Energy Efficient Design and Performance of Commercial Buildings in Developing Countries

Essam E. Khalil

Cairo University, Cairo, Egypt
Khalile1@asme.org

Abstract

Energy Performance of Buildings should include a general framework for the calculation of energy performance and building categories together with thermal characteristics of building, air conditioning, ventilation, lighting and appliances aspects considered. These include Active solar systems contribution to domestic water heating based on renewable energy sources, CPH production and District cooling systems. This paper reviews the energy sources available in Egypt, their distribution and utilization in commercial sectors. 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 proposed Standard would be largely based on International Standards and appropriately modified to suit local practices. 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 is targeted to develop a common procedure for an "energy performance certificate". The present work is to provide transparent information regarding output data (reference values, benchmarks, etc.) and to define comparable energy related key values (kWh/m^2, kWh per person, kWh per apartment, kWh per produced unit etc.). Proposals to develop a common procedure for an "energy performance certificate" and CO_2 emissions are given.

1. Introduction and Key Features

Analyses of energy performance would be initiated from power generation pattern in a country, Figure 1, energy consumption by sector and energy consumption by utility as shown in Figures 2 and 3 for Egypt, as an example. In commercial buildings Air conditioning systems can consume as much as 56% of the total energy used in the building. Therefore it is a challenge to design an optimum HVAC airside system that provides comfort and air quality in the air-conditioned spaces with efficient energy consumption. The conditions of the air to be maintained are dictated by the need for which the conditioned space is intended and comfort of users. So, the air conditioning embraces more than cooling or heating. The comfort air conditioning is defined as "the process of treating air to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the comfort requirements of the occupants of the conditioned space" [1]. Air conditioning, therefore, includes the entire heat exchange operation as well as the regulation of velocity, thermal radiation and quality of air, as well as the removal of foreign particles and vapors [2].

It is probable, that one calculation method will not cover all aspects and building categories of the proposed 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 [1-3], could be valuable in a process of approving models.

2. Energy Efficiency Indicators

Till now, the guidelines and design standards don't provide restricted utilization strategies of the conditioned air in the spaces. Indeed, this situation creates several inefficient systems and consequently expensive energy invoice. In some critical facilities, such as hospitals, HVAC designers face the problem of balancing between the attaining comfort conditions and the efficient energy utilization. The relation between the HVAC system designs and the optimum conditions and optimum energy utilization is still under investigation up today. In recent researches [4,5], the effect of ventilation design on the comfort and energy utilization is investigated. The effect of the displacement ventilation on humidity gradient in a factory located in the hot and humid region is illustrated [4]. It was found the strong dependence relation

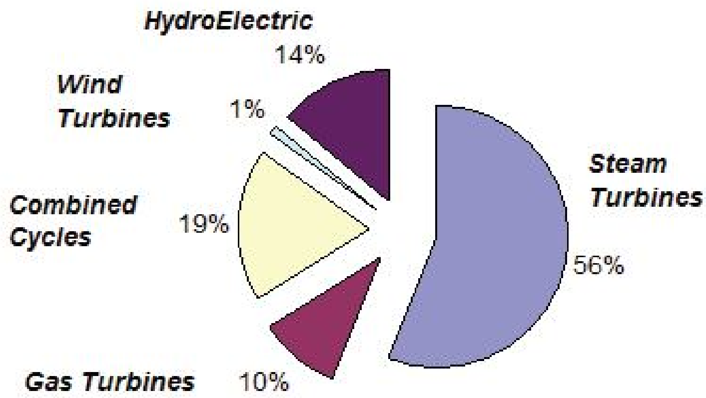

Figure 1. Current power generation technologies in Egypt, with power generation shown by plant type. Total generated = 108 MWhr.

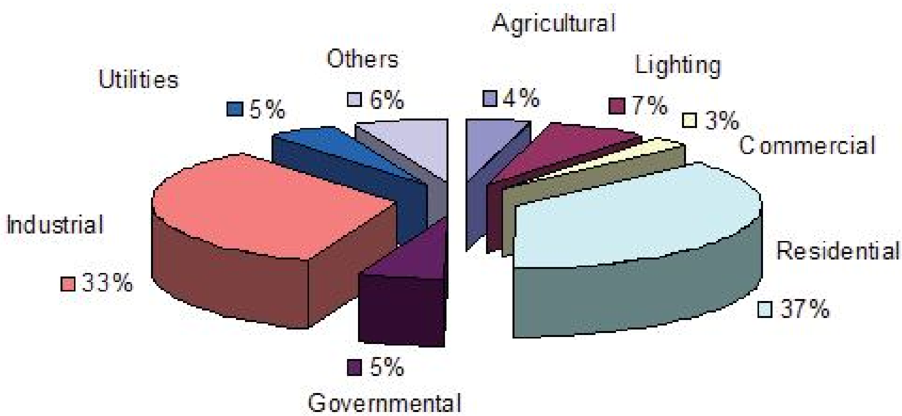

Figure 2. Energy consumption by sector 2006/2007 in Egypt.

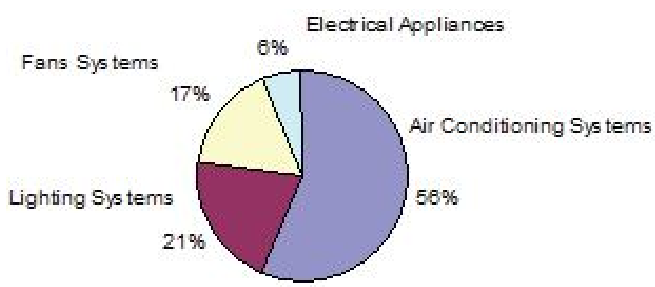

Figure 3. Building energy consumptions by utility in Egypt.

between the correct supplying conditions and comfort. Indeed, the displacement ventilation is recommended as an energy efficient system, however, the created humidity and temperature gradient, because this system gives the designers the suitable tolerance to select more economize supply conditions [4]. In recent years, new design traditions of the ventilation systems, such as the under-floor ventilation systems are growing to overcome the problems of the current systems. The under-floor air supply is recommended as an alternative to the ceiling air supply in the office buildings to overcome the lack of flexibility in the ceiling systems and to improve the comfort conditions [5-8]. Actually, the energy utilization mainly depends on the optimum utilization of the conditioned air in the conditioned spaces. The currently popular HVAC residential window and Split units were further investigated in terms of energy costs and energy efficiency ratio as follows,1 $ =5.45 LE.

Table 1. HVAC units characteristics (Window Units).

Cooling Capacity, kW	Power Consumption, W	EER	COP
2.64	1023	8.8	2.58
3.66	1429	8.75	2.56
5.28	2000	9.0	2.64
7.03	2697	8.9	2.61

Table 2. HVAC Units Costs (Window Units).

Cooling Capacity, kW	Power Consumption, W	Air Flow, m^3/hr	Unit Cost, LE
2.64	1023	540	1400
3.66	1429	630	1700
5.28	2000	1020	2000
7.03	2697	1275	2400

Table 3. HVAC Units Estimated Energy Costs (Window Units).

Cooling Capacity, kW	Power Consumption, kWh per day at 40ºC Outdoor	Air Flow, m^3/hr	HVAC Cost, LE/ day
2.64	10.23	540	2.046
3.66	14.29	630	2.858
5.28	20.00	1020	4.0
7.03	26.97	1275	4.394

Note: Calculated at 10 hours/day and 0.2 LE/kWh.

Table 4. HVAC Units Characteristics (Split Units).

Cooling Capacity, kW	Power Consumption, W	EER	COP
2.78	1056	9.0	2/64
3.66	1389	9.0	2.64
5.57	2111	9.0	2.64
7.03	2775	8.65	2.64
8.8	3409	8.8	2.58
10.26	3784	9.25	2.71

Table 5. HVAC units costs (Split Units).

Cooling Capacity, kW	Power Consumption, W	Air Flow, m^3/hr	Unit Cost, LE
2.64	1056	509	3400
3.66	1389	509	3700
5.28	2111	798	4000
7.03	2775	956	4400
8.8	3409	1528	5500
10.26	3784	1528	6000

Table 6. HVAC units estimated energy costs (Split Units).

Cooling Capacity, kW	Power Consumption, kWh per day at 40 C Outdoor	Air Flow, m^3/hr	HVAC Cost, LE / day
2.64	10.56	509	2.112
3.66	13.89	509	27.78
5.28	21.11	798	4.222
7.03	27.75	956	5.550
8.8	34.09	1528	6.818
10.26	37.84	1528	7.568

Note: Calculated at 10 hours/day and 0.2 LE/kWh.

2.1 Introduction to Energy Standards and Labeling

As the world becomes increasingly dependent on electrical appliances and equipment, energy consumption rapidly rises every year. Many programs have been established in various countries to increase end-use equipment energy efficiency. One of the most cost-effective and proven methods for increasing energy efficiency of electrical appliances and equipment is to establish energy efficiency standards and labels as defined here below.

Energy Efficiency Standards

Energy efficiency standards are a set of procedures and regulations that prescribe the energy performance of manufactured products, sometimes prohibiting the sale of products less energy-efficient than the minimum standard. The term "standard" commonly encompasses two possible meanings:

1. A well-defined protocol (or laboratory test procedure) by which to obtain a sufficiently accurate estimate of the energy performance of a product in the way it is typically used, or at least a relative ranking of the energy performance compared to other models; and
2. A target limit on energy performance (usually a maximum use or minimum efficiency) formally established by a government-based agency upon a specified test standard.

Energy Labels

Energy efficiency labels are informative labels affixed to manufactured products indicating a product's energy performance (usually in the form of energy use, efficiency, and/or cost) in order to provide consumers with the data necessary for making informed purchases. Energy labels serve as a complement to energy standards. They provide consumers information that allows those who care to select more efficient models. Labels also allow utility companies and government energy conservation agencies to offer incentive s to consumers to buy the most energy-efficient products. The effectiveness of energy labels is highly dependent on how information is presented to the consumer.

Rationale and Benefits

Energy efficiency in developing countries plays an important role in achieving global sustainable development. Energy-efficiency improvements can slow the growth in energy consumption, save consumers money and reduce capital expenses for energy infrastructure. Energy consumption is growing rapidly in these countries, yet energy efficiency remains far below levels in developed countries. Energy-efficiency improvements can slow the growth in energy consumption, save consumers money and reduce capital expenses for energy infrastructure. For most developing countries, the foreign exchange needed to finance energy sector expansion is a significant drain on reserves. Additionally, energy efficiency reduces local environmental impacts, such as water and air pollution from power plants, and mitigates greenhouse gas emissions. Standards and labeling programs provide enormous energy savings potential that can direct developing countries towards sustainable energy use. Improved end-use efficiency from Standards and Labeling programs can contribute significantly to developing economies. T he main benefits are:

1. Less need to build new power plants. The cost of saving 1 kWh of energy through energy-efficiency programs has proven much less expensive than producing 1 kWh of energy by building a new power plant.
2. Reduced greenhouse gas emissions. Less energy production means less carbon dioxide emissions from power plants. This contributes to environmental benefits such as slowing down environmental pollution and global warming and preserving natural resources and the ecosystem.
3. Improved competitiveness for local manufacturers. Local companies that upgrade the efficiency of their products can compete better with multi-national companies, especially with lower production costs.
4. Higher consumer disposable income. Less spending on electric bills increases consumer purchasing power for other products, which helps local businesses.
5. Increased cash flow in the local economy. With higher disposable income, consumers are more willing to spend, thus, injecting money into the local economy.
6. Improved Trade Balance. Decrease in energy demand will reduce the consumption of indigenous resources (i.e. natural gas and oil), allowing more to be exported (for Lebanon, less to be imported). Increased export earning (or less import spending) helps alleviate trade deficit of Arabian countries.
7. Avoided future energy deficit as power demand rises. Energy exporting countries have become net importers due to dramatic increases in electricity demand. Energy-efficiency programs can help slow down the demand and prevent energy deficit in the future.

2.2 Energy Standards & Labeling

Table 7 below summarizes the International Energy Labeling activities in recent years that had achieved their goals and impact on national economy.

Table 7. Summary of pioneering international programs and their achievements.

Country or Region	Program	Achievements
Australia	Mandatory Standards & Labeling	• 11% reduction in energy consumption of labeled appliances in 1992 • Approximately equals 94 GWh of saved energy or 1.6% decrease in total household electricity consumption
Europe	Mandatory Standards and Labeling	• Germany: 16.1% increase in market efficiency (1993 - 1996) • Netherlands: 12.6% increase in market efficiency (1992 - 1995) • United Kingdom: 7.3% increase in refrigerator/freezer efficiency (1994 - 1996)
Philippines	Mandatory Standards and Labeling	• 25% increase in average efficiency of all air conditioners (after first year) • Energy Savings: 6 MW in demand and 17GWh in consumption (after first year)
Egypt	Mandatory Standards and Labeling	• 10% decrease in refrigerator energy consumption (after 3 years) • 20% decrease in air-conditioner energy consumption (after 3 years)
Thailand	Voluntary Labeling	• 14% decrease in refrigerator energy consumption (after 3 years) • Energy Savings: 65 MW in demand and 643 GWh in consumption.
United States	Mandatory Standards and Labeling	• 98% increase in refrigerator efficiency (1972 - 1988) • More than 3% reduction in US annual residential consumption from appliances and lighting equipment

3. Building Blocks of a National Standards & Labeling Program

A national standards and labeling program is defined as a set of elements that ensure that energy efficiency standards and labeling efforts are effective, appropriate, strengthened over time, and sustained. The building blocks fall into two categories, technical/policy and process. They include:

3.1 Technical/Policy

1. Accredited Testing Facilities .Facilities should be internationally accredited be staffed with competent testing personnel, and have the capacity to test models in a timely manner. Appropriate Testing Procedures .Testing procedures are the methods by which the energy efficiency level of a product is deduced. The selected procedures should reasonably reflect the usage patterns and climate particular to a country. This builds consumer confidence that test results accurately reflect the energy usage he/she will experience.
2. Energy Labels .Standards and labels can be established separately or as complementary programs. Many types of labeling programs exist.
3. Energy Efficiency Standards can be mandatory or voluntary and based either on maximum energy consumption or minimum energy efficiency.
4. An energy policy framework that is conducive to energy efficiency is critical to the longevity of a national standards program. Supportive policies include government procurement requirements, voluntary programs, incentives to manufacturers, consumer awareness campaigns, and demand-side management and integrated resource planning.

3.2 Proposed Process

1. Compliance with voluntary and mandatory standards and labeling requirements must be ensured through a credible enforcement scheme to guarantee program effectiveness. Programs evaluation will inform necessary program modifications, justify further activities, and provide the documentation necessary to sustain the standards and labeling programs over the long-term.
2. The legislative process should ensure that standards and labels are periodically reviewed and raised ("ratcheted" upward) as the overall product efficiency on the market improves. The changes will mostly depend on the results of program evaluation.
3. In the program design and improvement process, input from all stakeholders (government, private companies, consumer associations, etc.) should be considered. Co-operation between the stakeholders is the key to the success of programs. However, the local and national governments must also hold its decision final, after carefully considering all suggestions.

4. Concluding Remarks

It can be concluded that it is important to incorporate 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. It is recommended to:

1. Develop standardized tools for the calculation of the energy performance of buildings
2. Define system boundaries for the different building categories and different heating systems
3. Prepare models for expressing requirements on indoor air quality, thermal comfort in winter and when appropriate in summer, visual comfort, etc.
4. Define comparable energy related key values (kWh/m2, kWh per person, kWh per apartment, kWh per produced unit etc.) and to develop a common procedure for an "energy performance certificate"
5. Design, construct and operate a solar decathlon (Building) that can meet the rural and desert requirements and save the diminishing fossil fuel sources.

5. References

1. Khalil, E.E. "Energy Performance of Buildings Directive in Egypt: A New Direction, HBRC Journal, Vol. 1, 2005.
2. Medhat, A.A. and Khalil, E.E. "Thermal Comfort Meets Human Acclimatization in Egypt" Proceeding of Healthy Building, Vol.2, pp25, June 2006.
3. Khalil,E.E. "Energy Performance Of Commercial Buildings In Egypt: A New Direction", Proceedings, Energy2030, Abu Dhabi, November 2006
4. Kosonen, R. "Displacement ventilation for room air moisture control in hot and humid climate", Roomvent 2002, pp 241-244, 2002.
5. Leite, B.C.C. and Tribess, A. "Analysis of under floor air distribution system: Thermal comfort and energy consumption", Roomvent 2002, pp 245-248, 2002.
6. Kameel, R., and Khalil, E. E., "Prediction of turbulence behaviour using k-ε model in operating theatres", Roomvent 2002, pp 73-76, 2002.
7. Khalil, E.E."Arab-Air Conditioning And Refrigeration Code For Energy-Efficient Buildings", Arab Construction World, Vol 28, NO.8, pp.24-26, August 2008
8. Khalil, E.E. "Air Conditioning and Refrigeration Code For Energy-Efficient Buildings In The Arab World", Journal of Kuwait Society of Engineers, Vol 100, pp 94-95, September 2008.

Author Biography

Prof. Dr. Essam Eldin Khalil is Professor of Mechanical Engineering at Cairo University, Department of Mechanical Engineering, Cairo, Egypt.