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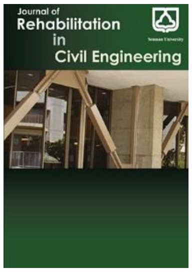

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# Energy Life Cycle Analysis of a Residential Building with the Help of BIM in Different Climates of Iran

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## ABSTRACT

With energy resource scarcity and energy crisis in the world, energy efficiency has become a subject of great importance. In warm and humid climates along with cold and mountainous ones, annual energy consumption is too high to achieve desirable living conditions in built environments, and hence energy efficiency measures and practices in such buildings is of utmost priority. Given the direct relationship of amount energy consumption and comfort level of occupants in residential buildings, energy saving and energy efficiency are of increasing importance specifically in the residential sector. In this study, a combination of building information modeling (BIM) and building performance modeling (BPM) is applied to identify appropriate dimensions and building materials to reduce energy in the lifecycle of a building. To perform this modeling, we evaluated various software applications employed in different studies and after identifying their advantages and disadvantages, finally Autodesk Revit and Autodesk Ecotect were chosen. Moreover, suitable building materials and optimum sizes are computed corresponding to different weather conditions and climates in Iran. In another part of this study, the breakdown of energy consumption in the commercial and residential areas in Iran is examined. Given the 38% share of space heating in total building energy consumption, the essential role of thermal insulation of external walls is emphasized. The effect of insulating in this region is calculated and marked applying simulation of energy consumption. Utilizing a suitable insulation system, can save 35% in lifecycle energy consumption.

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## 1. Introduction

Reducing energy consumption is very important. Furthermore, it should be noted that in many countries, about 40% of the total energy demand is for residential buildings and 60% of total energy consumption in residential areas is for heating living spaces [1]. Moreover, a large part of the energy is applied in air conditioners, especially in hot and humid regions [2]. On the other hand, the energy consumed in buildings can be reduced to a considerable extent utilizing thermal insulation materials.

There is no complete information in relation to the optimum thickness of the materials used in the building. The application of thicker layers to cover and insulate the building can have adverse effects on the operation of the building and the initial cost of the project enhances to some extent which may not be easily offset in short term.

Zachariadis has predicted that the amount of electricity consumption will increase up to three times more by 2030, consequently the require for reducing energy consumption will be more visible. Energy consumption in many areas of the residential sector will increase as a result of the application of heating and cooling equipment to reach the comfort temperature [3].

In many studies in different areas, optimum thickness of insulation is computed based on heating and cooling loads and other parameters such as cost of insulation materials and energy, efficiency of cooling and heating systems, lifetime of system and building, inflation rates and discounts. That is the reason that the annual heating and cooling energy consumption should be available as a main data to optimize the thickness of the insulation. Most of the studies estimate required heating and cooling energy applying the concept of degree - time (degree – day / degree - hour) which is one of the easiest methods in stable conditions.

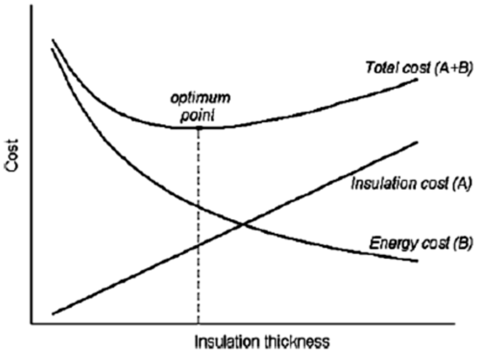

**Fig. 1**. The optimal thickness of insulation materials [4]

Pursuant to Figure 1 and given explanations of the importance of selecting the optimal point for the thickness of insulation materials, building lifecycle cost will be as low as possible [4].

The thickness is in fact influenced by several factors. We refer to some of the main factors below:

i. Type and cost of applied energy (gasoline, electricity, gas, renewable energy, etc.)

ii. Type of Heating, Ventilating and Air Conditioning[1] and its efficiency

iii. Price of the materials used for insulation

iv. Location of the project that includes weather conditions

v. Type of construction system of building, materials, shapes and direction of the building [5-6-7-8].

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[1] HVAC

## 2. Literature Review

Recent BIM developments provide interoperability with the energy performance simulation (EPS) tools with assessment of operational energy ability, although existing BIM software generally lacks interoperability with conventional LCA tools that are the main ways of assessing embodied energy [9]. Consequently, embodied energy assessment is often accomplished when the design has either been finished or developed to a relatively detailed level, when there is less scope to inspect different design decisions for reducing the building’ s total energy use [9]. This lack of interoperability also hinders the optimization of trade-offs between embodied and operational energy in a BIM-driven design process, increasing the time, effort, and risk of mistakes, misunderstandings and errors which may occur as a result to the manual re-entry of data to and from the BIM software [9].

In China and with regard to both cold and warm weather through the analysis of the cities of Changsha, Shanghai, Chengdu and Shaoguan, the analysis is conducted based on five samples of insulation materials with foam polyurethane, polyvinyl chloride (PVC) foam, expanded polystyrene, perlite and polystyrene molding [5]. Results from the optimum thickness of between 0.053 to 0.236 meters of expanded polystyrene revealed the fastest rate of return and the highest return on investment and energy. Moreover, a variety of colors and surfaces is examined in this study as well. The application of HTB2 modeling software is inspected in order to compute heat transfer in buildings and to contemplate the effect of isolation layer movement in between the layers of the wall, based on cold period of the year and the demand for two towers in Hong Kong.

In one of the experiments, a cube of 2.4 meters in dimension is made by applying traditional materials, (i.e. perforated bricks and plaster) in the Mediterranean region. Three types of insulation materials (polyurethane foam, mineral wool, polystyrene) were examined in this research. As a result, energy consumption in summer was dropped by 64% in winter and 37% in summer for the cube with polyurethane foam insulation. Furthermore, it has achieved 14% difference in traffic volume modeling and theory of numbers drawn from the facts in this experiment [10].

Now, referring to fundamental properties of insulation materials, there is no insulation which can meet all the important requires in this area. Jelle, B. P. has done one of the most complete conceptual and recent studies and has performed thorough comparison of all insulation materials in the past, present and future and has provided their features. This researcher also has examined a variety of criteria such as: thermal conductivity, crashes and punctures, adaptability to the building site and the ability to cut, mechanical strength, fire resistance, vapor diffusion gas burning time, resistance force, durability, longevity and conditions weather, freezing and thawing cycle resistance, water resistance, cost and environmental impact). Furthermore, the possibility of applying of some materials in the futures such as dynamic insulation materials, insulation materials made by nanotechnologies and Nano-materials with the ability to endure load has been inspected [11].

During the construction stage the main categories of emissions are related to the: 1)

Construction materials and waste, 2) Fuel consumption from the construction equipment (Diesel, Gasoline, LPG, and Natural gas), 3) Electricity consumption from the construction machinery [12]

Kanagaraj, et al. have determined a framework as (the integrated building design with high efficiency in energy consumption) that has provided guidelines for the design of such buildings in the commercial section of New Delhi, India, especially for the designers. Their case study of thermal performance was modeled by Ecotect version 5.6 and they also suggested to model the environmental plants, outdoor, sport spaces, type of roof and light design of the overall building in the software [13]. In a study by Ling, et al. the focus was on high-rise structures. They were trying to figure out the most optimal shape and angle for this type of buildings in hot and humid regions, with version 5.2, North-South direction was reported by square shape with a length to width ratio of 1, which the best form to receive the lowest radiation [14].

In 2010, a study was performed by Hernandez & Kenny[15]. In their study, they disagreed about ignoring some factors such as energies stored in zero net energy home, and they introduced a new procedure which contains the description of both exploitation phase energy, and embodied energy simultaneously in it. They also have presented a comprehensive definition of "zero energy buildings life cycle (LC-ZEB)"[15].

In a study by Ramesh, Prakash, & Shukla, embodied energy with 10-20% and 80-90% of phase operation were mentioned as the most important contributors to energy life cycle. They concluded that with a statistical analysis on 73 case studies involving office and residential buildings in 13 different countries with relatively cold weather [16].

## 3. Research Methodology

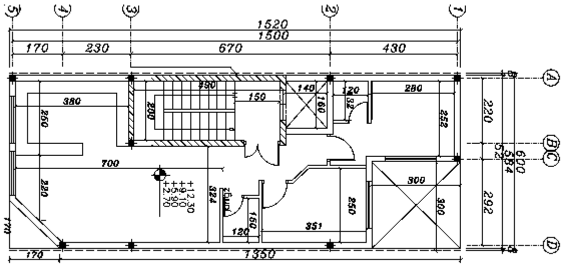

**Fig. 2.** Unit Plan Map of Residential Case Study

This study is conducted applying modeling and energy simulation on computer software. In this regard, modeling of an apartment with traditional architectural map of Iran was performed in Autodesk Revit software as depicted in Figure 2. Floor area of each floor of this 4-story apartment building is about 68 square meters and total building area of the building is approximately 272 square meters.The reasons for choosing this building are high cost per square meter of residential space in large cities, slow pace of population growth in Iran and moving towards families with less children that has enhanced the construction of houses with such low area. Consequently, the model which was completed in Revit software was imported to Ecotect software for analyzing thermal sighting software. In this application, as a result to the construction materials available in the country and dissimilar weather climates in Iran, 3 types of material for walls, 3 different types of insulation material for wall as well as a type of roof this building is applied. The building is modeled and analyzed after a variety of materials in four different climatic zone of Iran on behalf of the city of Tehran, Tabriz, Yazd and Bandar

Abbas from the perspective of lifecycle energy.

The modeling was performed by assumptions: proper implementation and seamless building systems such as roof, walls, windows, insulation doors, And the potential for damage on the run is not considered.

## 3.1. Modeling Procedure

### 3.1.1. Modeling Software Autodesk Revit

The Revit software includes a complete set of software that are applied for the implementation of the process of building information modeling (BIM). This software enables engineers and project managers to benefit from utilities and appropriate tools to the model and then for implementation. They can also model project details as required in the application and use it in all phases of the project (From the design phase to the demolition).

**Fig. 3.** 4-storey residential apartment image output from Revit software 2016

The building is modeled in Revit as presented in Figure 3 and buildings available in Tehran can be observed in Figure 4. The two buildings of the implementation details are fully adapted to each other.

**Fig. 4.** 4-storey residential building located in Tehran – Iran

At last, the output from Revit software must be complete and with appropriate format and geometric features to insert into the Ecotect software and for this purpose Green Building XML or gbXML[2] should be applied.

### 3.1.2. Autodesk Ecotect Software

Ecotect Autodesk software is one of the most efficient energy simulation engines, this software is widely used in the world with the aim of performance modeling of building. Because the simulation engine puts information such as the amount of carbon emissions and the amount of demand or consumption of water and energy of a project in the hands of decision-makers. Its other features can also be noted as computing the best construction direction in terms of energy consumption, climate impact and wind blow.

The entire building which is modeled in Ecotect software includes 38 thermal regionals. Only 12 districts are occupied and residential areas and as a result, only 12 regions are tested in the analysis. In this study, the application of heating and cooling systems is 24 hours a day. Although in this

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[2] Green Building XML

period, using economic and technical devices and natural ventilation in some areas seem to be far from reality. But for comparative purposes of this study where different climates of the country have considerable different temperatures, and in order to see the impact of building insulation on energy consumption during this time, the work hour of the device is contemplated to be 24 hours.

It is noteworthy to mention that the temperature of the air in the building by the standards of thermal comfort for the residents is considered between the ranges of 18 to 25 ° C because of the need for equal conditions in all climates for performing proper comparison. All times occupied by different spaces is also planned that the plan is conducted by contemplating the time which the space is applied in this study. On the other hand, according to the types of devices, efficiency of heating and cooling systems is 95%. In this study, based on ASHRAE standards and guidelines as well as suggestions of the software according to the type of application and consumer culture, coverage factor is 0.6 for shirt and pants home suit. Wind speed was set to 0.5 meters per second which means pleasant breeze.

### 3.2. Insulation Materials Commonly Available in Different Regions of the Country

There are many insulation materials for buildings in the world and in Iran. Some of these materials have good prices and their transportation costs are justified considering the possibility of production in the various regions. However, in contrast, some other materials were excluded from agenda because of the high cost of transportation and lack of access to different regions of the country.

Regarding the items which mentioned above, the most widely insulation materials applied in all regions of the country with a review of important factors such as price, shipping cost, popularity and ease of implementation with collecting information from local distributors of building materials in various cities are as follows:

i. Expanded polystyrene (EPS)

ii. The mineral rock wool

iii. Polyurethane

### 3.3. Conventional Materials for Side Cover Construction of Buildings in Different Parts of the Country

The study was conducted by considering of building codes and national regulation issues in Iran. the aim of this study was to determine the effect of insulation of buildings, so conventional materials were identified. The results include two types of wall construction materials, 1 Type of ceiling construction materials, 1 Type of window material construction and 1 type of door manufacturing that is generally applied more than other materials. It is noteworthy to mention that because of the necessity to implement the National Building Regulations of Iran which necessitates the application of Double-modeling windows, the usage of single-glazed windows is refused in this study.

## 4. Results and Discussion

An apartment with ground floor parking and 4-storey residential building located in Tehran, Iran, each floor consists of 2 bedrooms, living room and kitchen, has a usable area of 68 square meters and was built in 2015 and the apartment is selected as the case study. The building is concrete slab roof, walls with a clay brick and concrete flooring, the window to the wall is nearly 20%, Double-glazed windows with aluminum framework.

Climate is attributed to weather conditions of a geographic area such as temperature, humidity, atmospheric pressure, wind, rainfall and other meteorological characteristics of relatively long period of time. Current weather conditions are usually examined in meteorology while characteristics of long-term climate is concerned in in climatology.

Climate is computed with latitude and altitude in different regions of the world. Iran is a high Plateau at latitude of (40-25) degrees in the northern hemisphere and is in the hot zone.

Climate divisions, which is developed and based on studies and expert recommendations of Iranian scientists, environment in the field of architecture consists of four divisions generally as follows.

Yazd on behalf of the hot and dry climate (central plateau of Iran)

Tabriz on behalf of the cool mountain climate (mountain areas west of the country)

Tehran on behalf of the temperate wet climate (South shore of the Caspian Sea)

Bandar Abbas on behalf of the hot and humid climate (northern shore of the Persian Gulf and Sea of Oman)

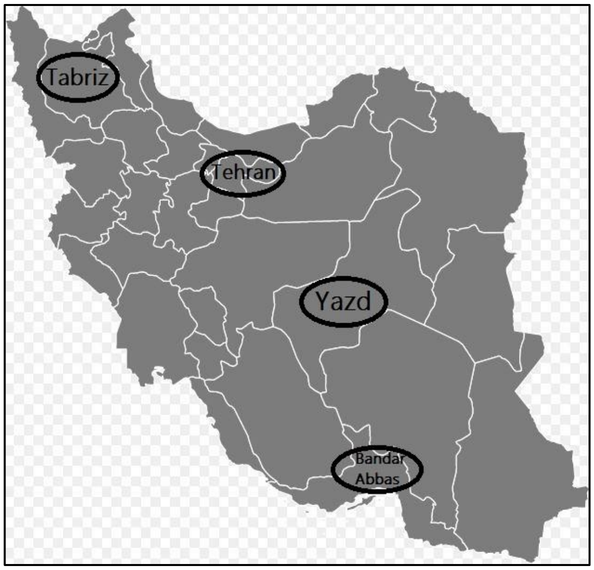

**Fig. 5.** climatic zoning map of Iran

### 4.1. Assessment of Different Energy Phases of Building

To compute the energy of the life cycle of the building, it is essential to perform an accurate estimate of energy demand and energy embodied phase of the operation. Because the embodied energy consumption of buildings depends on different factors in different climates and it is different in variety of geographic regions with a variety of different manufacturing processes, consequently in this research, identified sources are applied to calculate embodied energy.

#### 4.1.1. Embodied Energy Calculations of Building

In order to obtain embodied energy, building materials must be applied from the values of technical drawings. Latent energy is the sum of the amount of building materials utilized in building energy multiplied by their embodied energy coefficient. This process is computed with 3 kinds of manufactured materials for walls (walls with clay blocks, hollow concrete blocks and concrete blocks bubble) and by taking 3 types of insulation.

And it is used in Table 2 as well as the calculation of life cycle energy.

Early embodied energy in buildings, including energy consumed in the construction phase is as follows:

$$EE_i = \sum m_i M_i + E_c \quad (1)$$

Where the $EE_i$ is the initial embodied energy of the building, $m_i$ is the amount of building materials, $M_i$ is the energy for constructing building materials and $E_c$ is the energy applied in establishing and building site [16].

#### 4.1.1.1. Frequent Embodied Energy

Building materials being used in construction have a very wide range. Some of these materials are expected to have less efficient life than the life of the building, and on that account they will be replaced in the lifetime of the building.

Furthermore, buildings need regular maintenance with annual plan. Total energy consumption in any renovation or reconstruction of energy in buildings should be measured and included in its lifetime.

Total embodied energy which lies in the materials applied in the restoration and maintenance of building over the life cycle is called frequent embodied energy. The energy is computed by the following formula:

$$EE_r = \sum m_i M_i [(L_b/L_{mi}) -1] \quad (2)$$

Where $EE_{r,}$ is frequent energy used in buildings, $L_b$ is life span of buildings and $L_{mi}$ is life span of the consumption materials.

Embodied energy Lies heavily on the type of materials used in building, initial energy resources and the efficiency of the raw materials manufacturing process. [16].

**Table 1.** Physical characteristics of materials used in building modeling

| | Name of the material | Composition | Thermal conductivity (W/mk) | Density (Kg/ m$^3$) | Specific heat (J/Kg K) | Embodied Energy (MJ/m$^3$) | Heat capacity (KJ/m$^3$K) | Ref. |
|---|---|---|---|---|---|---|---|---|
| 1 | Clay blocks | Clay | 0.905 | 1700 | 800 | 2235 | 1360 | [17] |
| 2 | Concrete hollow blocks | Cement (7%), sand | 0.63 | 1200 | 1000 | 819 | 1200 | [18] |
| 3 | Blocks of concrete bubble | Cement, concrete and aluminum | 0.24 | 750 | 1000 | 818 | 750 | DB[3] |
| 4 | Expanded polystyrene | | 0.035 | 23 | 1470 | 2500 | 35 | DB , ICE[4] [19] |
| 5 | Polyurethane | | 0.028 | 30 | 1470 | 3045 | | [19] |
| 6 | Cementing | Cement and sand 6:1)( | 0.16 | 600 | 1000 | | 600 | DB |
| 7 | Situ concrete | Cement, gravel | 1.13 | 2000 | 1000 | 1465 | 2000 | [17] |

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[3] Design Builder Data Base

[4] Inventory of Carbon & Energy

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | and sand (4: 2: 1) | | | | | | |
| 8 | Mortar | Cement and sand (4: 1) | 0.88 | 2800 | 896 | | 2509 | DB , [19] |
| 9 | Marble | | 2.77 | 2600 | 802 | | 2085 | DB |
| 10 | Reinforced concrete | Cement, sand, aggregate (4: 2: 1) and Steel 2% | 2.5 | 2400 | 1000 | | 2400 | DB , [18] |
| 11 | Sand | | 2 | 1950 | 1045 | 156 | 2038 | DB |
| 12 | Rock wool | | 0.33 | 200 | 710 | 3360 | | [19] |

In table 2, several systems used in the modeled building are briefly stated. In this table, the wall thickness is 20 cm and 1 cm layer of insulation is intended. And this is on condition that the number of cases contemplated in the analysis are numerous and their embodied energy is calculated and presented in calculation of life cycle energy tables.

**Table 2.** Characteristics of construction for a variety of different modellings

| **Number of types** | **Title** | **Embodied Energy** (kWh/m$^2$) | **Ref.** |
|---|---|---|---|
| 1 | Walls with clay blocks | 28 | [17] |
| 2 | Hollow concrete block wall | 26 | [17] |
| 3 | Concrete block walls with bubble | 26 | [17] |
| 4 | Type 2 + polystyrene insulation | 28.31 | [17] and computing |
| 5 | Type 2 + insulated polyurethane foam | 29.11 | [17] and computing |
| 6 | Type 2 + rock wool insulation | 28.82 | [17] and computing |
| 7 | Type 2 + polystyrene insulation | 28.31 | [17] and computing |
| 8 | Type 2 + insulated polyurethane foam | 29.11 | [17] and computing |
| 9 | Type 2 + rock wool insulation | 28.82 | [17] and computing |

### 4.1.2. Operation Phase Energy of Building

Building energy application includes energy consumed in cooling systems, heating, ventilation, domestic hot water, household appliances and lighting during its lifetime. Energy modeling in this study is performed by Ecotect Autodesk simulation software that can simulate and estimate its energy load demand and are inserted in the lifecycle energy tables. This application is one of the most comprehensive tools for energy simulation and with its help detailed annual energy consumption of buildings is computed, contemplating the climatic conditions of each region. Energy-phase operation intended lifetime of the building is assumed to be fixed. While there is possibility of little modifications for it, with changing in climatic conditions or the behavior of people.

Tapping energy consumption depends greatly on the level of comfort, weather conditions and planning on operation. The energy application of the building during its life cycle can be obtained from the following equation:

$$OE=E_{OA}L_b \tag{3}$$

Where OE (kWh) is energy application throughout the life cycle of the building, $E_{OA}$ (kWh) is the annual energy consumption, $L_b$ (year) is operation and longevity of the building [14].

### 4.1.3. Energy of Transport and Building Demolition Phase

At the end of the service life of buildings, we need energy to demolish and carry them to the intended place which is called demolition energy and it can be calculated by following formula:

$$DE=E_D+E_r \tag{4}$$

Where DE (kWh) is energy destroyed, $E_D$ (kWh) energy needed for destruction and $E_r$ (kWh) is energy utilizing in transportation of demolition waste [14].

## 4.2. Calculation of Lifecycle Energy Consumption of Buildings

Life cycle energy is the sum of all mentioned energies consumed in the lifetime of a building and are computed as follows:

$$LCE = EE_i + EE_r + OE + DE \tag{5}$$

The energy consumption for renovation of buildings is very low and so it is contemplated in embodied energy of the building. Moreover, the energy consumption at the project site and the energy for building demolition and disposal of waste are neglected due to small share (approximately 1%). Units for Estimation of lifecycle energy is kilowatt-hours. Unification of all consumed energies and converting them into a single unit helps accelerate energy estimation. To allow the comparison of different buildings which have different area and life expectancy, size and age should be in same unit as well. As a result, kWh / m2. year is applied for the unit of energy for the entire life cycle of this study for a total area of 68 square meters and 50 years of useful life.

To study the energy consumption of building in different climatic conditions, a fixed residential apartment is modeled in 4 climate zones (warm and dry, hot and humid, temperate, cold and mountainous) and other conditions such as treatment of residents, comfort temperature and equipment used in the operation phase are contemplated the same.4 cities were considered in 4 climates in the country (Figure 5). First, the energy demand of buildings made with three kinds of building materials for walls, ceiling concrete slab, etc. are evaluated in Tehran and it was considered as the basis of comparisons with other climatic conditions. Modeling different buildings with dissimilar thick walls and the application of polystyrene insulation in the walls were conducted in the next step. Construction details of some of the case studies is given in Table 2.

### 4.2.1. Impact of Polystyrene Insulation thickness in different types of walls on building life cycle energy

To evaluate the effect of the thickness of the insulation walls on the entire energy lifecycle, all three kinds of wall materials were simulated with polystyrene insulation in Tehran, because if we have multiple variables, the thickness will influence the insulation and consequently the results won't be viable reliable. (Chart 1 and 2).

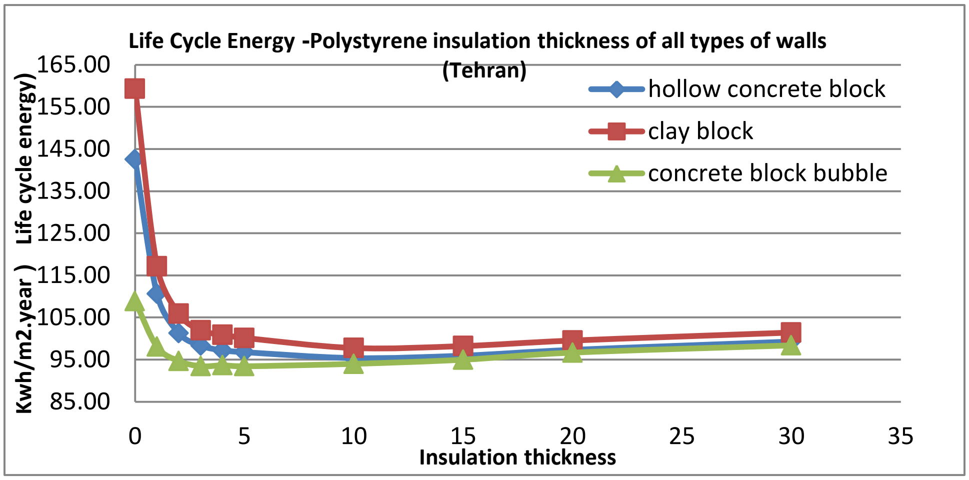

**Chart 1.** impact of polystyrene insulation thickness of energy on building life cycle

As had been anticipated, and pursuant to chart 1, insulation systems have a huge impact on the energy life cycle of buildings, however since the influence of insulation on the walls made of clay blocks, the insulation has more influence on wall made of this type of materials and the path to reduce lifecycle energy has been steeper.

### 4.2.2. The Impact of Different Insulation Thickness of the Wall on the Building Life Cycle Energy

thickness of different elements on the total energy lifecycle of the building and in continuation of the analysis stages, concrete hollow blocks were selected as the reference material as a result to their widespread use in all regions of the country, optimum thermal features, easy access and being more in Cost-effectiveness than from other types. Other variables were analyzed on this assumption. This basic model consists of a wall being made of hollow concrete blocks and concrete slab roof. At each stage of analysis, the type and thickness of the insulation applied in the walls is changed.

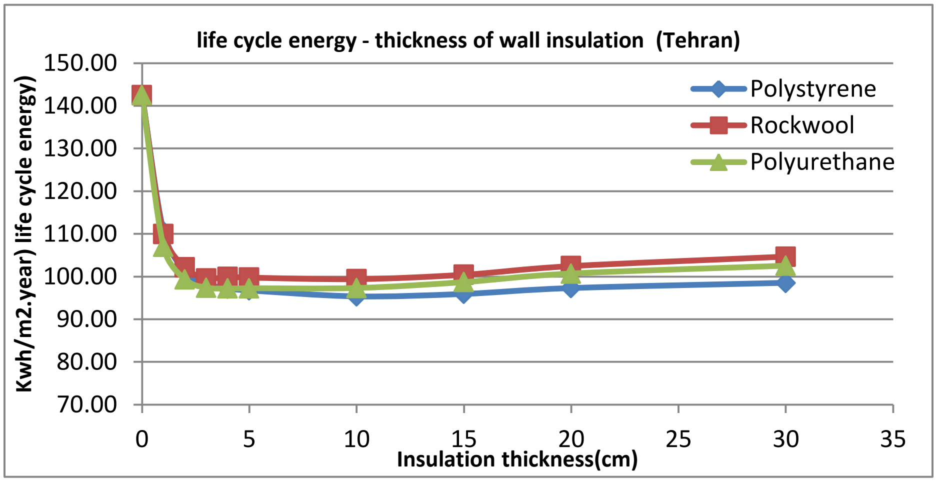

**Chart 2.** Effect of wall insulation thickness on the amount of building LCE in moderate climate (Tehran)

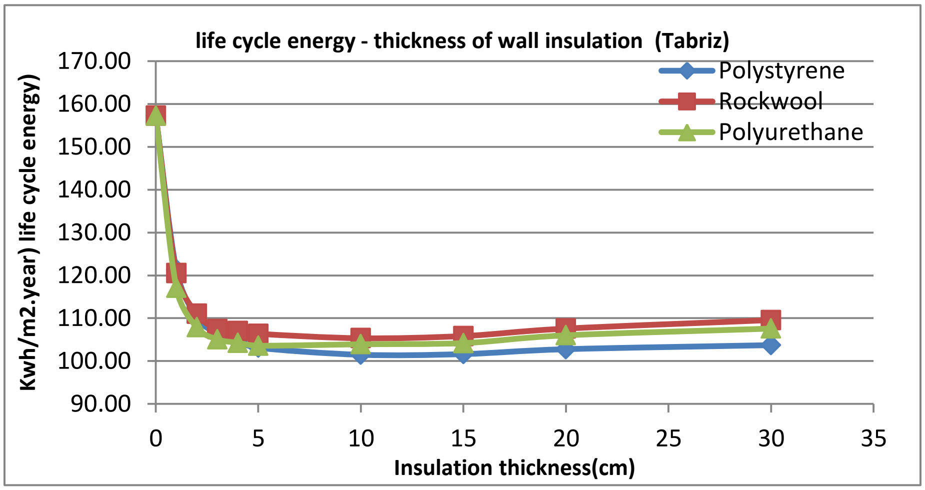

**Chart 3.** Effect of wall insulation thickness on the amount of building LCE in cold climate (Tabriz)

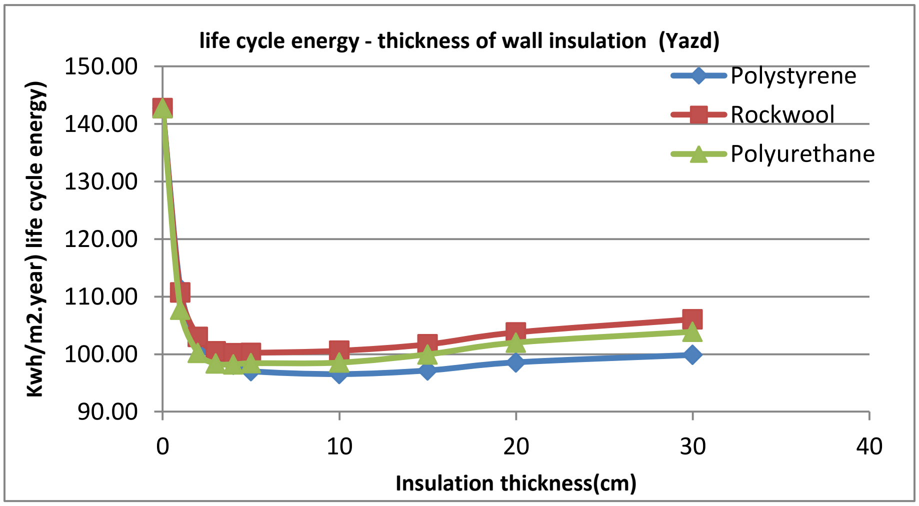

**Chart 4.** Effect of wall insulation thickness on the amount of building LCE in hot and dry climate (Yazd)

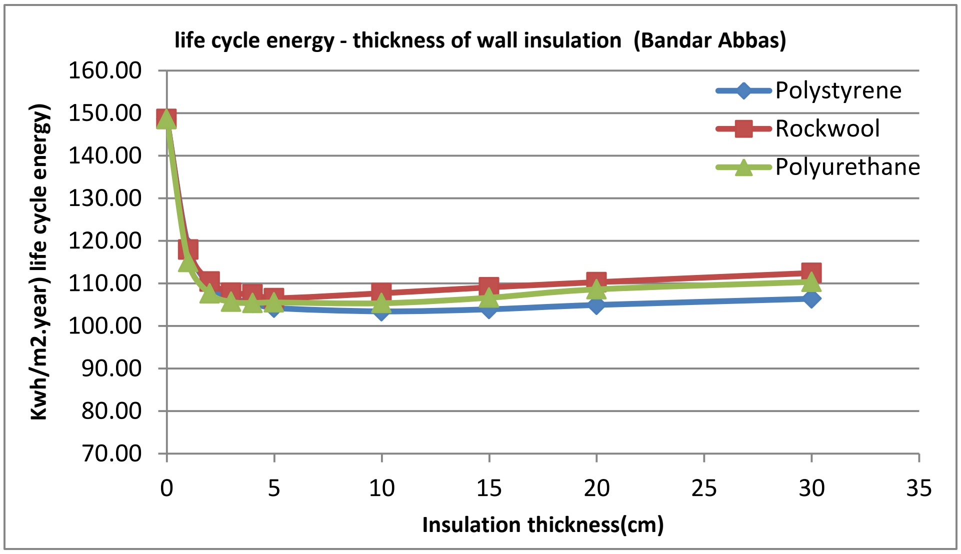

**Chart 5.** Effect of wall insulation thickness on the amount of building LCE in hot and humid climate (Bandar Abbas)

As it can be observed in Chart 2 to 5 most effective insulations can be achieved at low thicknesses. In thicknesses being more than 5 cm, as a result to the low influence of the added thickness on operation energy as well as increase of embodied energy, life cycle is associated with an upside bias.

### 4.2.3. Optimum Thickness of Insulation in Wall Elements

According to the graphs plotted in the fourth section in this study, it can be easily found that the use of insulation has significant impact on energy consumption of the building life cycle and the impact will reach to an optimum level in case of applying proper insulation material and proper thickness for each type of elements in building. In this section, the optimum thickness (under which the lowest energy life cycle is obtained) of any insulation in all weather conditions will be gained applying the figures mentioned and by the concurrent use of this insulation in walls, the lowest energy of entire life cycle of building is calculated. (Tables 3 to 5) in this calculation, the base model is selected in accordance with the contents listed in section 4-4-1 and various insulation materials are assigned to it based on the model.

**Table 3.** Calculation of energy buildings in dedicated mode thick of polystyrene insulation

| **Climate** | **Embodied energy of insulation** (Mj / m3) | **LCE** (kwh / m2.year) | **Exploitation energy** (kwh / m2.year) | **Embodied energy of the system** (kwh / m2.year) | **Wall insulation thickness** (cm) | **Insulation Material** |
|---|---|---|---|---|---|---|
| Moderate (Tehran) | 2500 | 85.43 | 40.92 | 44.51 | 10 | EPS |
| Cold Mountain (Tabriz) | 2500 | 88.45 | 41.63 | 46.82 | 10 | EPS |
| Hot and dry (Yazd) | 2500 | 87.26 | 42.75 | 44.51 | 10 | EPS |
| Hot and humid (Bandar Abbas) | 2500 | 98.11 | 53.60 | 44.51 | 10 | EPS |

**Table 4.** Calculation of energy buildings in dedicated mode thick of Rock wool insulation

| **Climate** | **Embodied energy of insulation** (Mj / m3) | **LCE** (kwh / m2.year) | **Exploitation energy** (kwh / m2.year) | **Embodied energy of the system** (kwh / m2.year) | **Wall insulation thickness** (cm) | **Insulation Material** |
|---|---|---|---|---|---|---|
| Moderate (Tehran) | 3360 | 90.78 | 39.89 | 50.89 | 10 | Rock wool |
| Cold Mountain (Tabriz) | 3360 | 94.37 | 40.37 | 54.00 | 10 | Rock wool |
| Hot and dry (Yazd) | 3360 | 92.84 | 48.18 | 44.66 | 4 | Rock wool |
| Hot and humid (Bandar Abbas) | 3360 | 105.14 | 57.36 | 47.78 | 5 | Rock wool |

**Table 5.** Calculation of energy buildings in dedicated mode thick of Polyurethane insulation

| **Climate** | **Embodied energy of insulation** (Mj / m3) | **LCE** (kwh / m2.year) | **Exploitation energy** (kwh / m2.year) | **Embodied energy of the system** (kwh / m2.year) | **Wall insulation thickness** (cm) | **Insulation Material** |
|---|---|---|---|---|---|---|
| Moderate (Tehran) | 3045 | 87.20 | 44.28 | 42.92 | 4 | Polyurethane |
| Cold Mountain (Tabriz) | 3045 | 92.69 | 44.13 | 48.56 | 5 | Polyurethane |
| Hot and dry (Yazd) | 3045 | 88.92 | 46.00 | 42.92 | 4 | Polyurethane |
| Hot and humid (Bandar Abbas) | 3045 | 99.36 | 59.77 | 39.59 | 4 | Polyurethane |

### 4.2.4. Calculation of Energy Consumption reduction in various combinations

Different materials assigned to the walls, ceiling and both elements simultaneously have a different impact on operation energy consumption and so on the total lifecycle energy of the building. In this section by calculating the percent of energy consumption reduction in the operation phase as well as the building life cycle rather to the basic sample, we are trying to express the very significant importance of insulation in buildings. In Table 6 the maximum amount of life cycle energy reduction is marked in bold. This amount represents the most optimal mode for using insulations with polystyrene insulation in the roof and walls which are presented in table 3 with the specified thicknesses.

**Table 6.** Table of percent of reduction in energy utilization and life cycle of the building with the most optimal insulation thickness of 4 Provinces of Iran

| **Wall specifications** | Moderate (Tehran) | | Cold Mountain (Tabriz) | | Hot and dry (Yazd) | | Hot and humid (Bandar Abbas) | |
|---|---|---|---|---|---|---|---|---|
| | **Operational energy** (kwh / m2.year) | **LCE** (kwh / m2.year) | **Operational energy** (kwh / m2.year) | **LCE** (kwh / m2.year) | **Operational energy** (kwh / m2.year) | **LCE** (kwh / m2.year) | **Operational energy** (kwh / m2.year) | **LCE** (kwh / m2.year) |
| Type 1 hollow concrete block | 116.52 | 142.51 | 131.28 | 157.28 | 116.76 | 142.76 | 122.61 | 148.61 |
| Type 2 Concrete blocks bubble | 82.89 | 108.89 | 93.73 | 119.73 | 83.56 | 109.56 | 90.78 | 116.78 |
| %Reduction in energy consumption compared to 1 | 28.86 | 23.59 | 28.61 | 23.88 | 28.43 | 23.25 | 25.96 | 21.42 |
| Type 1 + polystyrene insulation in the wall | 55.48 | 95.36 | 61.59 | 101.47 | 56.65 | 96.53 | 63.58 | 103.46 |
| % Reduction in energy consumption compared to 1 | 52.38 | **33.08** | 53.08 | **35.48** | **51.48** | **32.38** | **48.15** | **30.38** |
| Type 1 + rock wool insulation in the wall | 54.73 | 99.40 | 60.66 | 105.33 | 61.75 | 100.19 | 64.98 | 106.53 |
| % Reduction in energy consumption compared to 1 | **53.03** | 30.25 | **53.79** | 33.03 | 47.12 | 29.82 | 47.01 | 28.32 |
| Type 1 + polyurethane insulation walls | 59.93 | 97.21 | 63.49 | 103.59 | 60.95 | 98.23 | 68.15 | 105.43 |
| % Reduction in energy consumption compared to 1 | 48.57 | 31.79 | 51.63 | 34.13 | 47.80 | 31.19 | 44.42 | 29.05 |

In addition to the specified combinations in Table 5, a combination with the most optimum thicknesses of the polystyrene insulation and with changing door's material type from a wooden core to an insulated core were analyzed. Under which there was a relative increase in life cycle energy due to higher amounts of U for the door with insulated core rather to the base model.

## 5. Conclusion

This paper investigated the effect of insulation systems, consisting of a variety of common materials in Iran. The study was done in different climates, to help simulate the performance and insulation of buildings to optimize building lifecycle energy consumption and energy utilization in the best possible way.

As a result of this modeling and energy simulation, the polystyrene was selected as the best building insulation from perspective of lifecycle energy of the building in any of the 4 climates of the country. The combination of this type of insulation with optimal thickness reveals between 30.38 to 35.47 percent reduction in energy lifecycle of buildings, depending on the region of energy analysis to the result of basic sample with the application of double-glazed windows and doors with wooden core and the walls with 20 cm of blocks of hollow concrete blocks, and this amount of energy savings according to the type and number of floors in the building plans has a great impact on preservation of the environment and reducing energy consumption for the use of insulation systems.

Some of the results obtained from the aid of reviewed process diagrams portrayed in the fourth section of this study are briefly described below:

1. Pursuant to the National Building Regulations in Iran, only double-glazed windows were applied in the modeling performed in this study.

2. Bubble concrete blocks use presented the best results among 3 types of modeled materials (hollow concrete blocks, concrete blocks and blocks bubble babies) in terms of energy. But because of the large price difference compared to the second hollow concrete blocks, which was the second option (approximately 2-3 times of the price in the summer of 1395, Iran), Bubble concrete block was removed from the priority and hollow concrete blocks were chosen as the base material.

3. In estimating the optimum thickness of insulation materials of the wall from the perspective of the life cycle, polystyrene insulation was selected as the most optimal materials. Though in some climates and less than 5 cm thickness, polyurethane insulation had better performance.

4. The insulation systems of buildings in consonance totheir impact on energy studies, have highest and lowest impact on buildings lifecycle in cold and mountainous areas and hot and humid areas, respectively.

Finally, it is noteworthy to mention that utilization of calculated elements for reducing building energy consumption in this study has great spiritual benefits in addition to material interests, including the most important ones are as follows:

1. Increasing the thermal comfort inside buildings

2. Improvement of mental and physical performance of occupants in buildings

3. Reducing the possibility of residents' dehydration in buildings

4. Reducing the risks of developing various longtime diseases dependent on thermal conditions of the region

5. Increasing efficiency and reducing tiredness

6. Reducing additional unwanted and extra noise inside the building

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