Cost-Effective Requirements Levels for Energy Performance of Buildings in Lebanon

A. Mourtada[1], J. Ordoqui[1], J.L. Thibon[1] and A. Karaki[2]

[1] *Application Européenne de Technologies et de Services, Lons, F 64140-France*
[2] *Department of Mechanical Engineering, Faculty of Engineering III, Lebanese University, Hadeth, Beirut, Lebanon*

ABSTRACT

This paper presents the energy and economic analysis used to determine cost effective requirements levels to the thermal standard for buildings in Lebanon. The heating and cooling energy use for different buildings types (18 buildings) according to the variation of envelop parameters was simulated for realistic cooling and heating schedules and five Lebanese climatic zones. Parameters investigated included, construction type, insulation levels, window sizes and solar protection. The energy simulation program VISUAL-DOE.3 was used for the energy use simulations. A total of 680 model runs were conducted.

Cost-effective insulation and envelop parameters options for the building-owners and builders were determined and suggested as economical acceptable solutions to improve the energy performance of buildings in Lebanon.

The results show that the cost-effective measures may reduce: thermal cooling energy and cooling needs by + 23 to 33% and the heating energy by +18 to 40% according to building type and climatic zone. The pay back time of proposed requirements will be from 2 to 9 years for residential buildings and from 3.2 to 8.3 years for commercial buildings according to the climatic zone

Therefore, the total quantity of CO_2 emissions avoided on a 20 years horizon is 1 million tons approximately.

KEWORDS

Energy, economy, building, code, analysis, performance.

PREFACE

This study has been developed in the context of Project “Capacity Building for the adoption and application of Thermal Standards for Buildings in Lebanon”. The project was funded by the Global Environment Facility, Managed by the United Nations Development Programme, and Executed under the Lebanese General Directorate of Urban Planning, Ministry of Public Works and Transport. The project falls under the Climate Change focal area and aims at the establishment of Thermal Standards for Buildings, and at enabling their adoption and application through the provision of capacity building and information dissemination.

METHODOLOGY OF ENERGY AND ECONOMIC ANALYSIS

This effort sought answers to some key questions. How much energy could be saved by the envelop conservation measures? How much increase in construction cost would occur? What would the financial impacts on building owners and the economic and environmental impacts on the nation be?

The methodology used in this study is similar to other recent international energy and economic studies [1, 2, 3]. Key steps include acquiring weather data (definition of climatic zones and preparation of hourly weather files), developing typical building descriptions, conducting parametric energy simulations from the base case building, plus simulations for combined energy conservation measures.

Establishment of Climatic Zones for Building Regulations in Lebanon

For the establishment of climatic zones for building regulations, the study used the heating Degree-day (HDD), the cooling Degree-Day (CDD), the seasonal temperature extremes and the specific humidity of the hottest month. More specifically, the most important climatic parameters used to establish the climatic zones were [4]:

- the mean minimum temperature of the coldest month (January),
- the daily gap of the hottest month (August), and
- the specific humidity (or absolute humidity) of the hottest month (August).

Zone A1, Coastal
A1< 500 m: Warm and short winter, Summer Hot and humid, Daily gap Small all year.

Zone A2, Western Mid-mountain
501<A2 < 900 m: Cold and long winter increasing with altitude, Summer Hot and humid with maximum daily temperatures differing slightly from A1, Daily gap Small all year.

Zone B1, Western Mid-mountain
901<B1<1500M: Cold and long winter increasing with altitude, summer Cool, daily gap More pronounced than zones A1 and A2.

Zone B2, Western High Mountain
1501<B1<1500 m: Long and rigorous winter, summer Cool, daily gap More pronounced than zones A1 and A2

Zone C, Inland Plateau and Eastern mountain: Cold and Long Winter, summer hot in day cool in night with very low humidity and High daily gap.

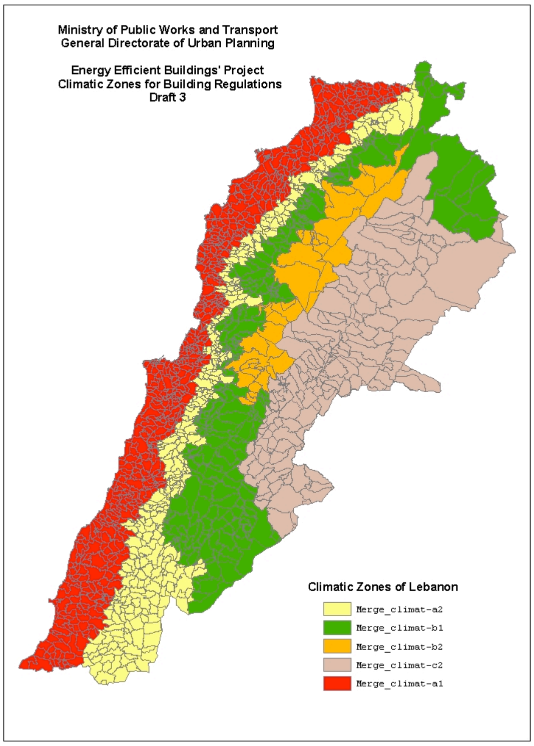

Figure 1: Climatic Zones for Thermal Standards for Buildings in Lebanon

Proposal of outdoor design conditions

Recommended design temperatures for winter are presented for two frequency levels for each climatic zone representing temperatures that have been equalled or exceeded by 99% or 97% of the total hours during the months of December, January and February (a total of 2,160 hours).

Recommended design dry-bulb and wet-bulb temperatures for summer conditions are presented in table 1 for three frequency levels for each climatic zone representing temperatures that have been equalled or exceeded by 1.0%, 2.5% or 5.0% of the total hours during the months of June through September (a total of 2928 hours). The coincident wet-bulb temperature listed with each design dry-bulb temperature is the average the coincident wet-bulb temperatures occurring at the specific dry-bulb temperature retained.

TABLE 1
Proposed Outdoor Design Conditions for Lebanon

Climatic Zone	Winter (ºC)		Summer (ºC)					
	Design Dry-Bulb		Design Dry-Bulb			Design Wet-Bulb		
	99%	97.5%	1%	2.5%	5%	1%	2.5%	5%
A1	6	7	34	33	32	26	26	25
A2	2	3	33	32	31	24	23	23
B1	-2	-1	32	31	31	22	22	21
B2	-10	-7	31	30	30	22	21	21
C	-5	-4	37	36	35	22	21	21

Typical Buildings (base-case)

Descriptions of typical buildings are developed (through consultation with local architects and engineers and lebanese construction industry professionals) that represent current Lebanese construction practice. The 18 buildings simulated are described in the report of the "Impact Assessment study" [5]. The energy-related features and construction costs are defined for these base-case buildings. The figure 2 presents the specific thermal energy cooling and heating needs (kWh per m^2 per year) for the 18 base case buildings. This figure shows that the energy cooling needs are most important in climatic zone A1 (cooling degree-days CDD, base 24 º C = 1100) and the energy heating needs is most important in climatic zone B2 (heating degree-days HDD, base 18 º C = 3000). A number of assumptions have to be made concerning the building description and occupants' energy use behaviors especially for residential buildings and schools (according to the reality use of cooling and heating in different buildings types and different climates zones).

Envelop parameters

All the building types (18) were modeled (defined for VisualDOE.3 software) for different envelop parameters (window to wall ratio, Orientation of building, overhang, lateral fins, shading coefficient of glazing, wall and roof color, thermal inertia). 34

different parameter's values for each base case building are considered. The envelope's parameters simulated for each typical building are showing in table 2.

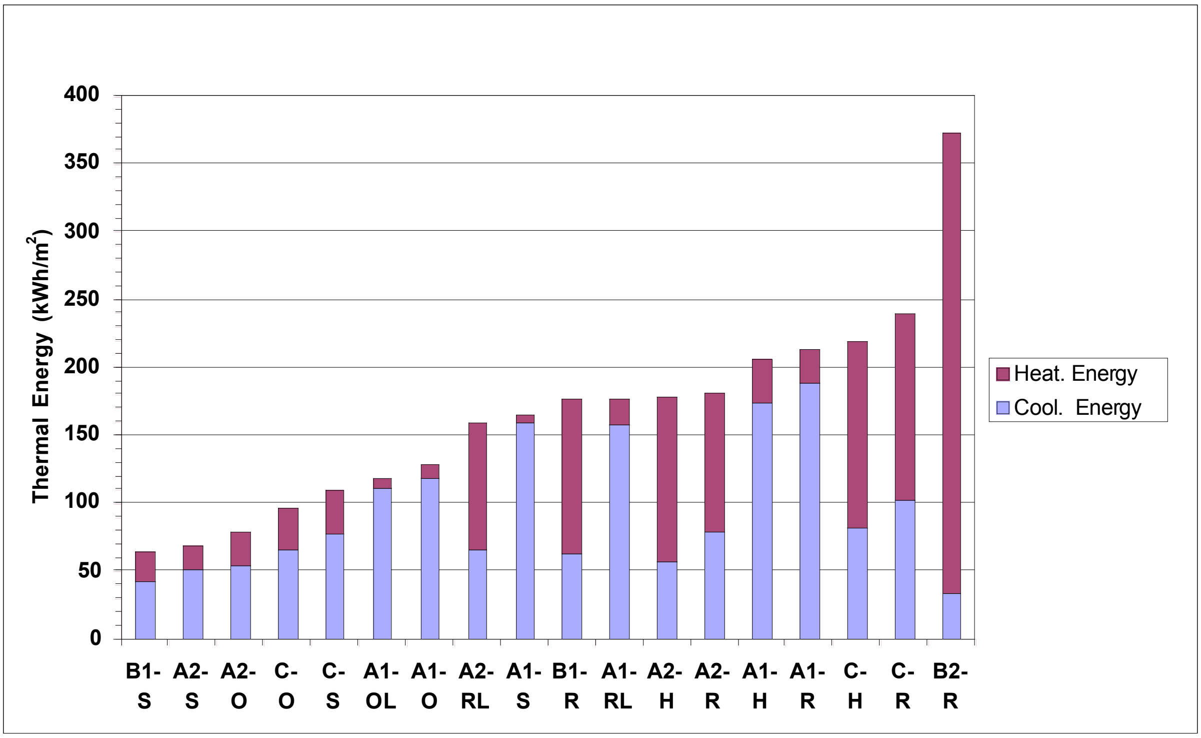

Figure 2: Specific Thermal Energy needs (Heating and Cooling) per year for Base Case Buildings before corrections (kWh/m^2.year)

S : School O : Office OL : Office Large H : Hotel
R : Residential (normal standing) RL : Residential Large (high standing)
A1, A2, B1, B2, C : Climatic zones

TABLE 2
Envelop parameters used for simulation

Envelop Parameters	**Base-case***	**Values for simulation***
Orientation	North/South N/S	East/West E/W, South-West/North-east SW/NE, South-Eat/ North-West SE/NW
Roof Color	Medium	Clear, Dark
Roof Insulation	R-ETP = 0cm	R-ETP = 2, 4, 6 and 8 cm R-ETP "Equivalent Thickness of Polystyrene"
Wall Color	Medium	Clear, Dark
Wall Insulation	W-RTP = 0cm	W-RTP = 2, 4, 6 and 8 cm W-ETP "Equivalent Thickness of Polystyrene"
Windows to the gross exterior wall area ratio Ratio "WWR"	WWR=0.25	WWR = 0.15, 0.30, 0.45, 0.6 and 0.90
Windows U-value	Ug= 5.8 W/m^2. K	Ug = 4 W/m^2.K, Ug = 3.3, Ug = 2.6 and Ug = 2.2
Glass Shading Coefficient.	SC = 0.95	SC = 0.71, SC = 0.60, SC = 0.50, SC = 0.30
Overhangs Projection Factor	PF=0	PF=10, PF=30, PF=50 PF=100 (Large of overhang/Height of window), PF in %
Lateral Fins Projection Factor (Large of Lateral Fin/Large of window), Fi in %	Fi=0	Fi=0, Fi=10, Fi=30, Fi=50 Fi=100 (Large of Lateral Fin/Large of window), Fi in %
* Values can be different for some building types		

Analyses conducted

Two types of energy and cost analyses are conducted, using the base case descriptions that represent current practice in Lebanon. First, a set of energy and cost parametric analyses are conducted separately across multiple values of energy measures. The envelop parameter alternatives (particularly the insulation level of windows, wall and roof) were compared using a life-cycle cost analysis in which the net present value of the cost of the insulation, heating and cooling energy are calculated [6]. The Net Present Value of the life-cycle costs (20 years) of energy conservation measures, energy and cooling and heating appliance costs was calculated for various levels of parameters, in 5 climatic zones. 9 scenarios related to the prices of energy and the discount rates (3 scenarios oil price x 3 scenarios discount rate = 9 scenarios) are considered. Finally, energy and economic analyses are conducted on combined sets of the most effective conservation measures. The results of the economic analysis for combined measures allow us to determine the incremental cost and the net present value for each combination. Then requirements for Thermal Standard For Buildings in Lebanon are proposed.

PROPOSED THERMAL STANDARD FOR BUILDINGS IN LEBANON

In climatic zones A1 and A2 in Lebanon, cooling energy during the summer far exceeds heating energy during winter. A large part of cooling energy is due to solar heat gains through glazing, which are often large, especially in prestigious buildings. The proposed standard consists of two parts, one dealing with the maximum value of the thermal transmittance of the envelope elements and one dealing with the solar heat gain coefficient of window.

The standard assumes that for relatively low window to wall area ratio WWR ≤ WWR-req one can be satisfied with single glazing using standard glass, without fixed shading devices like side fins and Overhangs. WWR-req varies from 0.18 to 0.24 according to building type and climatic zone. For other WWR, WWR-eq (equivalent window to wall ratio) is calculated according to Eqn. 1, by multiplying WWR by the shading coefficient, SC (defined as the amount of the solar gain through the glazing to the solar gain) and by an orientation factor (Fai), which is related to the projection factor of the fixed shading device and to the orientation of the window. WWR-eq should be ≤ WWR-req.

$$\textbf{WWR-eq} = \Sigma(\text{Awi} \times \text{SCwi} \times \text{Fai}) / \Sigma\text{Av} + 2\,\Sigma(\text{Awhi} \times \text{SCwhi}) / \Sigma\text{Ah} \qquad (1)$$

Awi = Area of the individual window (m^2).
SCwi = Shading coefficient of window
Fai = Architectural shading factor.
Av, Ah = Area of all vertical surfaces (opaque walls + windows) and area of horizontal surfaces (roofs + skylights) (m^2).
Awhi = Area of the individual skylight (m^2).
SCwhi = Shading coefficient of skylight

The thermal transmittance requirement U-req addresses the following building envelop components: Roofs, Walls, Windows and Skylights, Floors (exposed and semi exposed), and Slabs on ground (table 3). The maximum thermal transmittance requirement can be demonstrated using one of two approaches: the individual component approach or the overall building envelope approach.

TABLE 3
Maximum Thermal Transmittance required U-req (W/m^2.K) for envelop component of large residential and non residential buildings vs. climatic zone.

Climatic Zone	U-value Roof	U-value Wall	U-value Window & Skylight	U-value Ground Floor		U-value Opaque Door
				Exposed	Semi-exposed	
A1	0.95	1.35	NR	Not Required	Not Required	3.00
A2	0.76	1.35	4.00	0.76	1.35	3.00
B1	0.66	1.00	3.30	0.76	1.20	2.75
B2	0.55	0.66	2.60	0.55	0.80	2.60
C	0.66	0.80	3.30	0.66	1.00	2.75

Exposed: ground floor in direct contact with the exterior air.
Semi-exposed: ground floor above a non air-conditioned space.

CONCLUSION

Requirements for the proposed Thermal Standard for buildings in Lebanon [8] may:

- reduce Energy bills for cooling and heating by +17% in A1, by +28% in A2, by +40% in B1, B2 and C,
- increase the Cost of Construction by 5.5 to 9.6 US $/m2 and increase the Net Present Value (NPV) of Increment Cost by +6.3 to 8.1 US $/m^2 for Low-Rise Residential Buildings in climatic zones A1, A2, B1 and C,
- increase the Cost of Construction by 6.7 to 11.6 US $/m^2 and increase the NPV of Increment Cost by +5.5 to 9.6 US $/m^2 for large residential and commercial buildings.

Globally, the proposed Lebanese Thermal Standard increases the cost of construction by 6 % [9]. Therefore, the total quantity of CO2 emissions avoided on a 20 years horizon is 1 million tons approximately. In the future, it is necessary to introduce requirements for HVAC equipment, lighting, water heating systems service, energy management and develop an energy efficiency building code EEBC. The proposed Thermal Standard for Buildings should constitute the chapter envelop of the future EEBC.

References

[1] J. Huang, J. Deringer, J. Masud and B. Hagler. (2003). The Development of Residential and Commercial Building Energy Standards for Egypt. *Proceeding Energy Conservation in Buildings Workshop December 15-17,* Kuwait.

[2] J. Cumper and S. Marton. (1992), Energy and economic analyses for the Jamaica Energy Efficiency Building Code. *Final report, submitted to the joint UNDP/World Bank (ESMAP), Washington, D.C.*.

[3] J. L. Thibon A. Mourtada, A. Kouassi and J. Nintin. (1993). Energy and economic analyses for the Ivorian Energy Building Code. *Final report, submitted to the joint UNDP/World (ESMAP), Washington, D.C.* 1-174.

[4] J. L. Thibon, A. Mourtada, J. Lempegnat and P. Riou. (2004). Climatic Zoning for the Thermal Standards for Buildings in Lebanon. *Final report submitted by AETS APAVE-SUD to the joint UNDP/DGU under the project GEF LEB/99/G35*, 1-90.

[5] C. Abdallah, A. Haddad and A. Karaki. (2003). Impact Assessment Study of energy conservation measures for envelop of buildings in Lebanon. *Final report submitted to the joint UNDP/DGU under the project GEF LEB/99/G35*, 1-264

[6] A. Mourtada (1996). Cost and Energy Effects of the Ivorian Energy Building Code. *Building and Environment* **31 :3**, 259-272.

[7] International Survey of Building Energy Codes. (2000), *Australia Greenhouse Office*, 1-96.

[8] Thermal standard for Buildings in Lebanon: for new residential and non residential building. (2004). *Submitted by AETS APAVE-SUD to General Directorate of Urban Planning, United Nations Development Programme under project funded by Global Environment Facility.* 1-20.

[9] J. Ordoqui, A. Mourtada and J. L. Thibon. (2003). Synthesis of Impact Assessment Results: Energy and Economy. *Technical Workshop on Thermal Standard for Buildings in Lebanon UNDP/DGU, Order of Engineers and Architects, December 4, Beirut, Lebanon*, 1-38.