performance
By eQUEST

Διπλωματική Εργασία

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Abstract

Building thermal and energy performance has been a big issue in our day and age. Many attempts to face this subject have been met with varying levels of success. A big part of this success is thanks to softwares specifically built to help us study the thermal performance of buildings, one of these softwares is eQuest.

We first started by studying the thermal and energy performance of houses in detail, then we learned and researched the types and thickness of materials used in the construction process.

We learned in great detail about eQuest and how it works, we then used it for our studies and research.

We simulated 2 scenarios on two different homes. One in Calgary, Canada and the other in Abu Dhabi. This helped us compare the thermal and energy performance of each house based on location and type of climate. This lead us to achieve our thesis goal, which is to compare the performance of a house located in cold climate and another in hot climate so we can use proper heating and cooling systems respectively.

We also researched the electricity cost of natural gas in each country, so we can compare the expenses of cooling and heating systems for each house, and by that we compared two houses in different weather and different countries using eQuest.

Contents

1. INTRODUCTION:

The thermal performance of a building refers to the process of modeling the energy transfer between a building and its surroundings. For a conditioned building, it estimates the heating and cooling load and hence, the sizing and selection of HVAC equipment can be correctly made. For a non-conditioned building, it calculates temperature variation inside the building over a specified time and helps one to estimate the duration of uncomfortable periods. These quantifications enable one to determine the effectiveness of the design of a building and help in evolving improved designs for realizing energy efficient buildings with comfortable indoor conditions. The lack of proper quantification is one of the reasons why passive solar architecture is not popular among architects. Clients would like to know how much energy might be saved, or the temperature reduced to justify any additional expense or design change. Architects too need to know the relative performance of buildings to choose a suitable alternative. Thus, knowledge of the methods of estimating the performance of buildings is essential to the design of passive solar buildings.

In this chapter, we will discuss a simple method for estimating the thermal performance of a building and introduce a few simulation tools used for more accurate calculations.

Various heat exchange processes are possible between a building and the external environment. These are shown in Fig. 1.1. Heat flows by conduction through various building elements such as walls, roof, ceiling, floor, etc. Heat transfer also takes place from different surfaces by convection and radiation. Besides, solar radiation is transmitted through transparent windows and is absorbed by the internal surfaces of the building. There may be evaporation of water resulting in a cooling effect. Heat is also added to the space due to the presence of human occupants and the use of lights and equipment. The interaction between a human body and the indoor environment is shown in *Fig. 1.2.* Due to metabolic activities, the body continuously produces heat, part of which is used as work, while the rest is dissipated into the environment for maintaining body temperature. The body exchanges heat with its surroundings by convection, radiation, evaporation and conduction. If heat is lost, one feels cool. In case of heat gain from surroundings, one feels hot and begins to perspire. Movement of air affects the rate of perspiration, which in turn affects body comfort.

The thermal performance of a building depends on a large number of factors. They can be summarized as (1) design variables (geometrical dimensions of building elements such as walls, roof and windows, orientation, shading devices, etc.); (2) material properties (density, specific heat, thermal conductivity, transmissivity, etc.); (3) weather data (solar radiation, ambient temperature, wind speed, humidity, etc.); and (4) a building's usage data (internal gains due to occupants, lighting and equipment, air exchanges, etc.). A block diagram showing various factors affecting the heat balance of a building is presented in *Fig. 1.3.* The influence of these factors on the performance of a building can be studied using appropriate analytical tools. Several techniques are available for estimating the performance of buildings. They can be classified under Steady State methods, Dynamic methods and Correlation methods. Some of the techniques are simple and provide information on the average load or temperature, on a monthly or annual basis. Others are complex and require more detailed input information. However, the latter perform a more accurate analysis and provide results on an hourly or daily basis. In this chapter, we discuss a simple method that is easy to understand and amenable to hand calculations.

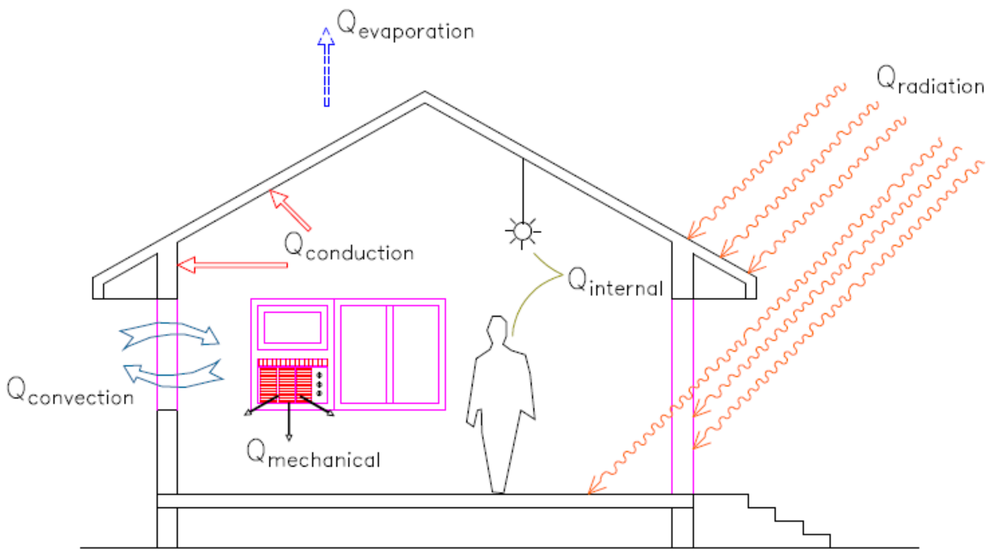


Fig. 1.1 Heat exchange processes between a building and the external environment

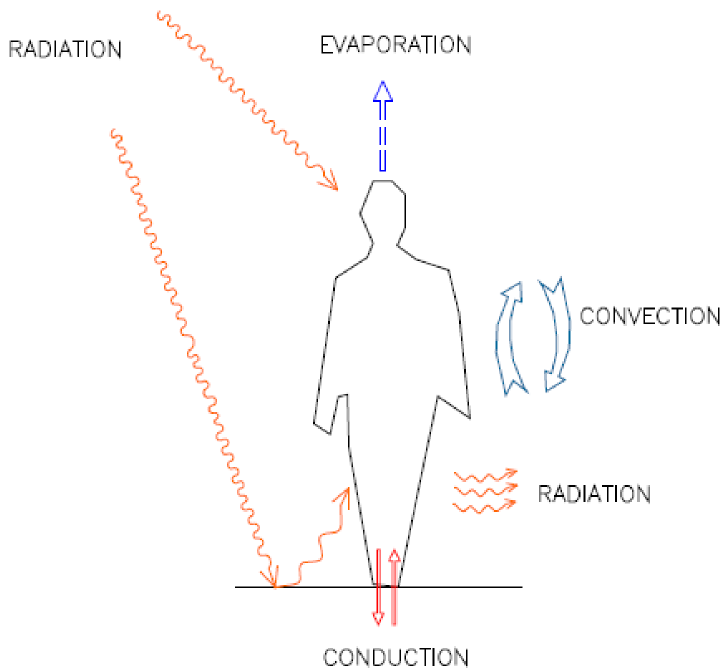


Fig. 1.2 Heat exchange processes between a human body and the indoor environment

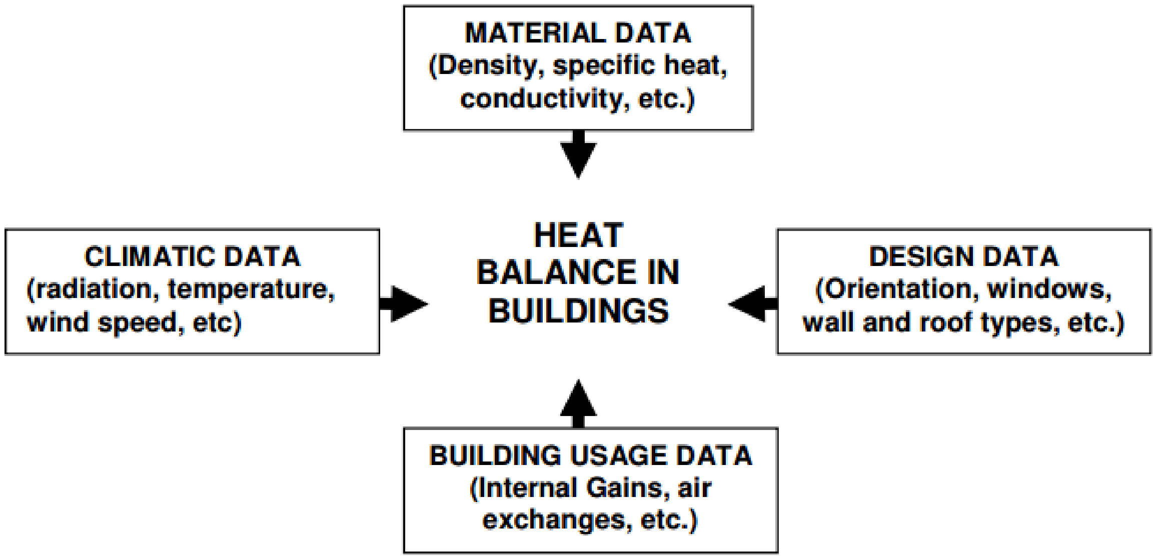


Fig. 1.3 Thermal simulation flow paths of a building

To understand the process of heat conduction, convection and radiation occurring in a building, consider a wall having one surface exposed to solar radiation and the other surface facing a room *(Fig. 1.4).* Of the total solar radiation incident on the outer surface of the wall, a part of it is reflected to the environment. The remaining part is absorbed by the wall and converted into heat energy. A part of the heat is again lost to the environment through convection and radiation from the wall's outer surface. The remaining part is conducted into the wall; where it is partly stored − thereby raising the wall temperature − while the rest reaches the room's interior surface. The inner surface transfers heat by convection and radiation to the room air, raising its temperature. Heat exchanges like these take place through opaque building elements such as walls and roofs. Additionally, mutual radiation exchanges between the inner surfaces of the building also occur (for example, between walls, or between a wall and roof). Such heat transfer processes affect the indoor temperature of a room and consequently, the thermal comfort experienced by its occupants.

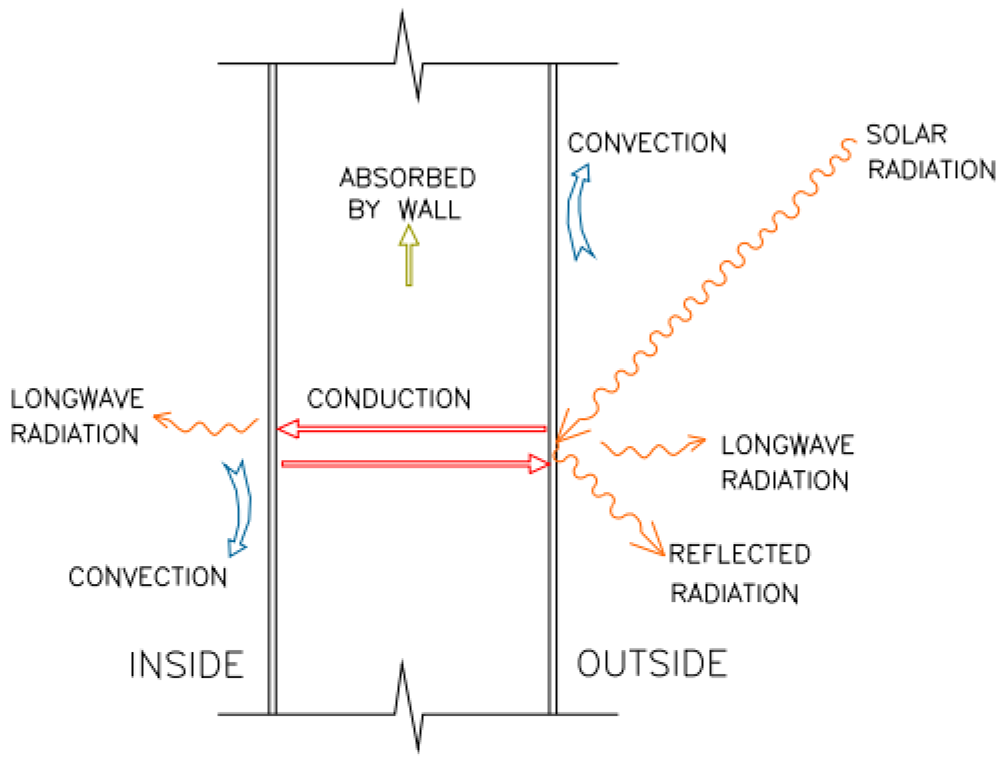


Fig. 1.4 Heat transfer processes occurring in a wall

1.1 HEAT TRANSFER:

1.1.1 Conduction:

Thermal conduction is the process of heat transfer from one part of a body at a higher temperature to another (or between bodies in direct contact) at a lower temperature. This happens with negligible movement of the molecules in the body, because the heat is transferred from one molecule to another in contact with it. Heat can be conducted through solids, liquids and gases. Some materials conduct more rapidly than others. The basic equation of heat conduction is

$$Q_{conduction} = \frac{K \cdot A \cdot (T_h - T_c)}{L} \qquad (1.1)$$

Where $Q_{conduction}$ = quantity of heat flow (W)

k = thermal conductivity of the material (W/m-K)

A = area (m2)

L = thickness (m)

T_h = temperature of the hot surface (K)
T_c = temperature of the cold surface (K)

For a given temperature difference, the higher the thermal conductivity of a material of fixed thickness and cross-sectional area, the greater is the quantity of heat transferred.

1.1.2 Convection:

The convection is the transfer of heat from one part of a fluid (gas or liquid) to another part at a lower temperature by mixing of fluid particles. Heat transfer by convection takes place at the surfaces of walls, floors and roofs. Because of the temperature difference between the fluid and the contact surface, there is a density variation in the fluid, resulting in buoyancy. These results in heat exchange between the fluid and the surface and is known as free convection. However, if the motion of the fluid is due to external forces (such as wind), it is known as forced convection. These two processes could occur simultaneously. The rate of heat transfer (Q convection) by convection from a surface of area A, can be written as

$$Q_{Convection} = h \cdot A \cdot (T_s - T_f) \qquad (1.2)$$

Where, h = heat transfer coefficient (W/m2-K)
T_s = temperature of the surface (K)
T_f = temperature of the fluid (K)

The numerical value of the heat transfer coefficient depends on the nature of heat flow, velocity of the fluid, physical properties of the fluid, and the surface orientation.

1.1.3 Radiation:

Radiation is the heat transfer from a body by virtue of its temperature; it increases as temperature of the body increases. It does not require any material medium for propagation. When two or more bodies at different temperatures exchange heat by radiation, heat will be emitted, absorbed and reflected by each body. The radiation exchange between two large parallel plane surfaces (of equal area A) at uniform temperatures T_1 and T_2 respectively, can be written as

$$Q = \varepsilon_{eff} \cdot A \cdot \sigma \cdot (T_1^4 - T_2^4) \tag{1.3}$$

$$\varepsilon_{eff} = [{}^{1}/_{\varepsilon_1} + {}^{1}/_{\varepsilon_2} - 1]^{-1}$$

Where Q12 = net radiated exchange between surfaces (W)
σ= Stefan-Boltzmann constant (5.67x10-8 W/m2-K4)
A = area of surface (m2)
T1 = temperature of surface 1 (K)
T2 = temperature of surface 2 (K)
ε_1 and ε_2 = emissivity of surfaces 1 and 2 respectively

In case of buildings, external surfaces such as walls and roofs are always exposed to the atmosphere. So the radiation exchange (Q radiation) between the exposed parts of the building and the atmosphere is an important factor and is given by

$$Q_{radiation} = A \cdot \varepsilon \cdot \sigma \cdot (T_s^4 - T_{sky}^4) \tag{1.4}$$

Where A = area of the building exposed surface (m2)
ε = emissivity of the building exposed surface
T_s = temperature of the building exposed surface (K)
T_{sky} = sky temperature (K)

T_{sky} represents the temperature of an equivalent atmosphere. It considers the fact that the Atmosphere is not at a uniform temperature, and that the atmosphere radiates only in certain wavelengths. There are many correlations suggested for expressing sky temperature in terms of ambient air temperature.

Equation (1.4) can be written as:

$$\frac{Q_{radiation}}{A} = h_r(T_s - T_a) + \varepsilon\Delta R \tag{1.5}$$

Where Ta = ambient temperature (K)

$$h_r = \varepsilon \cdot \sigma \cdot (T_s^4 - T_a^4)/(T_s - T_a)$$

h is the radiated heat transfer coefficient, and DR is the difference between the long wavelengths Radiation incident on the surface from the sky and the surroundings, and the radiation emitted by a black body at ambient temperature. For horizontal surface, DR can be taken as 63 W/m^2 and for a vertical surface, it is zero.

For building applications, usually convective and radiated heat transfer coefficients are combined to define surface heat transfer coefficient. This Table presents values of the surface heat transfer coefficient for a few cases

Table 1.1 Values of surface heat transfer coefficient

Serial No.	Wind Speed	Position of Surface	Direction of Heat Flow	Surface Heat Transfer Coefficient (W/m^2-K)
1.	Still air	Horizontal	Up	9.3
		Sloping 45°	Up	9.1
		Vertical	Horizontal	8.3
		Sloping 45°	Down	7.5
		Horizontal	Down	6.1
2.	Moving air 12 (km/h)	Any position	Any direction	22.7
	Moving air 24 (km/h)	Any position	Any direction	34.1

1.1.4 Evaporation:

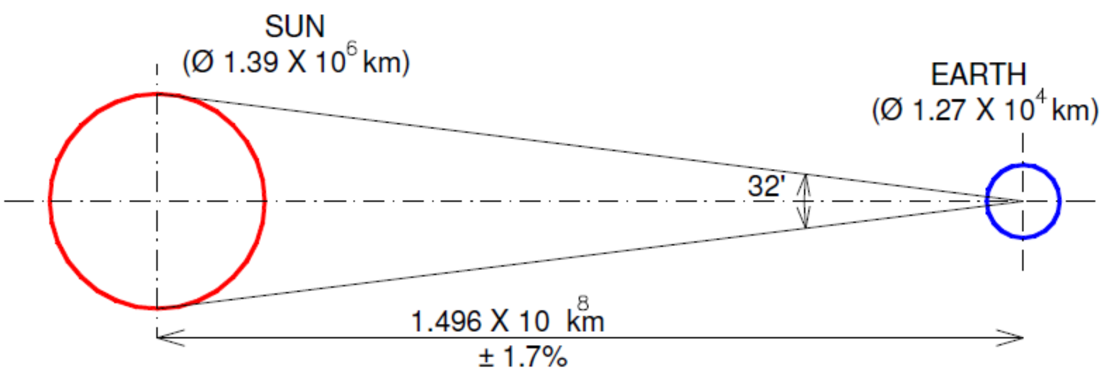
Evaporation generally refers to the removal of water by vaporization from aqueous solutions of non-volatile substances. It takes place continuously at all temperatures and increases as the temperature is raised. Increase in the wind speed also causes increased rates of evaporation. The latent heat required for vaporization is taken up partly from the surroundings and partly from the liquid itself. Evaporation thus causes cooling.

The rate of evaporation depends on:

- The temperature (rate of evaporation increases with increase in temperature)
- The area of the free surface of water (larger the surface exposed, greater is this rate)
- The wind (rate is faster when wind blows than when the air is still)
- The pressure (lower the external pressure, more rapid is the evaporation)

1.2 SOLAR RADIATION:

The sun is the only source of heat and light for the entire solar system. It is made up of extremely hot gaseous matter, and gets progressively hotter towards its center. The heat is generated by various kinds of fusion reactions. The sun is approximately spherical in shape; about 1.39x106 km in diameter and its average distance from the earth is 1.496x108 km *(Fig. 1.5)*. The solar disc subtends a very small angle of 32' at any point on the earth's surface and hence, the radiation received from the sun directly on the earth's surface can be considered parallel for all practical purposes.



1.5. Sun-Earth geometric relationship

The earth is approximately spherical in shape, about 1.27x104 km in diameter. It revolves around the sun in an elliptical orbit taking a year to complete one revolution. At the same time, it also rotates about its own axis once every 24 hours. The energy flux received from the sun outside the earth's atmosphere is of nearly constant value and is termed as the Solar Constant (Isc). It is defined as the energy received outside the atmosphere, per second, by a unit surface area normal to the direction of sun's rays at the mean sun-earth distance; its value is accepted as 1367 W/m2. However, because the earth revolves round the sun in an elliptical orbit with the sun as one of the foci, there is a variation in the extraterrestrial radiation. Hence, the intensity of extraterrestrial radiation on a plane normal to sun's rays on any day is given by:

$$I_{ext} = I_{sc} \cdot [1.0 + 0.033\cos(\frac{360n}{365})] \quad (1.7)$$

where n is the day of the year and is

$$1 \leq n \leq 365 \quad (1.8)$$

Solar radiation is received on the earth's surface after undergoing various mechanisms of attenuation, reflection and scattering in the earth's atmosphere. Consequently, two types of radiation are received at the earth's surface: one that is received from the sun without change of direction, called beam radiation, and the other whose direction has been changed by scattering and reflection, called diffuse radiation. The sum of these two types is known as total or global radiation.

1.2.1 Radiation on Tilted Surfaces:

External surfaces of buildings receiving solar radiation are generally tilted, except for the flat roof, which is a horizontal surface. Consequently, it is required to estimate radiation on such surfaces from the data measured on a horizontal surface. A tilted surface receives three types of solar radiation, namely beams radiation directly from the sun, diffuse radiation coming from the sky dome, and reflected radiation due to neighboring buildings and objects. The estimation of the last component is very complicated. However, its contribution is much less compared to the first two sources. Therefore, the reflected component from the surrounding ground surface is generally taken for simple calculations. However, simulation software like DOE2.1E performs a more detailed calculation for accounting the effects of neighboring buildings and trees.

1.2.1.1 Unshaded surface:

For a surface tilted at an angle b and with no shading, hourly incident solar radiation can be estimated as:

$$I_T = I_g \cdot r \qquad (1.9)$$

where **r** is the global radiation tilt factor and is given by

$$r = \left(1 - \frac{I_d}{I_g}\right) r_b + \left(\frac{1+\cos\beta}{2}\right)\frac{I_d}{I_g} + \rho\left(\frac{1-\cos\beta}{2}\right)$$

$$r_b = \frac{\cos\theta}{\cos\theta_z}$$

$$\cos\theta = sin\varphi(sin\delta\cdot cos\beta + cos\delta\cdot cos\gamma\cdot cos\omega\cdot sin\beta) + cos\ \varphi(cos\delta\cdot cos\omega\cdot cos\beta - sin\delta\cdot cos\gamma\cdot sin\ \beta\ ) + cos\delta\cdot sin\gamma\cdot sin\omega\cdot sin\beta)$$

$$\cos\theta_z = sin\Phi\cdot sin\delta + cos\varphi\cdot cos\delta\cdot cos\omega \qquad (1.10)$$

I_g = mean hourly global solar radiation (W/m2)

I_d = mean hourly diffuse solar radiation (W/m2)

ρ = reflectivity of the ground surface

ϕ = latitude of a location (degree). By convention, the latitude is measured as positive for the northern hemisphere.

δ = declination angle (degree). It is defined as the angle made by the line joining the centres of the sun and the earth with its projection on the equatorial plane. It can be calculated from the following relation:

$$\delta(^{o}) = 23.45\ \sin[\frac{360}{365}(284 + n)] \qquad (1.11)$$

n = day of the year

γ = surface azimuth angle (degree). It is the angle made in the horizontal plane between the line due south, and the projection of the normal to the surface on the horizontal plane. By convention, the angle is taken to be positive if the normal is east of south and negative if west of south.

β = slope (degree). It is the angle made by the plane surface with the horizontal.

ω = hour angle (degree). It is the angular measure of time and is equivalent to 15º per hour. It is measured from noon based on local apparent time (LAT), being positive in the morning and negative in the afternoon.

The local apparent time (LAT) can be estimated from Indian Standard Time (IST) using the following equation:

LAT = IST – 4 (Reference longitude – Local longitude) + ET (1.12)

The second term in the equation becomes positive for any country in the western

Hemisphere. The reference longitude for India is 82.5 E. The Equation of Time (ET) correction is plotted in *Fig. 1.6* and it can also be calculated from:

$$ET = 229.2\,(0.000075 + 0.001868 \cos(B) - 0.032077 \sin(B) - 0.014615 \cos 2B - 0.04089 \sin 2B) \qquad (1.13)$$

Where B = (n - 1) 360/365 and n is the day of the year.

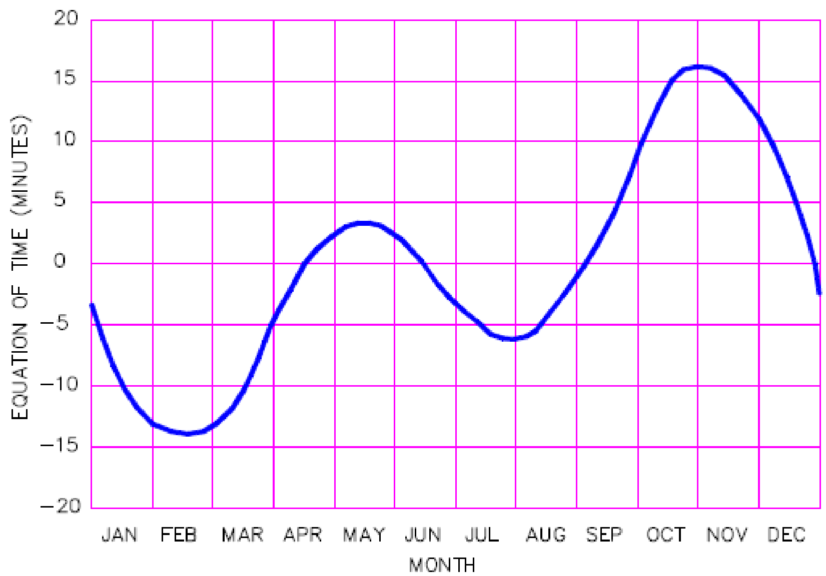


Fig.1.6 Equation of time correction

Equation *(1.9)* can be used to calculate hourly radiation on any tilted surface.

1.2.1.2 Shaded surface:

If a surface is shaded, the radiation incident on it gets modified, and depending on the type of shading, its estimation becomes complicated. To illustrate, let us consider the simple case of a horizontal rectangular overhang on a wall .The height and width of the wall are H and W respectively, the depth of the overhang is P.

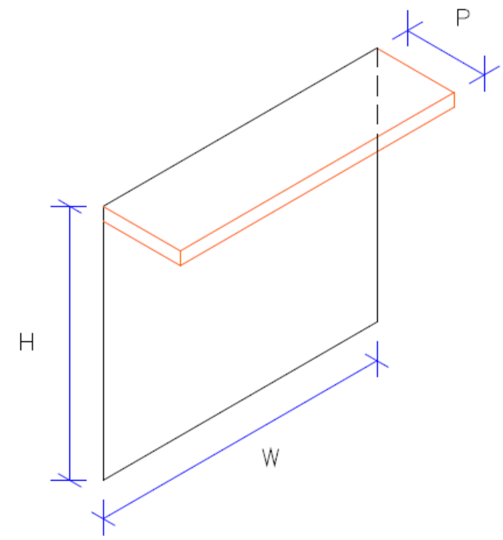


Fig.1.7. Horizontal rectangular overhang on a wall

Hourly solar radiation on the wall can be written as:

$$I_T = I_g \cdot r \tag{1.14}$$

Where $r = (1 - \frac{I_d}{I_g}) r_b f_i + \frac{I_d}{I_g} F_{r-s} + 0.5\rho$ (1.15)

f_i= fraction of unshaded area

And F_{r-s} = view factor of the wall for radiation from the sky.

fi is given by

$$f_i = \frac{A_i}{WH} \tag{1.16}$$

Ai is the unshaded area of the wall and is given by

$$A_i = WH - A_{shade} \tag{1.17}$$

The shaded area (Anshade) of the wall at any time, on any day is given by:

$$A_{shade} = [W - 0.5 \tan(\gamma_s - \gamma)] p \tan(90 - \theta_z) \sec(\gamma_s - \gamma) \tag{1.18}$$

γs = solar azimuth angle (degree). It is the angle made in the horizontal plane between the line due south, and the projection of the sun's rays on the horizontal plane. By convention, the angle is positive if the normal is east of south, and negative if west of south. It is given by:

$$\cos\gamma_s = (\cos\theta_z \sin\Phi - \sin\delta)/\sin\theta_z \cos\Phi \tag{1.19}$$

Fr-s for a wall of relative width w (= W/H) and relative projection p (= P/H) is presented in this Table:

Table 1.2 Wall radiation view factor for the sky, Fr-s

w	$F_{r\text{-}s}$ at p=								
	0.10	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00
1.0	0.46	0.42	0.40	0.37	0.35	0.32	0.30	0.28	0.27
4.0	0.46	0.41	0.38	0.35	0.32	0.27	0.23	0.19	0.16
25.0	0.45	0.41	0.37	0.34	0.31	0.25	0.21	0.15	0.12

1.3 SIMPLIFIED METHOD FOR PERFORMANCE ESTIMATION:

Based on the concepts discussed in previous sections, we can calculate the various heat exchanges taking place in a building.

1.3.1 Conduction:

The rate of heat conduction (Q_{cond}) through any element such as roof, wall or floor under steady state can be written as

$$Q_{cond} = AU\Delta T \tag{1.20}$$

where

A = surface area (m^2)

U = thermal transmittance (W/ m^2- K)

DT = temperature difference between inside and outside air (K)

It may be noted that the steady state method does not account for the effect of heat capacity of building materials.

U is given by

$$U = \frac{1}{R_T} \tag{1.21}$$

Where RT is the total thermal resistance and is given by :

$$R_T = \frac{1}{h_i} + \left(\sum_{j=1}^{m} L_j\, lk_j\right) + \frac{1}{h_0} \qquad (1.22)$$

h_i And h_o respectively, are the inside and outside heat transfer coefficients. L_j is the thickness of the j^{th} layer and k_j is the thermal conductivity of its material. U indicates the total amount of heat transmitted from outdoor air to indoor air through a given wall or roof per unit area per unit time. The lower the value of U, the higher is the insulating value of the element. Thus, the U-value can be used for comparing the insulating values of various building elements.

Equation $Q_{cond} = AU\Delta T$ is solved for every external constituent element of the building i.e., each wall, window, door, roof and the floor, and the results are summed up. The heat flow rate through the building envelope by conduction is the sum of the area and the U-value products of all the elements of the building multiplied by the temperature difference. It is expressed as:

$$Q_c = \sum_{i=1}^{N_c} A_i U_i\, \Delta T_i \qquad (1.23)$$

Where:

i = building element N_c = number of components

If the surface is also exposed to solar radiation then,

$$\Delta T = T_{so} - T_i \qquad (1.24)$$

Where Ti is the indoor temperature; T_{so} is the sol-air temperature, calculated using the expression:

$$T_{so} = T_o + \frac{\alpha S_T}{h_o} - \frac{\varepsilon \Delta R}{h_o} \qquad (1.25)$$

Where,

T_o = daily average value of hourly ambient temperature (K)

α = absorbance of the surface for solar radiation

S_T = daily average value of hourly solar radiation incident on the surface (W/m^2)

h_o = outside heat transfer coefficient (W/m^2 -K)

ε= emissivity of the surface

ΔR = difference between the long wavelength radiation incident on the Surface from the sky and the surroundings, and the radiation emitted by a black body at ambient temperature.

Values of heat transfer coefficient (ho) at different wind speeds and orientation are presented in the table

1.3.2 Ventilation:

The heat flow rate due to ventilation of air between the interior of a building and the outside, depends on the rate of air exchange. It is given by:

$$Q_v = \rho V_r c \Delta T \quad (1.26)$$

Where,

r = density of air (kg/ m3)

V_r = ventilation rate (m3/ s)

C = specific heat of air (J/ kg-K)

ΔT = temperature difference ($T_o - T_i$) (K)

Table 1.3 Recommended air change rates

Space to be ventilated	Air changes per hour
Assembly hall/ Auditorium (smoking)	3-6
Bedrooms / Living rooms (smoking)	3-6
Bathrooms/ Toilets	6-12
Cafes/Restaurants (smoking)	12-15
Cinemas/Theatres (non –smoking)	6-9
Classrooms	3-6
Factories(medium metal work - smoking)	3-6
Garages (smoking)	12-15
Hospital wards (smoking)	3-6
Kitchens (common - smoking)	6-9
Kitchens (Domestic - smoking)	3-6
Laboratories	3-6
Offices (smoking)	3-6

If the number of air changes is known, then

$$V_r = \frac{NV}{3600} \quad (1.27)$$

Where,

N = number of air changes per hour

V = volume of the room or space (m3)

Thus,

$$Q_v = \rho c \frac{NV}{3600} \Delta T \quad (1.28)$$

The minimum standards for ventilation in terms of air changes per hour (N) are presented in Table 1.3.

1.3.3 Solar Heat Gain

The solar gain through transparent elements can be written as:

$$Q_s = \alpha_s \sum_{i=1}^{M} A_i S_{gi} \tau_i \qquad (1.29)$$

Where,

α_S = mean absorptivity of the space

A_i = area of the i^{th} transparent element (m^2)

S_{gi} = daily average value of solar radiation (including the effect of shading) on the i^{th} transparent element (W/m^2)

τ_i = transmissivity of the i^{th} transparent element

M = number of transparent elements

1.3.4 Internal Gain:

The internal heat gain of a building is estimated as follows:

- The heat generated by occupants is a heat gain for the building; its magnitude depends on the level of activity of a person. *Table 1.4* shows the heat output rate of human bodies for various activities. The total rate of energy emission by electric lamps is also taken as internal heat gain. A large part of this energy is emitted as heat (about 95% for ordinary incandescent lamps and 79% for fluorescent lamps) and the remaining part is emitted as light, which when incident on surfaces, is converted into heat. Consequently, the total wattage of all lamps in the building when in use must be added to the Qi.

- The heat gain due to appliances (televisions, radios, etc.) should also be added to the Qi. If an electric motor and the machine driven by it are both located (and operating) in the same space, the total wattage of the motor must be included. If the horse power (hp) of a motor is known, its corresponding wattage can be calculated by multiplying it by 746 (1 hp = 746 W). If the motor alone is in the space considered, and if efficiency is Meff, then energy release into the space is 746 (1-Meff) hp. The load due to common household appliances is listed in *Table 1.5*.

Table 1.5 Heat production rate in a human body

Activity	Rate of heat production	
	(W)	(W/m^2)
Sleeping	60	35
Resting	80	45
Sitting, Normal office work	100	55
Typing	150	85
Slow walking(3 km/h)	200	110
Fast walking(6 km/h)	250	140
Hard work(filing, cutting, digging, etc.)	more than 300	More than 170

Table 1.6 Wattage of common household appliances

Equipment	Load (W)
Radio	15
Television(black/white)	110
Refrigerator	120
Television(colour)	250
Coffee machine	400
Vacuum cleaner	800
Washing machine	2500
Dishwasher	3050
Water heater	3500

Thus the heat flow rate due to internal heat gain is given by the equation:

Qi = (No. of people × heat output rate) + Rated wattage of lamps + Appliance load (1.30)

1.3.5 Evaporation:

The rate of cooling by evaporation (Qev) from, say, a roof pond, fountains or human perspiration, can be written as:

$$Q_{ev} = mL \tag{1.31}$$

Where m is the rate of evaporation (kg/s) and L is the latent heat of evaporation (J/kg-K)

1.3.6 Equipment Gain:

If any mechanical heating or cooling equipment is used, the heat flow rate of the equipment is added to the heat gain of the building.

Suppose we have a room that is 5 m long, 4 m wide and 3 m high, as shown in *Fig. 4.8*. If the room is maintained at 23.3 ℃ by an air-conditioner, how may we calculate the load on the appliance using the steady state approach?

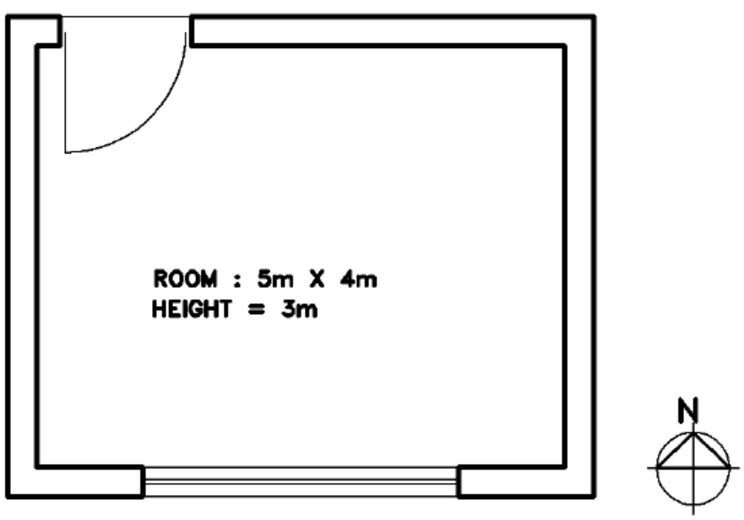


Fig 1.8 Plan of a single zone room

We have the following data available:

Month: May
Ventilation rate: 2 h-1
Artificial light: Three 100 W bulbs continuously used
Occupants: Four persons (normal office work; 24 hours occupancy)
Window: (1.5m X 3m) on south wall, single glazed
Door: (1.2m X 2m) on north wall
$U_{glazing}$ = 5.77 W/m2-K
U_{wall} = 3.00 W/m2-K
U_{roof} = 2.31 W/m2-K
U_{door} = 3.18 W/m2-K
Daily average outside temperature in May: 32.7 ºC
Absorbance of external wall surfaces: 0.6
Outside heat transfer coefficient: 22.7 W/m2-K
Inside design temperature: 23.3 ºC
Daily average solar radiation on south wall: 111.3 W/m2
Daily average solar radiation on east wall: 158.2 W/m2
Daily average solar radiation on north wall: 101.1 W/m2
Daily average solar radiation on west wall: 155.2 W/m2
Daily average solar radiation on roof: 303.1 W/m2
Daily average solar radiation on window: 111.3 W/m2 (no shading)
Mean absorptivity of the space: 0.6
Transmissivity of window: 0.86
Absorptivity of glazing for solar radiation: 0.06
Absorptivity of wood for solar radiation: 0.0
Density of air: 1.2 kg/m3
Specific heat of air: 1005 J/ kg-K

Under the steady state approach (which does not account the effect of heat capacity of building materials), the heat balance for room air can be written as

$$Q_{total} = Qc + Qs + Qi + Qv \tag{1.32}$$

From *Eq. (1.25),* with DR = 0 for vertical surfaces, the values of sol-air temperatures are:

$$T_{so}^{south} = 32.7 + \left(0.6 \times \frac{111.3}{22.7}\right) = 35.6℃$$

Similarly,

$T_{so}^{east} = 36.9°C$
$T_{so}^{north} = 35.4°C$
$T_{so}^{west} = 36.8°C$
$T_{so}^{door} = 32.7°C$
$T_{so}^{glazing} = 33.0°C$

For the roof, $\Delta R = 63 \text{ W/m}^2$ and hence $T_{so}^{roof} = 38.2°C$

Qc = 3.00 (15 – 4.5) (35.6 – 23.3) + 3.00 x 12 (36.9- 23.3) + 3.00 (15 – 2.4) (35.4 – 23.3) + 3.00 x 12 (36.8 – 23.3) + 3.18 x 2.4 (32.7 – 23.3) + 2.31 x 20 (38.2 –23.3) + 5.77 x 4.5 (33.0 – 23.3)
= 2832.4 W

Using Eqs. (1.26 – 1.30),
Qs = 0.6 x 4.5 x 111.3 x 0.86 = 258.4 W
Qi = 3 x 100 + 4 x 100 = 700 W
Qv = 1.2 x 1005 (2 x 5 x 4 x 3/3600) (32.7 – 23.3) = 377.9 W

Thus, Qm = 2832.4 + 258.4 + 700 + 377.9 = 4168.7 ≈ 4.2 kW

Remarks: Now, the problem facing a designer is to make sense of this quantity. As the total heat gain rate is positive; it represents the total heat entering the building. How does 4.2 kW translate practically? Let us consider it from two angles.

- The COP of a standard window air conditioner of 1.5 tons cooling capacity is about 2.8. So the power required is 1.5 kW (i.e., 4.2 kW/2.8)
- Suppose the machine were to be used for 8 hours a day; then it would consume 12 kWh per day (1.5 kW × 8 hours = 12) or 12 units (One kWh is equivalent to one unit) of electricity supplied by the power company. At a rate of Rs. 4 per unit, expenses would amount to Rs. 48 per day.

1.4 Effect of Exterior Surface Color on the Thermal Performance of Buildings:

THE COLOUR of the outside surface of a building envelope is expected to influence the thermal performance of a building significantly as it determines the amount of absorbed solar radiation and, therefore, its inward transmission
into the building . Givoni and Hoffman have carried out some experiments with different colors. The experimental measurements reported for two colors, namely white and grey, showed a difference of 3℃ in the room air temperature when measured only 0.1 m below the ceiling. While it remained only 1℃ when measured 1.2 m above the floor. The temperatures, as expected, were higher for grey colored enclosure.
Givoni, however mentioned that the effect of external color on room air temperature depends on various other parameters also, particularly the heat resistance and heat capacity of the building. It was observed that for low U value building with high thermal capacity (heavy construction), the effect of external color is not so significant as for a low thermal resistance (high U value) and low heat capacity building.
It is expected that the effect of external surface color on the room temperature inside a building will depend on other parameters also, the most important from the point of view of passive design being:

- rate of air ventilation in the building
- Direct solar radiation gain into the building.

1.5 COMPUTER-BASED TOOLS:

The above example illustrates the steady state calculation of heat gain or loss for a single zone conditioned building. The method can also be extended to multi-zone or multi-storied buildings, but the algebra becomes complicated. Besides, the effects of:

- variation of outside air temperature and solar radiation with time
- shading by neighboring objects
- self-shading
- thermal capacity of the building (i.e. the ability of building materials to store heat during

Daytime and release it back to the environment later) add to the complexity of the calculations. Consequently, one resorts to computer-based tools known as building simulation tools. A number of such tools are now available to do quick and accurate assessment of a building's thermal and Day lighting performance. These tools can estimate the performances of different designs of the building for a given environmental condition. From these results, a designer can choose the design that consumes minimum energy. Thermal calculations also help to select appropriate retrofits for existing buildings from the viewpoint of energy conservation. Thus, by integrating the simulation of thermal performance of a building with its architectural design, one can achieve an energy efficient building.

A number of tools are available for simulating the thermal performance of buildings; they address different needs. For example, an architect's office requires a tool that is quick and gets well integrated into the design process. On the other hand an HVAC engineer would look for a tool that would accurately predict the energy a building would consume, for optimum sizing of the air-conditioning systems.

For example:

1.5.1 eQUEST

eQUEST is an easy to use building energy use analysis tool that provides
Professional-level results with an affordable level of effort. This is accomplished by combining a building creation wizard, an energy efficiency measure (EEM) wizard and a graphical results display module, with an enhanced DOE-2.2-derived building energy use simulation program.
eQUEST features a building creation wizard that guides the user through the process of creating an effective building energy model. This involves following a series of steps that help one to describe the features of the design that would impact energy use such as architectural design, HVAC equipment, building type and size, floor plan layout, construction material, area usage and occupancy, and lightning system. After compiling a building description, eQUEST produces a detailed simulation of the building, as well as an estimate of how much energy the building would use.
Within eQUEST, DOE-2.2 performs an hourly simulation of the building design for a one-year period. It calculates heating or cooling loads for each hour of the year, based on factors such as walls, windows, glass, people, plug loads, and ventilation. DOE-2.2 also simulates the performance of fans, pumps, chillers, boilers, and other energy-consuming devices. During the simulation, DOE-2.2 tabulates the building's projected use for various end uses.
eQUEST offers several graphical formats for viewing simulation results. It allows one to perform multiple simulations and view alternative results in side-by-side graphics. It offers features like: energy cost estimating, day lighting and lighting system control, and automatic implementation of common energy efficiency measures (by selecting preferred measures from a list). (1)

2. Περιγραφή του eQUEST (Quick Energy Simulation Tool):

2.1 Πράγματα που πρέπει να γνωρίζετε πριν να ξεκινήσετε με eQUEST :

Το eQUEST αποτελείται από τρία Wizards, υπάρχει το SD Wizards, το DD Wizard και το EEM Wizard. Τα Wizards του eQuest προορίζονται για να απλοποιηθεί και να επιταχυνθεί η διαδικασία της προετοιμασίας της κατασκευής μοντέλων για ανάλυση προσομοίωσης. Σε σύγκριση με τα συμβατικά εργαλεία προσομοίωσης, τα Wizard του eQUEST μπορούν να χρησιμοποιηθούν είτε για τη διεξαγωγή ταχύτατης ανάλυσης είτε για προετοιμασία λεπτομερών μοντέλων που θα χρησιμοποιηθούν σε άλλη ανάλυση. Το eQUEST περιέχει τρία Wizards, τον σχηματικό οδηγό Σχεδιασμού (οδηγός SD), τον Οδηγό Σχεδιασμού Ανάπτυξης (DD Οδηγό), και τα μέτρα ενεργειακής απόδοσης. Ο SD Οδηγός και ο οδηγός DD χρησιμοποιούνται για να δημιουργήσουν μοντέλα κτιρίων. Ο Οδηγός EEM χρησιμοποιείται για την αξιολόγηση εναλλακτικού σχεδιασμού κτιρίων.

Το eQUEST ξεκινά με διπλό κλικ στο desktop, από το κουμπί Έναρξη, ή από τον Windows Explorer (η προεπιλεγμένη τοποθεσία είναι "C: \ Program Files eQUEST 3…”). Το Startup Options Dialog παρουσιάζεται Επιλέξτε." Δημιουργία ενός νέου έργου μέσω του Οδηγού " (the default) και πατήστε OK.

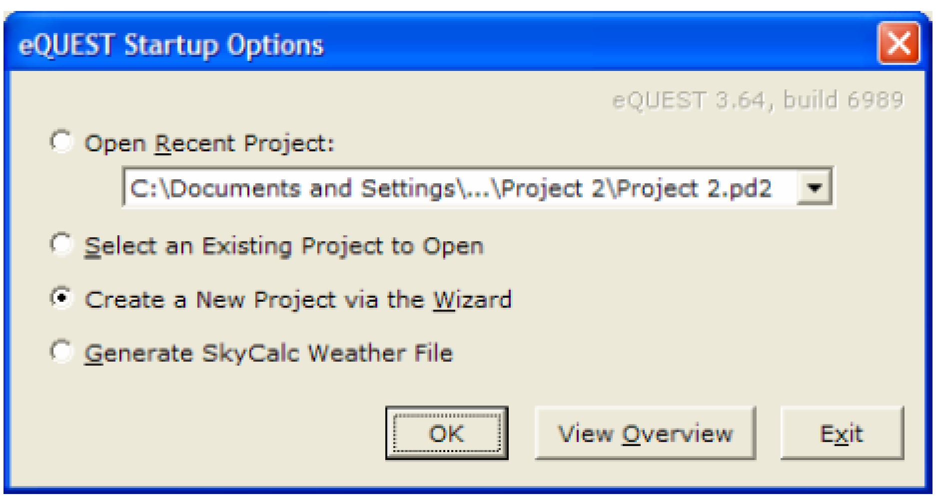


Fig 2.1 eQUEST Startup Options Dialog

Σημειώσεις:

Οι διαθέσιμες startup options είναι:

- Ανοίχτε ένα πρόσφατο αρχείο. Ο κατάλογος διατηρείται για αρχεία στον τοπικό υπολογιστή, που απαριθμούνται με αντίστροφη χρονολογική σειρά (πιο πρόσφατο πρώτα). Αυτός ο κατάλογος διατηρείται σε όλες τις ενημερώσεις του προγράμματος και στις εκ νέου εγκαταστάσεις.
- Ανοίξτε ένα υπάρχον αρχείο. Η ενεργοποίηση αυτής της επιλογής επιτρέπει στο χρήστη να περιηγηθεί στο μηχάνημα για ένα αρχείο εισόδου eQUEST. Μεταγενέστερα θα αποθηκεύσει τα αρχεία στο «πλοήγηση θέσης».
- Δημιουργήστε ένα νέο αρχείο μέσω των Wizards. Αυτή είναι η προεπιλεγμένη επιλογή και το κύριο πλεονέκτημα eQUEST σε σχέση με τα άλλα εργαλεία μοντελοποίησης. Χρησιμοποιήστε αυτή την επιλογή στην εκκίνηση για τη δημιουργία νέων μοντέλων eQUEST "από το μηδέν". Οι σελίδες που ακολουθούν απεικονίζουν τη χρήση του Οδηγού σχηματικού σχεδιασμού.
- Δημιουργήστε ένα αρχείο καιρού Skycalc. Αυτό είναι ένα υπολογιστικό φύλλο που βασίζεται στο skylighting, ένα εργαλείο σχεδιασμού διαθέσιμο στο www.EnergyDesignResources.com .

Επιλέξτε «create a new project via the Wizards», και Schematic Design Wizard (1)

Η Επιλέξτε «create a new project via the Wizards», και Design Development Wizard (1)

2.2 Διαφορές μεταξύ του SD και το DD Wizard:

Υπάρχουν δύο βασικές διαφορές μεταξύ του Wizard SD και του DD Wizard:

1) Το SD wizard μπορεί να δημιουργήσει μόνο ένα ενιαίο κέλυφος κτιρίου. Ένα κέλυφος του κτιρίου παραπέμπει σε οποιαδήποτε περιοχή του κτιρίου που μοιράζεται το ίδιο (ή παρόμοιο) αποτύπωμα, HVAC ζώνες, ύψος οροφής, τύπος κατασκευής ή φάκελος HVAC. Το Wizard DD μπορεί να χρησιμοποιηθεί για τη δημιουργία κτιρίων που απαιτούν πολλαπλά κελύφη.
2) Το SD wizard μπορεί να δημιουργήσει έως και δύο πρότυπα του συστήματος HVAC (από τα οποία θα δημιουργηθεί ένα ή περισσότερα συστήματα HVAC στο μοντέλο σας). Τ DD Wizard μπορεί να χρησιμοποιηθεί για να δημιουργήσει πολλά πρότυπα τύπο του συστήματος HVAC και παρέχει μεγαλύτερη ευελιξία στην εκχώρησή του σε κτήριο με πολλά δωμάτια.

Οι χρήστες μπορούν να αρχίσουν το eQUEST project τους σε κάθε wizard. Το SD wizard project μπορεί να μετατραπεί σε αρχείο DD Wizard ανά πάσα στιγμή, όμως, τα αρχεία DD wizard δεν μπορούν να μετατραπούν σε ένα αρχείο Wizard SD.

2.3 Εισαγωγή στο DD Wizard :

Για πιο πολύπλοκα κτίρια, π.χ., για κτίρια με ορόφους διαφορετικών σχημάτων ή για κτίρια που έχουν προχωρήσει στο στάδιο της ανάπτυξης του σχεδιασμού, το Design Development (DD Wizard) παρέχει πρόσθετη ευελιξία διαμόρφωσης. Το DD wizard ομαδοποιεί τις οθόνες εισαγωγής, π.χ. κελύφους κτηρίου, συστήματα Air-Side. κ.λπ. Η οργάνωση για την DD Wizard παρουσιάζεται παρακάτω.

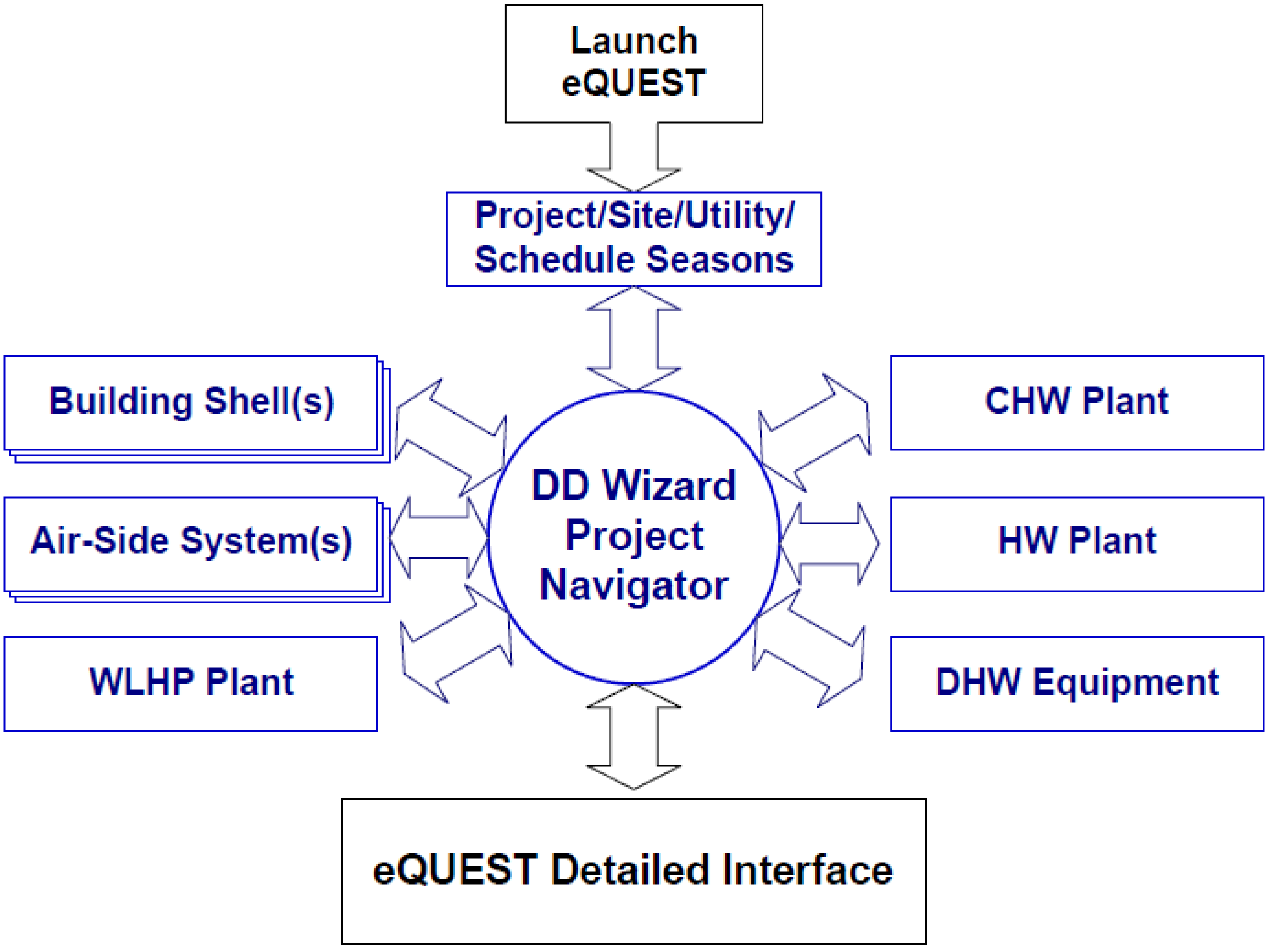
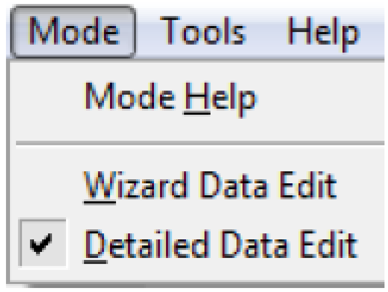


Fig 2.2 DD Wizard project navigator (1)

Στο DD Wizard, οι χρήστες μπορούν να ορίσουν πολλά κελύφη κτιρίου (για παράδειγμα, ξεχωριστά κτίρια, δάπεδα, πτέρυγες, κλπ), και πολλαπλά συστήματα Air-Side HVAC, ωστόσο, επιτρέπει την περιγραφή μίας μόνο κεντρικής μονάδας ανά αρχείο . Η περιγραφή πολλαπλών κεντρικών μονάδων επιτρέπεται στην Λεπτομερή οθόνη. Η κεντρική οθόνη στο DD Wizard είναι ο πλοηγός, ονομάζεται έτσι επειδή όλες οι άλλες ομάδες του DD Wizard συνδέονται μεταξύ τους μέσω αυτού.

Επιλέγοντας μία από τις δύο επιλογές της γραμμής εργαλείων το πρόγραμμα επιστρέφει στα παράθυρα λειτουργίας των Schematic Design Wizard ή Design Development Wizard. Όπως αναφέρθηκε, υπάρχει η δυνατότητα επεξεργασίας Mode Tools Help του μοντέλου του κτηρίου και από την επιλογή Detailed Mode Help Interface Για να πραγματοποιηθούν αλλαγές στο μοντέλο του κτηρίου από αυτή τη λειτουργία, είναι Wizard Data Edit απαραίτητη η αλλαγή της επιλογής «Mode» από «wizard Detailed» σε «Detailed Data Edit». Με την επιλογή αυτής της λειτουργίας του προγράμματος οποιαδήποτε πραγματοποιηθεί δεν θα αποθηκευτεί για τον τρόπο επεξεργασίας εάν ο χρήστης του κτηρίου. επιθυμεί να επιστρέφει στην επιλογή των Wizard. Αυτή η αλλαγή γίνεται από την καρτέλα του μενού Mode.



3. Προσομοίωση κτηρίου με το λογισμικό eQUEST στον Καναδά :

Στο κεφάλαιο αυτό παρουσιάζονται τα δεδομένα που χρησιμοποιήθηκαν για την προσομοίωση του κτηρίου με το λογισμικό eQUEST στο Καναδά (συστήματα θέρμανσης). Συγκεκριμένα γίνεται μία περιγραφή του κτηρίου όσον αφορά το αρχιτεκτονικό σχέδιο και το διαχωρισμό σε θερμικές ζώνες. Επίσης αναφέρονται τα δομικά υλικά του εξωτερικού και εσωτερικού τοίχου, οροφής και τους εδάφους. Επίσης δίνονται όλα τα απαραίτητα στοιχεία εσωτερικά φορτία και για τα συστήματα HVAC που έχει για τα το κτήριο.

Οι επόμενες εικόνες είναι οι κατόψεις του προτού και δεύτερου όροφο του κτιρίου που μελετάται , όπως δόθηκαν από τους αρχιτέκτονες στο Καναδά.

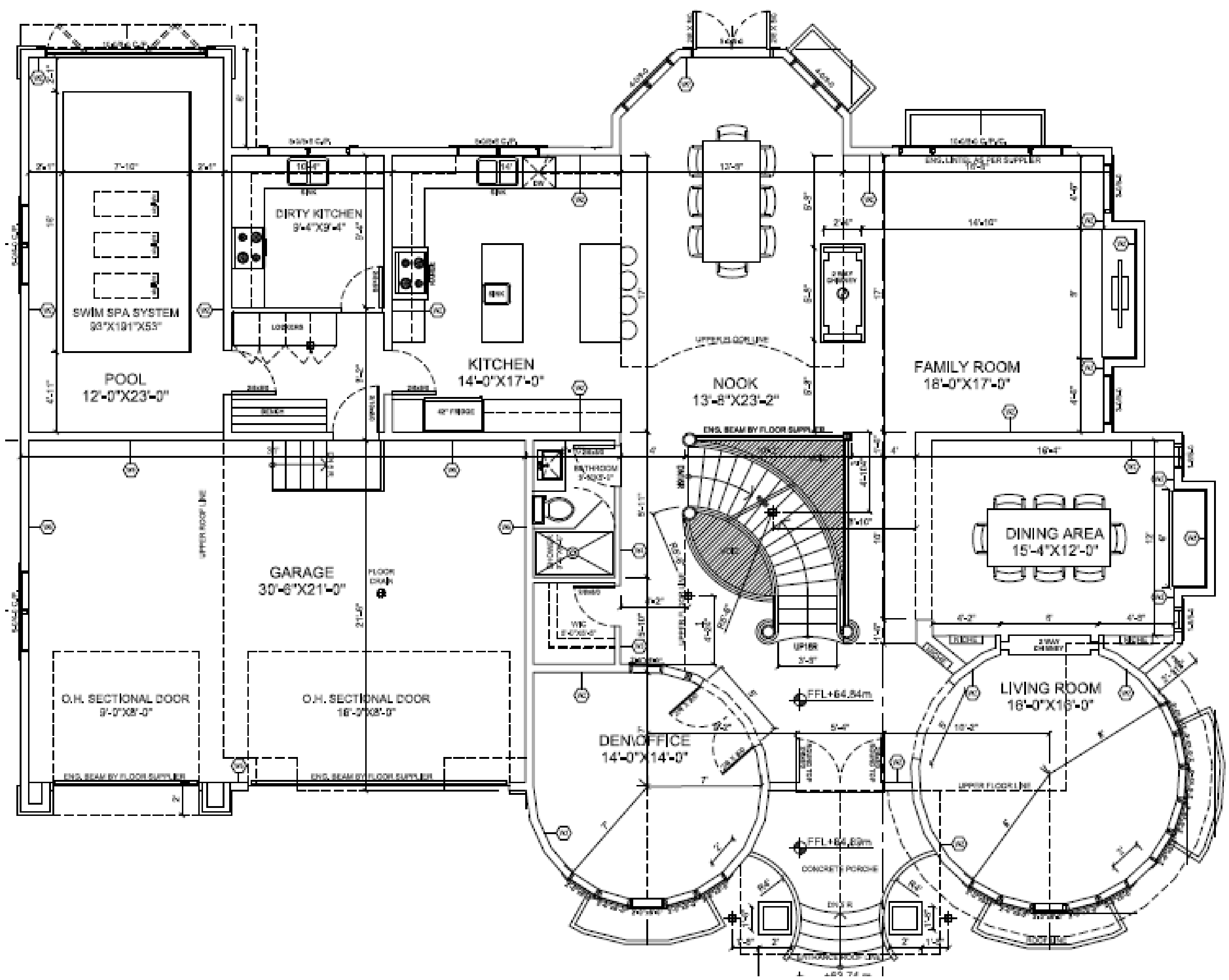


Fig 3.1 κάτοψη του πρώτο όροφο του σπιτιού (2)

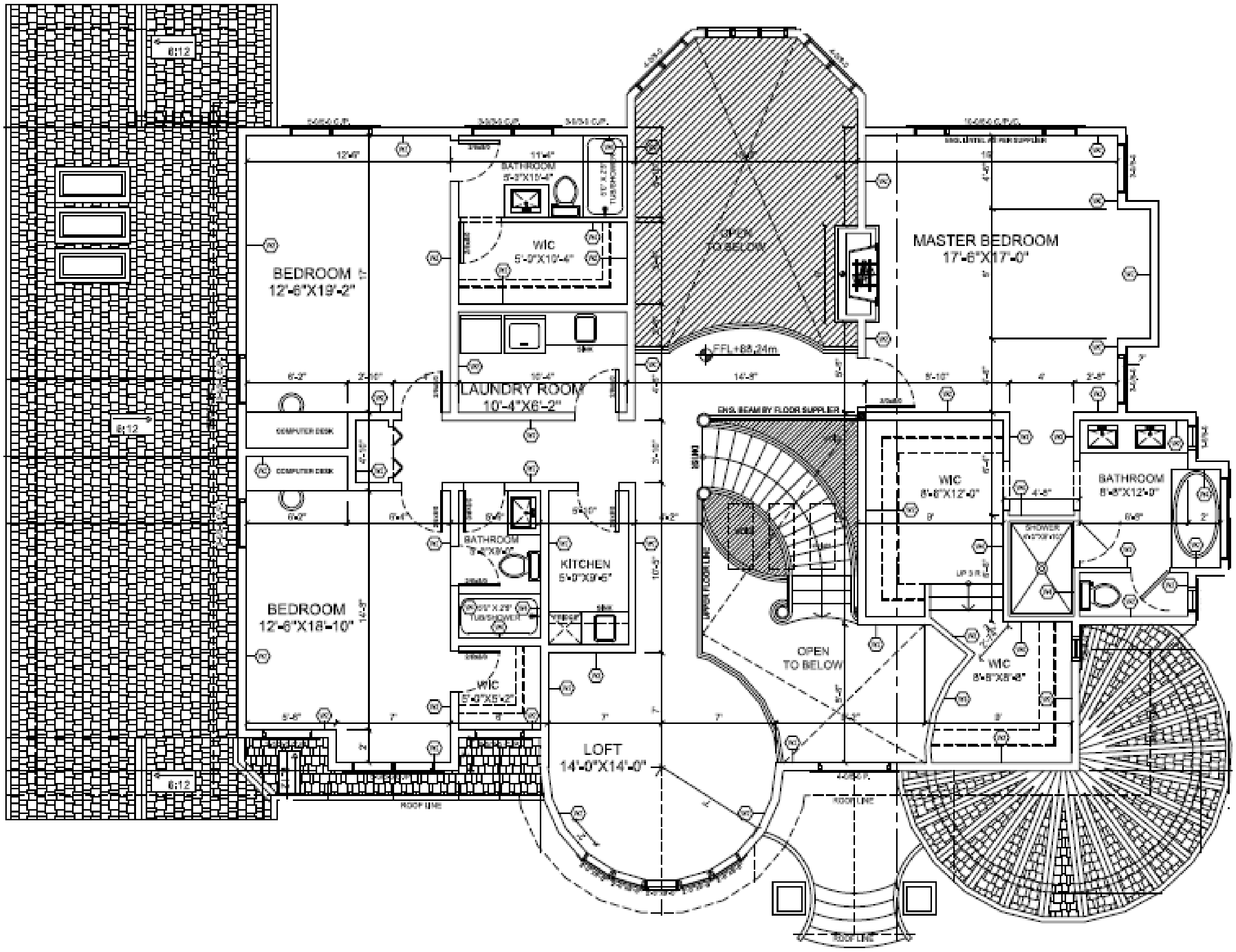


Fig 3.1 κάτοψη του δεύτερο όροφο του σπιτιού (2)

Ξεκινάμε βήμα-βήμα να μελετάμε ένα παρόμοιο κτίριο με αυτό που είδαμε προηγουμένως και να το σχεδιάσουμε με το πρόγραμμα eQUEST .

3.1 Κτιριακό κέλυφος:

3.1.1 Πρώτη σελίδα:

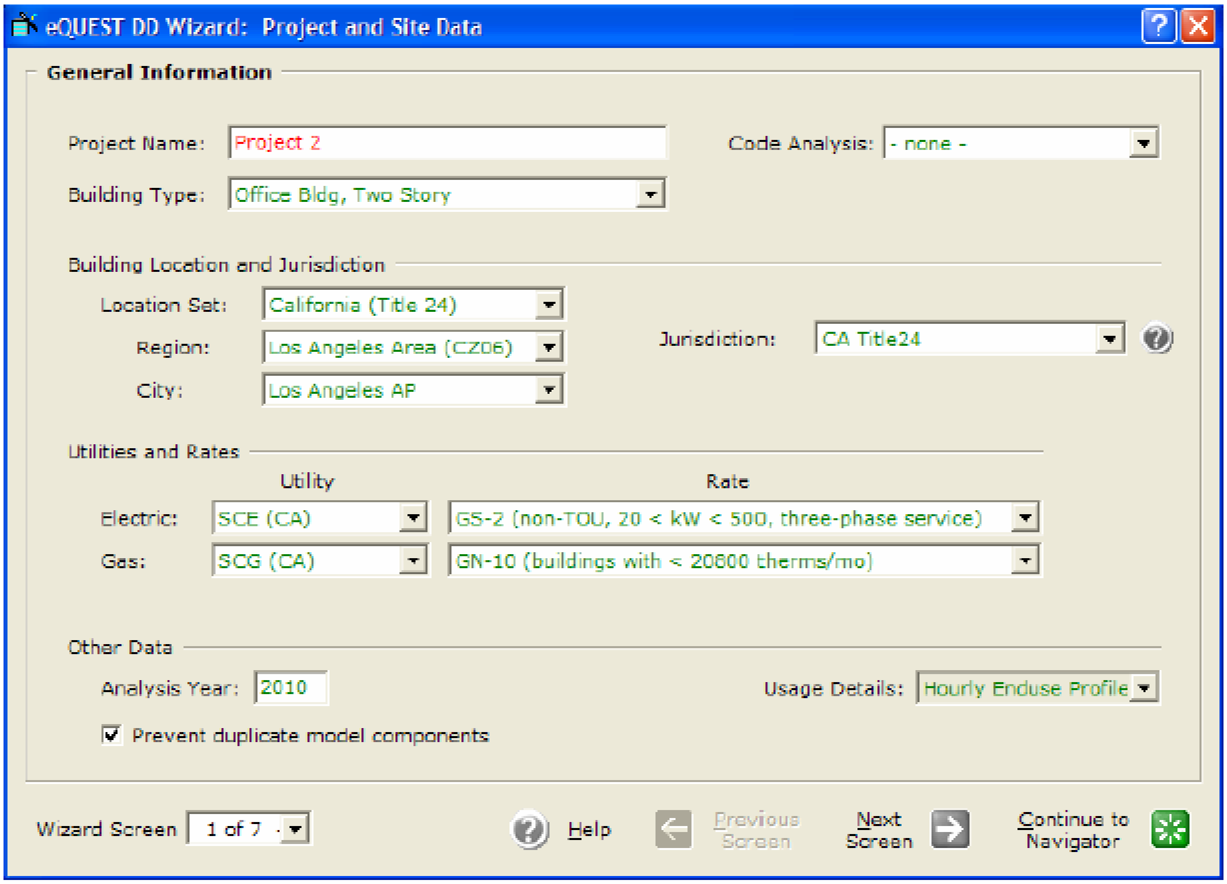


Fig 3.3 General Information, first page.

1. Όνομα Αρχείου. Επιλέξτε ένα όνομα αρχείου που χρησιμοποιείται για να ονομάσετε το φάκελο των αρχείων, όπου εδώ το ονομάσαμε Καναδάς.

2. Τύπος κτιρίου .Αυτή η επιλογή χρησιμοποιείται για να οριστούν διάφοροι παράμετροι του κτιρίου (π.χ., το μέγεθος του κτιρίου, τύπος συστήματος HVAC κλπ.). Εδώ ορίζεται κτίριο με 2 ορόφους.

3. Αρχείου καιρού. Υπάρχουν 4 επιλογές: "California (Title24)" ,"Όλες οι eQUEST Περιοχές» , «Καναδέζικες Τοποθεσίες" και "Επιλογή από το χρήστη" Εάν το αρχείο καιρός δεν είναι στο σκληρό δίσκο, όταν η προσομοίωση εκτελείται (), λαμβάνεται αυτόματα από την ιστοσελίδα DOE-2. Σε αυτή τη περίπτωση και αφού το συγκεκριμένο σπίτι βρίσκεται στο Καναδά οπότε έχουμε τα αρχεία καιρού που θέλουμε , επιλέγεται 2 MANOR ROAD NW CALGARY, ALBERTA .

4. Θέρμανση/Ψύξη. Καθορισμός συστήματος HVAC και εξοπλισμού των εγκαταστάσεων (εάν υπάρχουν). Σε αυτή τη περίπτωση έχουμε μόνο θέρμανση ,επειδή το κτίριο βρίσκεται στο Καναδά ,σε κρύα περιοχή ,όπου δεν χρειάζεται ψύξη το καλοκαίρι.

5. Έλεγχος του φυσικού φωτισμού. Ενεργοποιεί απενεργοποιεί στην οθόνη το φυσικό φωτισμό που σχετίζονται.

6. Λεπτομέρειες Χρήσης. «Απλοποιημένη On Off ωριαία Προφίλ » είναι προκαθορισμένα προφίλ χρήσης ώρα-από-ώρας. Επειδή μελετάται οικιακό κτίριο, το ωράριο είναι 24ωρη λειτουργία.

3.1.2 Wizard εξαρτήματα :

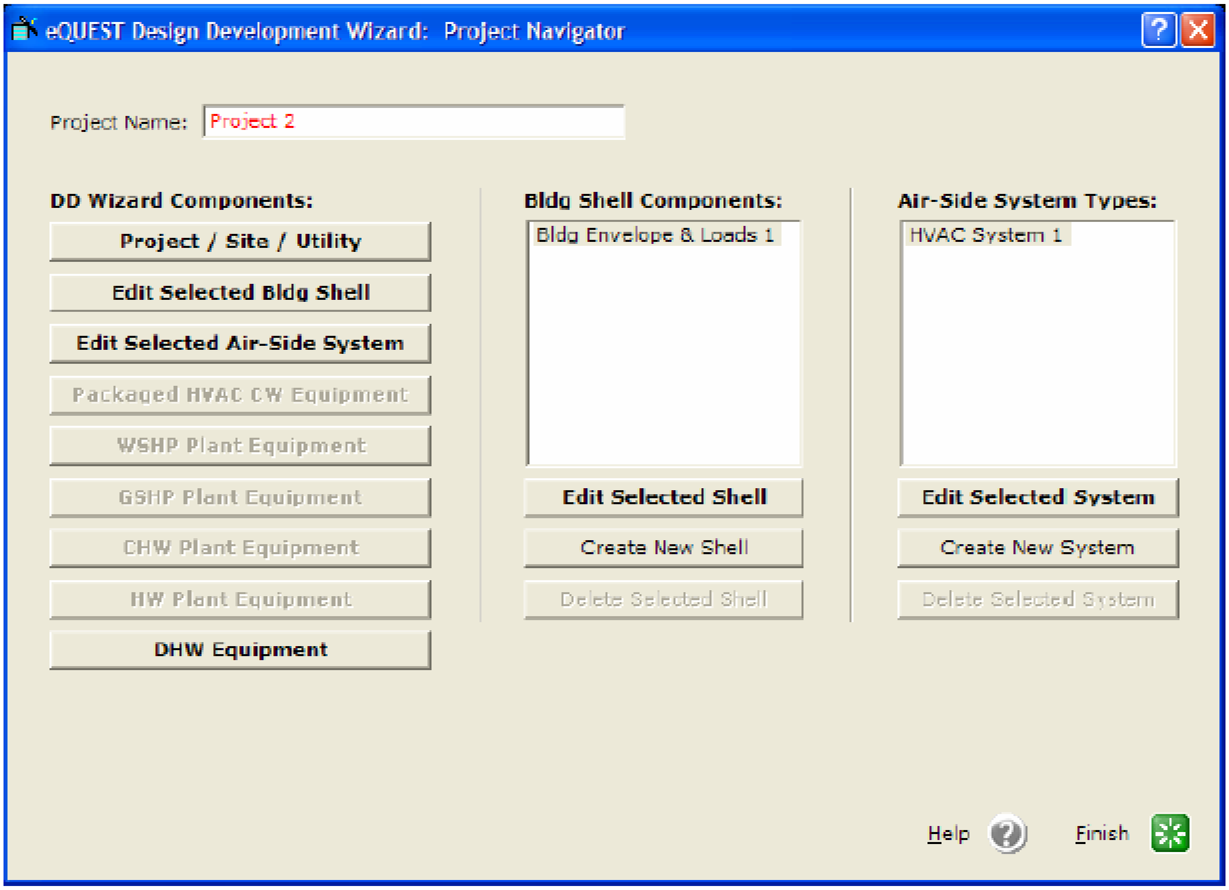


Fig 3.4 DD Wizard components

Μπορείτε να δημιουργήσετε πολλαπλούς ορισμούς σύστημα air-side. Αυτό προσθέτει ευελιξία στο τρόπο που ορίζονται οι τομείς του αρχείου για εξυπηρέτηση διαφορετικών συστημάτων HVAC.

- Air-Side Συστήματα. Καθορισμός πολλαπλών air-side προτύπων του συστήματος HVAC
- Πακέτο HVAC κλιματισμού νερού συμπυκνωτή Equip. Ορίστε WC DX εξοπλισμός
- WSHP εξοπλισμός. Ορίστε την πηγή νερού και προδιαγραφές αντλιών θερμότητας (μόνο ένα plant WSHP ανά αρχείο)
- GSHP plant equipment. Ορισμός επίγειας πηγής και προδιαγραφές αντλιών θερμότητας (μόνο ένα GSHP plant ανά σχέδιο)
- CHW και HW εξοπλισμός. Χρησιμοποιήστε το για να αποκτήσετε πρόσβαση σε κεντρικές προδιαγραφές ψύξης και θέρμανσης εξοπλισμού.

- DHW Εξοπλισμός. Χρησιμοποιήστε το για να αποκτήσετε πρόσβαση σε εγχώριες προδιαγραφές εξοπλισμού ζεστό νερό (προς το παρόν, μόνο ένας DHW συστήματος ζεστού νερού χρήσης ανά αρχείο).

Εδώ σ αυτή τη περίπτωση το σπίτι είναι φτιαγμένο από ένα κέλυφος και δύο ορόφους . Και έχουμε χρησιμοποιήσει ένα σύστημα HVAC που είναι φτιαγμένο από ένα boiler και ένα default σύστημα σωλήνες για ζεστό νερό και multiple coils που πάνε κάτω απ το πάτωμα ,για θέρμανση του κτιρίου.

3.1.3 Γενικές πληροφορίες κέλυφους:

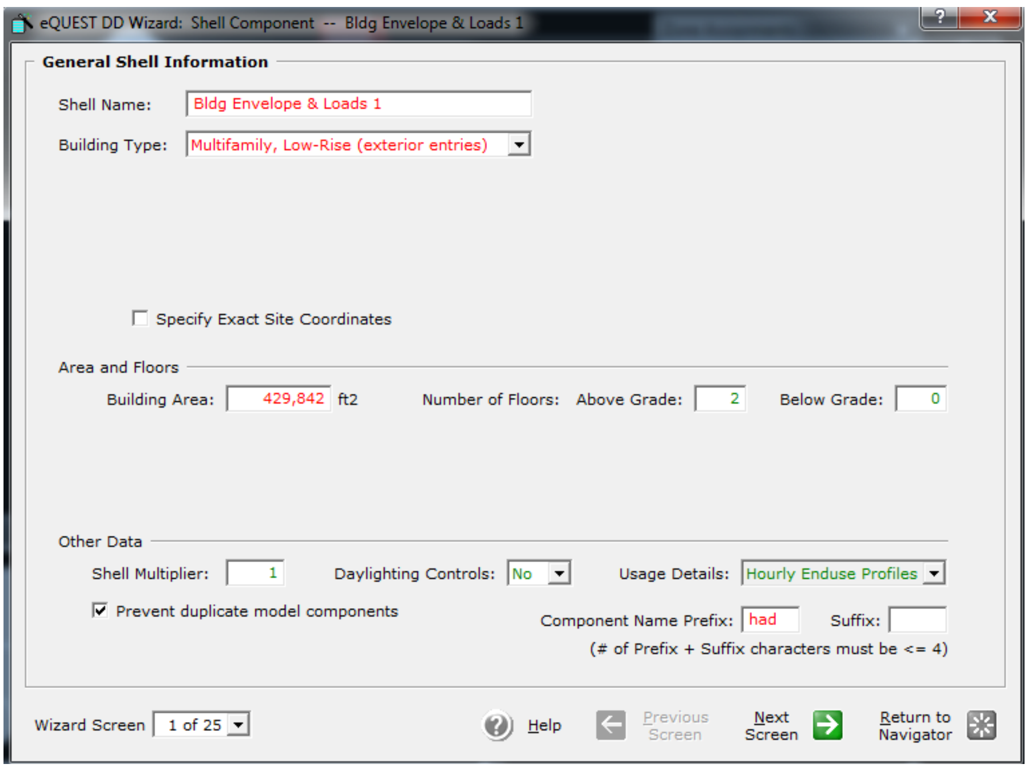


Fig 3.5 General Shell information

Σε αυτή τη σελίδα έχουμε τα εξής πράγματα:

- Όνομα Shell. Χρησιμοποιήστε αυτό το πεδίο για να αναφέρουμε το τρέχον επιλεγμένο στοιχείο κελύφους.
- Αριθμός ορόφων , όπου εδώ είναι 2 όροφοι.
- Εμβαδόν κτιρίου , που είναι *4298.42 sq.ft (399.33 sq.mts)*
- Αριθμός κελυφών , εδώ έχουμε έναν κέλυφος.

- Λεπτομέρειες Χρήσης. «Απλοποιημένη τα δρομολόγια On Off χρονοδιαγράμματα βήμα λειτουργία. Ωριαία Προφίλ »είναι προκαθορισμένα προφίλ χρήσης ώρα-από-ώρας. λόγω που είναι για οικιακό σπίτι ,οπότε χρησιμοποιείται καθόλη την μέρα 24/24 365/365 .
- όνομα prefix , για παράδειγμα εδώ χρησιμοποιήσαμε HAD .

3.1.4 Σχέδιο κτιρίου:

Στη επόμενη εικόνα βλέπουμε με ποιο τρόπο γίνεται η σχεδίαση του κτιρίου στο πρόγραμμα eQUEST από το μηδέν, ξεκινάμε από ένα σημείο και σχεδιάζουμε κάθε πλευρά ξεχωριστά . Για την ακρίβεια βλέπουμε αριστερά τα X και Y του κάθε σημείου και με αυτό το τρόπο ξέρουμε πως να βάλουμε κάθε σημείο ακριβώς . Εδώ προσπαθήσαμε να κάνουμε ένα παρόμοιο σχέδιο με αυτό που μας το δώσανε οι αρχιτέκτονες από Καναδά .

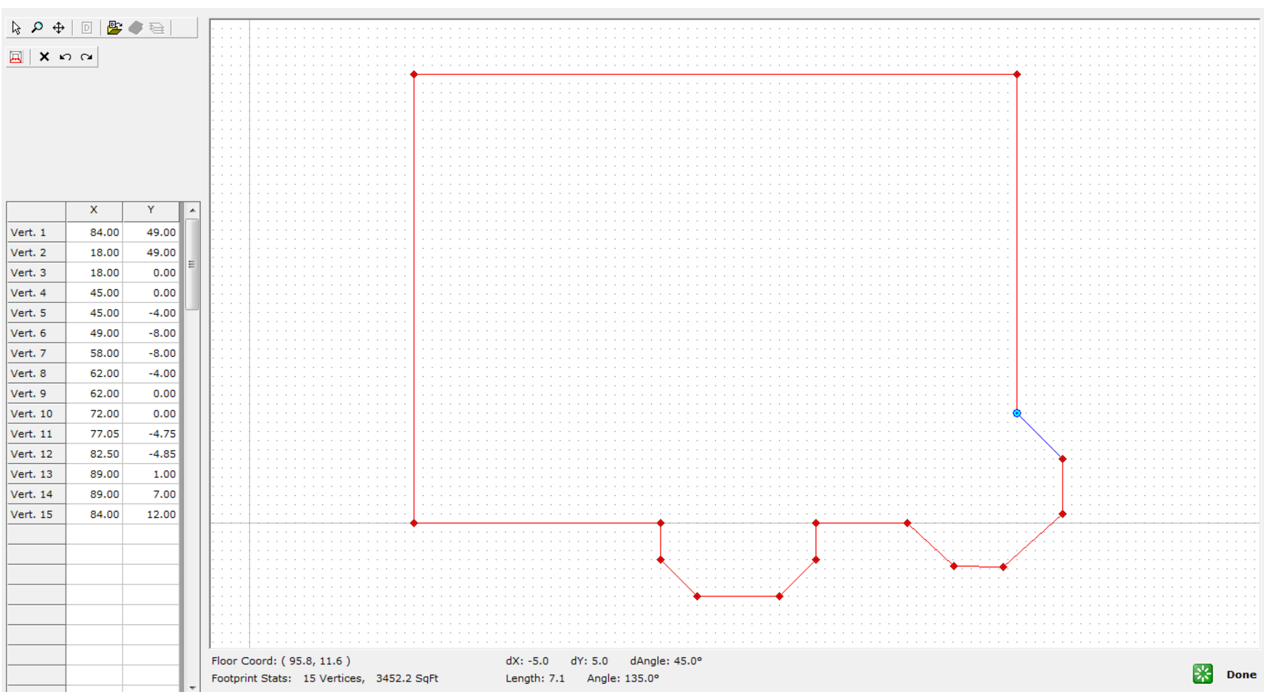


Fig 3.6 custom building footprint

Στη επόμενη εικόνα παρουσιάζονται τα γενικά στοιχεία για τον εξωτερικό σχέδιο του κτιρίου. Μετά το σχεδιασμό του κτιρίου μπορούμε επομένως να διαλέξουμε πόσο ύψος έχει κάθε όροφος. Σε αυτή τη περίπτωση έχει ο πρώτος όροφος ύψος 10 ft και ο δεύτερος 9 ft .Επίσης έχει να βάλεις εμβαδόν ορόφου ,όπου ο πρώτος όροφος έχει 214.921 sq.ft. Στη συνέχεια επιλέγουμε το προσανατολισμό του κτιρίου ,όπου σε αυτή τη περίπτωση το κτίριο είναι στραμμένο στο νότο.

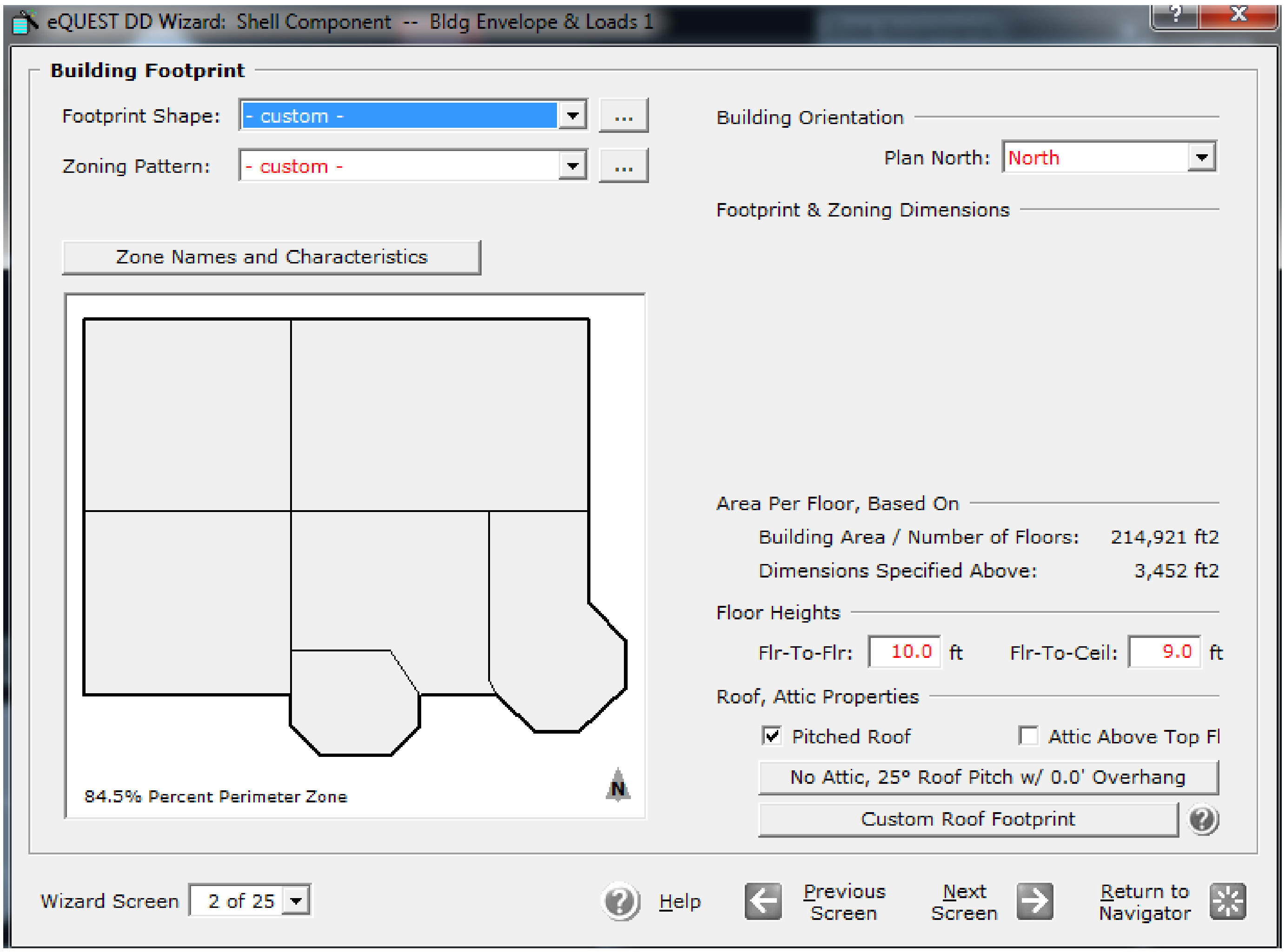


Fig 3.6 Building footprint

3.1.5 Σοφίτα και στέγη:

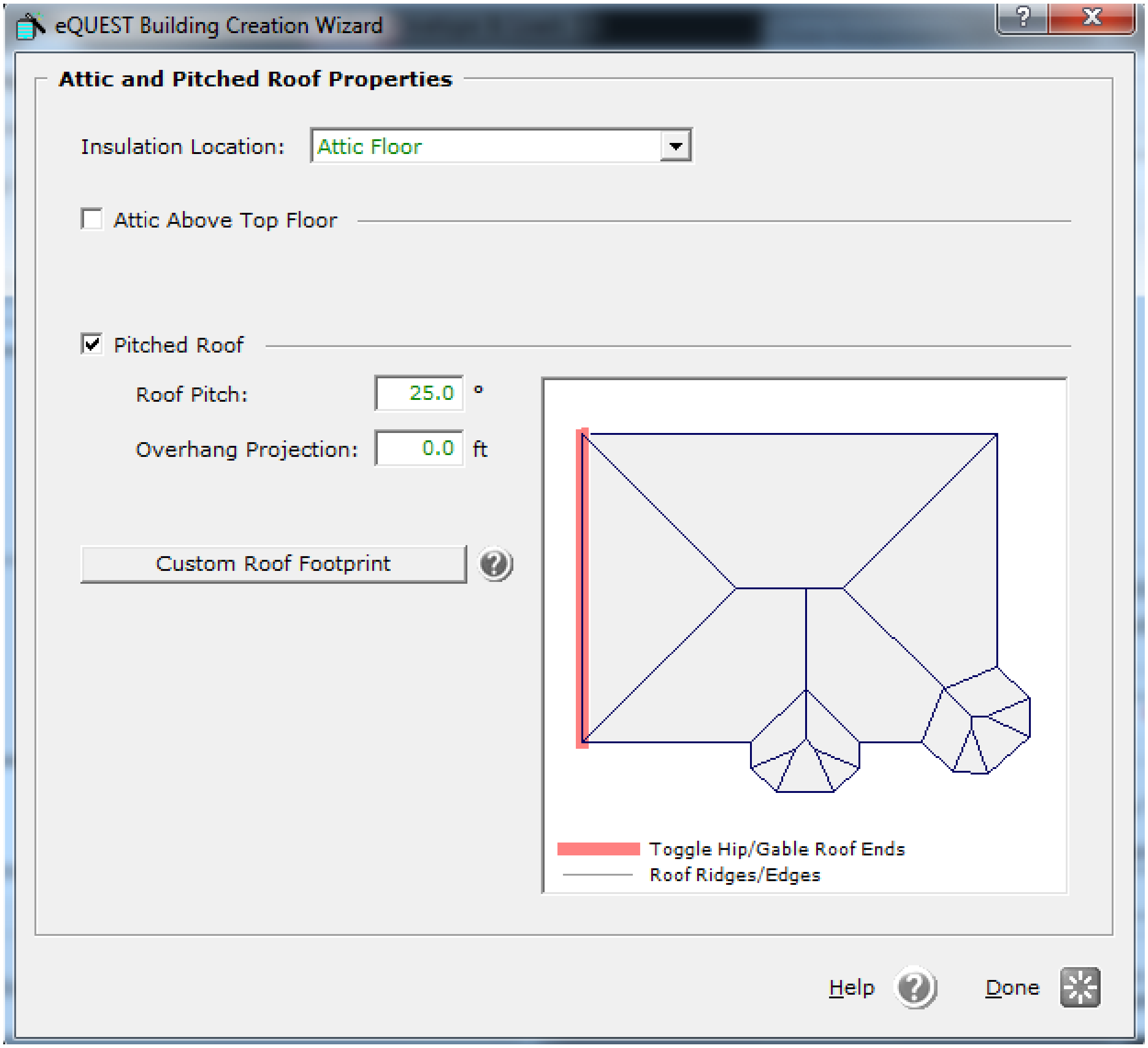


Fig 3.7 Attic and pitched roof properties

Αυτή η οθόνη, χρησιμοποιείται για τον ορισμό των χαρακτηριστικών της επικλινούς στέγης.

- Μόνωση. Η επιλογή στέγης σημαίνει την ύπαρξη μιας σοφίτας κάτω από αυτή (δηλ. Αυτή η λειτουργία δεν μπορεί να χρησιμοποιηθεί για να καθορίσει τη θολωτή οροφή).
- Εναλλαγή Hip / Gable Roof Ends. Αριστερό κλικ στη παχιά, ασθενώς κόκκινη γραμμή (απεικονίζεται ανωτέρω) για εναλλαγή μεταξύ ισχίου και αέτωμα στέγες.

- Οροφή. Αναφέρετε τη κλίση για την στέγη. Η κλίση μπορεί να υπολογιστεί ως $\tan^{-1}$ (rise/run). Για παράδειγμα, μια στέγη με άνοδο 5" σε 12" run= $\tan^{-1}$ (5/12) = 26.6 μοίρες.
- Προεξοχή προβολής. Χρησιμοποιείται για να επεκταθεί η γραμμή οροφής για να δημιουργήσετε μια soffit/overhang.
- Gable προβολής. Ο έλεγχος αυτός εμφανίζεται μόνο αν υπάρχει τουλάχιστον ένα αέτωμα στο τέλος της στέγη.
- Κουμπί Προσαρμογή Αποτύπωμα Root. Εάν το αποτύπωμα ενός κτιρίου είναι υπερβολικά πολύπλοκο (π.χ., πάρα πολλές γωνίες), η αυτόματη διαδικασία δημιουργία στέγη στο eQUEST δεν θα είναι σε θέση να δημιουργήσει την στέγη. Αυτό το κουμπί παρέχει πρόσβαση σε μια οθόνη σχεδίασης που επιτρέπει στους χρήστες να απλοποιήσει το σχήμα του αποτυπώματος της οροφής (βλέπε επόμενη σελίδα).

3.1.6 Κελύφους του κτιρίου: έθιμο αποτύπωμα στέγη:

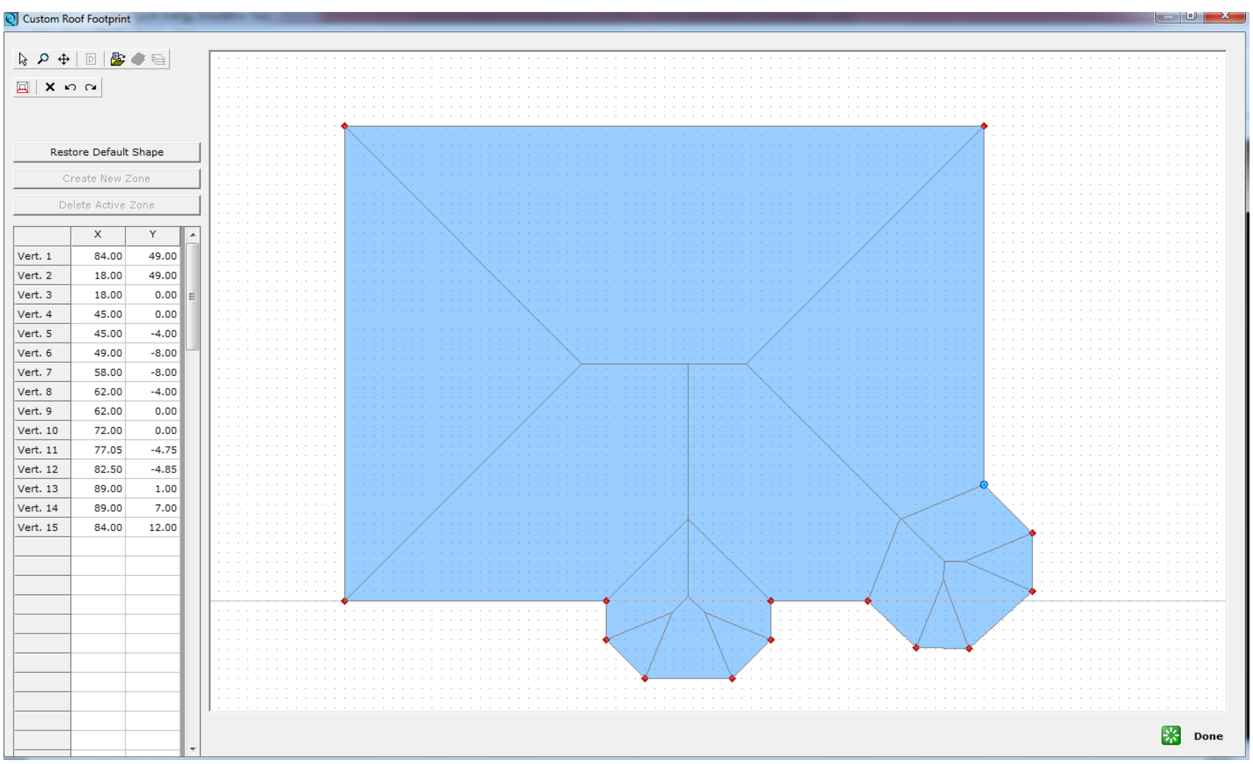


Fig 3.8 Custom roof footprint

Αυτή η οθόνη χρησιμοποιείται για να απλοποιήσει τα σχέδιο οροφής για επικλινείς στέγες που σχετίζονται με κτιριακό συγκρότημα κάλυψης .Κατά την είσοδο αυτή την οθόνη, το πολύγωνο αποτύπωμα στέγη εμφανίζεται σε μπλε χρώμα. Επιλέξτε οποιαδήποτε κορυφή του υφιστάμενου αποτυπώματος στέγη πολύγωνο με αριστερό κλικ. Στο χρώμα της επιλεγμένης κορυφής θα εμφανιστούν είτε ως κυανό (γαλάζιο) ή ανοικτό κίτρινο. Μεταφορά και απόθεση ενός μπλε αντιγράφου στην κορυφή. Μεταφορά και απόθεση ενός κίτρινο στην κορυφή μετακομίζει (κινήσεις) την κορυφή. Εναλλαγή του χρώματος της ενεργού κορυφής με ένα κλικ στην κορυφή. Κάντε δεξί κλικ για να σβήστε snap-to-grid, εάν είναι επιθυμητό. Άμεσα επεξεργαστείτε τις συντεταγμένες της κορυφής στο υπολογιστικό φύλλο στο αριστερό, εάν είναι επιθυμητό. Τα λοιπά κουμπιά της γραμμής εργαλείων (όπως φαίνεται στα δεξιά) περιγράφονται παρακάτω .

Pointer, select this tool before selecting a vertex
Zoom in / out, select this tool then left mouse click & stroke vertically to zoom
Pan, select this tool then drag & drop to pan the drawing tablet
Open CAD drawing file, use this to import DWG & DXF files
Drawing selector, click this plus either the zoom or pan buttons to zoom or pan the CAD drawing image (rather than the drawing tablet)
CAD file properties, click this to view/edit the CAD drawing image properties
CAD drawing layers, click this to view/review layers in the CAD drawing (i.e., can be used to turn off unnecessary layers that clutter the image)
View Properties, click this to edit the view properties, e.g., turn off or adjust snap-to-grid
delete button, use this to delete the currently active item
undo / redo, for use with drawing changes

3.1.7 Ζώνη ονόματα και τα χαρακτηριστικά:

Στις επόμενες δύο εικόνες βλέπουμε χάρτη του σπιτιού που δείχνει τα δωμάτια του ,στη πρώτη βλέπουμε το χάρτη που δόθηκε απ τους αρχιτέκτονες στο Καναδά και βλέπουμε της ονομασίες που έχουν δώσει σε κάθε δωμάτια. Στη περίπτωση μας κάναμε κάτι παρόμοιο ,και ονομάσαμε κάθε δωμάτιο ,που πραγματικά είναι ξεχωριστή zone στο πρόγραμμα eQUEST ,(Π.Χ : Entrance ,office ,kitchen , κτλ).
Το επόμενο πράγμα που μπορούμε να κάνουμε σ αυτή τη σελίδα είναι να διαλέξουμε για κάθε zone αν θα έχει θέρμανση η όχι ,η αν θα θερμαίνεται με άλλο σύστημα θέρμανσης. Στη περίπτωση μας , όλα τα δωμάτια θερμαίνονται με το ίδιο τρόπο , εκτός απ το Garage , που δεν έχει καθόλου θέρμανση.

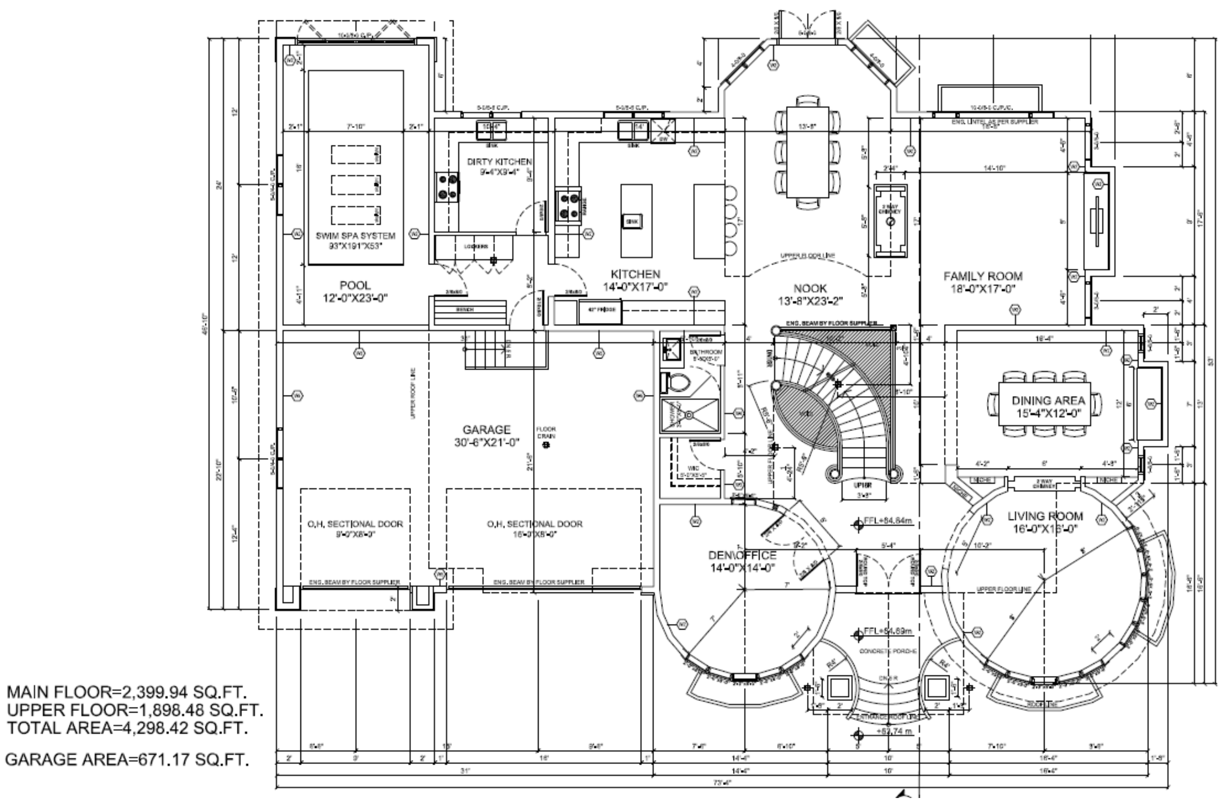


Fig 3.9 Zone names and characteristics as given by engineers (2)

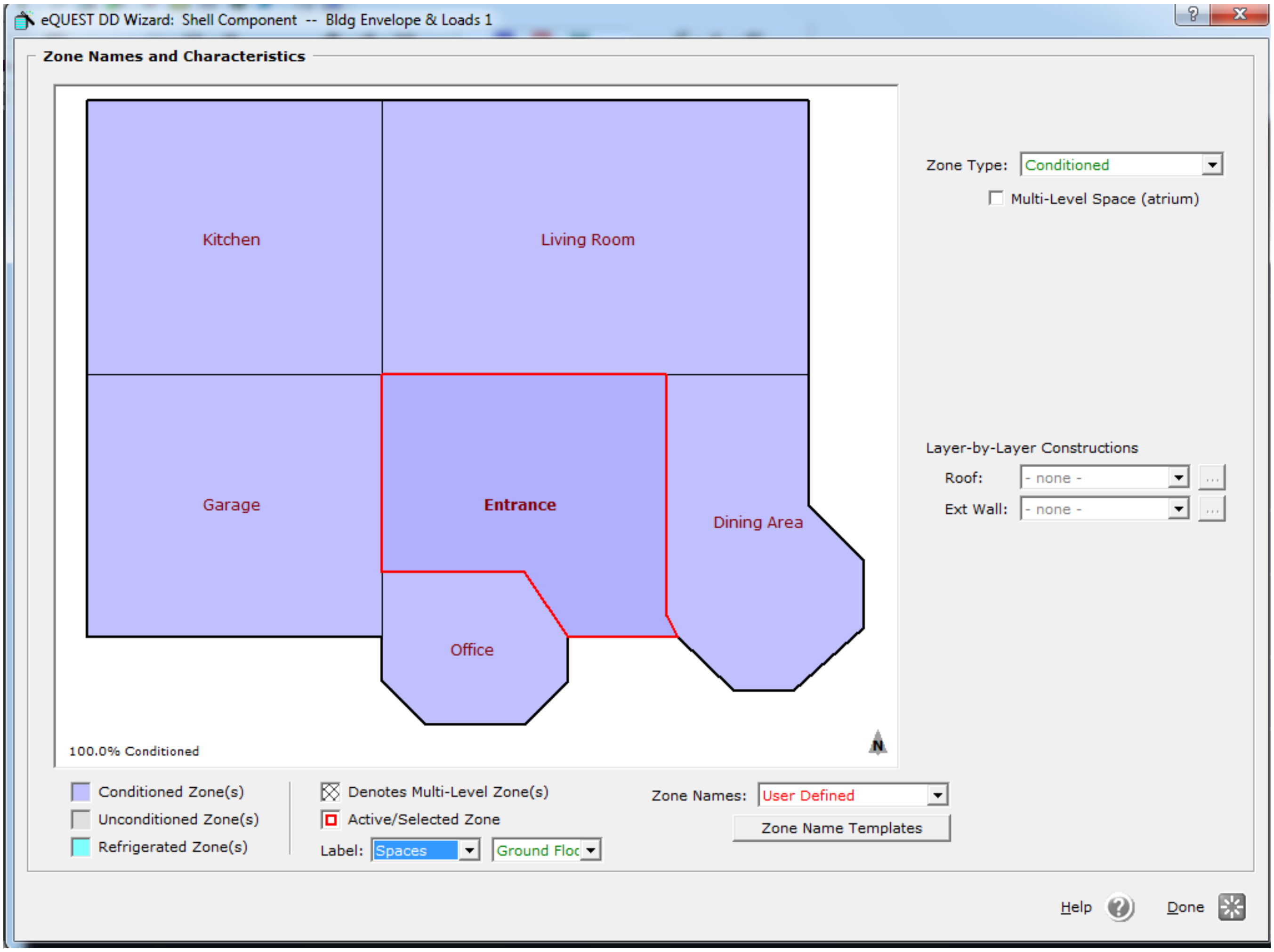


Fig 3.10 Zone names and characteristics as drawn on eQUEST

3.1.8 Κατασκευή του κτιριακού κελύφους:

Σε αυτό το σημείο διαβάζουμε τη κατασκευή των τοίχων και το πάτωμα layer by layer. Με αυτό το τρόπο γίνεται ο σχεδιασμός του κέλυφος, όπου χρησιμοποιήσαμε τα στοιχεία που δόθηκαν από τους αρχιτέκτονες του Καναδά (*Fig.3.13 , 3.14 , 3.15)*, για να φτιάξουμε τους τοίχους και το πάτωμα layer by layer , και βάλαμε κάθε υλικό όπως είναι στη πραγματικότητα ,και βάλαμε και το αντίστοιχο πάχος σε κάθε υλικό .
Με αυτό το τρόπο μπορούμε να παίξουμε με το πάχος και τη ποιότητα του κάθε μετάλλου για να καταφέρουμε τη καλύτερη μόνωση του κτιρίου. Έτσι μειώνονται οι απώλειες θερμότητας του κτιρίου.

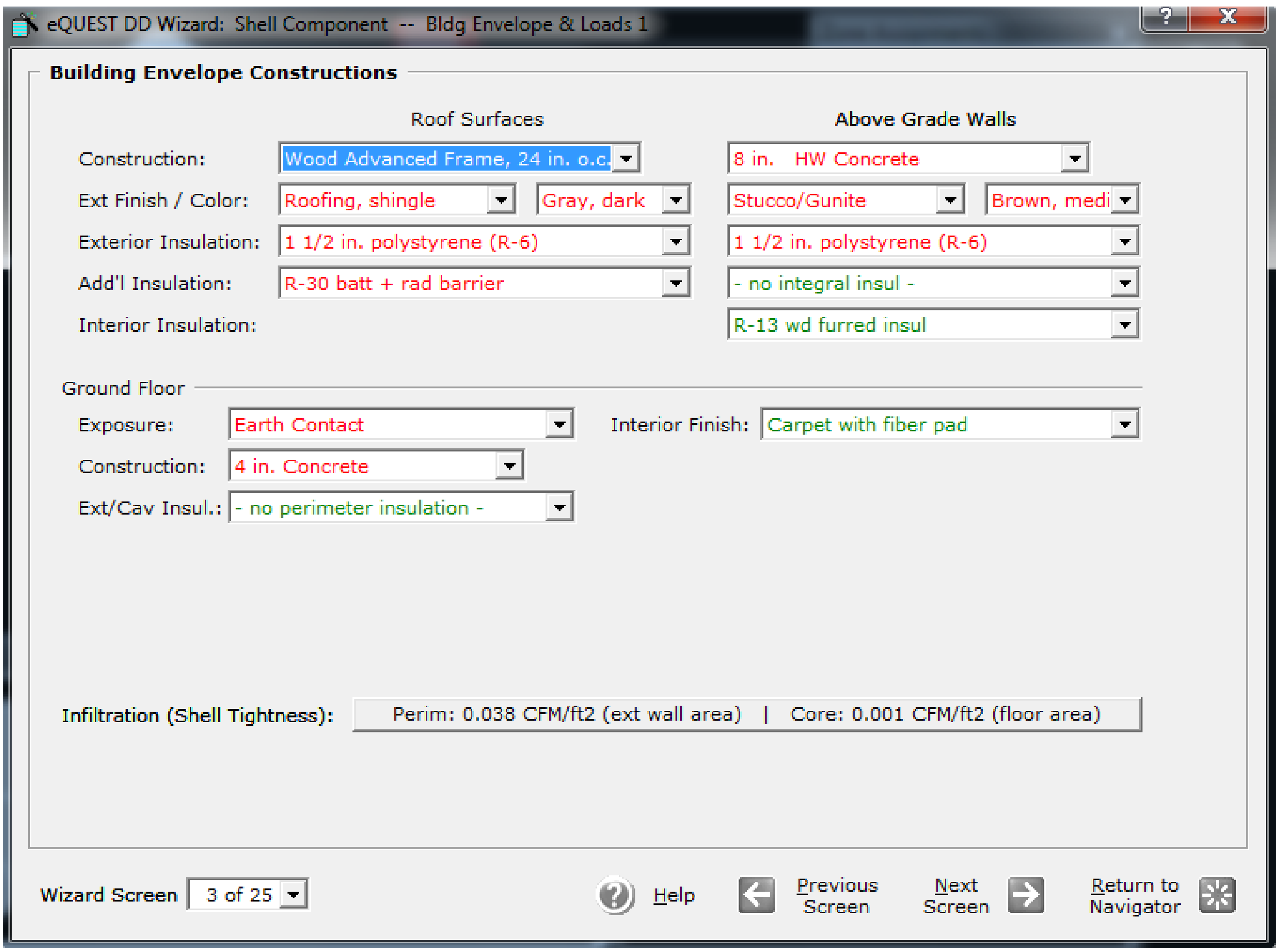


Fig 3.12 Building envelope constructions

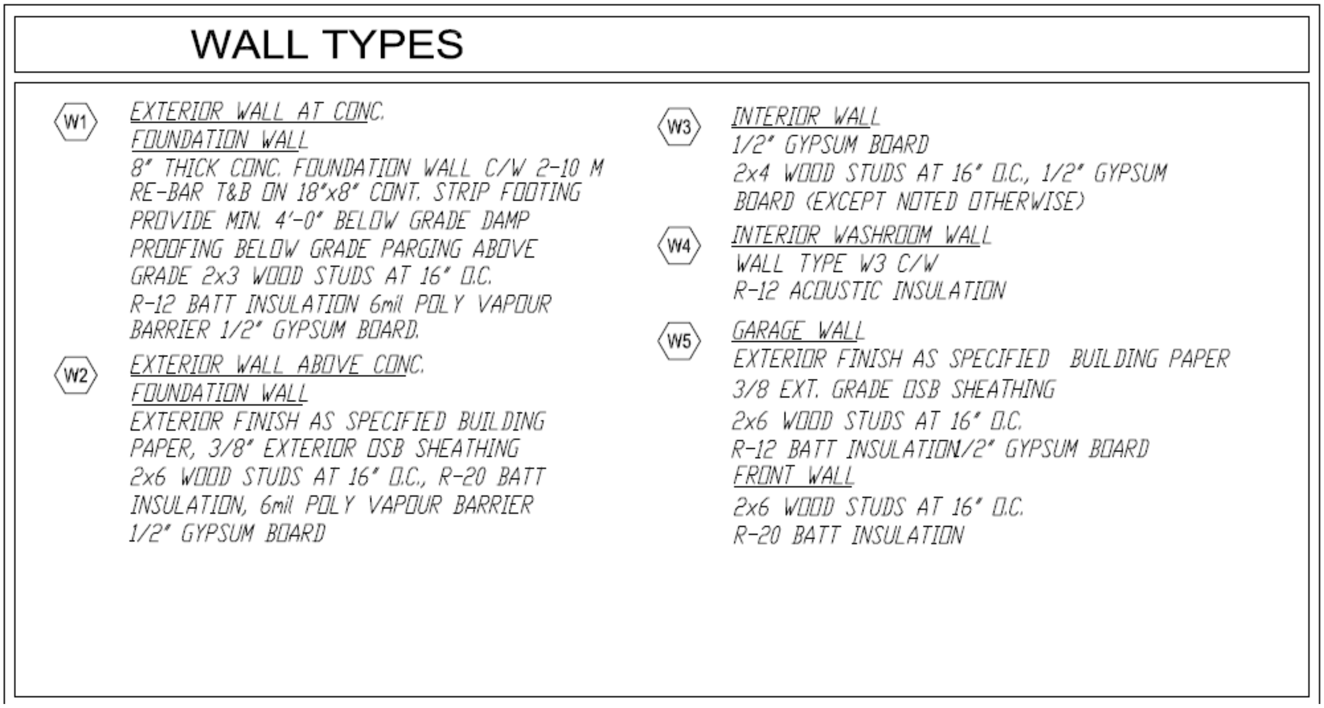


Fig 3.13 Wall types as given by engineers (2)

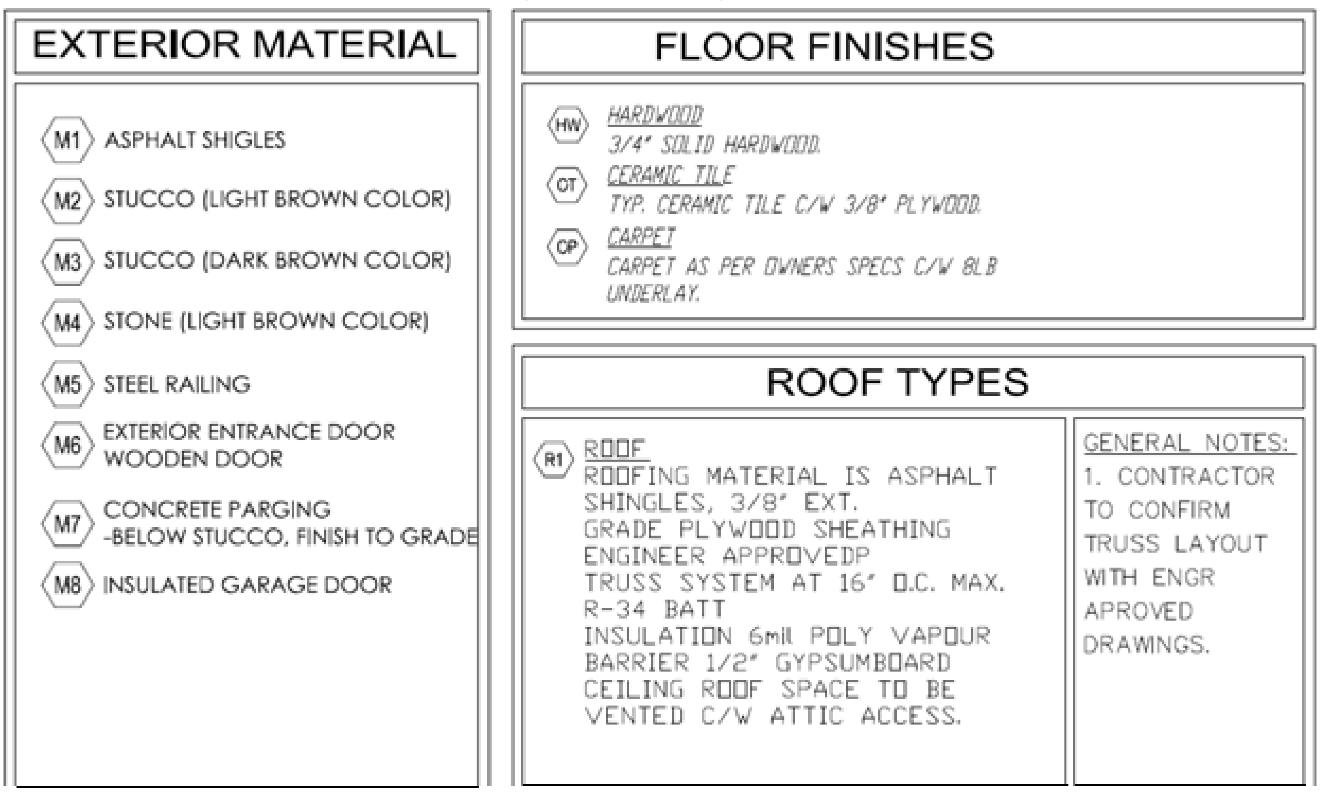


Fig 3.14 Exterior, Floor and Roof material as given by engineers (2)

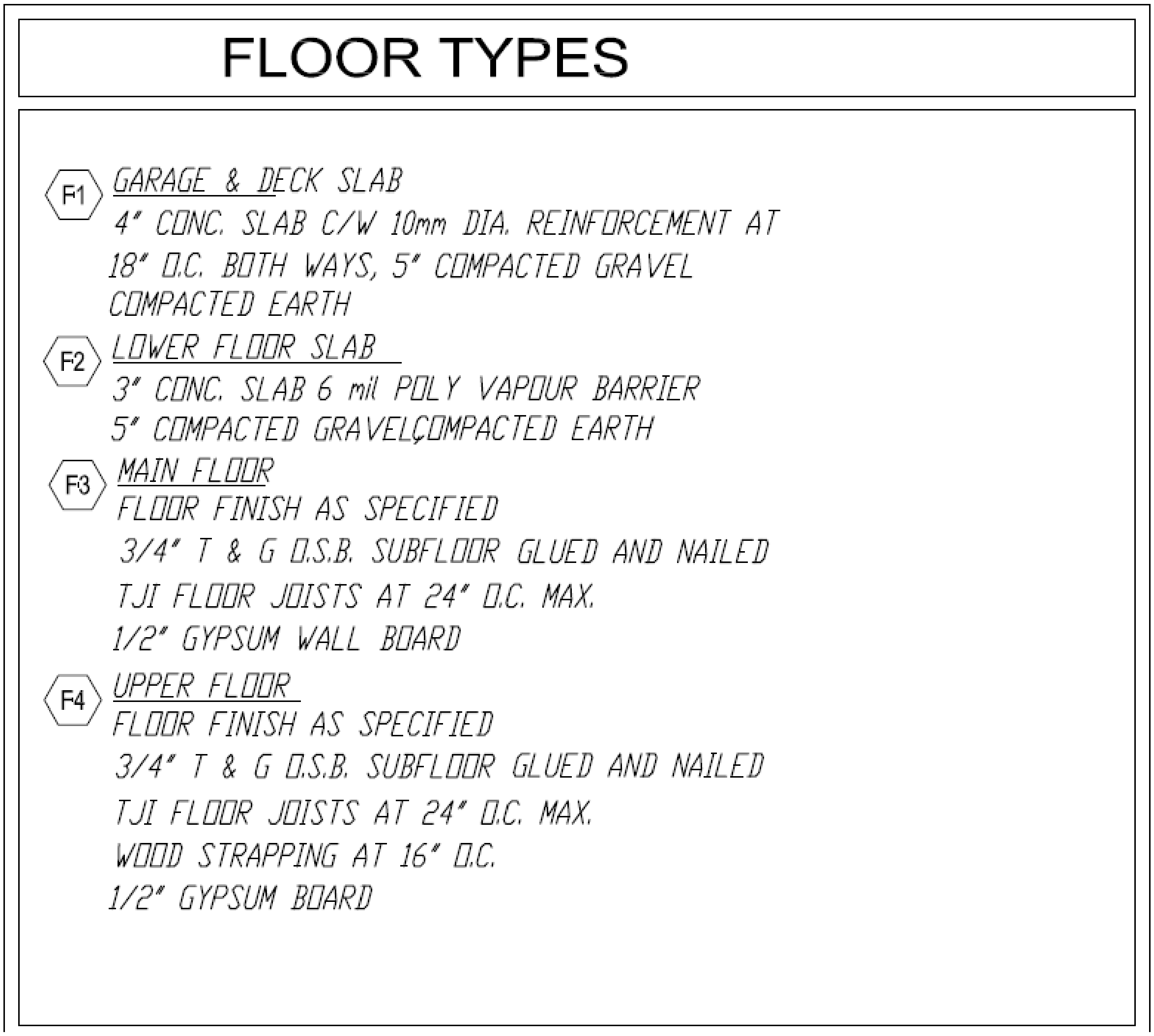


Fig 3.15 Floor type as given by engineers (2)

3.1.9 Κατασκευή Εσωτερικό κτιρίου:

Στη επόμενη εικόνα βλέπουμε πως κατασκευάζουμε το εσωτερικό κομμάτι του κτιρίου , από τους εσωτερικούς τοίχους και το πάτωμα . Βάζουμε τα υλικά με τον ίδιο τρόπο που τα βάζαμε και προηγουμένως στο εξωτερικό κομμάτι . Τα υλικά τα που χρησιμοποιούνται είναι αυτά που δόθηκαν απ τους αρχιτέκτονες (*Fig.3.13 , 3.14 , 3.15).*

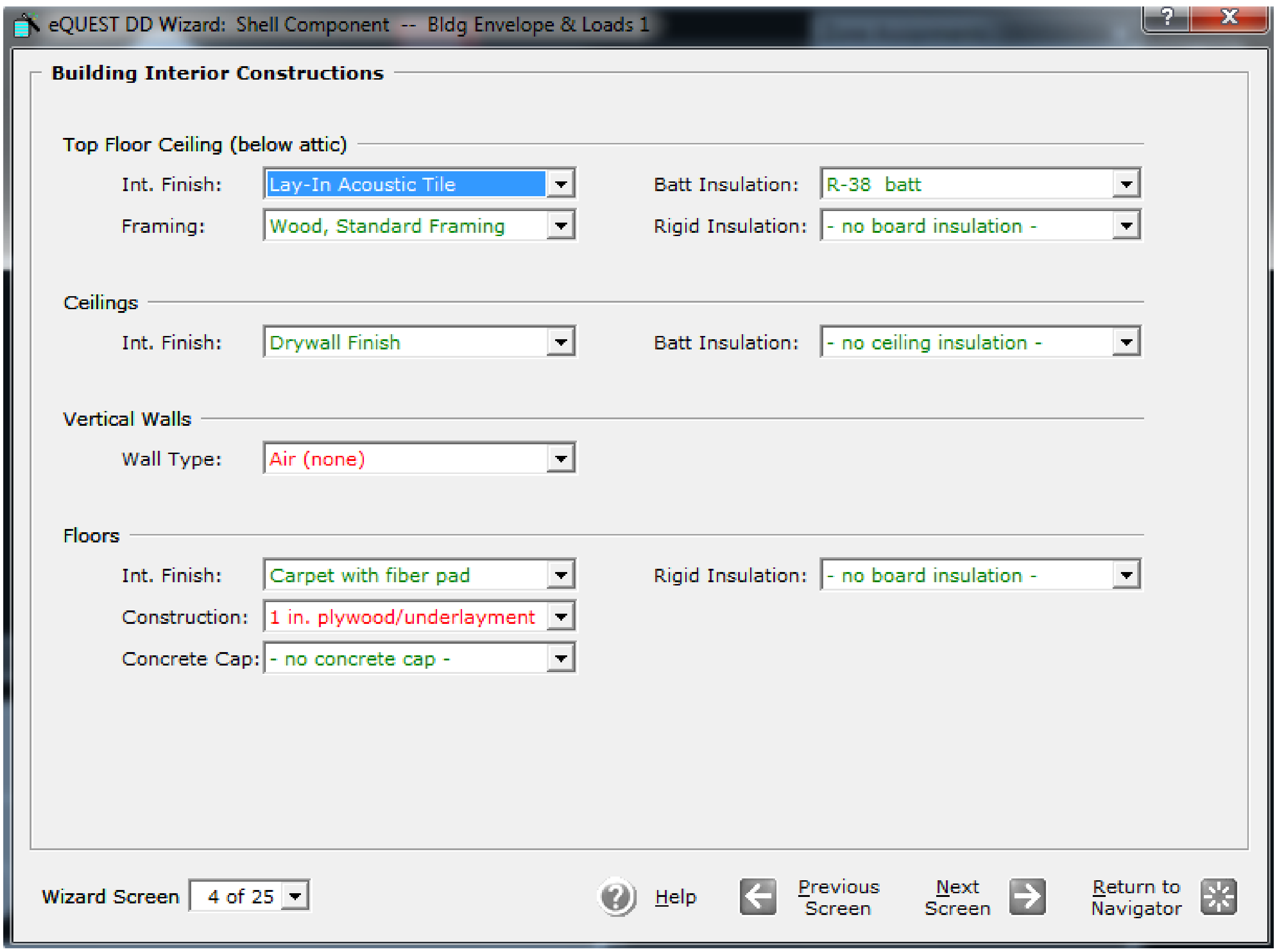


Fig 3.16 Building interior constructions on eQUEST

3.1.10 Εξωτερικές πόρτες:

Βλέπουμε στο *(Fig.3.17)* με ποιο τρόπο βάζουμε της εξωτερικές πόρτες του κτιρίου. Μπορούμε να διαλέξουμε 3 διαφορετικούς τύπους πόρτας και τις τοποθετούμε στις πλευρές που θέλουμε *(Fig.3.17)* . Επομένως διαλέγουμε το ύψος και πάχος της πόρτας και από τι υλικό είναι το καθένα.

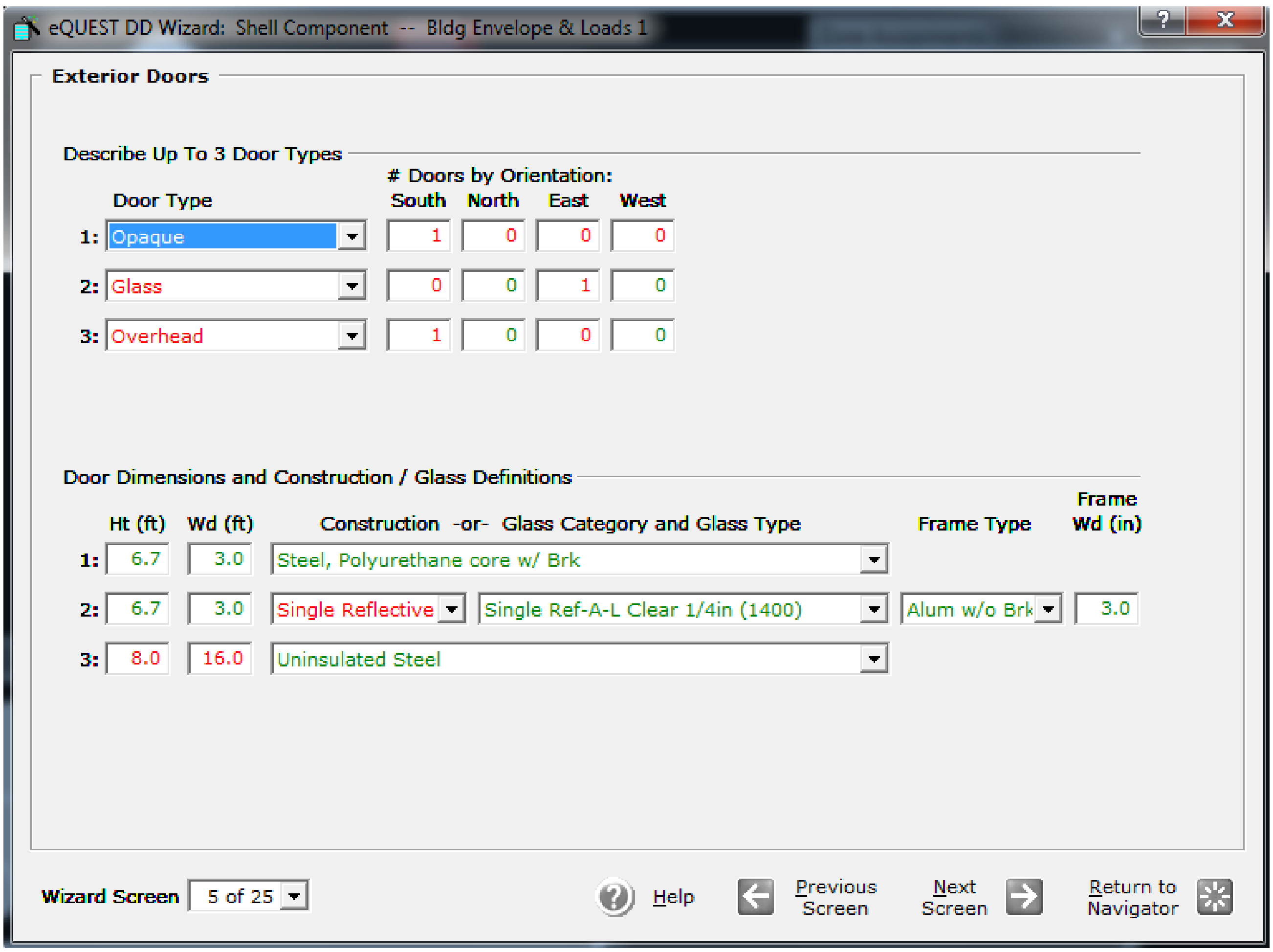


Fig 3.17 Exterior doors on eQuest

3.1.11 Εξωτερικά παράθυρα:

Με τον ίδιο τρόπο που φτιάξαμε τις πόρτες στη προηγούμενη ενότητα ,φτιάχνουμε τα παράθυρα και βάζουμε τα υλικά τους. Επίσης επιλέγουμε τη πλευρά που είναι τοποθετημένοι οι υαλοπίνακες (Fig 3.18).

Επίσης εδώ μπορούμε να βάλουμε στα παράθυρα σκίαση, όπως παρουσιάζονται στο (Fig 3.19).

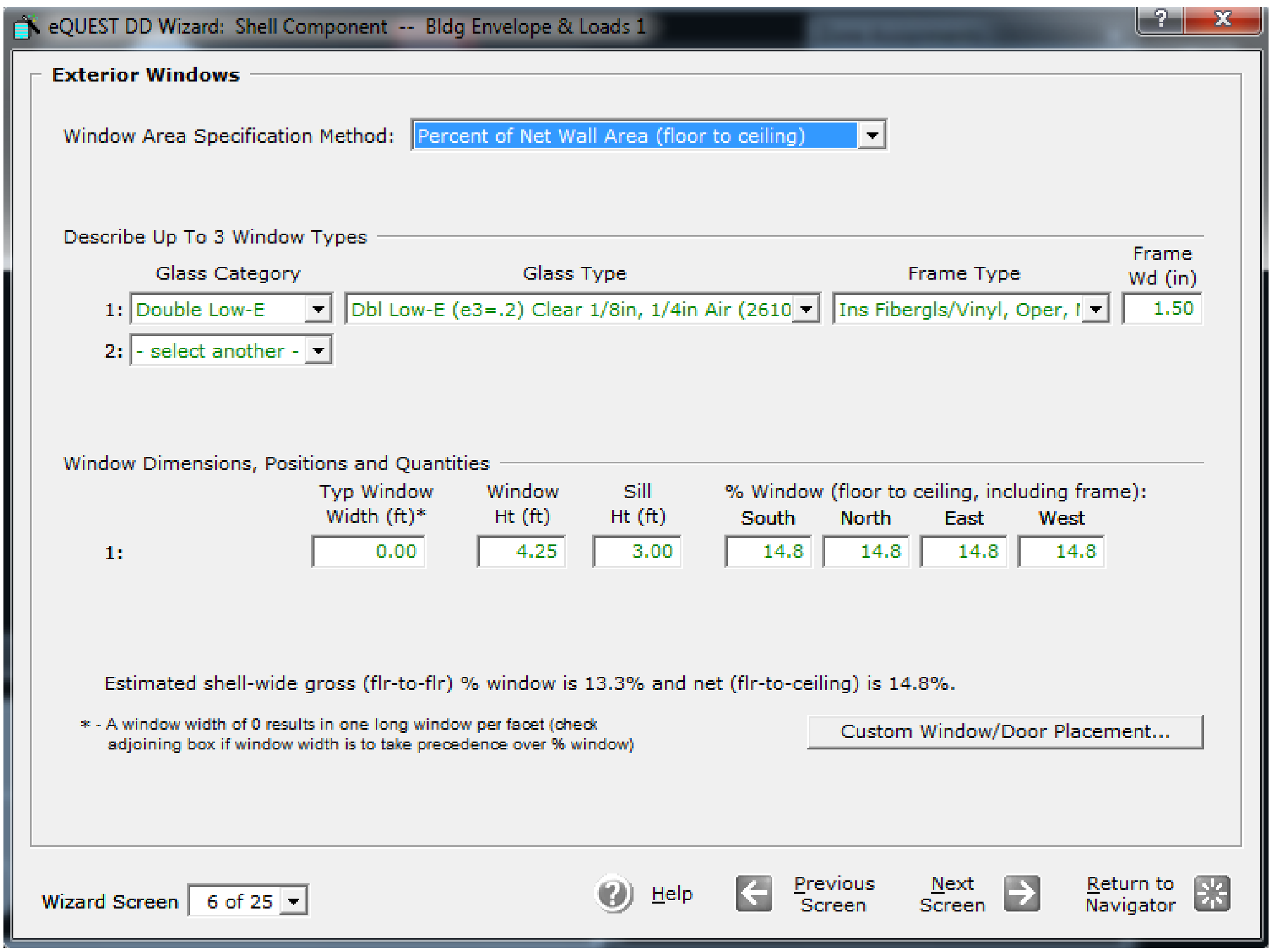


Fig 3.18 Extirior windows.

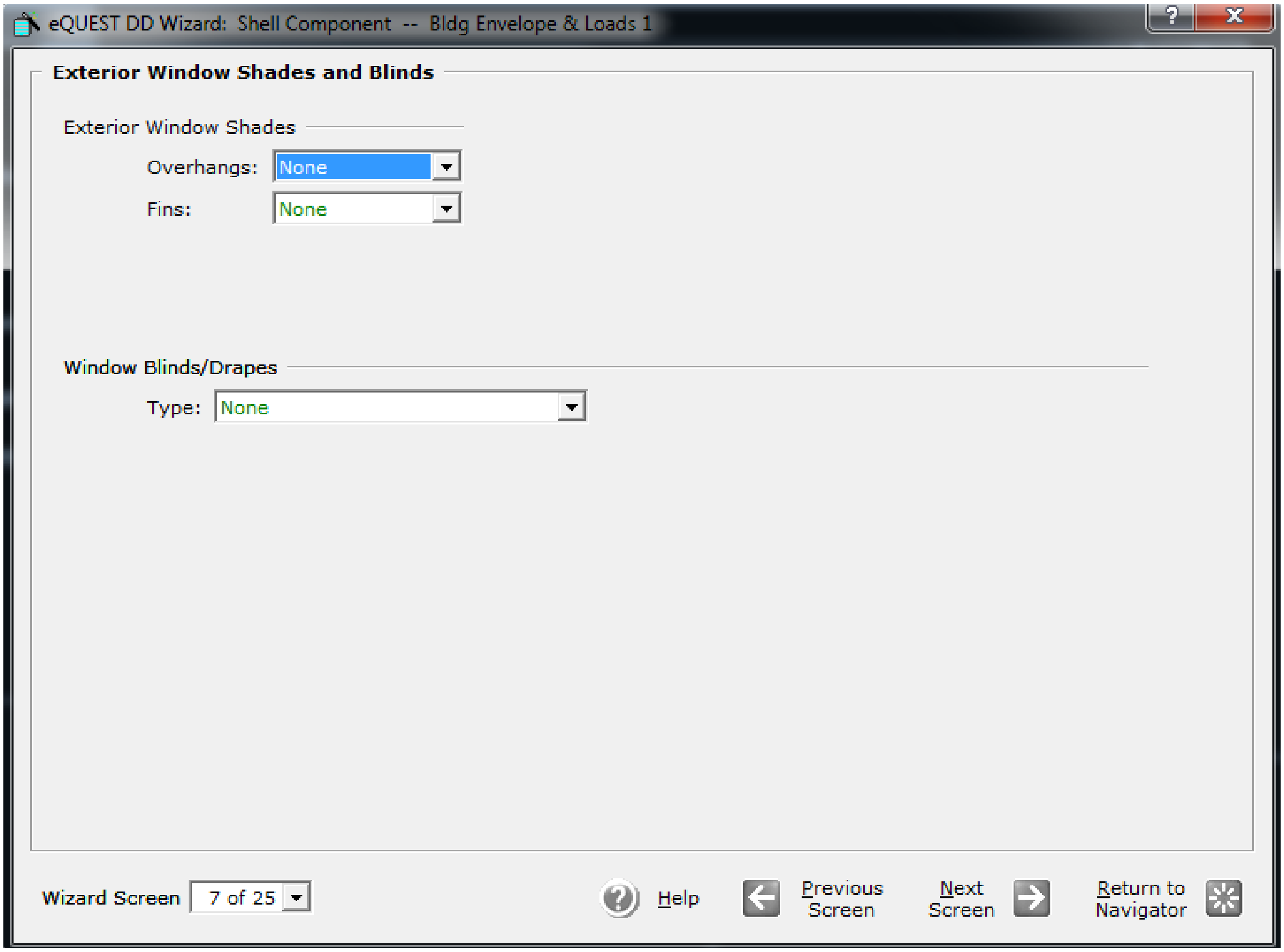


Fig 3.19 Exterior window shades and blinds on eQUEST.

3.1.12 Φεγγίτες οροφής :

Εχουμε τη δυνατότητα να βάλουμε φεγγίτες στο κτίριο μας.

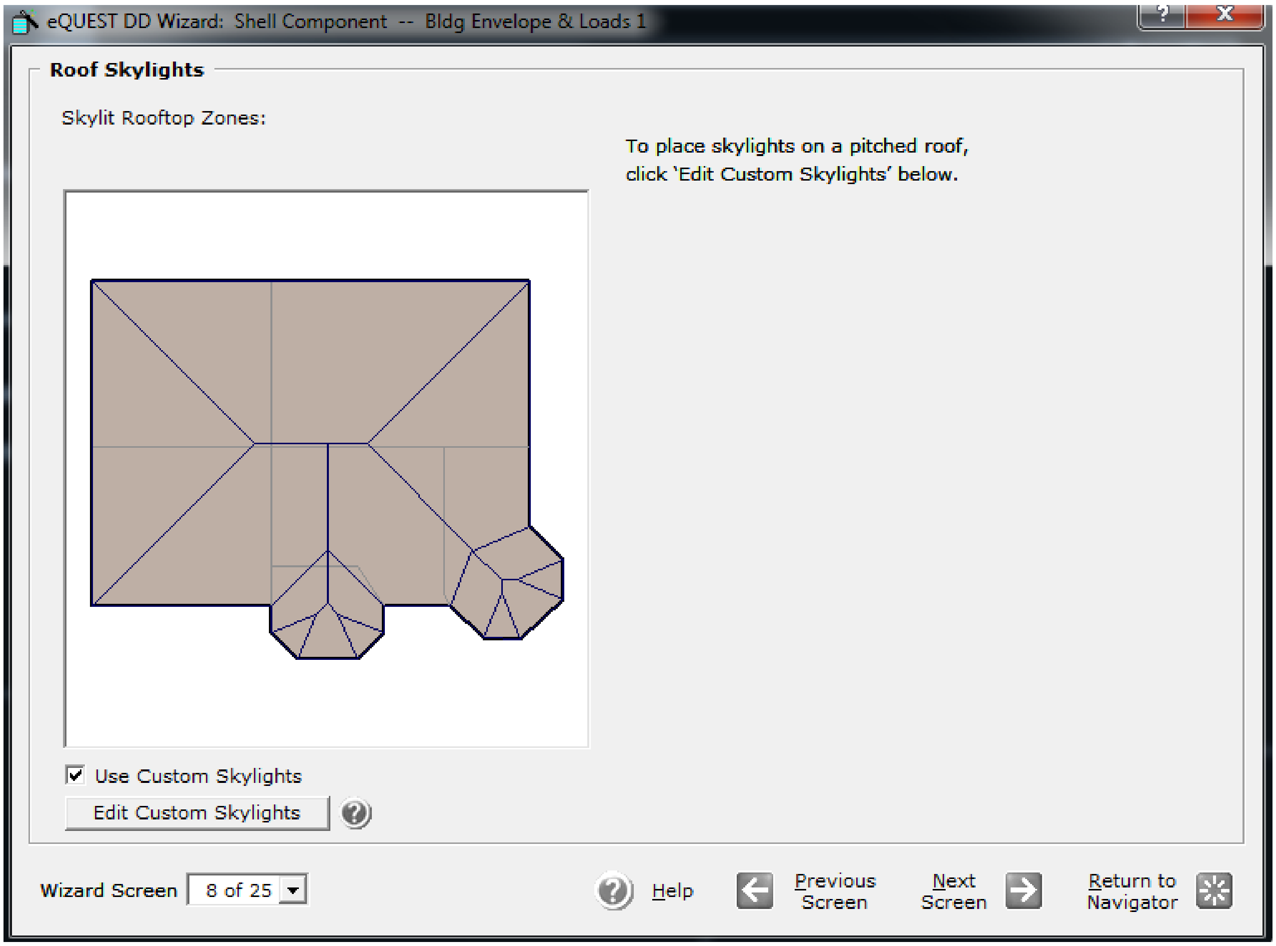


Fig 3.20 Roof skylights on eQUEST.

3.2 Detailed interface :

Μια συνολική αναθεώρηση του λεπτομερούς Interface του Equest είναι πέρα από το πεδίο της παρούσας ανάλυσης. Ωστόσο, μια σύντομη περιγραφή θα βοηθήσει το νέο χρήστη να χρησιμοποιήσει κάποιες λειτουργίες του Λεπτομερούς Interface, π.χ., να επιβεβαιώσει 2-D και 3-D γεωμετρία.

Πολλά σημαντικά κουμπιά βρίσκονται στην επάνω γραμμή εργαλείων του Λεπτομερούς Interface. Αυτά είναι εν συντομία σε αυτή την ενότητα. Περισσότερες πληροφορίες σχετικά με αυτά που βρίσκονται στο τμήμα γρήγορης εκκίνησης αυτού του οδηγού.

Σημαντική Σημείωση: Αν και είναι δυνατό να επεξεργαστείτε οποιαδήποτε ή όλες τις εισόδους του μοντέλο εντός του Detailed Interface, αυτό δεν συνιστάται για αρχάριους χρήστες. Σημειώστε ότι οι όποιες αλλαγές έγιναν στο πλαίσιο του Detailed Interface δεν κοινοποιούνται πίσω στους Wizard ή στην EEM Wizard (δηλαδή, δεν αποθηκεύονται στο αρχείο INP).

Οι αλλαγές που έγιναν στο Λεπτομερές Interface θα χαθούν και το αρχείο INP θα αντικατασταθεί από τις εισόδους που περιέχονται μέσα στο SD ή DD Wizard. Ομοίως, η EEM οδηγός μπορεί να επικοινωνεί μόνο με την SD & DD. Οι τυχόν αλλαγές στο Αναλυτικό Interface αγνοούνται από τους χρήστες EEM .

Οι έμπειροι χρήστες θα βρουν πλεονεκτήματα σε μοντέλα επεξεργασίας άμεσα μέσα στο Detailed interface. Για να επεξεργαστείτε το Detailed Interface, οι χρήστες θα πρέπει πρώτα να αλλάξουν τη λειτουργία του Wizard Data Edit στα Detailed Data Edit mode. Αυτό γίνεται από το μενού. Τραβήξτε προς τα κάτω το μενού Mode και επιλέξτε Detailed data edit (βλέπε παρακάτω σχήμα)

Detailed Interface, Mode Menu options

Fig 3.21 Warning message issued when changing from Wizard edit mode to detailed edit mode

Detailed interface

3.3 House maps:

In the next two pages we will see different images of the building, starting with the map given by engineers (*Fig 2.22)*, then a 2D view of the building from eQUEST.
After that we'll see 3D view of the house front-side and back-side as given on maps, and then as simulated on eQUEST.

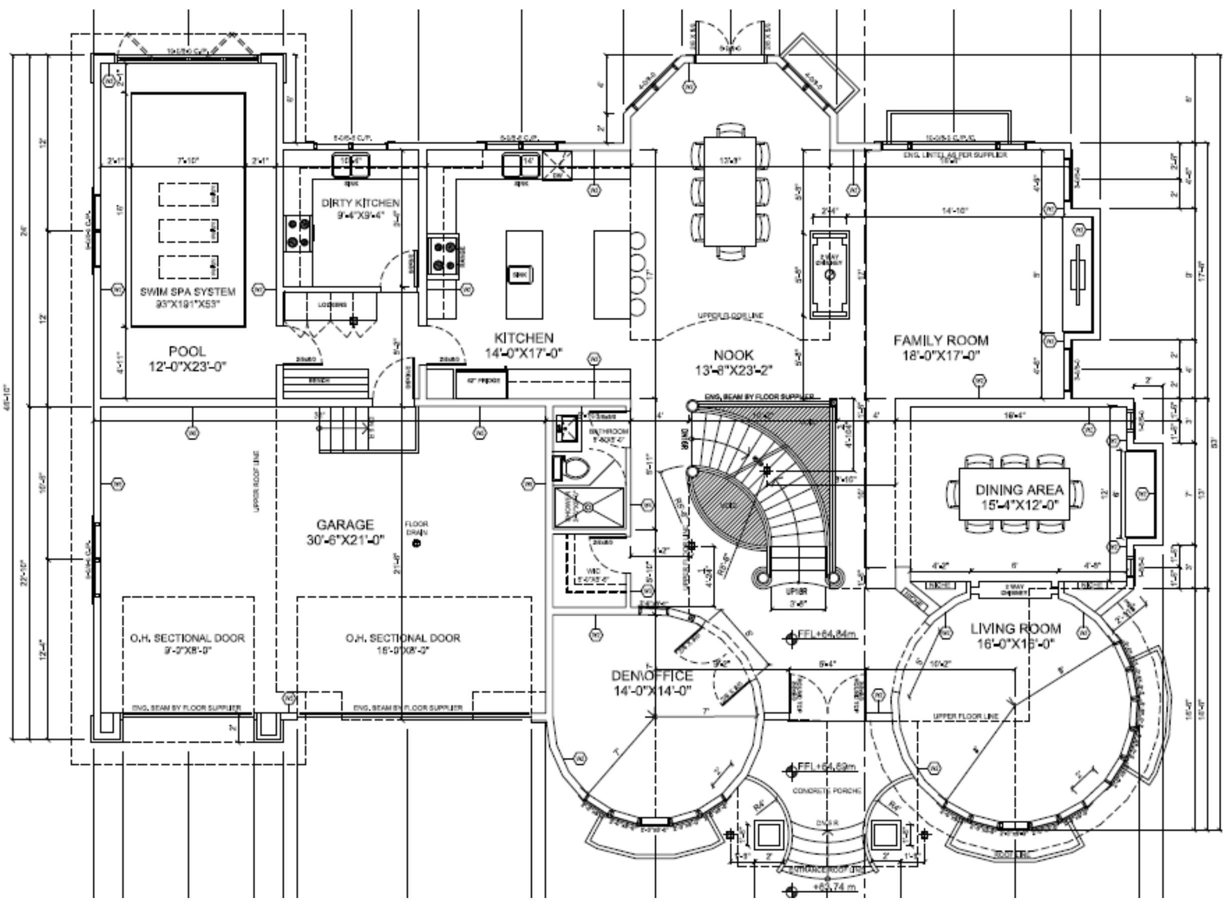


Fig 3.22 Building shell Module, 2D view as given by engineers. (2)

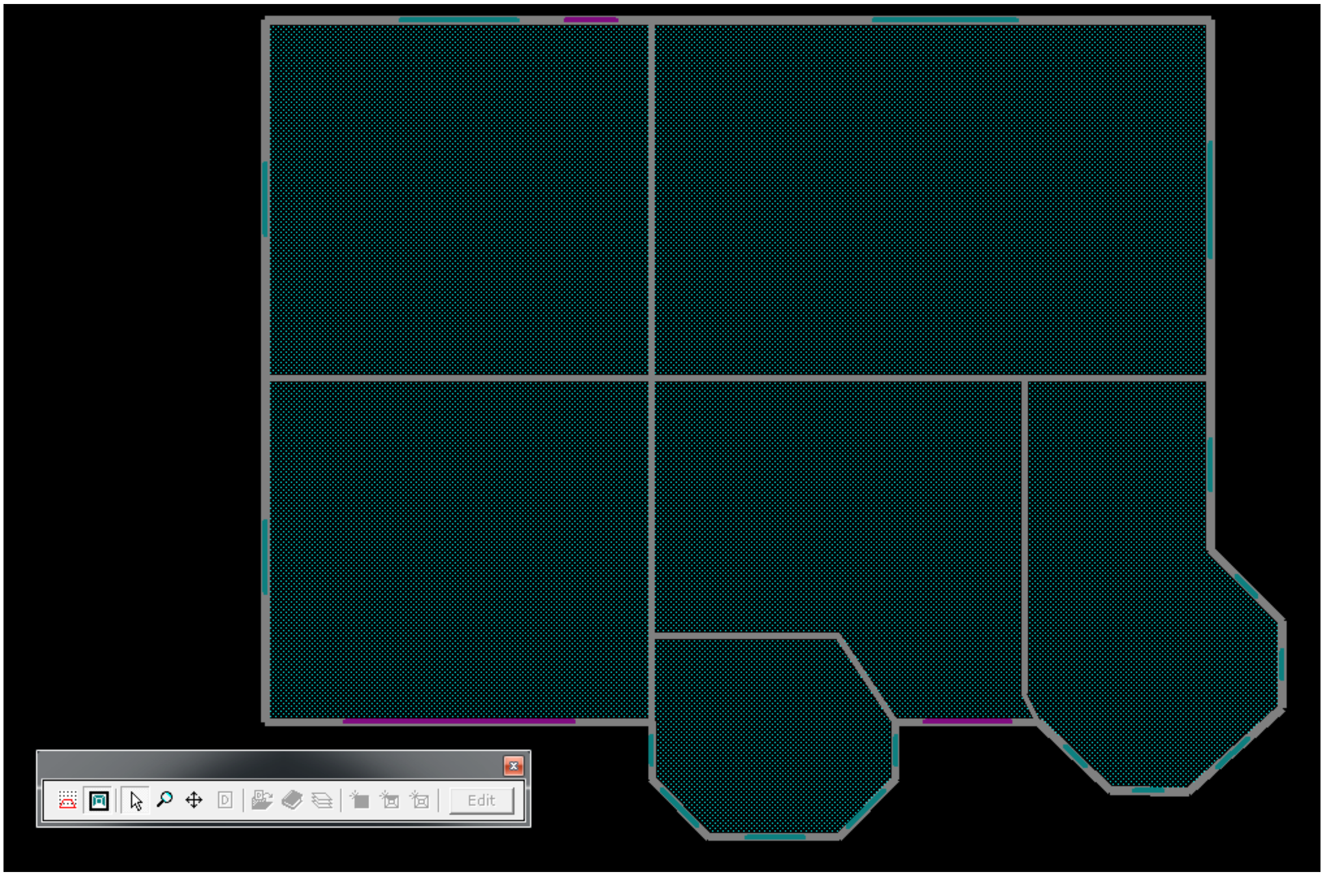


Fig 3.23 Building shell Module, 2D view on eQUEST.

Fig 3.24 Building shell module, 3D view as given by engineers(Front-side). (2)

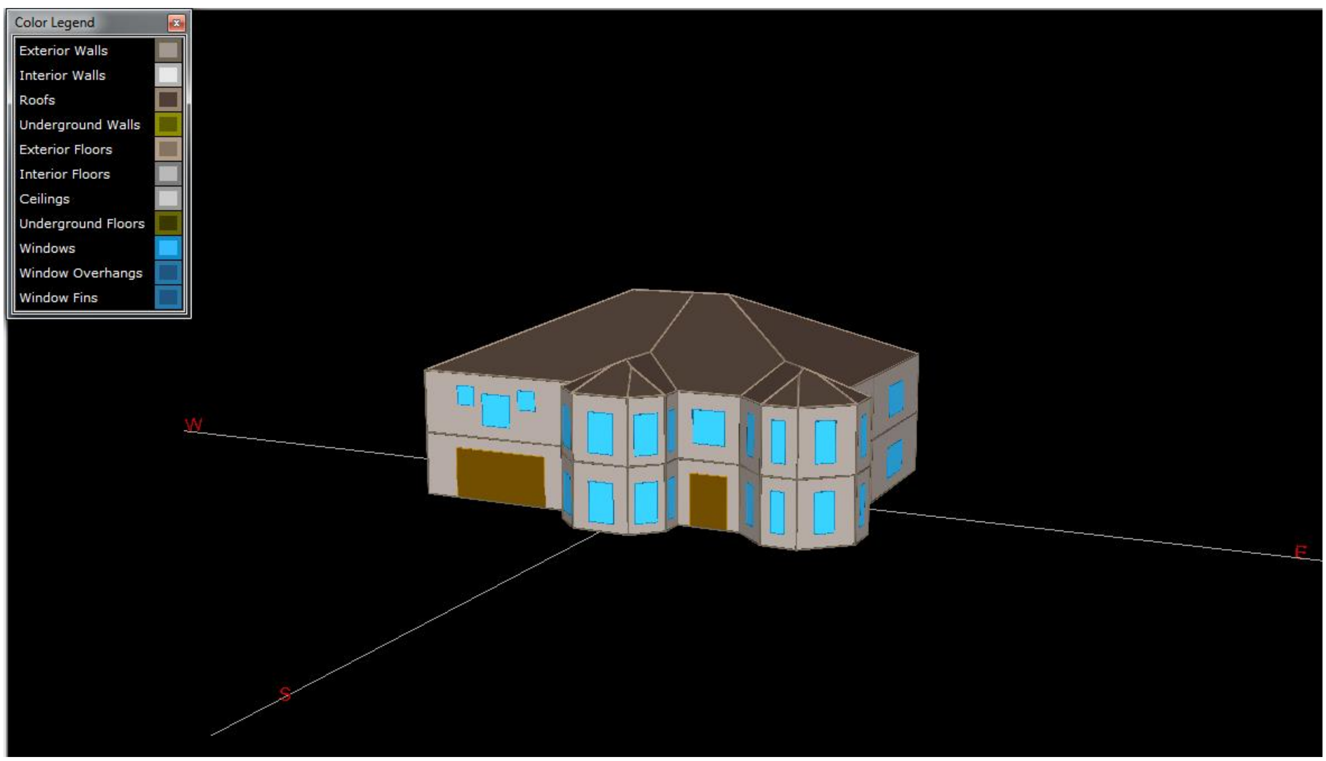


Fig 3.25 Building shell Module, 3D view on eQUEST (Front-side).

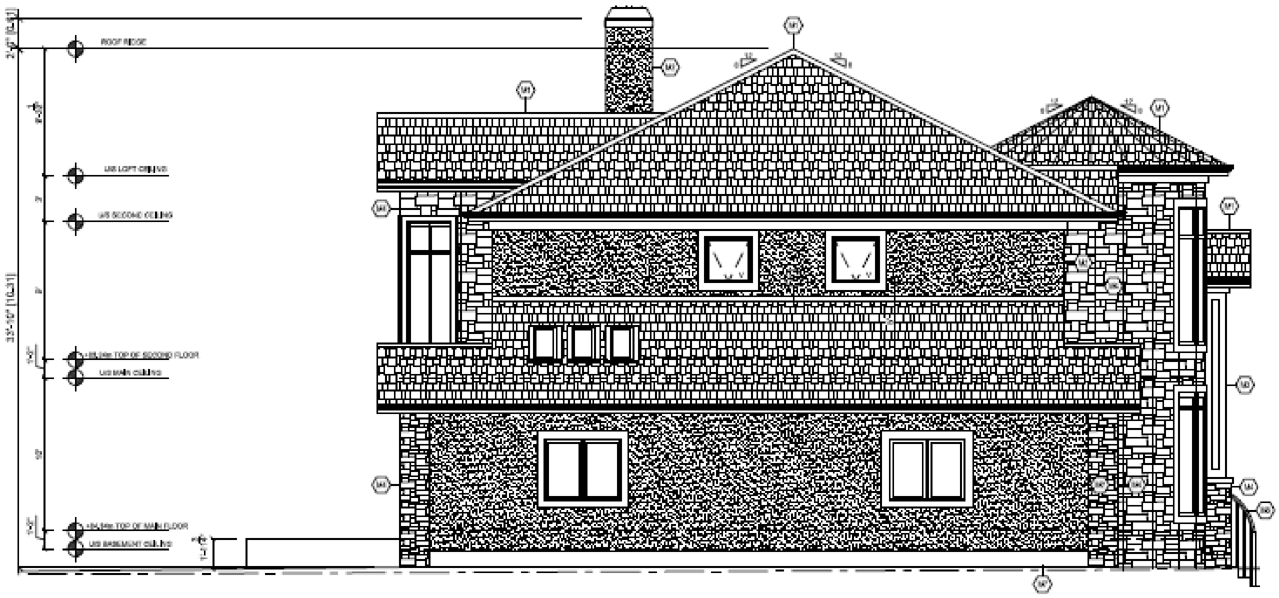


Fig 3.26 Building shell module, 3D view as given by engineers (back-side)

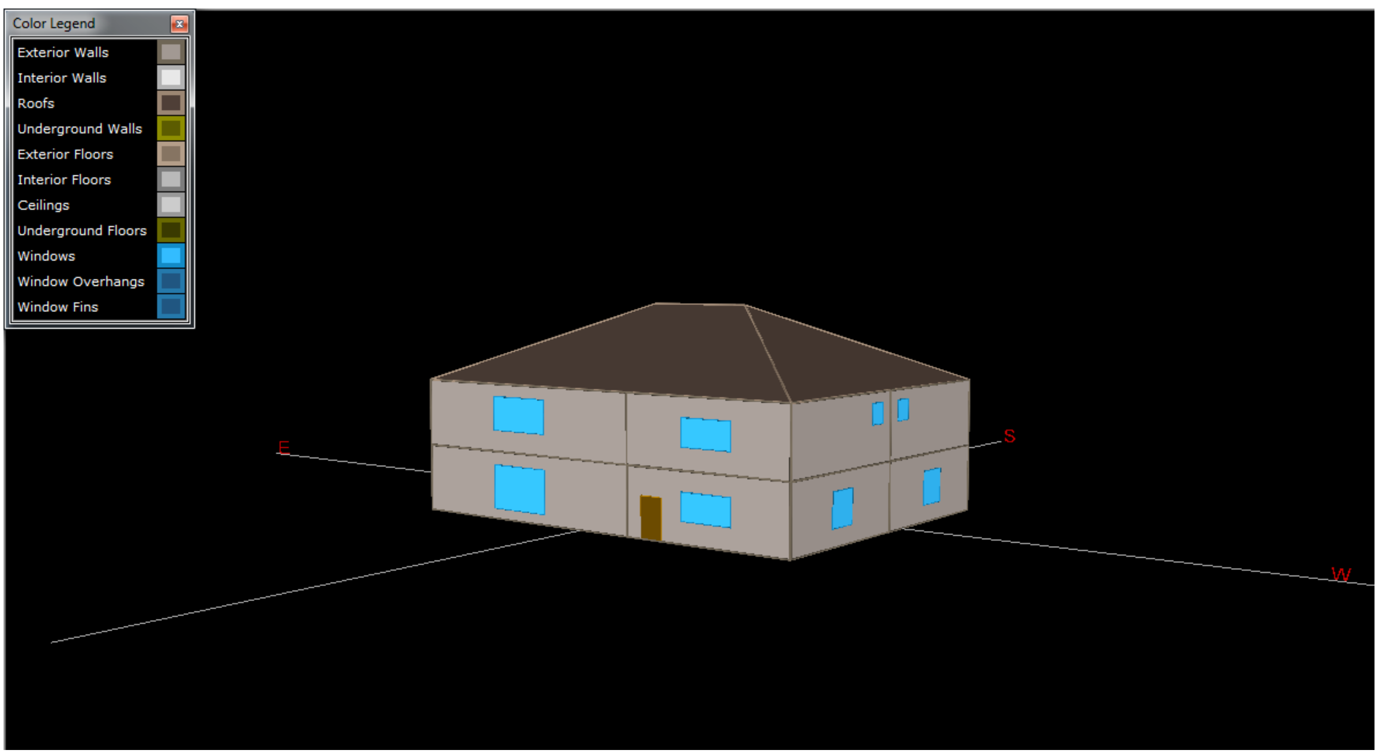


Fig 3.27 Building shell module, 3D view on equest (back-side)

3.4 HVAC sytems :

For the HVAC systems, there are some steps to follow to install the right systems, first of all by clicking on the Water-Side-HVAC button in the navigation bar *(Fig 2.28),* it take us to a page that allow us to choose heating systems that we need for heating the house and heating water, so it gives us a lot of options of boilers, coils, plants etc. to use .So after asking the engineers in Canada about what systems do they use, we came up with the systems shown in *(Fig 2.29)* .
The next step was to choose the right installations that we should use in the house ,so came up with the Floor panel heating coil as shown on (Fig 2.30) ,as was recommended by engineers .
By this combination we got the best heating system for this house in Canada, we can see in the next chapter the consumption of electricity and natural gas was.

Fig 2.28 Navigation bar , HVAC part selected.

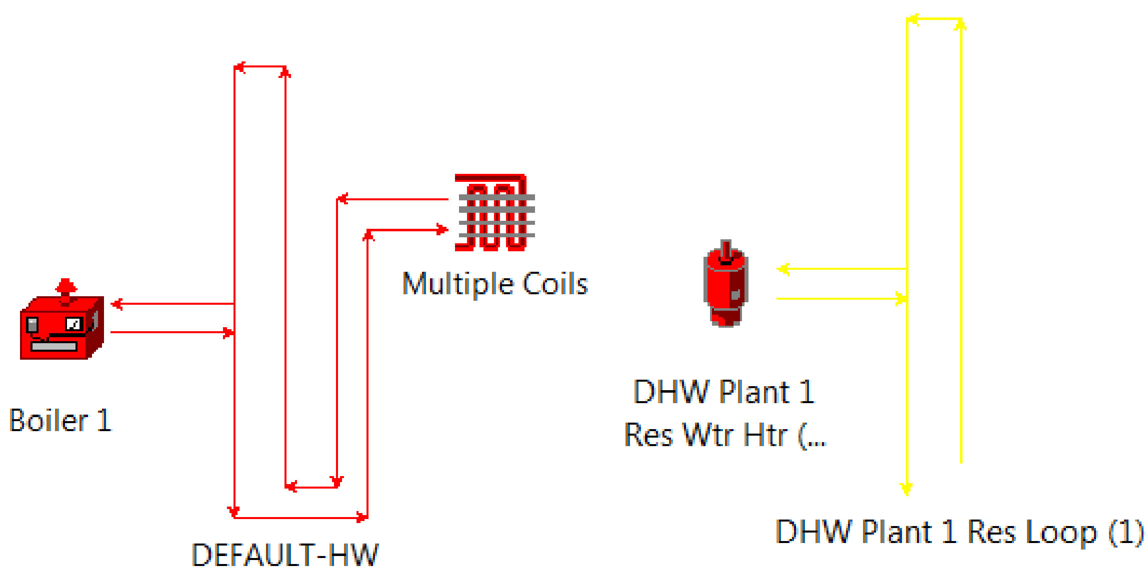


Fig 2.29 Water-side HVAC, on eQUEST.

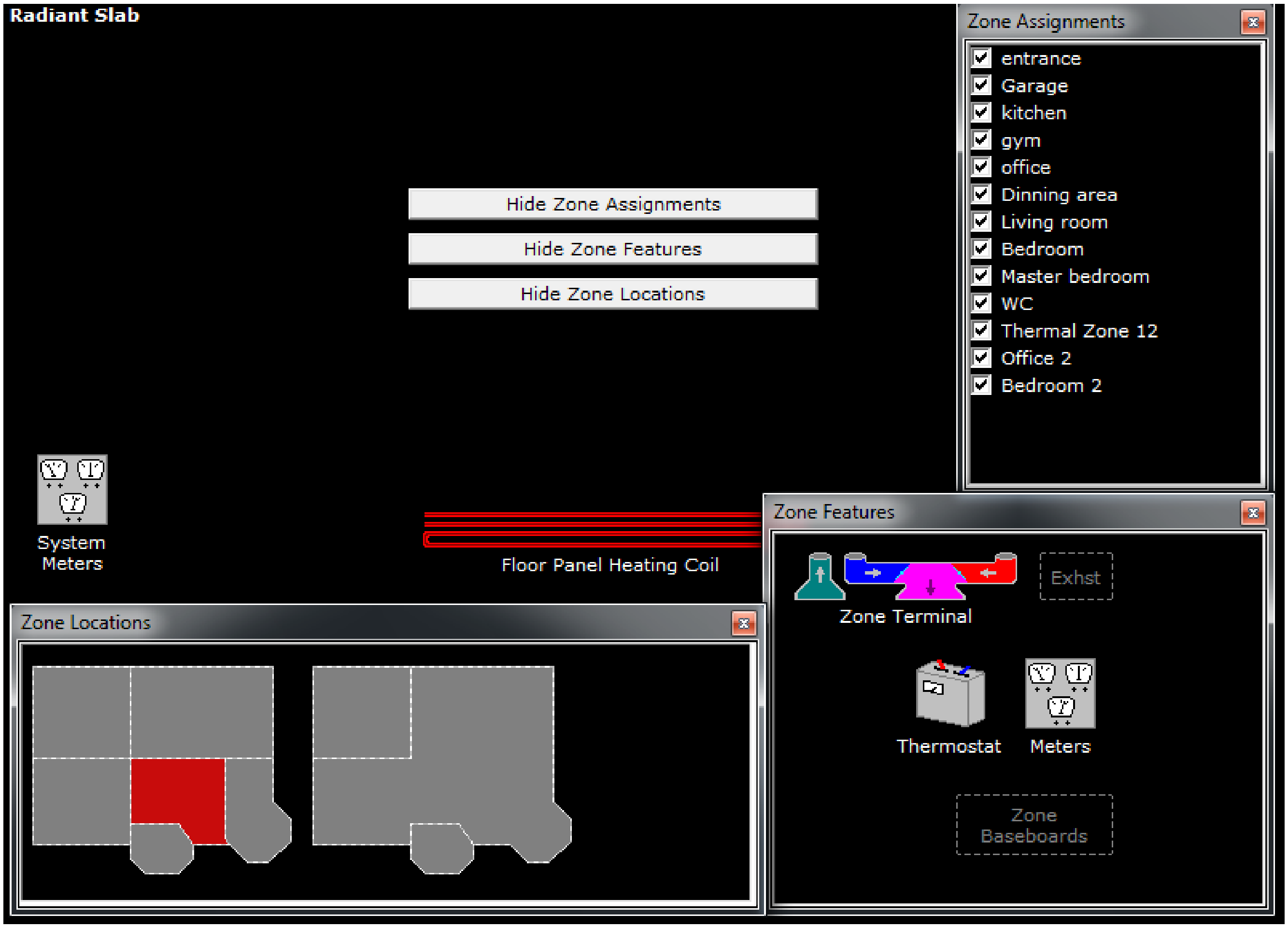


Fig 2.30 *Air-side HVAC, on eQUEST*

4. Energy simulation and results in Canada on eQuest :

4.1 Consumption:

In the next Figure (Fig.4.1) we can see the electric consumption of the house per month as given by eQUEST. And as we can see water heating, misc. equipment and area lightning are the most 3 thing consuming electricity.

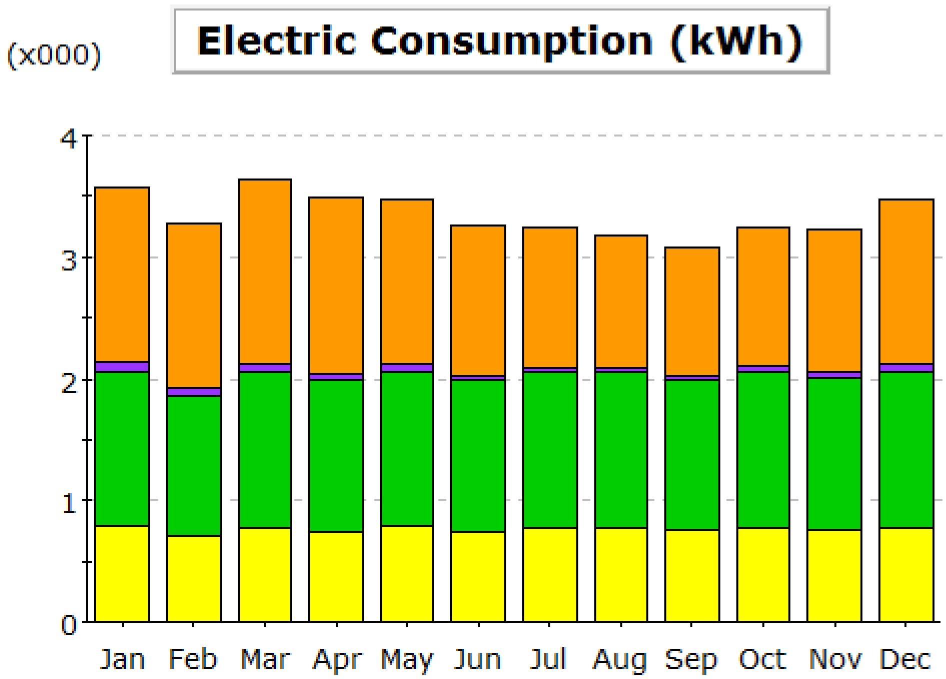


Fig 4.1 Electric consumption of the house

Fig 4.2 Electric uses by color

.

*Table 4.1 Electric consumption per month (KwH*000)*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.44	1.36	1.52	1.45	1.36	1.22	1.14	1.08	1.04	1.14	1.17	1.35	15.27
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	0.07	0.06	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.05	0.06	0.07	0.66
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	1.28	1.16	1.28	1.24	1.28	1.24	1.28	1.28	1.24	1.28	1.24	1.28	15.07
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.78	0.70	0.77	0.75	0.78	0.75	0.78	0.78	0.75	0.78	0.76	0.78	9.17
Total	3.57	3.28	3.64	3.50	3.48	3.25	3.24	3.18	3.07	3.25	3.23	3.47	40.16

In this table (Table 4.1) we can see the electric consumption per month by numbers as given by eQUEST. The most three consumption of electricity are: water heating, area lightning, pumps and aux, and other equipment, in a typical house in Canada.

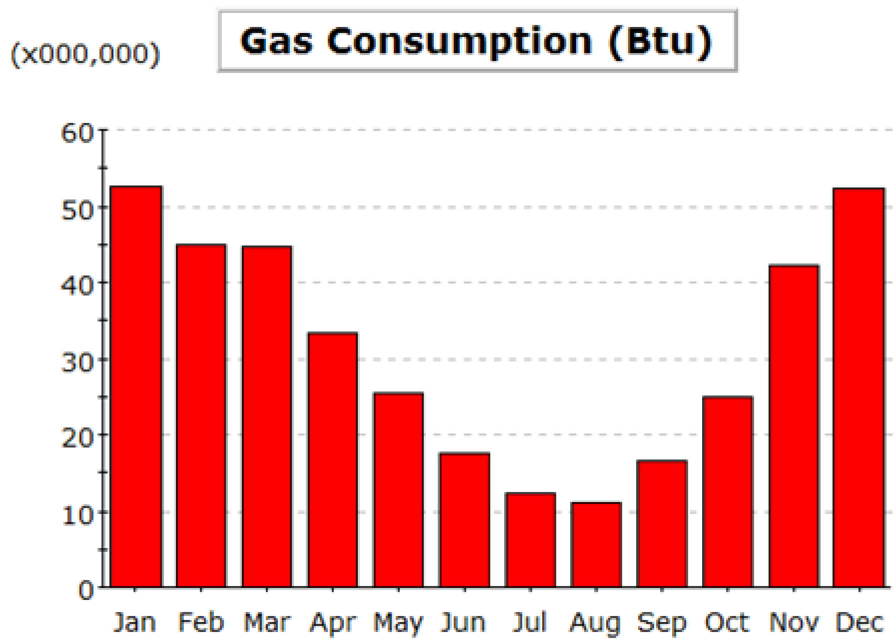


Fig 4.3 Gas consumption of the house per month (Million Btu)

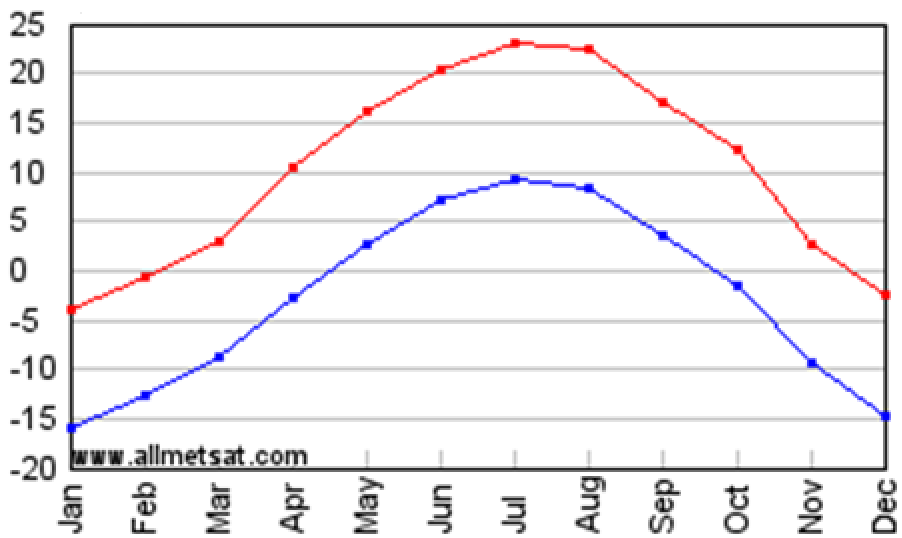


Fig 4.4 Calgary annual temperatures. (3)

As the monthly temperature decreases as the gas consumption increases, that means in July and August where the temperature is high, gas consumption is at it lowest and the opposite in January and December.

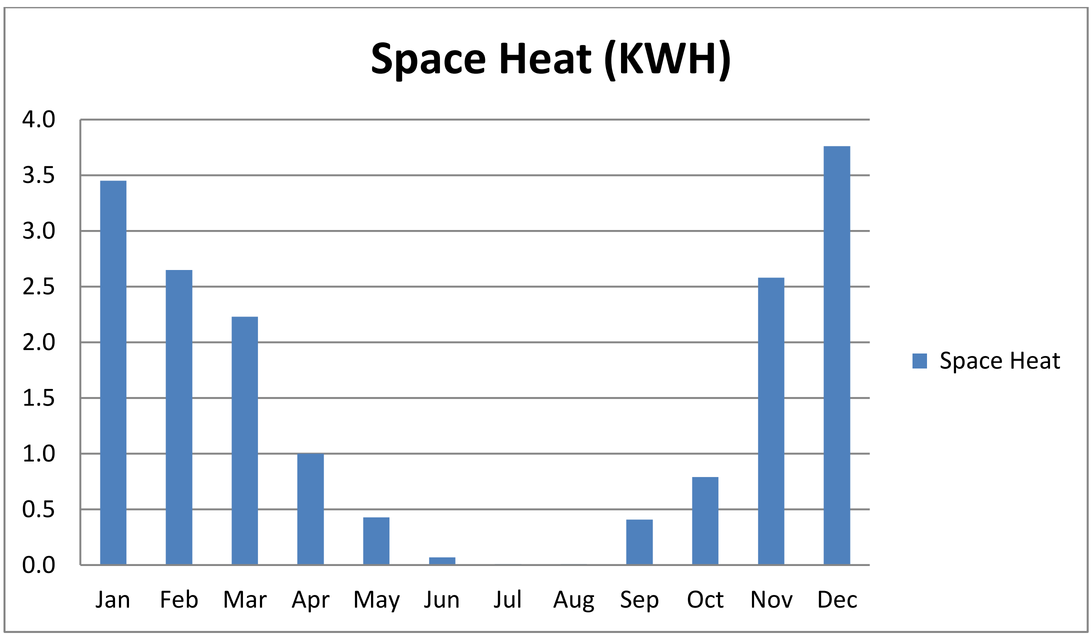


Fig 4.5 Space heat per month (kWh)

Table 4.2 Gas consumption per month (Million Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	52.48	45.03	44.74	33.39	25.55	17.44	12.40	11.13	16.62	25.03	42.14	52.46	378.43
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	52.48	45.03	44.74	33.39	25.55	17.44	12.40	11.13	16.62	25.03	42.14	52.46	378.43

In this table (Table 4.2) we can see the gas consumption per month by numbers as given by eQUEST. As we can see natural gas is only used in this case for space heating.

Table 4.3 Annual Energy consumption by Enduse.

	Electricity kWh	Natural Gas MBtu	Steam Btu	Chilled Water Btu
Space Cool	-	-	-	-
Heat Reject.	-	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	378.43	-	-
HP Supp.	-	-	-	-
Hot Water	15,274	-	-	-
Vent. Fans	-	-	-	-
Pumps & Aux.	657	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	15,066	-	-	-
Task Lights	-	-	-	-
Area Lights	9,166	-	-	-
Total	40,163	378.43	-	-

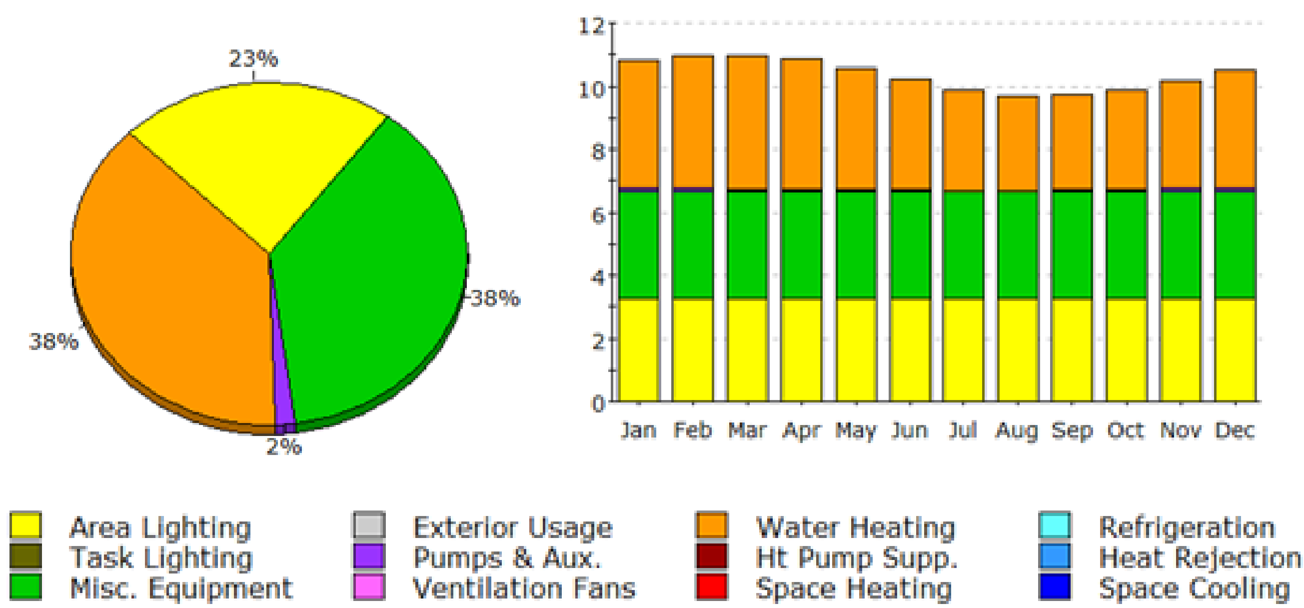


Fig 4.6 Electric demand (KW)

Table 4.4 Electric demand (KW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	4.05	4.23	4.24	4.15	3.82	3.49	3.20	3.02	3.00	3.16	3.44	3.77	43.58
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	0.09	0.09	0.08	0.07	0.07	0.07	0.03	0.03	0.06	0.07	0.09	0.10	0.86
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	40.85
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	38.97
Total	10.80	10.98	10.97	10.87	10.54	10.21	9.88	9.70	9.72	9.88	10.19	10.52	124.26

In the next Figure (Fig 4.7), we did a small diagram of how much the electric demand for hot water in % of the total electric demand.

And how much in (Fig 4.8) the electric demand for area lightning in % of the total electric demand.

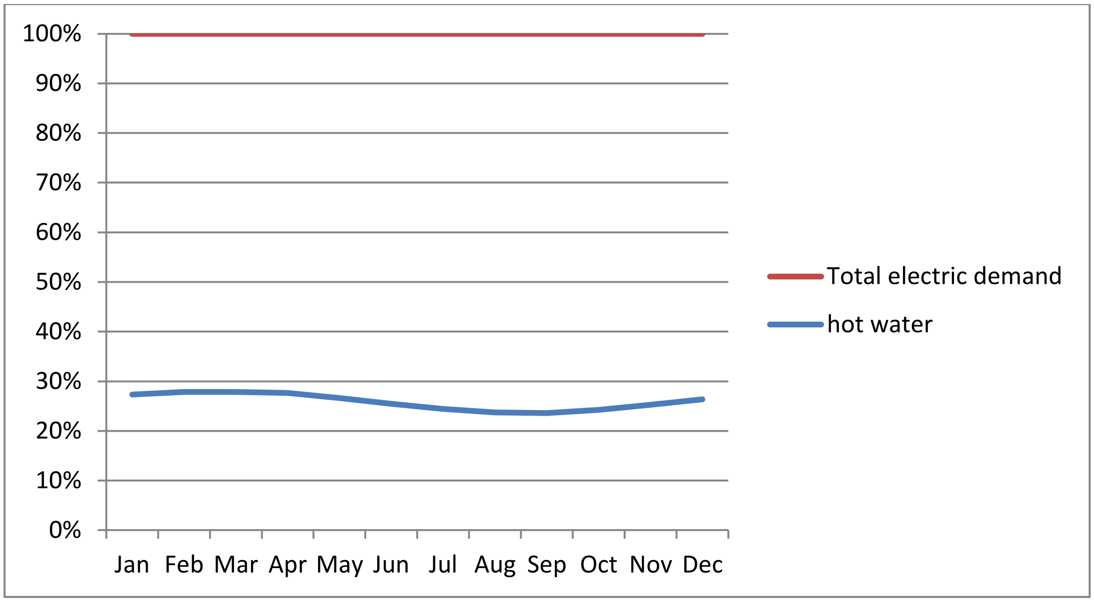


Fig 4.7 % of electric demand for hot water per total demand

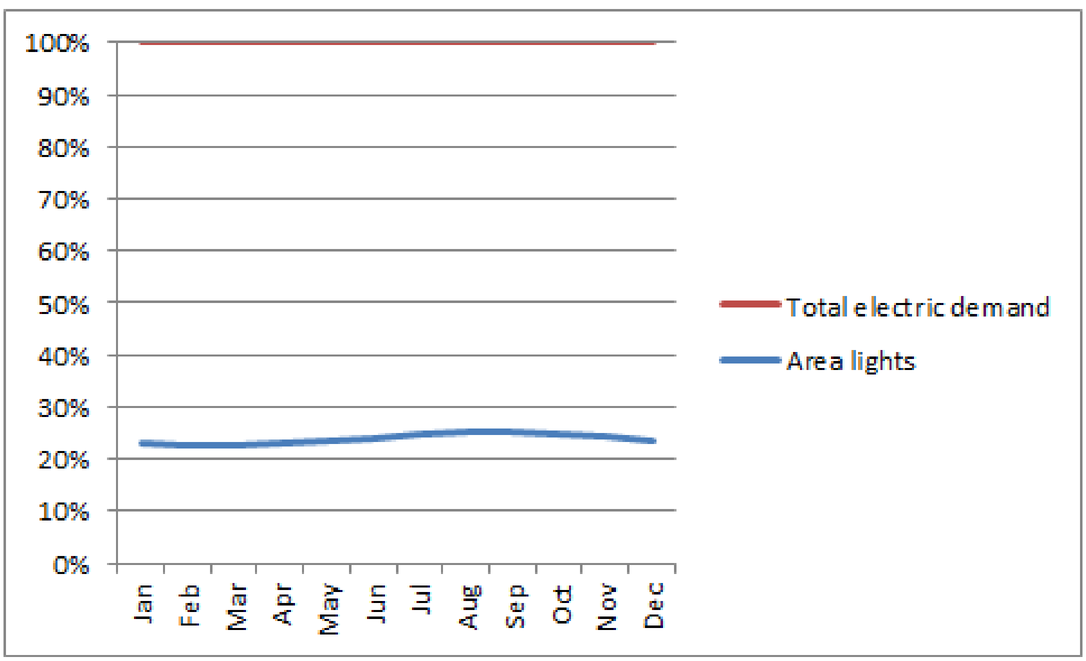


Fig 4.8 % of electric demand for Area lights per total demand

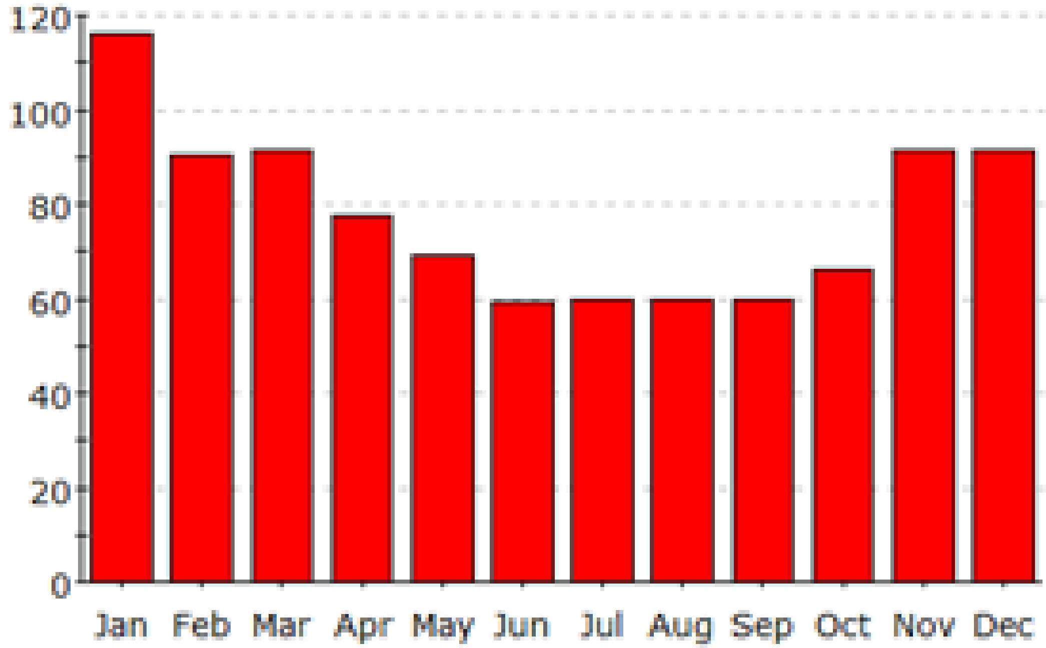


Fig 4.9 Gas demand (Btu/Hr×000)

In *(Fig 4.9)* and *(Table 4.5)* we can see the gas demand per month in diagram and by numbers in the house we simulated given by eQUEST.

Table 4.5 Gas demand (Btu/Hr×000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	116.21	90.40	91.35	77.60	68.97	59.33	59.73	59.65	59.60	66.10	91.57	91.57	932.08
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	116.21	90.40	91.35	77.60	68.97	59.33	59.73	59.65	59.60	66.10	91.57	91.57	932.08

In *(Fig 4.10)* we can see the annual energy consumption either electric use or fuel use by endues.

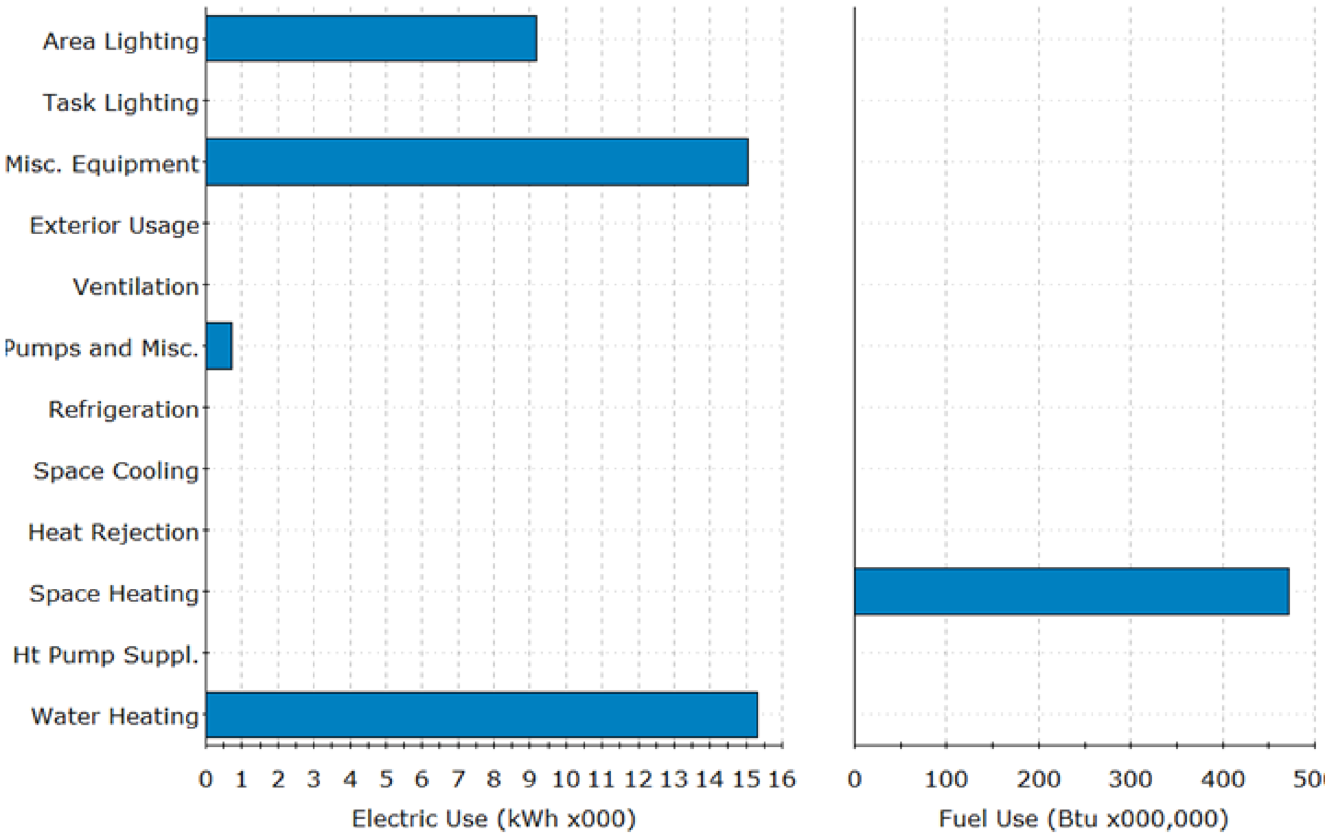
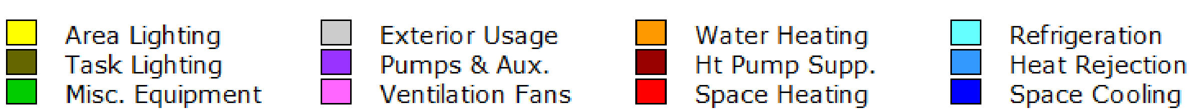


Fig 4.10 Annual Energy consumption by endues.

In *(Fig. 4.11)* we can see the monthly Electric Peak day load profiles, given by baseline design data by eQUEST.



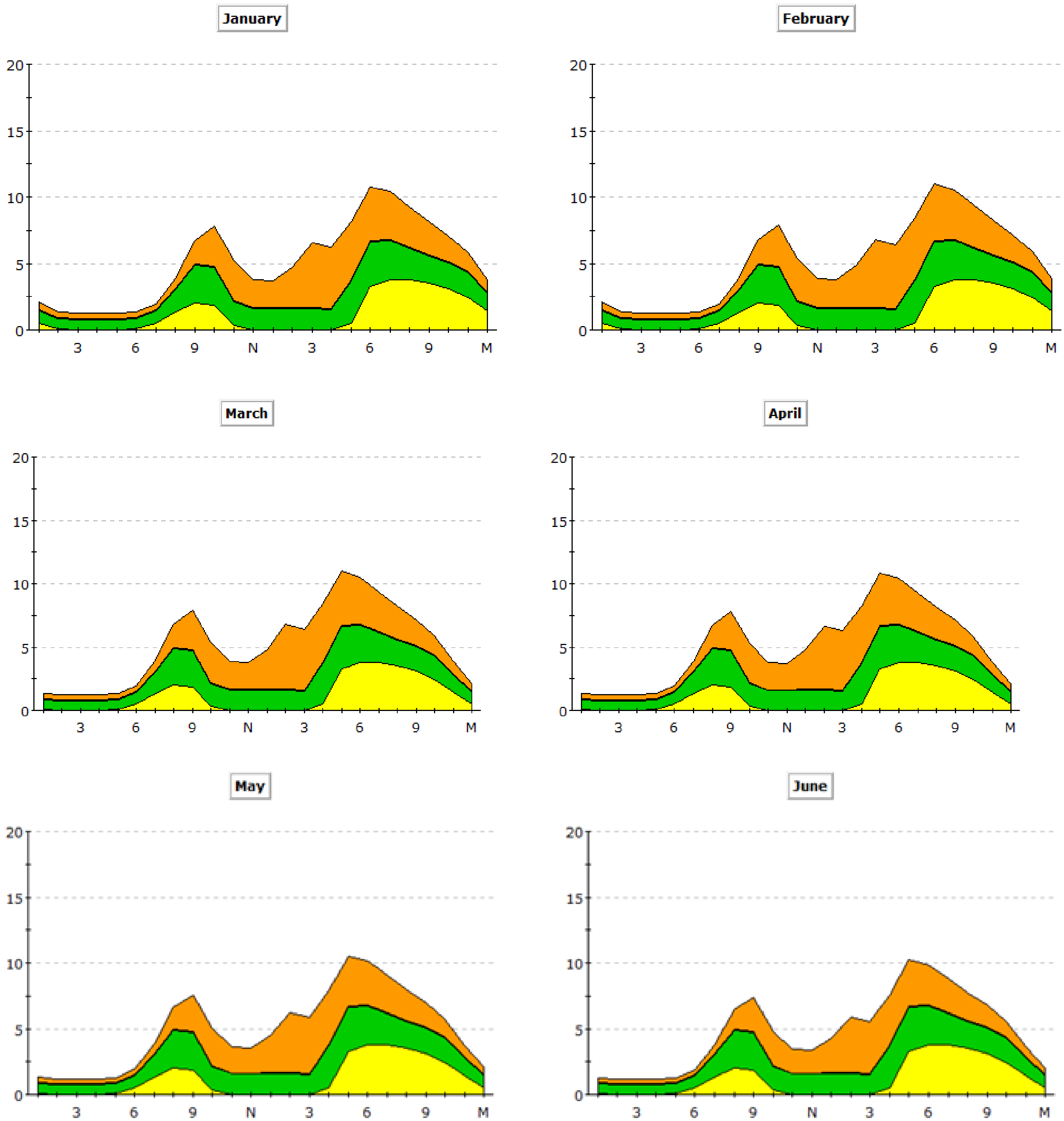


Fig 4.11 Annual energy consumption

4.2 Costs:

In this part we did a little research about prices of natural gas in Canada, and as conclusion we managed to calculate the economics costs of space heating for the house we simulated on eQuest.

So as we see in *(table 4.6) daily cost of natural gas Dollars per Million Btu* $\approx \mathbf{2.54}$ **$/BTu**$\times \mathbf{10^6}$ .From (*Table 4.2)* the total annual gas consumption is **378.43 BTu**$\times \mathbf{10^6}$. So the Annual cost for space heating is **961.21 $ per year**.

And by that we calculated approximately the total costs per year for space heating for the house we simulated on eQUEST in Canada.

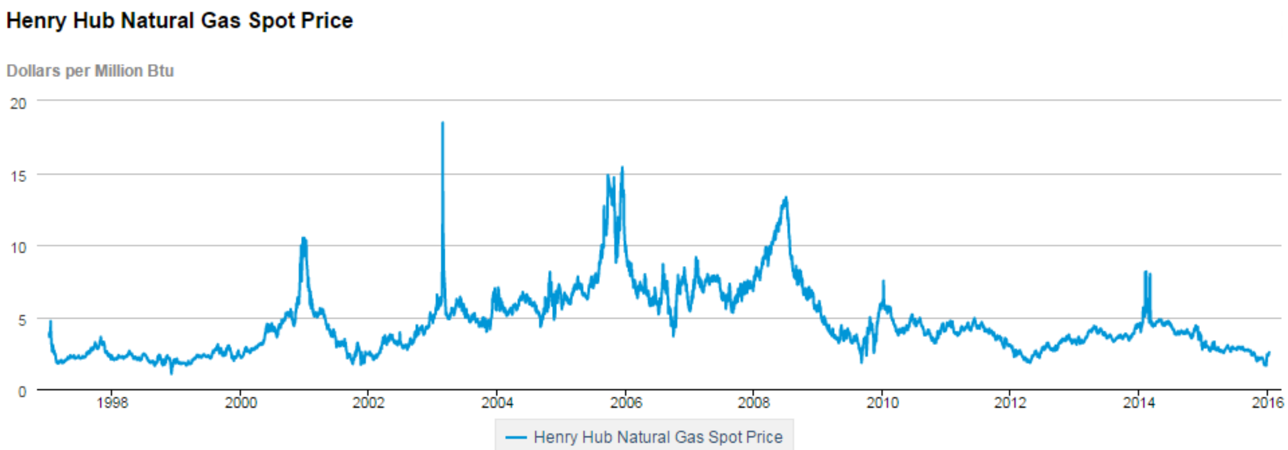


Fig 4.12 Annual cost of natural gas Dollars per Million Btu. (4)

Table 4.6 Daily cost of natural gas Dollars per Million Btu. (4)

Week Of	Mon	Tue	Wed	Thu	Fri
2015 Dec-14 to Dec-18	1.70	1.66	1.70	1.79	1.74
2015 Dec-21 to Dec-25	1.76	1.73	1.63	1.63	1.63
2015 Dec-28 to Jan- 1	2.11	2.39	2.28	2.28	2.28
2016 Jan- 4 to Jan- 8	2.39	2.33	2.37	2.35	2.47
2016 Jan-11 to Jan-15	2.54				

4.3 Isolation role:

By comparing the gas consumption for space heating by changing the glasses type and thickness *Fig.8*, as calculated by the program eQUEST, we can see that gas consumption has decreased a bit while changing normal glasses to double. But a big difference appeared when we used the triple glasses. That means that good isolation plays a big role in preventing thermal losses, and by that, economical losses.

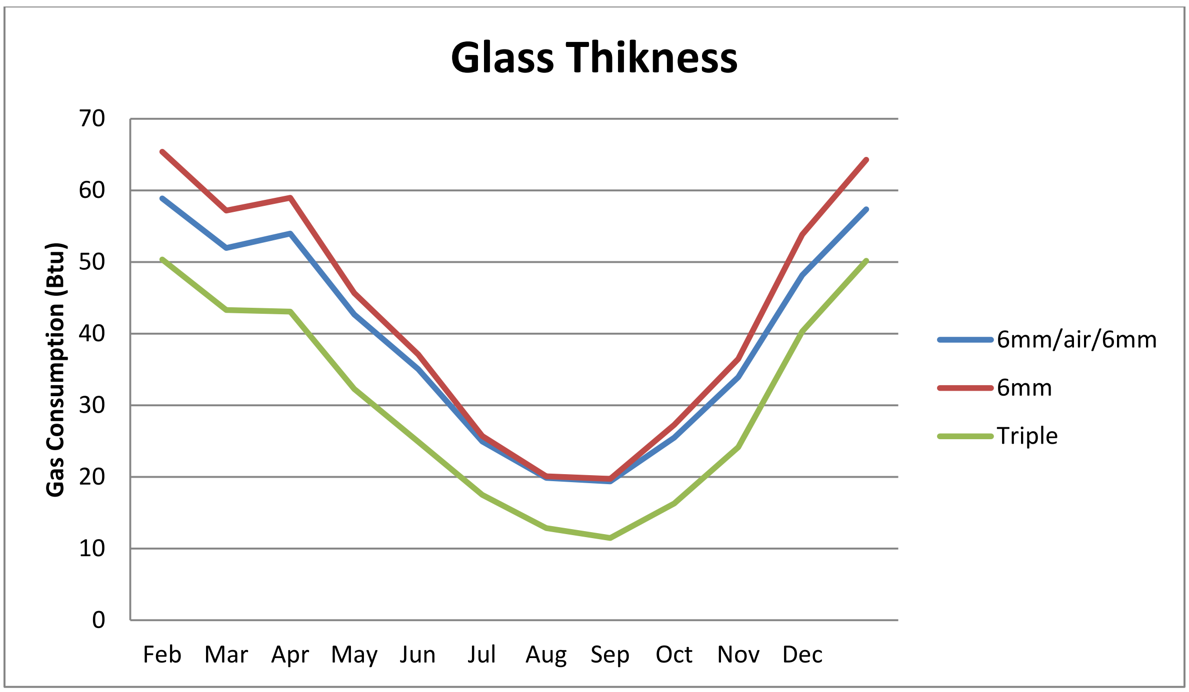


Fig 4.12 Comparing gas consumption for space heating by changing glass type and thickness.

Table 4.7 Glass type code

	GTC Name	Description	Num Layers	Shading Coefficient	U-value (center)	Solar Reflectance	Visible Reflectance	Film Cond. 1	Film Cond. 2	Film Cond. 3	Picture	Drawing
1	2610	Dbl Low-E (e3=.2	2	0.840	2.610	0.207	0.243	25.470	3.240	7.900		50,017
2	1400	Single Ref-A-L Cl	1	0.230	4.900	0.515	0.400	25.470	3.300	6.150		50,003

4.4 U-Value:

What is a U-value? Heat loss, thermal mass (5)**:**

Although the main focus of environmental performance of buildings is now on carbon usage, there is still a need to consider thermal performance of the building fabric as a contributing factor. Thermal performance is measured in terms of heat loss, and is commonly expressed in the construction industry as a U-value or R-value. U-value calculations will invariably be required when establishing construction strategies.

U-value or thermal transmittance (reciprocal of R-value):

Thermal transmittance, also known as U-value, is the rate of transfer of heat through a structure (which can be a single material or a composite), divided by the difference in temperature across that structure. The units of measurement are W/m^2K. **The better-insulated a structure is, the lower the U-value will be**. Workmanship and installation standards can strongly affect the thermal transmittance. If insulation is fitted poorly, with gaps and cold bridges, then the thermal transmittance can be considerably higher than desired. Thermal transmittance takes heat loss due to conduction, convection and radiation into account.

Calculating U-value:

The basic U-value calculation is relatively simple. In essence, the U-value can be calculated by finding the reciprocal of the sum of the thermal resistances of each material making up the building element in question. Note that, as well as the material resistances, the internal and external faces also have resistances, which must be added. These are fixed values.

There are a number of standards that cover calculation methods for thermal transmittance. These are listed in the Useful links and references section at the end of this article.

Simple U-value calculations can be made in the following way, by considering the building element's construction layer-by-layer. Note, however, that this does not account for cold bridging (by wall ties for example), air gaps around insulation, or the different thermal properties of e.g. mortar joints. This example considers a cavity wall:

Material	Thickness	Conductivity (k-value)	Resistance = Thickness ÷ conductivity (R-value)
Outside surface	–	–	0.040 K m²/W
Clay bricks	0.100 m	0.77 W/m·K	0.130 K m²/W
Glasswool	0.100 m	0.04 W/m·K	2.500 K m²/W
Concrete blocks	0.100 m	1.13 W/m·K	0.090 K m²/W
Plaster	0.013 m	0.50 W/m·K	0.026 K m²/W
Inside surface	–	–	0.130 K m²/W
Total			**2.916 K m²/W**
U-value =		1 ÷ 2.916 =	0.343 W/m²K

Table 4.8 Material U-value (5)

Note that in the above example, the conductivities (k-values) of building materials are available in the Appendix; in particular from manufacturers. In fact, using manufacturer data will improve accuracy, where specific products being specified are known at the time of calculation. Although it is possible to allow for mortar joints in the above calculation, by assessing the % area of mortar relative to the blockwork bedded in it, it should be borne in mind that this is a crude technique compared with the more robust method set out in BS EN ISO 6946i.

Measuring U-value:

Whilst design calculations are theoretical, post-construction measurements can also be undertaken. These have the advantage of being able to account for workmanship. Thermal transmittance calculations for roofs or walls can be carried out using a heat flux meter. This consists of a thermopile sensor that is firmly fixed to the test area, to monitor the heat flow from inside to outside. Thermal transmittance is derived from dividing average heat flux (flow) by average temperature difference (between inside and outside) over a continuous period of about 2 weeks (or over a year in the case of a ground floor slab, due to heat storage in the ground).

The accuracy of measurements is dependent on a number of factors:

- Magnitude of temperature difference (larger = more accurate)
- Weather conditions (cloudy is better than sunny)
- Good adhesion of thermopiles to test area
- Duration of monitoring (longer duration enables a more accurate average)
- More test points enable greater accuracy, to mitigate against anomalies

Two complicating factors that can affect the thermal transmittance properties of materials include:

- Ambient temperature, due to latent heat among other factors
- The effects of convection currents (increased convection contributes to heat flow)

5. Building simulation with eQUEST in Abu Dhabi:

This chapter presents the data used for the simulation of the building with the software eQUEST in Abu Dhabi (Cooling systems). It is a description of the building in terms of architectural design and separate thermal zones.Also mentioned building materials of the outer and inner walls, ceiling and ground.Also given all the information necessary for internal loads and HVAC systems for the building.

With the same way that we simulated the first house in Canada, we simulate this one but it is located in Abu Dhabi, and with other Specialties. They both have the same area, but this one is made with a different way of construction, different material, and different exterior color. And because this one is located in a hot country, it didn’t need a heating system for the winter; we just used a cooling system that will be shown in the next pages.

5.1 Building shell

In the next two pictures (fig 5.1 and 5.2) we will see the front and back view of the house in Abu Dhabi simulated on eQUEST.

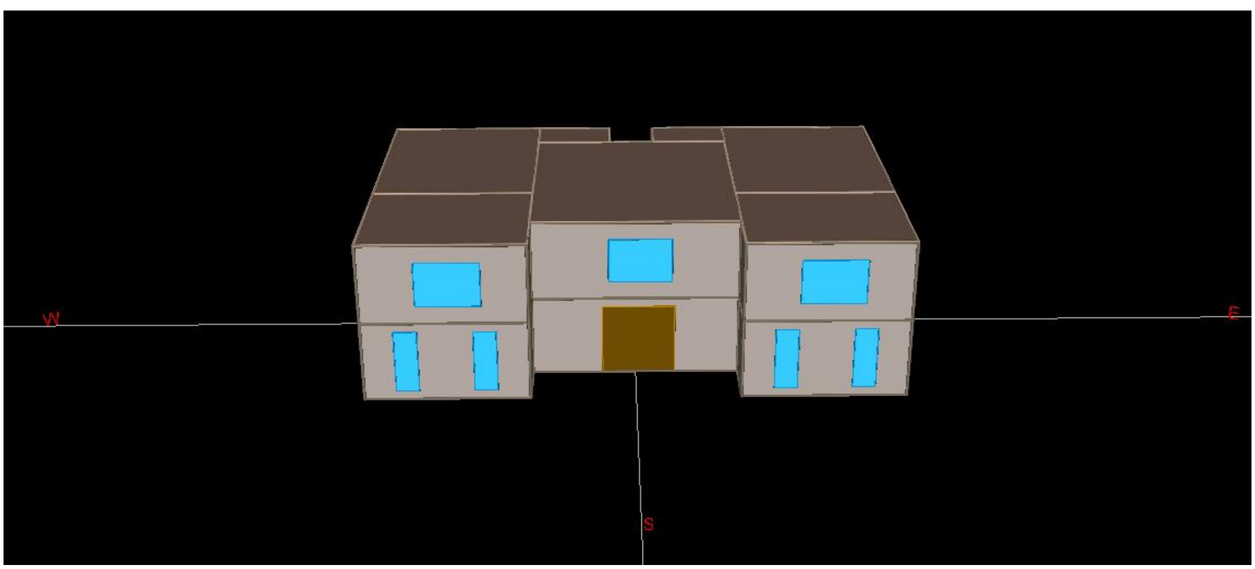


Fig 5.1 Front view of the house in Abu Dhabi

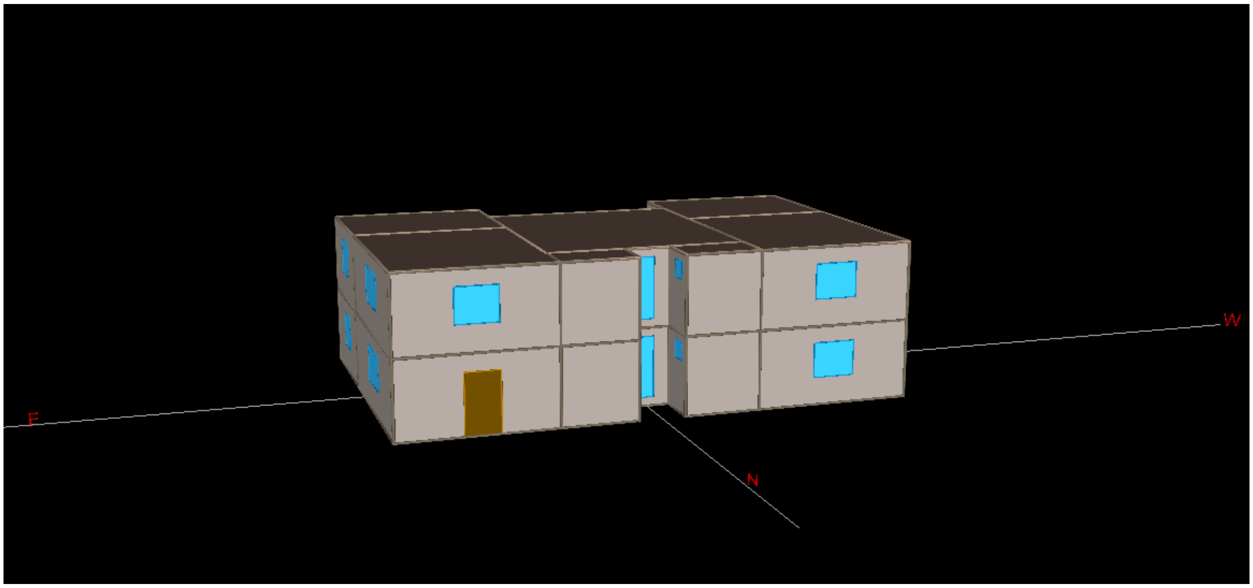
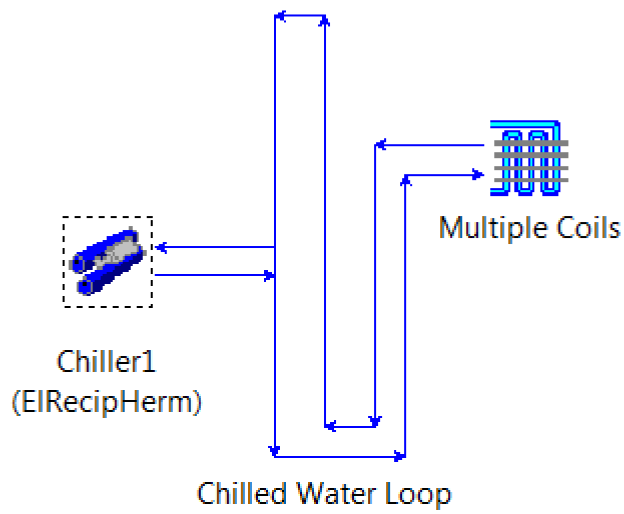


Fig 5.2 Back view of the house in Abu Dhabi

And as we just said in the introduction of the chapter, that we just have a cooling system, we'll show you what systems dud we used and how it is shown on eQUEST *(Fig 5.3)*
We used for space cooling a chiller (EIRecipHErm) with chilled water loop and multiple coils, and for hot water we used a DHW plant 1 res loop.



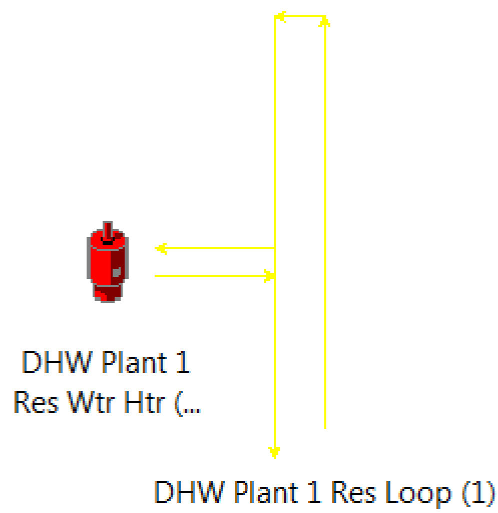


Fig 5.3 Cooling system and hot water plant on eQUEST

5.2 Consumption:

Στο παρακάτω διάγραμμα (σχήμα) φαίνεται η ενεργειακή κατανάλωση για όλους τους μήνες του έτους για το Abu Dhabi. Φαίνεται ότι το μεγαλύτερο μέρος της ηλεκτρικής κατανάλωσης δαπανάται για το κλιματισμό (space cooling). Ιδιαίτερα τους θερινούς μήνες η κατανάλωση ρεύματος για κάλυψη του φορτίου του κλιματισμού ξεπέρνα το 50% της συνολικής κατανάλωσης. Επίσης τα λοιπά ποσά ηλεκτρικής κατανάλωσης παραμένουν περίπου σταθερά κατά τη διάρκεια του έτους. Εξαίρεση αποτελεί το φορτίο ανανέωσης του αέρα (ventilation) το οποίο αυξάνει κατά τους θερινούς μήνες όπου απαιτείται μεγαλύτερη ανανέωση του αέρα.

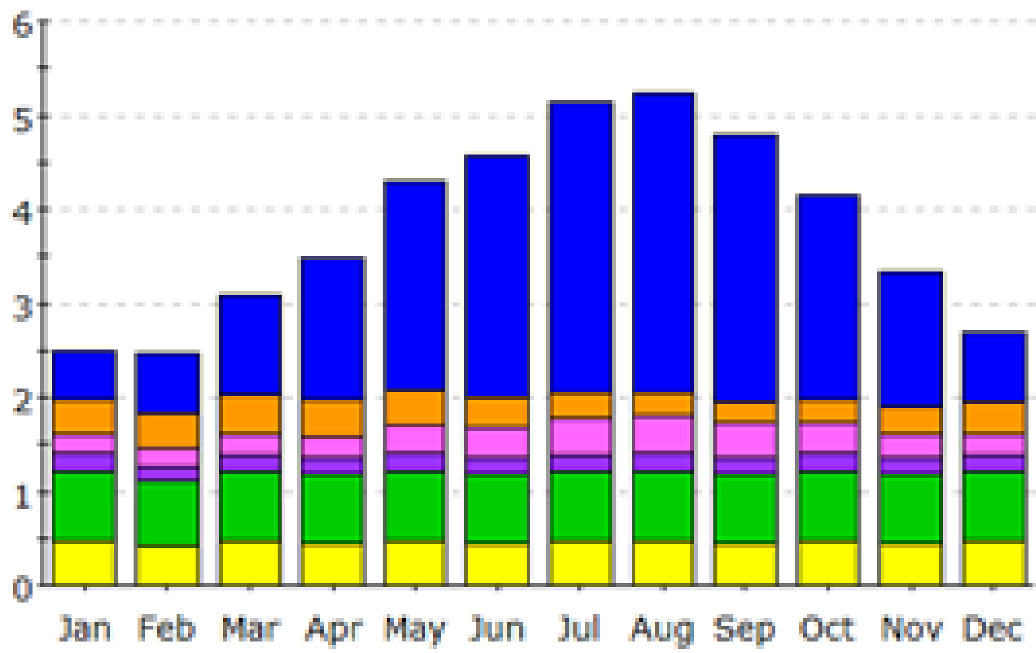


Fig 5.4 Electric consumption per month (MWh)

Ο επόμενος πίνακας δίνει αναλυτικά τις επιμέρους καταναλώσεις. Πιο συγκεκριμένα, η ετήσια κατανάλωση ενέργειας είναι 46MWh, η οποία επιμερίζεται ως εξής: 22 MWh για κλιματισμό, 4 MWh για παραγωγή ζεστού νερού χρήσης, 3 MWh για τον αερισμό του κτιρίου, 9 MWh για τη λειτουργία συσκευών, 5 MWh για φωτισμό και 2 MWh για τα λοιπά συστήματα (αντλίες, κλπ).

Table 5.1 Electric consumption (MWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.50	0.65	1.06	1.52	2.23	2.58	3.09	3.20	2.85	2.17	1.43	0.74	22.01
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.39	0.37	0.42	0.40	0.36	0.31	0.27	0.25	0.24	0.27	0.29	0.35	3.91
Vent. Fans	0.19	0.19	0.20	0.23	0.31	0.34	0.39	0.41	0.37	0.32	0.24	0.20	3.38
Pumps & Aux.	0.18	0.16	0.18	0.17	0.18	0.17	0.18	0.18	0.17	0.18	0.18	0.18	2.12
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.76	0.68	0.76	0.73	0.76	0.73	0.76	0.76	0.73	0.76	0.73	0.76	8.91
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.46	0.42	0.46	0.44	0.46	0.44	0.46	0.46	0.44	0.46	0.45	0.46	5.42
Total	2.48	2.48	3.08	3.49	4.30	4.57	5.14	5.25	4.80	4.15	3.32	2.69	45.75

Το επόμενο σχήμα δίνει τη μηνιαία κατανάλωση ηλεκτρισμού για κλιματισμό σαν ποσοστό της συνολικής μηνιαίας κατανάλωσης ηλεκτρισμού του κτιρίου.

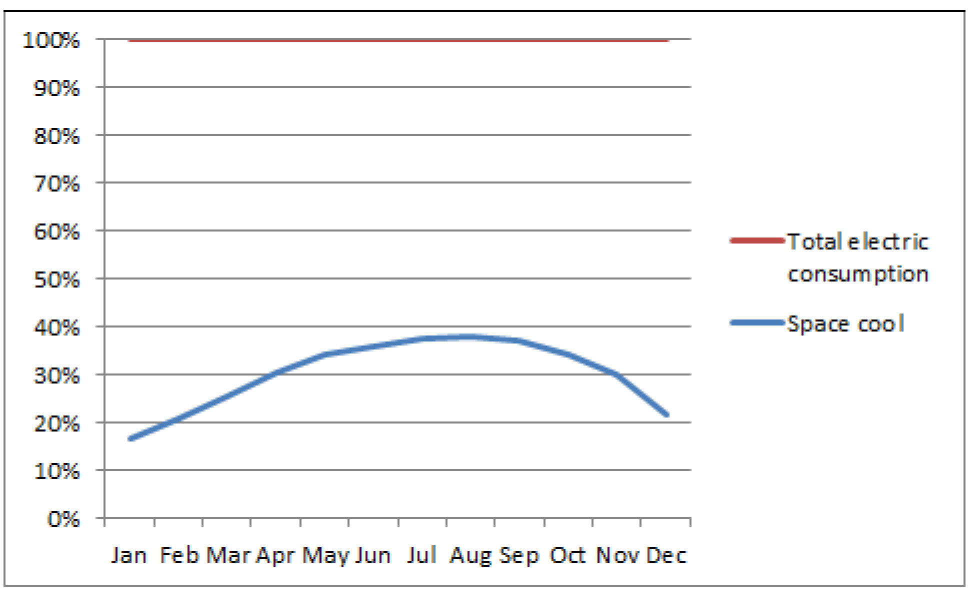


Fig 5.5 Space cool % of total electric consumption

5.3 Costs:

In this part we did a little research about prices of electricity in Abu Dhabi, and as conclusion we managed to calculate the economics costs of space cooling for the house we simulated on eQuest.
So as we can find *Table 5.1* the total cost for electric use in space cooling is **22.01 MWh,** and as shown in *Table 5.2* the electrical cost **is 0.21 AED/kWh**. By converting it to USD, the annual cost of electricity for space heating is **1258.42 $** per year.

And by that we calculated approximately the total costs per year for space Cooling for the house we simulated on eQUEST in Abu Dhabi.

Table 5.2 electrical costs in Abu Dhabi per kWh (6)

City / Nation	Water per 1,000 litres	Electricity per kWh
Kuwait	Dh2.64	3 fils
Abu Dhabi	Local: Dh1.7	5 fils
	Expatriate: Dh5.95	21 fils
Saudi Arabia	Dh0.29	5 fils
Oman	Dh5.28	10 fils
Bahrain	Local: 0.25	3 fils
	Expatriate: Dh2.92	0.16 fils
Qatar	Dh4.4	8 fils

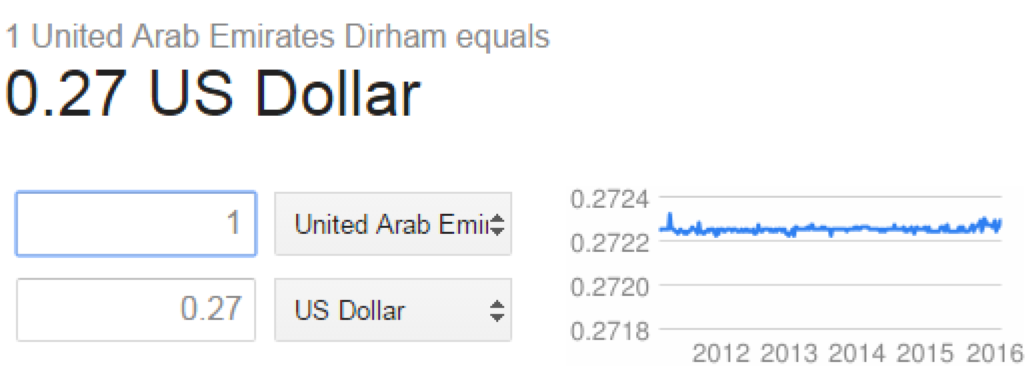


Fig 5.3 currency convertor UAE to USD (7)

6. Conclusions:

From the two examples we just did, the first one that was simulation of a house on eQUEST in a cold place, in our example it was Calgary, Canada, so we can only have heating systems in the house .The other one had been done in a hot country and in this example it took place in Abu Dhabi, were we used only cooling systems.

After simulating the two houses that pretty much has the same area ,the same interior loads and capacity of people living in it ,but there differences was the type of material used ,the thickness of concert ,of insulation ,the outside color of the building ,and a lot of other things that we already listed before detailed in each example, that plays a role in the building energy and thermal performance depending on the place that is located on each house and the type of weather that is there.

We came up with some results of the electric and gas needs of each house for heating, cooling, area lightning, hot water and a lot of other stuff. But what most concerns us is the electric or gas consumption for heating and cooling, so we took these two things from our previous results and compares it.

Table 6.1 Gas consumption in Canada (Million Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Heat	52.48	45.03	44.74	33.39	25.55	17.44	12.40	11.13	16.62	25.03	42.14	52.46	378.43

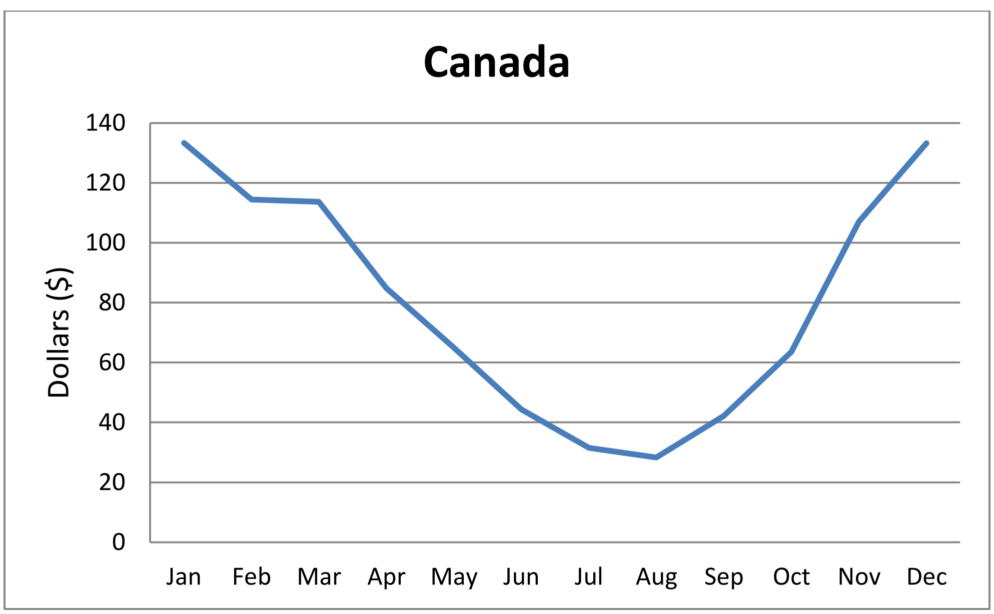


Fig 6.1 Expenses for *space heating in Canada ($)*

Table 6.2 Electric consumption in Abu Dhabi (MWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.50	0.65	1.06	1.52	2.23	2.58	3.09	3.20	2.85	2.17	1.43	0.74	22.01

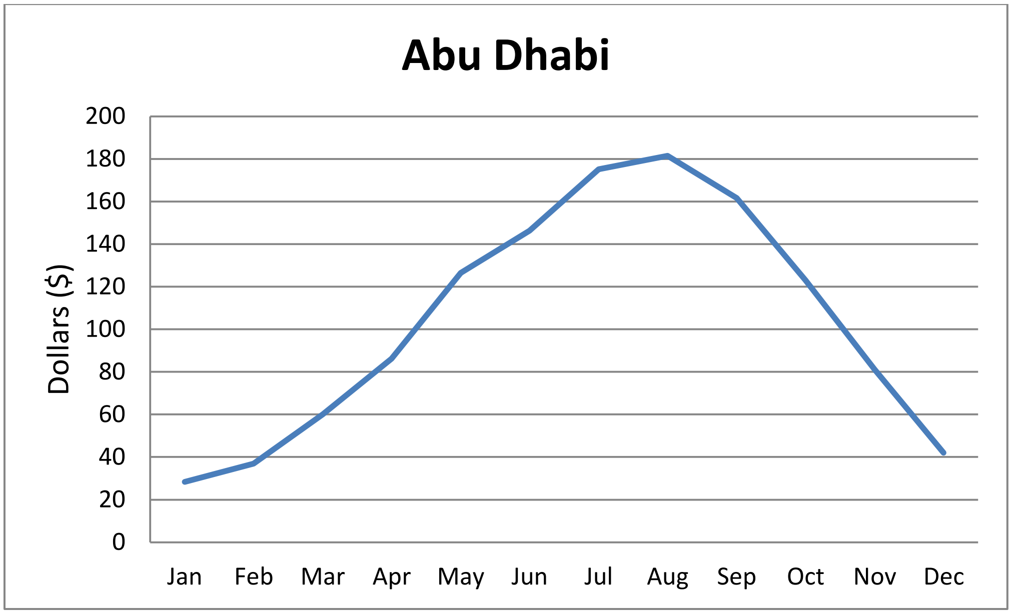


Fig 6.2 Expenses for space cooling in Abu Dhabi ($)

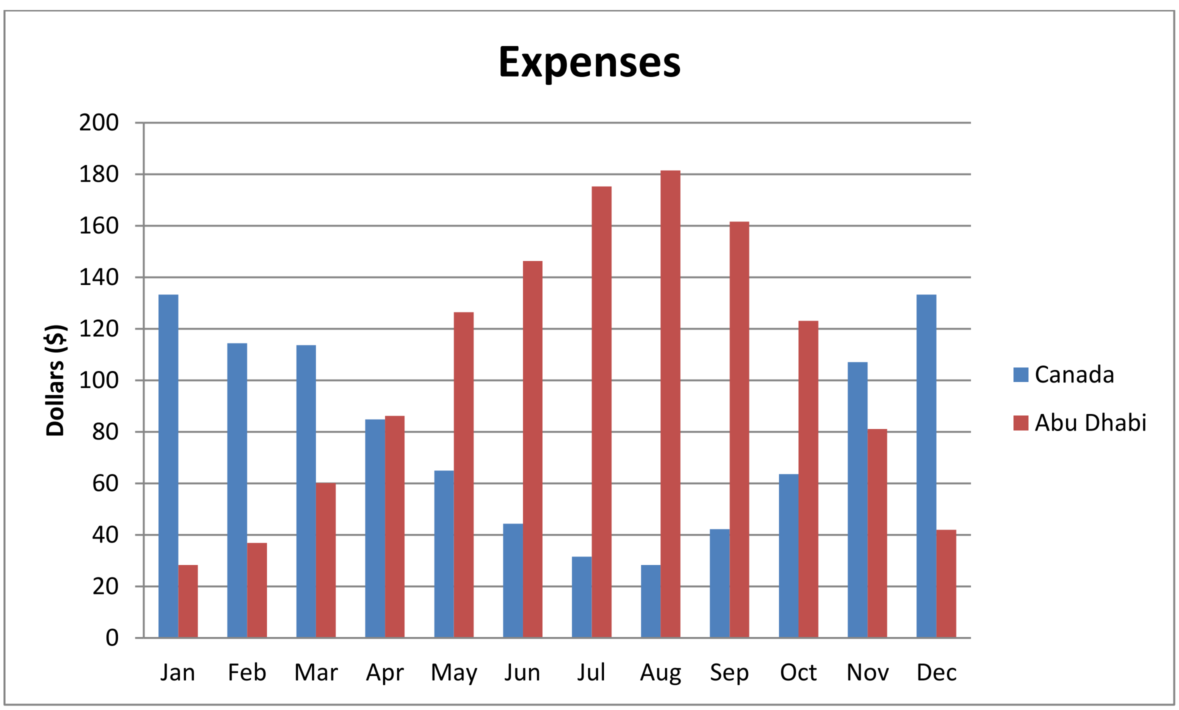


Fig 6.3 Comparing expenses in Canada and Abu Dhabi ($)

So as we can see in the charts, by converting the expenses to dollars so it can be compared, and putting it in a same chart we can see that total expense is nearly the same .the expenses in Canada are high in the winter seasons and the opposite in Abu Dhabi the expenses are high in the summer seasons which is expected.

After doing some researches, we found that in Canada, their houses are constructed in a way that they add more thickness to the insulation more than other countries and precisely hot countries, on the other side hot countries add more thickness of concert than cold countries.

The main difference between the results of these two studies is that in the cold country was mostly for cooling systems which is for natural gas, and in other case was for cooling which is electrical expenses, as for the others expenses for space lightning and miscellaneous equipment, it was approximately the same.
The other difference was expenses per months, which was exactly the opposite in each case, because of the different climate in each place, were we had cooling systems the expenses was high in summer and low in winter, and the opposite in the building which has heating systems only.

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APPENDIX:

Material table

Material	Density (kg/m^3)	Specific heat (kJ/kg-K)	Thermal conductivity (W/m-K)
Burnt brick	1820	0.88	0.811
Mud brick	1731	0.88	0.750
Dense concrete	2410	0.88	1.740
RCC	2288	0.88	1.580
Limestone	2420	0.84	1.800
Slate	2750	0.84	1.720
Reinforced concrete	1920	0.84	1.100
Brick tile	1892	0.88	0.798
Lime concrete	1646	0.88	0.730
Mud phuska	1622	0.88	0.519
Cement mortar	1648	0.92	0.719
Cement plaster	1762	0.84	0.721
Cinder concrete	1406	0.84	0.686
Foam slag concrete	1320	0.88	0.285
Gypsum plaster	1120	0.96	0.512
Cellular concrete	704	1.05	0.188
AC sheet	1520	0.84	0.245
GI sheet	7520	0.50	61.060
Timber	480	1.68	0.072
Plywood	640	1.76	0.174
Glass	2350	0.88	0.814
Sand	2240	0.84	1.740
Expanded polystyrene	34	1.34	0.035
Foam glass	160	0.75	0.055
Foam concrete	704	0.92	0.149
Rock wool (unbonded)	150	0.84	0.043
Mineral wool (unbonded)	73.5	0.92	0.030
Glass wool (unbonded)	189	0.92	0.040
Resin bonded mineral wool	99	1.00	0.036
Resin bonded glass wool	24	1.00	0.036
Asbestos mill board	1397	0.84	0.249
Hard board	979	1.42	0.279
Straw board	310	1.30	0.057
Soft board	249	1.30	0.047
Wall board	262	1.26	0.047
Chip board	432	1.26	0.067
Particle board	750	1.30	0.098
Coconut pith insulation board	520	1.09	0.060
Jute fibre	329	1.09	0.067
Wood wool board (bonded with cement)	674	1.13	0.108

Polyurethane foam (PUF)	30	1.570	0.026
Polyvinyl chloride sheet	1350	1.255	0.160
Cork tile	540	1.00	0.085
Plastic tile	1050	1.07	0.50
PVC asbestos tile	2000	1.00	0.85
Gypsum plasterboard	950	0.82	0.16
Brown cellulose fibres	37-51	1.35	0.045
Thatch (reed)	270	1.00	0.09
Thatch (straw)	240	1.00	0.07
Acoustic tile	290	1.34	0.058

Fig.1 PROPERTIES OF BUILDING MATERIALS

Surface	Emmisivity or Absorptivity		Reflectivity
	(Low temperature radiation)	(Solar radiation)	(Solar radiation)
Aluminium, bright	0.05	0.20	0.80
Asbestos cement, new	0.95	0.60	0.40
Asbestos cement, aged	0.95	0.75	0.25
Asphalt pavement	0.95	0.90	0.10
Brass and copper, dull	0.20	0.60	0.40
Brass and copper, polished	0.02	0.30	0.70
Brick, light puff	0.90	0.60	0.40
Brick, red rough	0.90	0.70	0.30
Cement, white portland	0.90	0.40	0.60
Concrete, uncoloured	0.90	0.65	0.35
Marble, white	0.95	0.45	0.55
Paint, Aluminium	0.55	0.50	0.50
Paint, white	0.90	0.30	0.70
Paint, brown, red, green	0.90	0.70	0.30
Paint, black	0.90	0.90	0.10
Paper, white	0.90	0.30	0.70
Slate, dark	0.90	0.90	0.10
Steel, galvanized new	0.25	0.55	0.45
Steel, galvanized weathered	0.25	0.70	0.30
Tiles, red clay	0.90	0.70	0.30
Tiles, uncoloured concrete	0.90	0.65	0.35

Fig.2 AVERAGE EMISSIVITIES, ABSORPTIVITIES AND REFLECTIVITIES OF SOME BUILDING MATERIALS.