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Potentials and Barriers of Energy Saving in Jordan's Residential Sector through Thermal Insulation

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Abstract

The residential sector in Jordan accounts for 21% of final energy consumption and 43% of total electricity consumption. More than 60 % of energy consumed in households is used for space heating and cooling. Thermal insulation of building is a decisive factor in reducing residential heating and cooling energy needs. Although thermal insulation codes have been adopted since the early eighties, enforcement of these codes has been limited. This resulted in sporadic implementation of thermal insulation in residential buildings that varies according to the ownership type, income and education levels. This paper presents an analysis of potential energy savings that can be achieved through retrofitting Jordanian households to comply with the existing thermal insulation codes. In addition, the legal, social, economic, and technical barriers of the use of thermal insulation are discussed in an attempt to bring a better understanding of how the projected savings can be assured.

Keywords: *Thermal insulation, building codes, residential buildings, energy saving.*

1. Introduction

Jordan is a non-oil producing country which suffers from inadequate supplies of natural resources including water, natural gas and crude oil. Consequently, 97% of total national energy needs are imported from neighbour Arab countries; which costs 17% of Jordanian gross domestic product [1]. The residential sector accounts for 21% of final energy consumption and 43% of total electricity consumptions [2]. Zarei and Zare [3] stated that urbanisation, the increasing of population, and the improvement of living standards are all contributors to increasing the residential energy requirements. On the other hand, Al-Ghandoor et. al. [4] found that population is the key factor on energy consumption while electricity and fuel prices have no effect on electricity and fuel consumptions. The urban subsector represents about 80% of households and responsible for 84% of the residential energy consumption in Jordan [5]. Jaber et. al. [6] revealed that space heating presents 61% of total consumption in households, which accounts for about 14% of total national energy demand. Further, they reported that traditional un-vented kerosene and LPG heating systems are the most common to provide space heating in urban areas.

Since more than 60 % of energy consumed in household is used for space heating, improvement of the physical building envelope or using more efficient space heating systems are two options that should be adopted. Jaber et. al. [7] recommended that a careful selection of boilers, air-conditioning systems, and lighting as well as thermal insulation, all could contribute in increasing the energy efficiency in this sector. While, Mohsen and Akash [8] stated that it is more convenient to focus on building fabric instead of the heating systems. In addition, Yang et. al. [9] found that thermal insulation of envelope plays the key role in the assessment of space heating and cooling especially in cold winter regions, while in mild regions orientation of building is the most important indicator in building energy efficiency assessment followed by outdoor and indoor shading and insulation; which both have the same weight. Further, through a research conducted by Tommerup and Svendsen [10] on energy saving measures in households in Denmark, it was found that well insulated external walls reduce the heat loss by 50% which in turn reduces the heating requirement by 46%.

Al Zyood et. al. [11] revealed that if building envelope is provided with 5.7 cm of thermal insulation and of trombe wall, this could reduce heating needs by about 82% and such system has less than 2 years payback period. While, Chvatal et. al. [12] stated that thermal insulation is important in heating season and any increase in insulation thickness will reduce the total U-value of envelope which directly reduces heating requirements. However, he showed that in summer; when the gains (internal or solar) are not well controlled, a highly insulated envelope may cause an increase in the indoor temperature, which could reach unacceptable comfort limits. This could possibly offset any savings obtained from increased insulation during the heating season. High indoor temperatures could enhance fungi which is one of serious sick building syndrome. Moreover, poor building insulation could enhance Fungi appearance in internal building corners because of thermal loses near the corners [13]. Suliman and Beithou [14] stated that improper insulated envelope is a significant factor that cause the indoor environment during the cold season to be uncomfortable, damp and unhealthy.

2. Current Status of Thermal Insulation in Jordan

Jordan was one of the first countries in the region to specify a thermal insulation code (since the mid-1980s). The Jordanian Thermal Insulation Code specifies the following:

- Design requirements concerning the U value for walls, roofs, and floors.
- Insulation materials types properties and standards.
- Principles of thermal design and dampness in buildings.

A summary of the maximum allowed U-values required by the code is presented in Table 1 [15]. It can be noticed that such code requirements for external walls and roofs cannot be achieved without the use of a minimum layer of 5 cm of insulating material such polystyrene or polyurethane.

Table 1. Thermal insulation code U-value requirements for different types of walls

Type of wall	Maximum U-value ($W/m^2{}^oC$)
External opaque walls (without openings)	0.57
External walls (with openings)	1.6
External roofs	0.55
Divider wall between two independent spaces	2.0
Divider roof section between two independent spaces	1.2

More recently, another code “Energy Efficient Building Code” has been adopted to face the increasing energy challenges. The code contains seven chapters covering: general considerations, architectural aspects, mechanical ventilation, heating and air conditioning, hot water supply, lighting, and electrical power. This combination of architectural, mechanical and electrical topics makes it one of the most comprehensive sustainable building-related code in the region.

Although compliance with all building codes is compulsory and is mandated by the national building law, enforcement mechanisms are either absent or ineffective. Design documents and drawings of all new buildings are inspected for compliance with the code by the Jordan Engineers Association before a building permit is granted. However, on-site inspection is rarely carried out to ensure that the construction follows the design requirements, and therefore the code requirements. This resulted in limited and sporadic compliance with the thermal insulation code, as well as other building codes. In a recent survey conducted in 2015 by Al-Sallami [16], it was found that only 23% of Jordanian dwellings are insulated either with polystyrene, polyurethane, or rock wool. Although this percentage reveals the scale of the problem, it represents a significant improvement in comparison with the reported percentage of only 6% in 1998 [8]. However, only 38% of the owners of insulated dwellings reported the use of insulation layer of 5cm thickness or more, which is required to meet the code specifications. This indicates that the use of thermal insulation is still a matter of choice for contractors and owners, and although the level of awareness is increasing, code compliance is still far from being widespread.

3. Barriers of Implementing Thermal Insulation in Jordan

In order to better understand the drivers and barriers that affect the decision of using thermal insulation in buildings and conforming to the existing thermal insulation code in Jordan, the data from the survey mentioned in the previous section [16] was used. It is worth mentioning that the survey was designed to gather information about a large number of indicators that can affect the energy use in local buildings. Households were selected randomly. The 375 surveys were distributed in different districts, but the number of completed surveys was 235. Out of the completed surveys, only 86% were considered and the rest excluded from calculations due to statistical considerations. The following factors have been identified: Ownership, income level, and education level.

Regarding the correlation between ownership and the use of thermal insulation, it can be seen from figure 1 that while 48% of owned dwellings are insulated, in one way or another, only 19% of dwellings that are rented are insulated. Such contrasting result indicates that owners are more likely to insulate their buildings if they actually live in them and tenants are very unlikely to pay extra costs to insulate swellings they do not own. Further analysis of the data revealed that 70% of the owned but uninsulated dwellings are apartments that were built by construction companies and not by their current owners. It can be concluded that implementing thermal insulation in residential buildings is strongly driven by its economic feasibility to the party who is constructing the building rather than the willingness to comply with existing codes. This on one hand confirms the weakness of supervision and enforcement mechanisms, and on the other reflects the lack of incentives for construction companies and contractors to voluntarily comply with the insulation code. The provision of a voluntary certification or rating system that can distinguish properly insulated dwellings can be an incentive for contractors who can directly benefit from such certification system in promoting their code-compliant properties to owners and tenants.

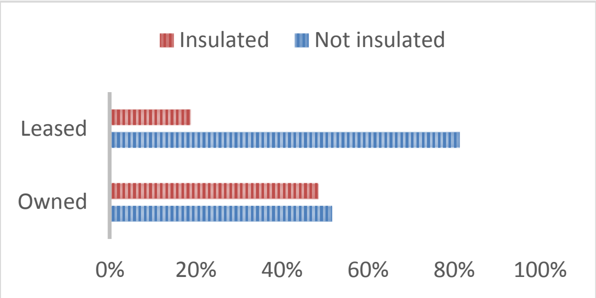

Figure 1. Percentages of insulated and uninsulated dwellings based on the type of ownership

Regarding the correlation of income level with the use of thermal insulation, Figure 2 indicates that a clear gap between low income and high income households when it comes to the use of thermal insulation. The initial cost of investment is most likely the reason behind this gap. While high income households are willing to invest in an energy conservation measure that pays back in several years, low income households find it difficult to source such investment. This in turn results in poor comfort conditions and in increased energy costs for low income households. The provision of eased, long term, low-interest financing schemes that target low income households can be very helpful in assisting them in overcoming the initial cost obstacle and implement thermal insulation in their dwellings without increasing their financial burdens.

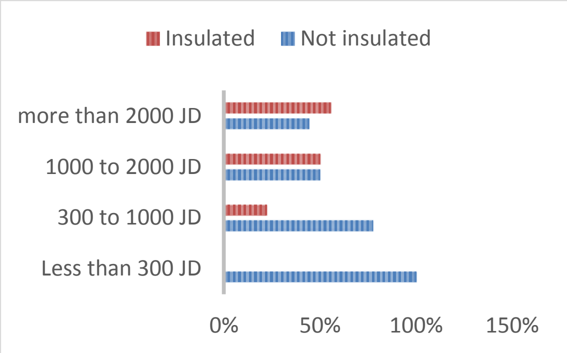

Figure 2. Percentages of insulated and uninsulated dwellings based on the monthly income level

Figure 3 shows the correlation between the education level of the head of the household and the existence of thermal insulation. It is interesting to note that while less than 10% of the dwellings headed by a person with relatively low education level are insulated, this percentage rises to nearly 60% in dwellings headed by a person with relatively high education level. Such gap can be attributed to the correlation between income level and the level of education in part, but clearly points to an awareness gap. Highly educated households are clearly more aware of the benefits and potential savings that can result from the implementation of thermal insulation in their dwellings. This highlights the need for awareness campaigns and program that can simplify the potential benefits of thermal insulation to all sectors of the society regardless of their level of education.

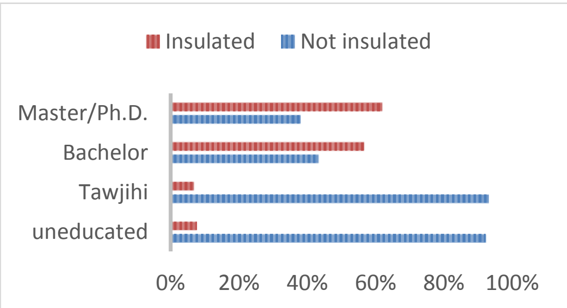

Figure 3: Percentages of insulated and uninsulated dwellings based on the education level

4. Potential Savings of Enforcing Thermal Insulation Codes

An essential element in raising awareness on the importance of thermal insulation and compliance to the thermal insulation code is evaluating the potential energy and economic savings that can be achieved. In order to do so, a simplified model has been developed. The model is based on the degree.day approach and allows for varying simple house/apartment layout, weather data, wall construction, window/wall ratios, glazing and shading properties,…etc. The degree.day approach is simple and is very useful in establishing energy models, baselines, comparative analysis of energy consumption, despite the fact that it only takes the dry bulb temperature into consideration and that it is based on average temperatures. Internal loads were also ignored for simplicity. The following is a description of the equations used in the model:

$$Q_t = Q_c + Q_i + Q_s \quad (1)$$

Where,
Q_t : Total heat gain/loss (kWh)
Q_c : heat gain/loss due to conduction through walls, windows, and roof (kWh)
Q_i : Heat gain/loss due to infiltration (kWh)
Q_s : Heat gain due to direct solar radiation (kWh)

$$Q_c = \frac{24}{1000}\, U\, A\, DD \quad (2)$$

Where,
U: Overall heat transfer coefficient (W/m^2.°C)
A: Area of wall, window, or roof (m^2)
DD: Heating/cooling degree day (°C.day)

$$U = \frac{1}{R_i + R_o + \sum R_l} \quad (3)$$

Where,
R_i: Inside surface convection resistance (m^2.°C/W)
R_o: Outside surface convection resistance (m^2.°C/W)
R_l: Conduction resistance in each layer of the wall or roof (m^2.°C/W)

$$R_l = \frac{t}{k} \quad (4)$$

Where,
t: Layer thickness (m)
k: Layer conductivity (W/m.°C)

$$Q_i = \frac{24}{1000}\,\frac{\rho c_p V}{3600}\, DD \quad (5)$$

Where,
ρ: Density of air (kg/m^3)
c_p: Specific heat of air (J/kg.°C)
V: Volume changed per hour based on the Air Change Method (m^3/h)

$$Q_s = I A_w (SC) \quad (6)$$

Where,
I: Incident solar radiation on the surface at a given orientation (kWh/m^2.month)
A_w: Window area (m^2)
SC: Shading coefficient

This calculation model was used with a modular house/apartment in order to calculate the effect of thermal insulation on the overall heating and cooling energy demand under the typical climatic conditions in Jordan. The model house was rectangular shape one story 20 m x 10 m, with a total floor area of 200 m^2. The climatic data used for the calculation are shown in Table 2 [17]. The reference for the degree.day calculation was 21.°C for all months. The resulting monthly degree.days are also shown in Table 2. It should be noted that the degree.days shown for the months of June till September are cooling degree.days (CDD) while they are heating degree.days (HDD) for the remaining months. The total HDDs are 1726 and the total CDDs are 441. The model was run twice: The first time with typical building constructing and in accordance with the specifications shown in Table 3. These specifications represent the typical construction and materials and methods normally used by contractors in Jordan. In the second time, the model was run with the same specifications but with adding a 5 cm layer of extruded polystyrene (k = 0.029 W/m.°C) within the wall and roof sections in order to achieve compliance with the thermal insulation code.

The resulting U value decreased from 2.63 to 0.48 W/m^2.°C for the wall section and from 2.24 to 0.46 W/m^2.°C for the roof section when the insulation layer was added. The resulting annual heating load went down from 50,716 kWh to 22,270 kWh and the annual cooling load went down from 15,838 kWh to 8,572 kWh. Therefore, the total heating/cooling load can be reduced by nearly 52% by simply adding the insulation layer to the walls and roofs. The details of the heating and cooling loads monthly variations before and after the insulation are shown in Figure 4 and Figure 5, respectively.

Assuming that such saving percentage can be implemented across the residential sector for uninsulated dwellings, and considering that this sector is responsible for 21% of the final energy consumption, of which 60% is consumed in space heating and cooling, a total of around 6% of the total national energy bill can be saved through enforcing code-compliant insulation to all new and existing buildings.

Table 2. Climatic data of Amman used for the model calculations

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Temp (°C)	8.0	9.0	11.8	16.1	20.7	23.8	25.3	25.6	23.7	20.5	14.9	9.8
Daily Solar irradiance (kWh/m^2)	2.7	3.7	5.0	6.8	7.8	8.4	8.2	7.5	6.4	4.8	3.6	2.7
Degree.days	403	336	285	147	9	84	133	143	81	16	183	347

Table 3. Building construction specifications

	Material	Conductivity (W/m.°C)	Thickness (cm)
Wall Section	Ajloun stone	2.46	7
	Concrete	1.17	5
	Hollow blocks	0.63	7
	Plaster	0.72	2
Roof Section	Concrete tile	1.2	2
	Gravel	0.28	3
	Concrete ribs	0.95	10
	Reinforced concrete	1.44	7
	Plaster	0.72	2

Windows	Aluminium single glazed (U = 5.7 W/m^2.°C)
Window/Wall ratio	0.15
Windows shading coefficient	0.8
Windows on North side	13.5 m^2
Windows on South side	8.5 m^2
Windows on East/West sides	5.4 m^2

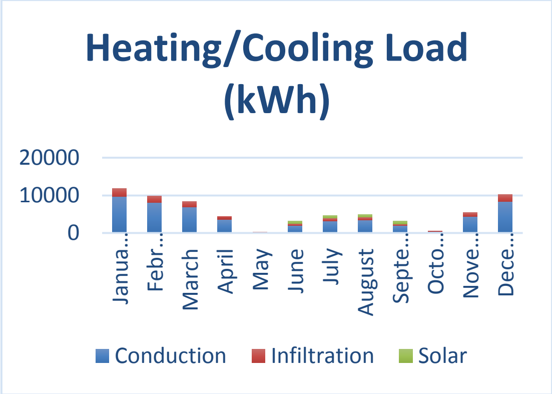

Figure 4. Heating and cooling load results for the model building without insulation

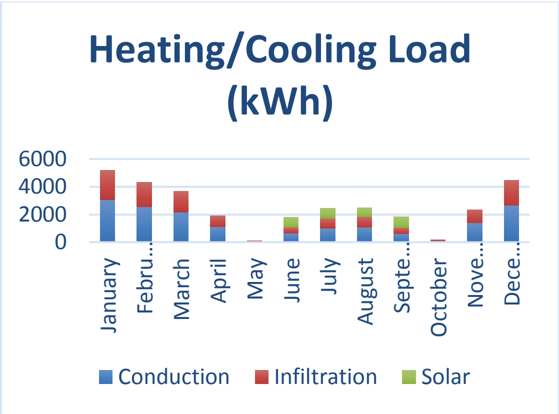

Figure 5. Heating and cooling load results for the model building with insulation

5. Conclusions

In this paper, it was demonstrated that although compliance with the thermal insulation code is compulsory, 77% of Jordanian dwellings lack any type of insulation and less than 9% comply with the code. This indicates that the use of thermal insulation is still a matter of choice for contractors and owners and code compliance is still far from being widespread.

Three factors that affect the decision of implementing thermal insulation in residential buildings were analysed: Ownership, income level, and education level. The findings indicate a strong relationship between each of these factors and the use of thermal insulation. The provision of a voluntary certification or rating system that can distinguish insulated dwellings can provide sufficient incentive for contractors and landlords to comply with the code. The cost of the initial investment and the lack of awareness are clear barriers to the implementation of thermal insulation. The income gap can be bridged through the introduction of eased, long term, low-interest financing schemes that target low income households. The education gap highlights the need for awareness campaigns and program that can simplify the potential benefits of thermal insulation to all sectors of the society regardless of their level of education.

A simplified model was developed and implemented to calculate the potential savings that can result from compliance with the thermal insulation code. Results indicated that the cooling and heating loads can be reduced by 52%. Considering such potential savings, the total national energy bill can be reduced by 6% if a national retrofitting program is implemented to all uninsulated residential buildings to bring them to comply with the thermal insulation code.

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