

# ENERGY-EFFICIENCY IN AIR-CONDITIONED BUILDINGS: AN OVERVIEW

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## ABSTRACT

The Egyptian community in its path for rapid development is endeavouring to make all necessary and appropriate measures to enhance the efficiency of energy utilization and increase the beneficitation of the energy resources. Throughout the Nation, Energy resources are widely used and consumption rates are in general exceeding the International accepted values. The use and application of new and renewable energy sources can be harnessed to design, construct and operate a solar building of moderate size for desert applications. The paper demonstrates the importance of incorporating an energy performance directive as a Standard in our region such a goal will aid energy savings in large buildings and set regulations to energy efficient designs that are based on Standard calculation methods. The target is to develop standardised tools for the calculation of the energy performance of buildings, with defined system boundaries for the different building categories and different cooling/heating systems. Endeavour to prepare models for expressing requirements on indoor air quality, thermal comfort in winter and when appropriate in summer, visual comfort, etc is targeted with a common procedure for an "energy performance certificate".

## KEYWORDS

Energy, Simulation, Codes, Policies

## ENERGY DECLARATION OF BUILDINGS

The GOE is now undertaking the development of the following codes with their compliance procedures and measures:

- Residential Energy - Building Codes
- Commercial Energy -Building Codes

The implementation of such project is sought to be realized through close co-operation and association with the Housing & Building National Research Centre HBRC. The HBRC is a governmental Body responsible for the research and development in the building Technology sector and is the umbrella under which the Egyptian National Codes are developed and issued.

Main Targets of Energy Performance Directive are:

1. "Legestitative authorities shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be. ...."
2. The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for cost-effective improvement of the energy performance....."

The following steps are required for the energy certification:

1. Develop methodologies for energy declaration of the buildings
2. Develop reference values (key numbers) and /or systems for benchmarking
3. Provide a labelling system for selected buildings

The primary use of energy declarations is, among others, to:

1. Create consciousness of energy efficiency in buildings and also improve the knowledge of energy use in buildings;
2. Use the information to determine if the building works as well as possible with regard to its technical design;
3. Use the information for benchmarking;

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4. Use the information for suggesting measures and recommendations for reducing the energy use;
5. Provide the information necessary to make calculations of the environmental impact due to the energy use, e.g. CO<sub>2</sub> emission;
6. Describe selected energy properties of the building;
7. Give the basis for a common energy performance certification of a building

It is believed that depending on the purpose of the energy declaration, different procedures can be of interest. Different actors need different information. For giving relevant advice to the property owner which measures are cost-effective a very careful examination and calculation of the building's energy balance is necessary. A careful analysis is also necessary to give relevant information to the users how they can decrease their energy use without decreasing, under an acceptable level, the indoor air quality and thermal comfort. The main purpose is to reduce the energy consumption in the commercial and Public buildings sector and hence also the carbon dioxide emissions.

One way to proceed is to carry out the energy calculations in different steps for existing buildings.

- The first is to collect measured energy-use, e.g. from energy bills, and make a benchmarking to decide if the actual building is better or worse compared to similar buildings. If the energy-use seems to be higher than the average for a comparable grouping of buildings.
- A second step is to make a careful energy calculation that can be compared to the measured energy use. This has to be carried out to identify the type of measures that can be recommended.
- Some important aspects that deem necessary to take into consideration when developing a common tool for energy declaration of buildings should be addressed, Olesen et al (2003) and Khalil (2003)

## ENERGY PERFORMANCE

The Energy Performance of Buildings should include a general framework for the calculation of energy performance and building categories to be included. Let us consider here the basic recommended method of calculation of energy performance of buildings; it should include at least, but not limited to, the following aspects:

- Thermal characteristics of the building (envelope and interior partitions, etc.).
- air-conditioning systems
- ventilation system
- Hot water supply and winter seasonal heating.
- built-in lighting installation for commercial sector
- Buildings Orientation ,position and outdoor climatic conditions
- passive solar systems and solar protection
- natural ventilation (available)
- Indoor climatic design conditions.

The positive influence of renewable energy sources on the environment should be included; such as:

- Active solar systems contribution to domestic water heating based on renewable energy sources.
- Combined Power and heat production.
- District cooling heating systems
- Natural lighting with goals to save electricity and cooling energy.

The categories of building suggested to be covered can include:

- a. Office Buildings
- b. Educational facilities
- c. Healthcare facilities and hospitals
- d. Hotels and restaurants
- e. Sporting facilities
- f. Department stores and commercial buildings
- g. warehouses, museums, cold stores, etc...

Calculation standards related to the directive

Starting from the contents of the calculation framework and looking at the currently available European and international standards Table 1, see EPD (2006), is the simple outcome summary. Preferably, as few calculation models as possible should be used to cover the different building

categories. It may, however, be necessary with more than one model, depending on the desired output and accuracy.

A simplified calculation method for cooling load and cooling energy use including efficiency losses should be established. Work in this field has just started internationally. The terms "air leakage", which is used in conjunction with the building envelope, and "air infiltration", used in ventilation design, should be coordinated as they effectively mean the same. Areas where information on logistics is missing are those for natural and hybrid ventilation systems, where calculation guidelines are missing, Kameel et al (2003). A comprehensive calculation method should clearly include:

- Method to build up internal gains by adding individual components from the bottom and up.
- Built-in lighting could be included, with the possibility to give credit for natural lighting in this approach.
- Calculation of energy supply from solar water heating and solar heating systems including active seasonal storage or the use of other renewable energy sources such as wind and geothermal.
- Indication of the bases for specific real energy use compared to design energy use.
- Energy use normalisation criteria, such as kWh/m<sup>2</sup>, for benchmarking purposes; a clear definition of which m<sup>2</sup> to be used is necessary.

## NEED FOR FURTHER DEVELOPMENT

The present work opens the field for further investigation to focus on some issues that have to be developed before the preparation and implementation of an energy directive for Egypt:

- i. Cooling load and energy use for cooling.
- ii. If we assume lighting has high priority, a method to calculate all internal gains should be developed.
- iii. A method for establishing the air change rate based on air leakage (air infiltration), airing and natural / hybrid / mechanical ventilation should also be developed.
- iv. Verification and normalisation methods for credibility and to compare between countries.
- v. Calculation schemes for the use of renewable energy sources in different applications in buildings and particularly in desert areas.

It is probable, that one calculation method will not cover all aspects and building categories of the Directive. For some applications, more advanced simulation models will have to be used to provide satisfying accuracy. The ongoing and future work on methods for validation and documentation of simulation tools at HBRC and Cairo University, Khalil (2005) and Medhat et al (2006) could be valuable in a process of approving models.

## THERMAL COMFORT

Along the lines outlined above, local climate conditions and comfort should be clearly specified. Thermal sensations greatly varied due to many parameters such as, nerves system modes, original acclimatization, peace of mind, and spirit harmony. These non-thermal parameters lead to physiologic classification for the Egyptian distributed on seven climatic regions as indicated in the figure. Investigations dealt with both males and females, healthy, Egyptian citizens over 16-years old from different governorates. All persons have nearly the same metabolic rates which, ranged from 0.70 to 2.00 met (1 met =58.20 W/m<sup>2</sup>) during summer; dressed with clothing that ranged from 0.10-to-1.20 clo, (1 clo = 0.155 m<sup>2</sup>. K/W) and their respective weights ranged from 60 to 90 kg. They were subjected to specific climate for over two hours inside different public buildings in their original locations. After being subjected to treated air, acclimatized to the indoor conditions; they were moved into a pre-adjusted zone. All of them had immediately expressed their reactions to the new indoor climatic conditions, warm, cool, fair, and same. Utilized questionnaire vote level was based on a minimum of 50 persons covering samples of Egyptian population and were computer based selected. Figure 1 demonstrated the different climatic zones in Egypt to be used for energy calculations, Medhat and Khalil (2006). It can also be concluded that all adults under 45-years of age prefer an effective temperature one degree lower than occupants over that age. Psychological parameters have no effects on the selection of effective temperatures especially as indicated on the other case studies of occupants have ages over 45-years ,Khalil(2005) and Medhat and Khalil(2006). (I.e. occupants feel

that they are in a dark, when they cannot see outside or individuals who are not comfortable unless they have open windows). Finally, the contrast between indoor and outdoor conditions plays a minor role in the acclimatization of Egyptian citizens, as most of them have no vital vote against contrast gradient.

## ENERGY COSTING

Air Cooled Units are available in size range of single packaged units of up to 800 kW (255 TR). The majority of the units on the local market are driven by reciprocating or screw compressors, one or a number of compressors per unit, for most installations in the range of 350-to-1750 kW(100-to-500 TR) the total installed capacity must be made up of multiples of packaged units that make up the installation equals to individual packaged units.. An analysis of the packaged units available on the market reveals a kW/TR requirement, excluding the chilled water pump and the air side, as schematically shown in Figure 2 as example; Direct Expansion units are denoted as D.X.units on Figure 2 which also indicates that the electrical requirements fall between 1.40-to-1.62 kW/TR for chiller units and 1.66-175 kW/TR for DX Units. In Egypt, the energy consumption for residential and commercial private buildings contributed with 35% of the total energy generated, Khalil (2004) the larger portion of this energy was consumed in the cooling processes. Therefore, the residential and tertiary sector is one of the most energy intensive sectors. Nevertheless; the new buildings will be constructed in accordance with new energy efficiency codes. Energy consumed by the older buildings themselves is very high. Heat losses in buildings are caused, not only by low standards building materials and construction, but also by poor insulation of heat and lack of energy efficiency awareness that presents the main reasons for high energy consumptions in residential buildings and describes the traditional methods that have been employed to achieve energy conservation in residential sector. The running cost relating to the electricity and water used by cooling units over a one year period is estimated according national cost. The water consumption in water-cooled units is estimated to be 0.013 m<sup>3</sup>/hr/TR for make-up water, while cost of air-cooled units could be similarly obtained, taking into considerations that water cost is subsidized by government.

## ARAB ENERGY IN BUILDINGS CODE

A Challenging task is to design, build and set the guidelines for a reliable energy code that satisfies the general needs of the Arab nations and tailor the energy utilization in buildings through:

- Set minimum energy efficiency levels of general energy consuming equipment in typical residential and or commercial buildings.
- Set the climatic data for the Arab world and build up the relevant building envelope data that are used for energy calculations based on local building materials and practices.
- Set the prescriptive energy in kw/square metre of floor area for different applications.
- Devise a methodology of trade-off of energy consuming elements to achieve an energy efficient building.

## CONCLUSIONS

From the above analyses, one may conclude the importance of incorporating an energy performance directive as a Standard in our region such a goal will aid energy savings in large buildings and set regulations to energy efficient designs that are based on Standard calculation methods. The proposed Standard would be largely based on International Standards and appropriately modified to suit local practices .The proposal is basically to:

1. Develop standardised tools for the calculation of the energy performance of buildings
2. Define system boundaries for the different building categories
3. Prepare models for expressing requirements on indoor air quality, thermal comfort in winter and when appropriate in summer, visual comfort, etc.
4. Develop transparent systems to determine necessary input data for the calculations, incl. default values on internal gains
5. Define comparable energy related key values (kWh/m<sup>2</sup>, kWh per person, kWh per apartment, kWh per produced unit etc.) The areas/volumes need to be defined.

6. Develop a method to translate net energy, used in the building, to primary energy and CO<sub>2</sub> emissions
7. Develop a common procedure for an “energy performance certificate”
8. Develop and compile relevant standards applicable for each individual building category.

## ACKNOWLEDGEMENT

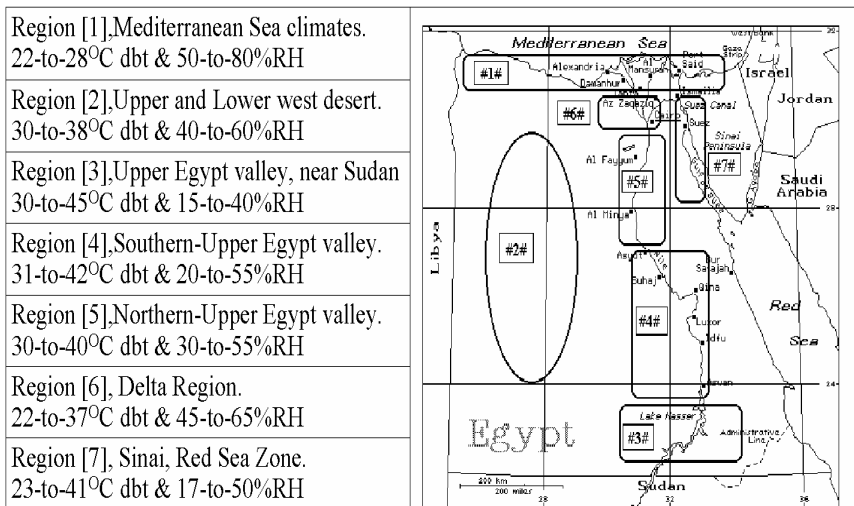
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## REFERENCES

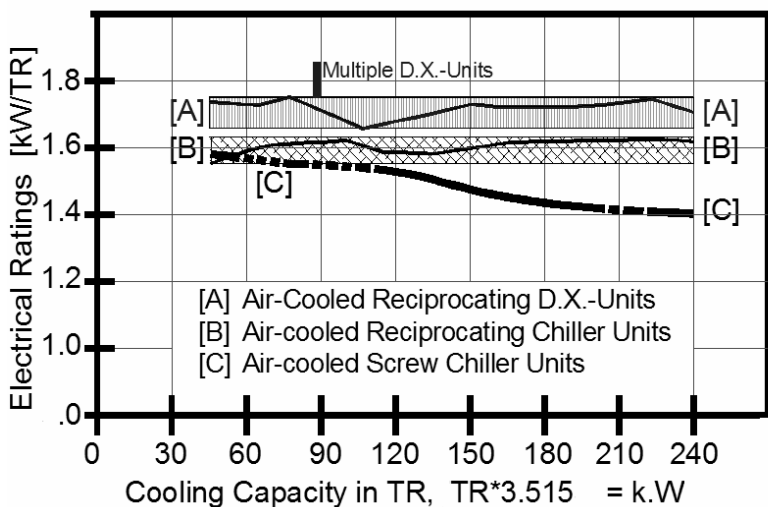
1. EPD, European Energy Performance Code, CEN, 2006
2. B.W.Olesen, M. Koschenz, C. Johansson, “New European Standard Proposal for Design and Dimensioning of Embedded Radiant Surface heating and Cooling Systems. ASHRAE Transactions, Volume 109, Part 2, 2003.
3. R. Kameel and E.E.Khalil, “Energy Efficiency, Merits, And Advantages of Various Air-Conditioning System in Commercial Buildings, In Egypt”, Proceedings of ASHRAE-RAL, Paper Ral.3-5, Cairo, 2003.
4. E.E.Khalil, “HVAC in Energy Efficiency Building Code, Egypt”, Proceedings of ASHRAE-RAL, Paper Ral.3-6, Cairo, 2003.
5. EN ISO 10077-2, Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical methods for frames.2005
6. EN 13363-1, Solar protection devices combined with glazing – Calculation of solar energy and light transmittance – Part 1: Simplified method.2005
7. EN ISO 13790, Thermal performance of buildings – calculation of energy use for space heating. 2006
8. E.E.Khalil, “Energy Efficiency in Air Conditioned Buildings: An Overview”, Proc.6<sup>th</sup> JIMEC, Amman, 2004.
9. E.E.Khalil “Energy Efficiency in Air Conditioned Buildings in Egypt, Proc.6<sup>th</sup> JIMEC, Amman, 2004.
10. E.E.Khalil, “Energy Performance of Buildings Directive in Egypt: A New Direction, HBRC Journal, Volume 1, 2005.
11. A.A.Medhat and E.E.Khalil, “Thermal Comfort Meets Human Acclimatization in Egypt” Proceeding of Healthy Building, June 2006, Lisbon, Portugal.

**Table 1:** List of energy related standards and aspects in Buildings.

Aspect	Sub-aspect	ISO Standards
Thermal characteristics	building components	ISO 6946, 10292, 13370, 10077, 13789
Calculations of design heat load.		ISO 13790, 13786
Air-conditioning installation	cooling load, efficiency	FDIS18618 -Under preparation
Orientation of buildings, outdoor climate		ISO 13790, 15927
Climatic data		ISO 9050



**Figure 1:** Map of Egypt showing main population climatic zones.



**Figure 2:** Air Conditioning Systems Electrical Energy Requirements in Egypt.