Reassessing the Numerous Proposed and Existing U-values for Lebanon

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ABSTRACT

Since 2005 a number of publications have proposed different U-values to be used in Lebanon in order to reduce the buildings' energy demand for cooling and heating. This research considers those different values from the two editions of the Thermal Standard for Buildings in Lebanon (2005 & 2010) and Lebanon Center for Energy Conservation LCEC guidelines (2014), in addition to recommended U-values from similar worldwide climates. In the second part of the paper, dynamic thermal simulation software (EDSL TAS) is used to test the proposed U-values in conjunction with typical local construction materials and using Bayrouth weather files (Meteonorm 7). The tridimensional model used for the simulations is based on a typical existing building with characteristics kept constant throughout the comparative study. Furthermore the same internal heat gains and patterns for occupancy and appliances, as well as window opening areas and schedules are also kept the same in all the simulations. For each case, the four main cardinal orientations are tested. The research compares the overall yearly energy demand for mechanically heated and cooled buildings, in order to assess which U-values will give the lowest energy demand under varying levels of internal heat gains.

INTRODUCTION

The concern to reduce buildings energy reliance on fossil fuel for internal comfort is, in today's social media language a "trending topic". The triggering incident for this concern can be traced back to the 1973 first OPEC crisis that resulted in an attempt to reduce dependency on fossil fuel. Later, the environmental impact of global warming and its close relationship with fossil fuels' CO_2 emission as the main culprit, consolidated the concern with fossil fuel consumption, especially considering that the built environment global end use emissions account for an estimated 40 to 50% of overall energy consumption.

Construction codes and bio-climatic design source books (Nicol et al, 2012; Szokolay, 2004; Yannas 1994; Littlefield, 2007) promote qualitatively and quantitatively the use of low U-values, or highly insulated construction, for temperate European or north American climates, whereas they include marginal notes with limited quantitative data stating that the use of thermal mass will greatly affect the thermal performance of any construction by reducing its internal temperature fluctuation. This reductive effect is further enhanced by its combination with night time, cooling ventilation. Kiel Moe's (2014) 'Insulating modernism', attacks all the buildings' insulation practice by going into a detailed historical overview on how insulation emerged in the refrigeration industry and was imposed into the architects as an ideal solution, without leaving any room for re-questioning its efficiency. He carries on with numerical demonstration of the drawback of insulation. He concludes that the alternative is the use of thermal mass, yet he only

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refers to limited built examples without any quantitative demonstration of their efficiency.

Moving to Beirut, Lebanon, whose coastal climate is defined by hot and humid long summer without precipitations, and warm short winters (TSB, 2010 & Kottek et al; 2006), its building stock is almost entirely made out of stone, concrete or related and combined construction material, all fitting within the definition of heavy weight construction. Based on the above described benefits of thermal mass, one would expect to find a very good example of low energy performing buildings. Yet it appears that for Beirut's internal summer comfort is highly reliant on mechanical cooling.

Furthermore, a number of local environmental bodies are active in the construction regulations field, yet working in parallel, and accordingly have recommended different U-values and energy benchmarks. This paper starts by listing all the available U-values (W/m²K), Table 1, from the different local sources, including the foreign ones used as a reference for appropriate local values along with those from similar climatic zones in a range of countries. The paper continues by listing different energy benchmarks (kWh/m².y), Table 2, as well as proposed limits of internal gains from occupants (W/m²) and the maximum energy per year from lighting (kWh/m².y)Table 3 (LCEC, 2014). The paper then, carries on the first round of parametric energy simulations using all the values listed above onto a typical apartment building rotated to check the four cardinal orientations. In a second round, the internal gains are exaggerated to check the resilience of the systems.

List of different bodies

The following list shows the different bodies whose published values are considered herein: Both the Thermal Standard for Buildings in Lebanon (TSB) (Republic of Lebanon 2005 & Order of Engineers 2010); and the National Energy Efficiency and Renewable Energy Action (NEEREA) (LCEC, 2014). In addition to those, Agence Libanaise pour la Maitrise de l'Energie et l'Environment (ALMEE) published The Thermal Insulation Market in Lebanon (Comair et al, 2011) where they interpreted the thickness of the insulation based on the TSB 2010. Also within the introduction of the TSB (2010) it is stated that data were collected from a variety of sources including: the TSB 2005; ASHRAE 90.1.2004; the RT2005 French Thermal Regulation, and the Tunisian Thermal Regulation ZT1, 2008. For both French and Tunisian case, only values relative to the Mediterranean zone (south of France and North-East of Tunisia) were considered (FFEM et al, 2010; French Republic, 2006 a&b) whereas for ASHRAE 90.1, zone 2's values are considered (ASHRAE 90.1;2007). Finally based on the climate classifications of Koppen-Geiger (Kottek et al, 2006) California falling within similar Beirut climate has its U-values shown herein.

Envelope U-Values

Table 1 combines all the U-Values for each of the external walls, the roof and the windows, from the above mentioned list. The values are considerably different from one source to the other, and hence the roof U-values range from 0.1 to 0.75 W/m²K, the external walls from 0.18 to 1.62 W/m²K. In both cases the lowest values are the LCEC guidelines (2014), which did not specify any value for the windows. Otherwise those windows U-Values range from 1.81 to 6.2 W/m²K which encompass triple glazing with low-e; to single panel windows, as well as the intermediate double glazing. When the source gave the values in imperial units for U-factor, a conversion factor of 5.678 is used to change into SI units to U-Values (ASHRAE 2013).

Table 2 shows the limited proposed cooling and heating energy benchmarks from sources where available. The "business as usual" as defined by the LCEC (2014) is for any typical building without any energy consideration, it is set for residential at 118 kWh/m² per year out of which only 3 are for heating. On the other hand the benchmark value for a building to start to be considered as energy efficient is 80 kWh/m² per year.

Table 3 shows the only available proposed internal gains from occupants, as well as the proposed yearly energy from lighting (LCEC; 2014).

Heavyweight Construction

The term thermal mass refers to any material that has the capacity to absorb, store and release heat (Littlefield, 2007; Szokolay, 2004). Concrete, masonry walls and stone finishes are high density material and at the same time with high thermal capacity, hence the term heavy weight refers to that type of construction, which is the main construction type in Lebanon. Szokolay (2004) defines heavy weight or thermal mass as a building with a density of 400kg/m³ and above. A calculation from a typical residential concrete local building in Beirut will give values above 500kg/m³

Table 1 All U-Values from different local and foreign sources. The Bold Numbers show similar values within different references.

Title	Year	Roof	Walls (W/m².K)	Window	Notes	Reference Number
ASHRAE 90.1.2007 (Zone 2 A,B)	2007	0.27	0.70	4.26	Window U-Value for up to 40% Wall Area	2;3
Thermal Standard for Buildings	2005	0.57	2.1	6.2		19
RT2005 H3[1]	2006	0.34	0.45	2.6		9;10
Tunisia ZT1[2]	2008	0.75	1.2	6.2	Low Window to Floor area Ratio (WFR)	8
			1.1	6.2	Medium to High WFR area ratio	
			0.8	3.2	Very High WFR area ratio	
Thermal Standard for Buildings	2010	0.71	1.6	5.8	Till 25% WFR area ratio	18
			1.6	4	For 26 -35% WFR	
			1.26	3.3	For 36-45% WFR	
Thermal Insulation Market in Lebanon [3]	2011	(3.2cm)	(1.2cm)	N.A.	Data given in thickness	6
		0.58-074	1.59-1.62		Calculated U-Value	
2013 Residential Compliance Manual California Energy Commission [4]	2014	0.14-0.17	0.71	1.81	Maximum 20% Window to Wall area Ratio Maximum 5% Window to Wall area Ratio for West Orientation	4
International Energy Conservation Code [5]	2015	0.15	0.71-0.44	1.98	Values of Roof & Walls converted from R-values, converted to SI. U-Values of Windows converted to SI	1
LCEC Guidelines on Preparing Technical Proposal for Non-Certified High Energy Performance Building	2014	0.1-0.15	0.18-0.31	N.A.		13

[1] French Thermal standards for H3 Zone: Mediterranean area of south France

[2] Tunisian Norms for Private Buildings ZT1 zone which is the Mediterranean area of North East Tunisia

[3] Calculated U-Value based on XPS insulation thickness. Density 26-75Kg/m3 and R=0.026-0.037 W/m.K

[4] All U-values converted to metric value by multiplying by a conversion factor 5.678

[5] R-Values Converted to U-Value by U=1/R ; Values of Window given in U-Value

Table 2 Yearly energy values in kW.h/m^2/year standards and benchmarks for residential and offices from different sources.

Title	Year	Residential Standard	Residential Benchmark	Office Standard	Office Benchmark	Reference Number
RT2005 H3*	**2006**		80**			9;10
Lebanon Thermal Standards	**2010**		80		85	18
LCEC Guidelines on Preparing Technical Proposal for Non-Certified High Energy Performance Building	**2014**	118	80	107	75	13

* French Thermal standards for the H3 Zone : Mediterranean area of south France
** Based on fossil fuel heating (as opposed to electrical heating which has higher value)

Table 3 Internal gains from occupants and maximum yearly energy from lighting (LCEC 2014)

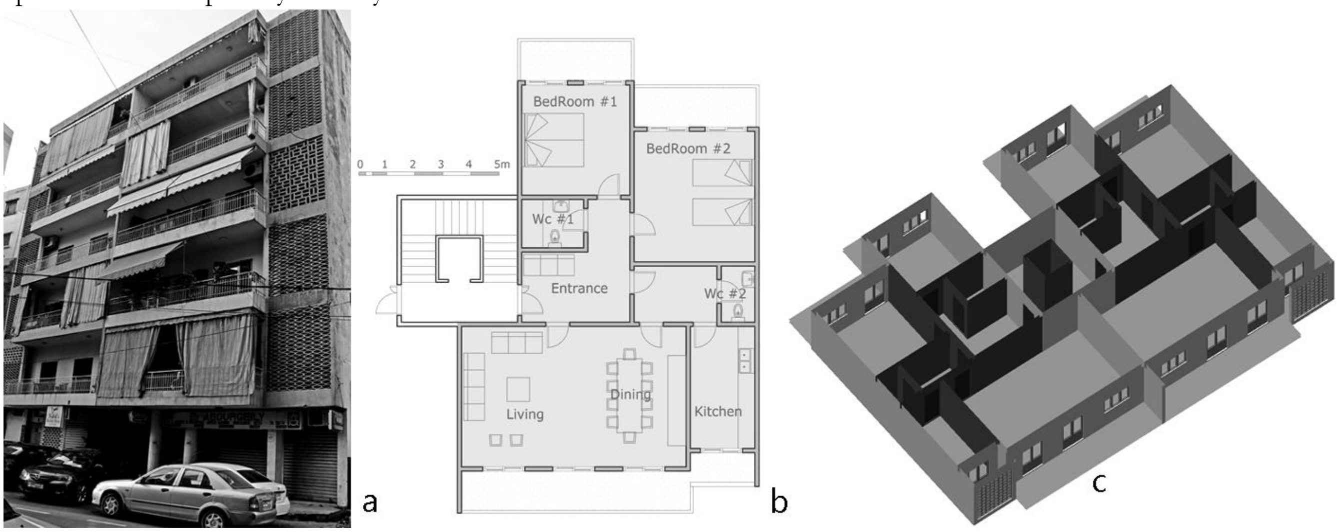
	Internal Gains from occupants (W/m^2)	**Maximum Yearly Energy from Lighting** (kWh/m^2)
Residential	5	13
Offices	14	17

Thermal Mass Behavior

Thermal performance of heavy weight construction is described as taking longer to warm up when exposed to solar gains and slower to respond to temperature variation (Littelfield, 2007; Szokolay, 2004). In the same way it takes longer to cool down and loose the extra heat. This stored heat will dissipate during the night provided there is the opportunity to do so due to diurnal temperature swing and adequate ventilation. This situation is ideal to maintain a comfortable indoor temperature when the temperature difference between day and night is considerable. Furthermore Szokolay (2004) considers it a very practical free-running solution to keep internal conditions within the thermal comfort zone. Littelfield (2007) and Szokolay (2004) both add that the practical effect of thermal mass lies in its surface area rather than in its thickness hence larger exposed area have more impact than effective thicknesses, and as such 5 to 12 cm are enough to provide a 24 hour cycle of heat absorption and release. Those thicknesses are available in any reinforced concrete construction, in any of the elements, slabs, walls and even some floor finishing; with not less than 5cm of uninterrupted thickness of solid material in/on any wall. Within the 2013 Residence Compliance Manual (2014) issued by the California Energy commission, it is stated that a 20 to 30cm concrete wall will have a combined dampening thermal time delay between 6 and 10 hours. Koch-Nielsen (2002) states that the process of cooling down thermal mass, or the heat dissipation, cannot be achieved without night time ventilation for hot and dry climates. This ventilation could be either natural or mechanically induced. He does not specify however hot and humid climates, but specifies that for warm and humid zones with little temperature fluctuation, thermal mass should not be applied; instead well ventilated light weight construction is the better choice of construction materials.

Building sample

For this study, the building that is taken as a prototype model for dynamic thermal simulation is located in the Ain er-Remmeneh area, on the outskirts of Beirut, and based on the users/owners testimony, it is one of the first residential and commercial developments to be built there in the late 1960's. Constructed of 5 floors, with two apartments on each, and a commercial ground floor, with a south-west main orientation for the living areas and blank exposed walls to its eastern and western façades. The building is made out of concrete slabs, plastered hollow concrete block walls, and all the windows have wooden frames. Each apartment is 110sqm and is made out of two bedrooms, one living and dining area, kitchen, two WCs and one entrance functioning as a small family living. The apartment is occupied by a family of four.



Error! No text of specified style in document.**igure-1** (a)The Building used as a model for the simulation; (b) Typical plan of one apartment; (c) 3D axonometric of the entire floor showing both apartments.

The apartment has individual split A/C units one in each bedroom and one in the living-dining area, which is seldom used, whereas the bedrooms' A/C are used during the night, when the main EDL power is available, hence not during the regular black outs when the neighborhood generator is the sole power supply. In the living area a fan and the open windows are used to provide some comfort throw ventilation from the summer heat and humidity.

This particular apartment has been monitored for ambient temperature and surface temperature from late August 2015 till early October 2015. The building is used as a typical generic model for the dynamic thermal model and simulation, over which the different U-values are tested.

Thermal Simulation

The EDSL TAS 9.3.2 thermal simulation software is used with the Bayrouth weather file 2000-2009 (Meteonorm 7). Four typical floors are modeled, each with the two adjacent apartments and cooling and heating yearly values per area are shown herein for the third and fourth floors, with the fourth considered as the roof or top floor and third as intermediate floor. Furthermore a total of four fully developed models with each having a different orientation (where the orientation is that of the main living areas) are simulated and analyzed.

The annual loads for cooling and heating are calculated for intermittent mode only when users are there, and occupancy is based on the observed apartment users' living patterns and remained unchanged in all the different simulations. Cooling temperature is based on 24^{o}C set-point and 50% RH threshold; as for heating it is based on 20 ^{o}C. The internal gains from lighting, users and equipments are the same throughout. For the LCEC values, 3 sets are done each with different window U-values from 6.41; 4.2 and 1.98 W/m^{2}K

Results

Run #1 Figure 2 shows all the values from the different orientation and runs for cooling and heating annual loads. The cooling load is always considerably higher than the heating load, averaging three to four time larger. Whereas the roof has higher heating and cooling values than the intermittent floor by less than 10%. As for orientation, the lowest values are always for the living areas with a north orientation followed by the south, and both East and West show almost the same values with very little difference. The highest values for a north orientation are 37 and 39 kWh/m² for intermediate and roof floor respectively, using the TSB 2005 U-values. Whereas the lowest values are from the LCEC with 4.2 W/m²K window U-values reaching 27 and 29 kWh/m². The south orientation will again have its lowest values with the same LCEC U-values at 35 and 37 kWh/m², and its highest values with the TSB 2005 at 49 and 52 kWh/m².

When it comes to east and west orientations, the highest values are 55 and 58 kWh/m² this time from the TSB 2005 intermediate floor and the base case for the roof. Whereas the lowest values 37 & 39 kWh/m² are still with the LCEC with 4.2 W/m²K windows U-values.

All achieved values are less than the 80 kWh/m² benchmark given by the local sources. Nevertheless, in order for the comparison to be feasible, one should note that major parameters that are intrinsic part of energy simulation are missing from the sources. Those are the specific weather files, the internal gains and the schedules of users, equipments and lighting. Also the number of users, the air exchange rate and volumes and finally the notion whether the cooling and heating are intermittent or continuous. All those missing factors render the comparison unsubstantial.

Run # 2 A second set of runs is performed to check the impact of increasing internal gains while pointing out the lack of benchmark values within the numerous local sources. For this scenario, the TSB (2010) and the LCEC (2014) models are considered as the base case and the overall internal gains are raised to 2.5 times, then, 5 times then 10 times greater, as shown in the table 4. Without a reference to assess whether the 10 times values might be over exaggerated or not, a house with considerable solar exposure will receive around noon time only an average of 600 to 800 W/m² summing up to a daily total well above the 1150W all internal gains combined. Yet what should be noted here, is the critical point where low U-values might not perform well, or at least as good as expected when internal gains are considerably high. In this case the percentage difference between the TSB and LCEC are decreasing with the increase of the internal gains. Starting at 40% for the base case at 53 and 38 kWh/m² for the TSB and LCEC respectively, it reaches negative 1% when internal gains are ten times higher than the initial base case.

What should be noted here is the efficiency of high insulation versus low insulation when there are no limits for internal gains, those could be from more users, different sort of physical activities, equipments and lighting as well as from solar gains.

CONCLUSION

With so many references for U-values and tentative energy benchmarks, a lot of missing valuable data are still hindering the local sustainable energy research scene. Theoretically, and based on thermal simulation software, the lower the U-Value the lower the energy. It seems that internal gains do have a considerable effect on reverting the impact of highly insulated buildings. Also major books and reference on sustainable design refer to the positive effect of adding thermal mass to any structure in order to reduce the cooling energy loads. Taking this into account, along with the overwhelming exposed heavy weight concrete structure in Lebanon, some contradiction exists: the simplest is that thermal softwares are not accurately simulating the performance of thermal mass. And if so extensive research should be focused on practical and comparative experiments to check the accuracy of the above. More so, one scholar (Moe; 2014) is strongly advocating the use of thermal mass, instead of high insulated buildings.

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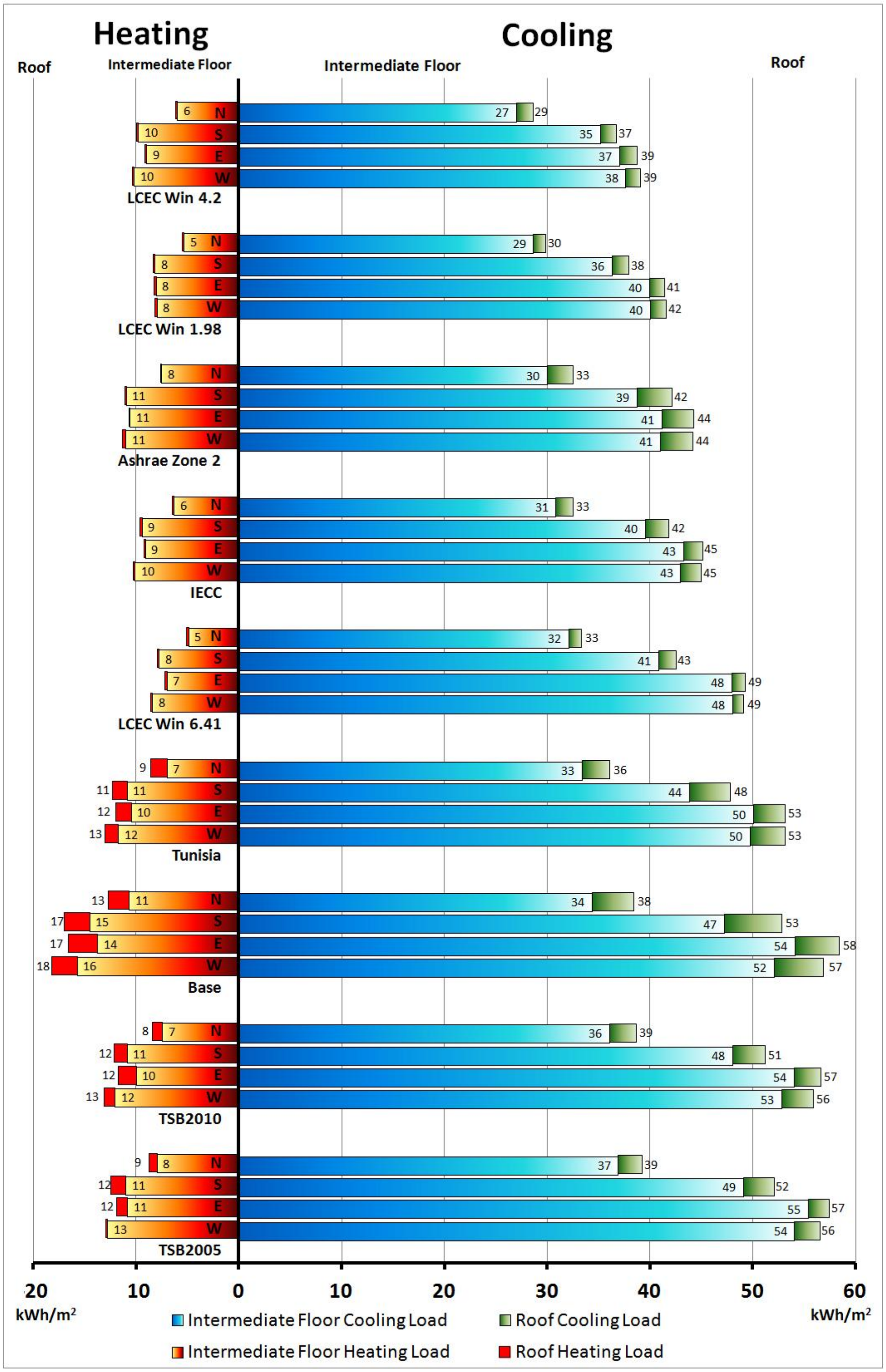

Figure 2 Overall summary of the cooling and heating load based on the different U-values from local, regional and international sources for a 110sqm residential apartment in Beirut.

Table 4 showing in the first two columns the increasing internal gains in total yearly and daily per area, followed by the corresponding energy values for both the LCEC & TSB along with the percentage difference between both.

	Internal Gains		Energy Cooling Values		
	Total kWh (per Year)	**Daily Total** (W/m^2)	**LCEC Base** (kWh/m^2)	**TSB Base** (kWh/m^2)	**% difference** (LCEC/TSB)
Base	4622	115	38	53	40%
x2.5 Internal Gains	11556	288	71	85	19%
x5 Internal Gains	23352	582	147	154	5%
x10 Internal Gains	46225	1151	323	321	-1%

NOMENCLATURE

TSB = Thermal Standard for Buildings in Lebanon
LCEC = Lebanon Center for Energy Conservation
NEEREA = National Energy Efficiency and Renewable Energy Action
RH = Relative Humidity
ICEC = International Energy Conservation Code
EDL = Électricité du Liban
OPEC = Organization of Petroleum Exporting Countries

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