ESL-IC-10-10-62

Energy Efficient Residential Building Code for Arab Countries

George B. HANNA

Consultant, Emeritus Professor, Institute of Building Physics and Environment,
Housing and Building National Research Center,
P. O. Box 1770, Cairo, Egypt,
E-mail: hannagb44@yahoo.com **&** hannagb44@hotmail.com

ABSTRACT: This paper presents an energy analysis to support the Egyptian efforts to develop a New Energy Code for New Residential Buildings in the Arab Countries. Also, the paper represents a brief summary of the code contents specially, the effectiveness of building envelope and weather data in reducing electrical energy consumption. The impacts of the following parameters were studied namely; walls and roof constructions, window size and glazing type for different geographical locations in the Arab Countries. Two different distinguish weather classification were developed and analyzed and presented in this study, the DDC18.3& DDH 25. The first was developed by the Author to calculate DD using a mathematical model on electronic spread sheet. The second depends on the hourly values for each geographical location. The analysis includes the capitals and major cities representing most of the Arab countries. It was determined that the window to wall ratio (WWR) of 15% minimizes the total annual electricity use for the buildings. The Solar Factors (SF) and Window Orientation Factors (OF) were calculated for the eight wall orientations. The Over All Transfer Value (OTTV) was calculated for each orientation for different variables, e.g. WWR, Glazing Type, Shading, wall color and mid and top floor. The results show that the mass and types of building materials; WWR (15%), glass type and shutters; orientation; wall insulation (25mm), wall solar absorptivity (α=.3); roof insulation and shading effect enhance the thermal performance and reduces the cooling load by 60%.

INTRODUCTION

Residential buildings consume more than 50% of the total electricity consumption. Artificial lighting is estimated to account about 40% of the electricity used in the residential sector and 35% of the electricity used for HVAC system. A significant increase in electricity demand is expected over the next few years with a growth rate over 10%. To improve the energy efficiency in residential buildings, a New Arab energy Building Code had been developed for new residential buildings [1]. As part of the development of the energy code, simulation analysis has been carried for new residential buildings to determine the most cost-effective energy efficiency measures suitable for Arab regions. Building envelope and fenestration components are considered one of the fundamental design features of energy-efficient buildings.

RESIDENTIAL BUILDING CODES

The Final Draft of the New Arab Building Energy Codes was approved by the League of Arab States (2010). The code contains 12 Chapters and 7 Appendices. It contains the following chapters:

1. SCOPE AND COMPLIANCE
2. GENERAL REQUIREMENTS
3. BUILDING ENVELOPE
4. NATURAL VENTILATION
5. HEATING VENTILATION & AIR
6. CONDITIONING
7. SERVICE WATER HEATING SYSTEM
8. DAY LIGHTING
9. LIGHTING
10. ELECTRICAL POWER
11. WHOLE BUILDING PERFORMANCE
12. DEFINITIONS, ABBREVIATIONS & ACRONYM.

ENERGY IN ARAB COUNTRIES

From the 1970s many countries throughout the world introduced building regulations aimed at reducing energy consumption in residential and commercial buildings, see table (1). Typically, these regulations concentrate on aspects of heat loss through the building envelope with minimum levels of insulation required being stated. Worldwide these regulations encompass resistance for individual opaque building elements. The simple prescriptive nature of most of the regulations reduces the need for complex calculation methods. Tables (2 & 3) show the crude oil and natural gas consumption during 2007 and the electricity consumption in most of the Arab Countries.

Table (1) Electricity Consumption for Selected Arab Countries

Arab Countries	Residential	Industry	Commercial
Egypt	37.1%	33.3%	2.5%
Tunis	25.0%	47.0%	--
Lebanon	5.0%	2.5%	2.2%
Jordon	33.0%	31.0%	15.0%
Bahrain	54.4%	17.4%	27.7%
Saudi Arabia	51.1%	22.1%	10.2%
Morocco	17.0%	34.0%	8.0%
Tunis	16.0%	35.5%	9.0%
Jordon	33.0%	31.0%	15.0%
Algeria	36.8%	37.6%	6.2%
Syria	49%	8%	31%

Table (2) Arab Energy Consumption 2007

Region	Petroleum Consumption	Dry Natural Gas Consumption
Country	(Thousand Barrels /Day)	Billion Cubic feet
Egypt	680.00	999
Libya	261.00	--
Morocco	184.00	--
Tunisia	88.50	--
Algeria	267.00	--
Sudan	85.70	--
Iraq	596.00	--
Jordan	106.00	79
Kuwait	325.00	441
Lebanon	94.00	0
Qatar	115.00	693
Saudi Arabia	2,210.00	2,594
Syria	269.00	221
United Arab Emirates	441.00	1,522
Yemen	141.00	--
Bahrain	36.00	400

Table (3): Electricity Consumption in Arab Countries (2003)

Rank	Country	Consumption (kWh/year)
1	Saudi Arabia	134,900,000,000
2	Egypt	78,160,000,000
3	United Arab Emirates	38,320,000,000
4	Kuwait	35,520,000,000
5	Iraq	33,300,000,000
6	Syria	25,280,000,000
7	Algeria	24,900,000,000
8	Libya	13,390,000,000
9	Tunisia	10,760,000,000
10	Lebanon	10,670,000,000
11	Oman	9,582,000,000
12	Qatar	9,053,000,000
13	Jordon	7,959,000,000
14	Sudan	2,943,000,000
15	Yemen	2,827,000,000

Energy in Egypt

The current national energy supply mix in Egypt is; 95% from fossil fuel; (petroleum products 39.3% and natural gas 55.2%); 5% from renewable resources (mainly hydro and limited wind). The electricity generation activity utilizes around 30% of the fossil fuel and natural gas resources in addition to all the hydro and wind energies resources, see Fig.1.

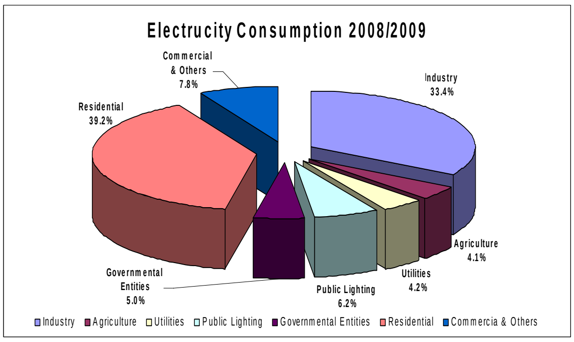

Figure 1 Electricity Consumption 2008/2009

BUILDING ENVELOP

Chapter two of the Code classified the climate of the Arab countries into several regions that have climatic conditions similar to selected cities of the Arab country. The climate must be identified in terms of the cooling degree-days based on 25 °C, CDD25, and the heating degree-days based on 18.3 °C, HDD 18.3. Three methods should be used to meet the building envelope requirements, namely; perspective, trade-off compliance and whole building performance.

Perspective Requirements: the sum of the R-values of the insulation materials installed in the wall,
cavities and insulating sheeting (where used) must meet or exceed the minimum required "Wall R-value" for the appropriate climatic region, see tables 4.

Table (4) Recommended Thermal Resistance [2] for Different Arab Countries compared with leading Countries ($m^2.^oC/W$).

Country	Roof	Walls	Floors
Austria	3.3	2.0-1.4	2.3-1.6
Belgium	2.4-1.3	1.5-1.0	-
Egypt	**1.67**	**1.0**	----
France	4.0-2.5	2.0-1.5	1.3-1.0
Jordon	**1.0**	**0.56**	--
Kuwait	**2.5**	**1.75**	--
Greece	2.0	0.9	2.0-0.3
Italy	2.6	1.7	--
New Zealand	3.0-1.5	1.7-0.6	1.7-0.9
painS	1.4-0.7	0.7-0.6	1.4-1.0
Turkey	2.63	1.7	--
U K	2.9	1.0	--
USA (various)	7.0-3.5	3.5-2.0	3.5-0.0
West Germany	3.3-2.2	1.2-0.7	1.8-0.8
Saudi Arabia	**1.754**	**1.3**	--
Republic of Lebanon	**2.27-1.75**	**1.85- 0.48**	---

Envelope Trade-Off Compliance: The calculated Overall Thermal Transfer Value (OTTV, W/m^2) requirements [4] for conditioned buildings may be used in the Prescriptive requirements.

To calculate the OTTV, the Solar Factors (**SF**) and the Orientation Factors (**OF**) must be calculated from the hourly, monthly and annual averages direct and diffuse solar radiations. The solar data were calculated for the eight orientations. were derived by normalizing the Maximum Solar Heat Gain Factors for June for each selected city in the Arab region [5].

Whole-Building Performance: The proposed design must comply with, if the annual (8760 hours) energy costs comply with the Standard design. The proposed design and the standard design must each be determined using the same approved energy analysis simulation tool, such as VDOE or Energy+.

Table (5): Glass Types Characteristics [4]

Name	U	SC	SHGC	TVIS
Single Glazing_Clear	6.17	.95	.81	.88
Single Glazing_Blue	6.17	.71	.61	.57
Single Glazing_Grey	6.17	.69	.59	.43
Single Reflective (Class A) [1] Clear High Emissivity	5.41	.36	.31	.20
Single Reflective (A) Tint Medium Emissivity	5.11	.29	.25	.09
Double Glazing BronzeTint	2.74	.57	.49	.47
Double Glazing GreenTint	2.74	.57	.49	.66
Double Glazing Tint Low Emissivity	1.78	.37	.28	.44
Double Glazing, Reflective (A) Clear Medium Emissivity (IG)[2]	2.35	.20	.17	.13
Double Glazing, Reflective (A)Tint, Medium Emissivity (IG)	2.35	.18	.15	.08

Natural Ventilation

The requirements in this section represent the minimum design parameters. It is recommended that the designer evaluate other energy conservation measures that may be applicable to all residential buildings.

The building form and external envelope must be designed and constructed to be able to satisfy the Natural Ventilation requirements, see table (8), in order to provide thermal comfort in occupied spaces and to reduce the energy consumption. These requirements are intended to reduce the energy consumption for conditioned spaces and to improve the thermal comfort of unconditioned spaces.

Table (6) OTTV, Degree Days Heating and Cooling for ten Climatic Regions for Arab Countries

No.	Climatic Region	Example of Cities in the Regions	Heating & Cooling Degree Days		OTTV (W/m^2)
			CDD25	HDD18.3	
1	Cold High Mountains	Lebanon heights, Syria, Height of Iraqi	**500**<	>**1500**	30
2	Moderate Cold Region	Middle & west of Syria, North of Jordon, East of Lebanon, South Sinai, Atlas Mountains	500<	1500 - 1000	40
3	Mediterranean Sea Cost Region	West Lebanon, Syria, North Coast Africa	500<	1000-500	45
4	Al Badin Region	North & West of Iraq	1000- 500	1500-1000	60
5	Desert Costal Regions	West Desert, Read Sea Cost, North of Saudi Arabia	1000- 500	>500	55
6	Semi Desert Regions	North Great Desert, Sinai, North West Saudi Arabia, South Jordon, East Syria	1000- 500	1000 - 500	55
7	Desert Regions	South of Egypt & Libya, Middle of Algeria, Middle if Iraq, North of Saudi Arabia	1500- 1000	1000>	60
8	Tropical Desert Regions	East & Middle of Saudi, Kuwait, south of Iraq & Egypt, North & Middle of Sudan	**2000**-1500	1500 - 500	65
9	Desert Region very Hot	North East Sudan, South East Saudi, South of Emirate	2000>	>**500**	70
10	Tropical Region (Near Equator)	South of Sudan, Pats of El Somali	1500 - 500	>500	55

Table (7): Degree Day Heating and Cooling for Selected Arab Cities for Different Categories.

City	Lat, °N	Log, °E	Eleva ,m	$T_{ao,avg}$	RH(%)	Ws(m/s)	DDC18.3	DDH25	Classification	Category
Doha	25.2	51.6	12.0	28	56	2.9	92	**1802**	**DDC10> 6000**	**A**
Dubai	25.3	55.3	5.0	28.1	51	3.0	27	1660		
Dhahran	26.3	50.2	17.0	27.4	50	3.4	205	1840		
Khartoum	15.6	32.5	382	28.6	21	4.1	2	1520		
Kuwait	29.2	48.0	55.0	26.3	39	3.1	487	1912		
Manama	26.3	50.7	2.0	26.9	60	3.6	151	1537		
Jeddah	21.7	39.2	12.0	28.3	59	2.8	0	1370		
Aswan	24.0	32..8	194.0	26.2	27	3.3	165	1385	**4000<DDC10 <5000**	**B**
Riyadh	24.7	46.7	612.0	26.2	29	2.7	340	1161		
Laxer	25.7	32.7	88.0	24.7	40	1.8	270	1107		
Baghdad	33.2	44.2	34	23.9	39	2.4	680	1495		
Cairo	30.1	31.4	74.0	21.9	58	2.9	397	409	**3000< DDC10 <4000**	**C**
Mousel	36.3	43.2	216	21.1	47	1.7	1153	1122		
Alexandria	31.2	30.0	7.0	19.9	67	3.2	561	153	**3000<DDC10< 4000**	**D**
Beirut	33.8	35.5	19.0	20.1	62	2.6	536	174		
Agadir	30.3	9.6W	74.0	19.3	71	2.1	529	26		
Sana'a	15.5	44.2	2190.0	18.4	39	1.5	503	4		
Tunis	36.8	10.2	4.0	19.4	69	2.7	809	202		
Tripoli	32.7	13.1	81.0	20.5	57	2.4	686	337		
Latakia	35.5	35.8	7.0	18.4	67	2.3	904	100		
Aleppo	36.2	37.2	393.0	17.6	58	3.6	1570	342		
Algeria	36.7	3.2	25.0	17.9	71	2.6	977	51	**DDC10< 3000**	**E**
Damascus	33.5	36.5	609.0	16.7	53	4.6	**1596**	172		
Amman	32.0	36.0	773.0	17.1	47	1.9	1504	127		

Table (8) Ventilation Requirements

Activity (adult male)	Meta-bolic rate, M (W)	Requirements For respiration: O_2 concentration of 16.3% in Expired air (s-1)	Requirements To maintain CO_2 at 0.5% assuming 0.04% CO_2 In fresh air ($1\ s^{-1}$)
Seated quietly	100	0.1	0.8
Light work	160 - 320	0.2 – 0.3	1.3 – 2.6
Moderate work	320 - 480	0.3 – 0.5	2.6 – 3.9
Heavy work	480 - 650	0.5 – 0.7	3.9 – 5.3
Very heavy work	650 - 800	0.7 – 0.9	5.3 – 6.4

LIGHTING

Table (9) shows the maximum allowable Lighting Power Density (LPD) for the overall dowelling unit and for each specific within the unit.

Table (9) shows the maximum allowable Lighting Power Density (LPD) for the overall

Space	Lighting Power Density (W/m^2)	Illuminance (Lux)	
		Minimum	Maximum
Bedroom	10	50	100
Living room	19	200	500
Reception room	19	200	500
Bath room	14	100	200
Kitchen	11	100	400
Lobby, Corridors, elevators and stairs	13	100	200
Total space (Flat)	**15**	-	-

Heating, Ventilation and Air Condition

Table (10) shows the minimum pipe insulation thickness in mm. Piping shall be designed and installed in accordance to table (1), dwelling unit and for each specific space within the dwelling unit. The minimum requirements for Energy efficiency (EER) for window or split units is 10 for cooling and 11 for cooling greater than 10 kW.

HOT WATER SYSTEM

Service water heaters, domestic boilers, storage tanks and pool heaters that are included in table 10 must comply with the relevant municipal codes.

Table (10) Minimum Pipe insulation thickness (mm)

Types of Pipes systems	Range of Fluid Temperature (ºC)	Pipe Diameter (mm)				
		< 25	25-35	50	63.5-102	127 & >
Heating Systems						
Hot water & steam						
Pressure/High Temperature	152-232	63.5	63.5	38.1	76.2	88.9
Pressure/ Medium Temperature	121-151	50.8	63.5	38.1	63.5	76.2
Pressure/Low Temperature	121-93	38.1	38.1	25.4	50.8	50.8
Low Temperature	93-48	25.4	25.4	12,7	38.1	38.1
Condensed Steam		25.4	25.4	38.1	50.8	50.8
Cooling Systems						
Child Water	4.4-12.8	12.7	12.7	19.05	25.4	25.4
Refrigerant or Brine Solution	< 4.4	25.4	25.4	38.1	38.1	38.1

Service Water Heating units for residential occupancy units of sizes greater than 100 liter storage and/or greater than 15 kW heating capacity must be located in a separate room remote from mishandling

Table (11) Water heating equipment

Performance Requirement	Rating Conditions	Component
Efficiency not less than 90%	$\Delta T < 45^{\circ}C$	Electric Inputs less than 12kW Capacity 50-450 Liters
Efficiency not less than 85%	$\Delta T < 45^{\circ}C$	Gas Fired less than 22 kW
Efficiency not less than 85%	$\Delta T < 45^{\circ}C$	Gas Fired larger than 22 kW
Efficiency not less than 80%	$\Delta T = 50^{\circ}C$	Gas Fired less than 38 liters storage

All piping forming part of a service water heating system and located outside the building envelope must be insulated to the level specified in the Insulation Code for heating system pipes. Where the pipe insulation has a thermal conductivity of more than, or less than, the range of the tables sited in the Insulation Code, thickness correction should be carried out in linear extrapolation of the table range.

ELECTRICAL POWER

The nominal cross-sectional area of wires and cables must be determined according to the Code of each Arab country of electrical installations in buildings, taking into consideration, the design current, ambient temperature, type of cable, type of insulation of cables, method of installation and grouping of cables.

WHOLE-BUILDING PERFORMANCE

Annual energy costs analysis for the Standard Design and the Proposed Design must each be determined using the same approved energy analysis simulation tool. The climate data used in the energy analysis must cover a full calendar year (8,760 hours) and must reflect approved coincident hourly data for temperature, solar radiation, humidity and wind speed for the building location.

STUDY CASE

An apartment building was used as a base case (BC) for this study. The residential building is a five-story building facing the NW direction. The apartment unit, Middle-income, Mid-rise (the floor area is 105 m^2).

The dimension of the building is 24m by 16m with a floor-to-floor height of 3.0 m. There are essentially two floors: a top floor, which would include roof loads, and a middle floor, which would not include roof loads. Climatic data needed to run the spread sheet was established to run the simulation for the different cases; such as WWR, SHGC, Roof insulation, etc.

The Overall Total Thermal Transfer Value (**OTTV**) for the building envelope indicates the amount of heat transferred into building through the building façades and roof per unit building envelope area. The **OTTV** equations for the walls and the roof were programmed into an Excel spreadsheet, developed by the author.

DISUCION AND RESULTS

Table (6) classified the Arab countries into 10 regions and every region have the CDD25, HDD18.3 and OTTV (W/m^2). CDD range between 500 and 2000 while HDD ranges between 1500 and 500. The OTTV ranges between 30 and 70.

Table (7) classifies the Arab countries into five regions according to the DDC10, DDC18.3 and DDH25. For example, the first region contains Doha, Dubai and Kuwait where DDC10 > 6000 where the outdoor weather is very hot and humid. The second region includes Riyadh and Aswan where 4000 <DDC10 < 6000 and the weather is recognized as very hot and dry. The OTTV analysis was applied to each city. The effect of the WWR was analyzed from 0.1 to 0.9.

Figure (2) shows the variation between $OTTV_w$ and WWR. The variation is linear when WWR increases the $OTTV_w$ increases. WWR ≤ 30% satisfy the complied OTTV for Energy Efficiency. The regression analysis was applied to get a general linear equation between OTTV and WWR for Cairo and Kuwait.

OTTV=296.8*WWR+28.4 (KUW) (1)

OTTV=323.9*WWR+21.3 (CAI) (2)

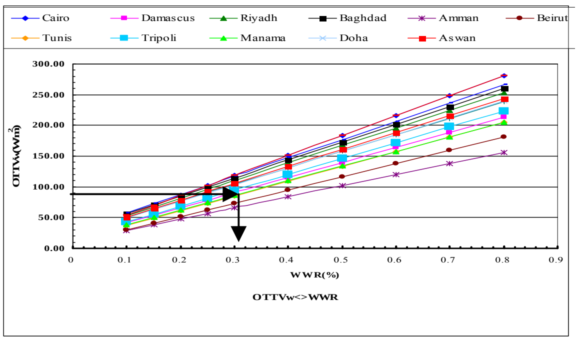

Figure (2) Relation between OTTV & WWR

.

Conclusion

It has been proven that increasing the glazing area of the façade, i.e. increasing the WWR, the OTTV increases, the building thermal efficiency decreases. The Total Overall Thermal Transfer value (**$OTTV_w$**) for the exterior walls should not exceed 90 W/m^2, ranges from 60 W/m^2 to 90 W/m^2. The **$OTTV_r$** should not exceed 12W/m^2 and could be taken as 10 W/m^2

Acknowledgement

The author wishes to acknowledge the Chair person of the Arab Energy building Codes Prof. Dr. Omima A.S. Eldin.

References

1. Energy Efficiency Residential Building Draft Code (2010), Final Draft the Arab Countries by the Ministry of Housing, HBRC, Egypt.
2. Energy Efficiency Commercial Building Code of Vietnam (2002). Second Draft.
3. Robertson G.L. (1998). Residential Energy Code-A New Zealand Proposal, Proceeding Clean and Safe Energy Forever, VOL.2, pp. 926-930.
4. ASHRAE (1997). Hand Book of Fundamentals, ASHRAE, Atlanta, GA.
5. Energy Efficiency Residential Building Code (2003), Ministry of Housing, HBRC, Egypt.