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A review of minimum U-values for Lebanon and the associated effect of Internal gains

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Abstract: Since 2005 various publications have proposed different U-values to be used in Lebanon to reduce the buildings' energy demand, creating confusion and a lack of specific and authoritative recommendation. Moreover, the various thermal performance guidelines are not easily comparable due to unexplained basic assumptions and guidance on the calculation of internal gains.

This study has two interrelated objectives: a) test the most appropriate U-values for the climate of Beirut, b) study the consequence of increased internal gains have on the cooling energy load in low U-value construction. The paper does dynamic thermal simulation of the various U-values from local and international sources. The analysis allows the comparison and ranking of these various U-values based on the overall yearly energy demand for cooling. This is followed by a sensitivity study where a range of increased internal heat gains are inputted onto a low and a high U-value model to demonstrate that an increase in internal gains results in both models having the same cooling loads. Low U-values under this scenario due not result in a lower annual energy load.

The study concludes that, although finding the appropriate U-value for hot climates seems uncontroversial, the effect of internal gains must be taken into consideration. Hence the importance of having consistent and harmonized national and regional benchmark values for U-values and internal gains.

Keywords: Internal gains, U-Values, Hot Climate, Lebanon

Introduction

Building energy codes in general identify U-values as their principal method of annual energy reduction. A number of local and international publications have proposed different U-values to be used in Lebanon and similar climate zones to reduce the buildings' energy demand for cooling and heating. With both national and international construction actors operating in Lebanon, this situation creates confusion and shows a lack of specific and authoritative recommendation, with many guidelines being provided by organizations with no regulatory or mandatory power. Moreover, the various thermal performance guidelines are not easily comparable as most of these publications either ignore or offer without justification guidance on the calculation of internal gains. Further complicating matters, Lebanon has four recognized climate zones where Beirut, the center of most development is exemplified by a coastal climate of a long hot and humid summer without precipitation and warm short winters (TSB, 2010 & Kottek et al; 2006). In addition, the dominant construction materials making up the building stock is almost entirely stone, concrete and related combinations, all fitting within the definition of heavy weight construction. Based on known benefits of thermal mass (Nicol et al, 2012; Szokolay, 2004; Yannas 1994; Littlefield, 2007), one would expect to find a very good example of low energy performing buildings. Yet it appears that Beirut's occupants, indoors summer thermal comfort is highly reliant on mechanical cooling.

Objectives

This study has two interrelated objectives: a) test, through thermal modeling, the impact of these different U-value standards on the annual energy load for Beirut and b) to study the consequences of increased internal gains on the annual energy load in low U-value construction.

Methodology

The paper reviews the impact of different U-values from the two editions of the Thermal Standard for Buildings in Lebanon (2005 & 2010), those from the Lebanon Center for Energy Conservation LCEC guidelines (2014) and finally, those proposed for similar climates. This is followed by energy benchmarks listing for yearly cooling and heating values, before checking the internal heat gains available values. The first phase of the research starts with dynamic thermal simulations to test the proposed U-values in conjunction with typical local construction materials in Beirut. The analysis allows the comparison and ranking of the various U-values based on the overall yearly energy demand for cooling and heating. In the second phase of the research a range of internal heat gains are inputted onto a low and a high U-value models to demonstrate that as these increase, the impact is disproportionate on and resulting in both models having similar cooling loads.

The study concludes that, although Building codes provide U-values for hot climate construction, an apparently uncontroversial focus, the need for providing internal gain parameters is of equal consideration for modeling annual energy demand in hot climates.

Envelope U-Values

U-Values for each of the external walls, the roof and the windows, from the different local and international sources are listed in table 1. The values are considerably different from one source to the other: the roof U-values range from 0.1 to 0.75 W/m^{2}K, the external walls from 0.18 to 1.62 W/m^{2}K. 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/m^{2}K which encompass triple glazing with low-e coating; to single glazed windows, as well as the intermediate double glazing. When the source gives 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).

The yearly cooling and heating energy demand benchmarks from sources where available are shown in table 2. The standard values are defined by the LCEC (2014) as "business as usual" in reference for any typical building without energy consideration, it is set for residential at 118 kWh/m^2 per year out of which only 3 are for heating. On the other hand, the benchmark value for a building to start being considered as energy efficient is 80 kWh/m^2 per year.

Table 1. All U-Values from different local and foreign sources expressed in W/m^{2}K

Title	Year	Roof	Walls	Window	Notes

Lebanon	**Thermal Standard for Buildings**	2005	0.57	2.1	6.2	
	Thermal Standard for Buildings	2010	0.71	1.6	5.8	Till 25% Window to Wall area ratio (WWR)
				1.6	4	For 26 -35% WWR
				1.26	3.3	For 36-45% WWR
	Thermal Insulation Market in Lebanon [1]	2011	(3.2cm) 0.58-074	(1.2cm) 1.59-1.62	N.A.	Data given in thickness Calculated U-Value
	LCEC Guidelines on Preparing Technical Proposal for Non-Certified High Energy Performance Building	2014	0.1-0.15	0.18-0.31	N.A.	
Mediterranean	**RT2005 H3[2]**	2006	0.34	0.45	2.6	
	Tunisia ZT1[3]	2008	0.75	1.2	6.2	Low Window to Floor area ratio (WFR)
				1.1	6.2	Medium to High WFR area ratio
				0.8	3.2	Very High WFR area ratio
Int'l Codes	**ASHRAE 90.1.2007 (Zone 2 A, B)**	2007	0.27	0.70	4.26	Window U-Value for up to 40% Wall Area
	International Energy Conservation Code [4]	2015	0.15	0.71-0.44	1.98	Values of Roof & Walls converted from R-values, converted to SI[5] U-Values of Windows converted to SI

[1] Calculated U-Value based on XPS insulation thickness. Density 26-75Kg/m3 and R=0.026-0.037 W/m.K
[2] French Thermal standards for H3 Zone: Mediterranean area of south France
[3] Tunisian Norms for Private Buildings ZT1 zone which is the Mediterranean area of North East Tunisia
[4] R-Values Converted to U-Value by U=1/R; Value of Windows given in U-Value
[5] All U-values converted to metric value by multiplying by a conversion factor 5.678

Table 2. Yearly energy values in kWh/m^2/year standards and benchmarks for residential

Title	Year	Residential Standard	Residential Benchmark
RT2005 H3*	**2006**		80**
Thermal Standard for Buildings (Lebanon)	**2010**		80
LCEC Guidelines on Preparing Technical Proposal for Non-Certified High Energy Performance Building (Lebanon)	**2014**	118	80

* 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)

When it comes to the internal heat gains from occupants, lights and equipment, LCEC & CIBSE values are shown in table 3 below. LCEC mentions the occupants' in terms of W/m^2

whereas the lighting's is given in total energy per year kWh/m^2, values which are then calculated to fit in the table in terms of W/m^2.

Table 3. Internal gains values and ranges of values including totals expressed in W/m^2 from LCEC and CIBSE

Source	Type	Occupants	Lighting	Equipment	Total
LCEC	Residential	5	1.5*	n.a.	**6.5**
LCEC	Offices	14	1.9*	n.a.	**15.9**
CIBSE	Offices	5-6.7	8-12	15	**28-33.7**

* Values Calculated from 13 and 17 kWh/m^2/year

Building sample

For this study, an actual apartment is taken as a reference for the dynamic thermal simulation. It is located in the Ain er-Remmeneh area, on the outskirts of Beirut. Made of 5 floors, with two apartments on each, and a commercial ground floor, it has 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. The occupants' behavior along with the schedule of lighting and equipment are recorded to be inputted as the internal gains in the thermal simulation model.

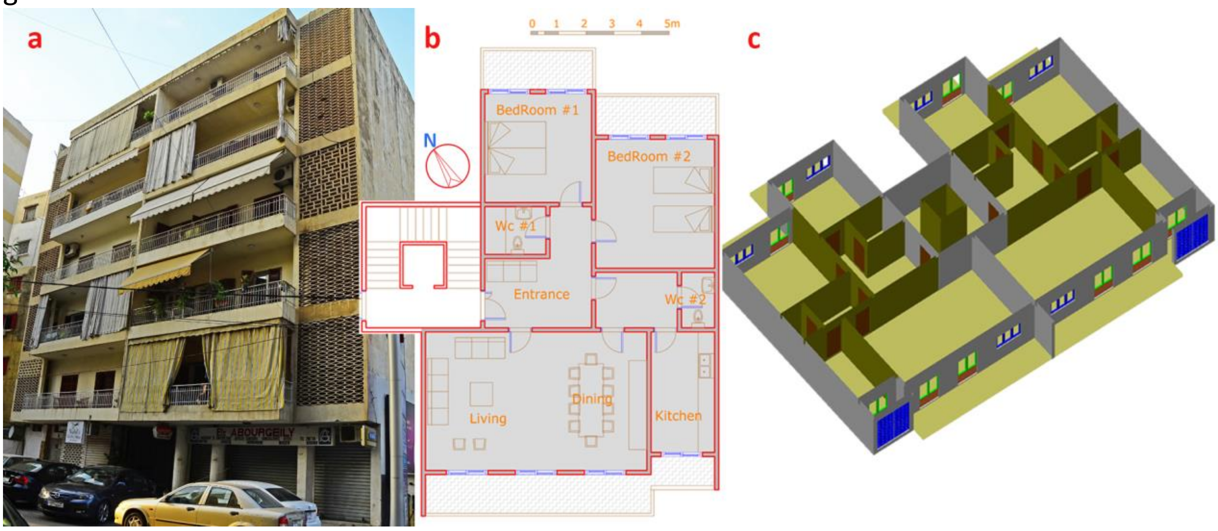

Figure 1. (a)The Building used as a model for the simulation; (b) Typical plan of one apartment; (c) 3D axonometric of the thermal model showing one entire floor with both apartments.

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 modelled, each with the two adjacent apartments. The orientation is kept the same with the living areas facing South-West, and cooling and heating yearly values per area are shown herein for the third and fourth floors, with the fourth considered as the top floor and third as intermediate floor.

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 with the same input for internal gains as observed and computed to be 4.8 W/m^2. Cooling temperature is based on 24^{o}C set-point and 50% RH threshold; whereas heating temperature is set at 20 ^{o}C. The internal heat gains from lighting, users and equipment are based on the observed, recorded and calculated data, and consequently are kept the same throughout. Although each reference has different U-value for windows, the simulations are keeping the same value of 5.68 W/m^2K for all the simulation in order to limit the variable, and focus on the basic argument of the research.

Results

Run #1 The cooling and heating annual loads using the different U-values from the references are shown in figure 2. The cooling load is always considerably higher than the heating load, up to three to four times larger. Although this difference is expected in a hot climate like Beirut's, nevertheless what is not expected is to see that local references miss to highlight the important role thermal mass plays in reducing the internal temperature fluctuation, but instead focus on insulated construction.

The top floor has higher heating and cooling values than the intermittent floor with the cooling values differences, much more pronounced: they start at a maximum of 10% higher with the base case at 57 and 52 kWh/m^2

The cooling yearly values for the intermediate floor changes between 48 and 54 kWh/m^2 for the LCEC values and the TSB2005 respectively. Whereas the top floor cooling values ranged between 49 and 57 kWh/m^2 with again the LCEC and the base case values respectively.

All runs reached values lower than the 80 kWh/m^2 set as a benchmark (table 2). This again raises the issue of the relevancy of the local sources when no specific guidelines or ranges of values for any of the many parameters involved in the thermal simulation are available (table 3).

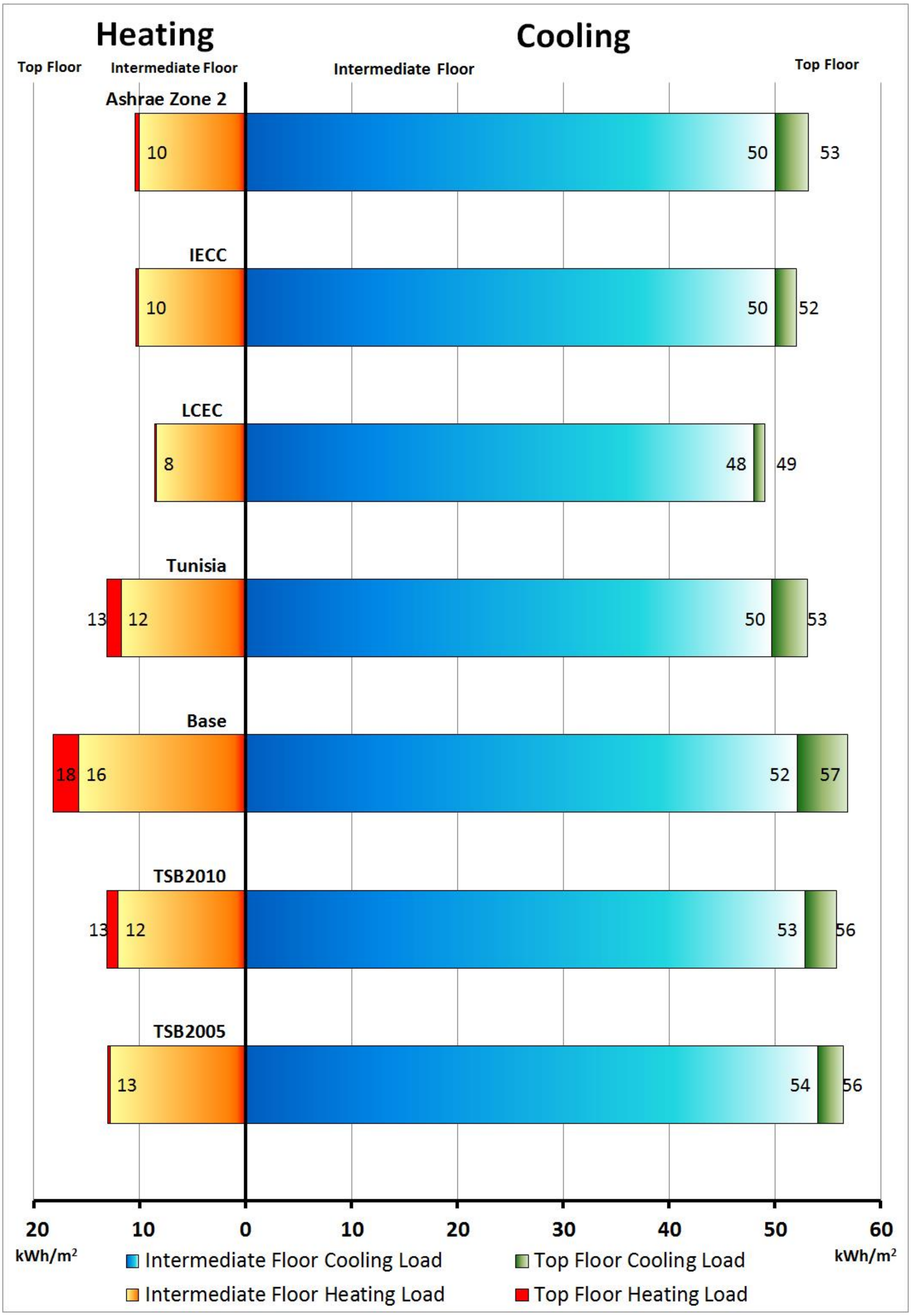

Figure 2 Overall summary of the cooling and heating load based on the different U-values from local, regional and international sources for a 110sqm residential apartment in Beirut.

Run # 2 This run carries the research to its second phase where the basic internal gains of 4.8 W/m^2, used in the first runs, and which were based on actual observation, are now raised to 2.5 times, and 5 times larger (table 4). The TSB2005 and the LCEC models are used for highest and lowest initial cooling load at 54 and 48 kWh/m^2 respectively.

The calculation of the cumulative total internal gains in all the different zones from users, equipment and lighting combined is done in two steps: starting with the total energy from these gains expressed in kWh/year, then this value is divided by the 365 days of the year, the 24 hours of the day and 110sqm of the total area, to have a final value expressed in W/m^2. Noting that the total energy is calculated by inputting the area of each zone with a specific schedule along a with a heat value also expressed in W/m^2.

Comparing the raised values of the internal gains to the available limited references, shown in table 3, both the base and the 2.5 times at 4.8 and 11.9W/m^2 respectively appears to be relatively lower than the expected at 6.5 and 15.9 W/m^2, even if compared to an office rather than a residential. Similarly, the 5 times larger value is still less than the expected range in offices varying between 28 and 33.7W/m^2. As a note, internal gains can change by having more people in the room, or even having the unprotected window allowing the unaccounted sun rays to penetrate the room at any time of the day.

Yet what should be noted here, is the critical point where low U-values construction is not performing well, when internal gains are high. In this case the percentage difference between the TSB and LCEC models are decreasing with the increase of the internal gains. Starting at 13% for the base case drops directly to 2% with the 2.5 time increase and reaches minus 4% difference.

Table 4. Showing in the first two columns the increasing internal gains in total yearly and daily per area with the available benchmarks, 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)	**Benchmark (Table 2)** (W/m^2)	**LCEC Base** (kWh/m^2)	**TSB Base** (kWh/m^2)	**% difference** (LCEC/TSB)
Base	4622	**4.8**	6.5	48	54	**13%**
x2.5 Internal Gains	11556	**11.9**	15.9	83	85	**2%**
x5 Internal Gains	23112	**24.2**	28-33.7	160	153	**-4%**

Conclusion

The paper reviewed the numerous U-values from different local and international sources, through thermal modeling, and carried on studying the consequence increased internal gains have on the cooling energy load in low U-value construction. In the first part and based on the thermal simulation the following statements apply: (a) cooling is typically 3 to 4 times higher than the heating, (b) cooling loads of the top floor range between 49-57 kWh/m^2 and are up to 10% higher than in intermediate floor ranging between 48-54 kWh/m^2. (c) all energy values are well below the 80 kWh/m^2 value set as a benchmark for a building to start being considered low energy. As for the second part when internal gains are increase 2.5 times, but still kept within the given range of values from local and international references, the difference between the previously lowest and highest energy model is reduced from 13% to only 2%. When they are increased 5 times, the difference becomes negative 4%, hence the previously best performing model with the low U-Values is now consuming 4% more energy than the model with the high U-Values. Finally, the paper concludes that set benchmark for internal gains are important for comparative studies, and more emphasis should be given for the effect thermal mass has on regulating the internal temperature in hot climates such as Beirut's.

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References

2012 International Energy Conservation Code 2011, International Code Council, Inc, U.S.A.

ASHRAE Standard 90.1 2007, ***Energy Standard for Buildings Except Low-Rise Residential Buildings,*** I-P Edition

ASHRAE 2013, ***Fundamentals*, **IP editions

California Energy Commission 2014, ***Residential Compliance Manuel*** *for the 2013 Building Energy Efficiency Standards,* Title 24; Part 6.

CIBSE 2006, ***Environmental Design CIBSE Guide A***, , London.

Comair F.G., Mourtada A., Chebad S., Matar T. & Sebrini C. 2011, ***Thermal Insulation Market in Lebanon***, ALMEE.

EDSL TAS, ***Environmental Design Solutions Limited*, **Version 9.3.2 www.edsl.net

FFEM & ANME 2010, ***La Mise en Place de la Réglementation Thermique et Énergétique en Tunisie***.

French Republic 2006 (a), ***Caractéristique Thermiques des Bâtiments Nouveaux et des Parties Nouvelles de Bâtiments***.

French Republic 2006 (b), ***Réglementation Thermique 2005 des Bâtiments Confortables et Performants***.

Koch-Nielsen, H. 2002, ***Stay Cool, a design guide for the built environment in hot climates,*** James & James Ltd.

Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. 2006, "**World Map of Koppen-Geiger Climate Classification updated**", *Meteorologishe Zeitschrift,* vol. 15, no. 3, pp. 259-263.

LCEC 2014, ***National Energy Efficiency and Renewable Energy Action (NEEREA)***, RCREEE; Banque du Liban

Littlefield, D. 2007, ***Metric Handbook, Planning and Design Data,*** 3rd edition, Elsevier Architectural Press.

Meteotest 2014, ***Meteonorm***, 7.

Moe, K. 2014, **Insulation Modernism**, Birkhauser

Nicol F; Humphreys M; Roaf S; 2012, ***Adaptive Thermal Comfort, Principles and Practice***, Earthscan; Routledge

Order of Engineers and Architects 2010, ***Thermal Standard for Buildings in Lebanon***, Order of Engineers and Architects of Beirut; LIBNOR; ECOTECH engineering; ADEME; ALMEE; LGBC; ASHRAE, Beirut.

Republic of Lebanon 2005, ***Thermal Standard for Buildings in Lebanon***, UNDP/GEF and MPWT/DGU, Beirut.

Szokolay, S.V. 2004, ***Introduction to Architectural Science: The Basic of Sustainable Design,*** Elsevier Architectural Press.

Yannas S; 1994, ***Solar Energy and Housing Design***, Volume 1, the department for Enterprise, Architecture Association