Developing a strategy for energy efficiency in the Egyptian building sector

Marco Caponigro¹, Athanasios Manoloudis², Agis M. Papadopoulos²*

¹ GOPA, International Energy Consultants GmbH, Bad Homburg, Germany
² Process Equipment Design Laboratory, Dept. of Mechanical Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece

Email: agis@eng.auth.gr

Abstract. Global warming is a major threat for each country worldwide, in particular however for the Middle East and North African (MENA) region. Furthermore, inefficiency has been a common feature of the energy use in most of the MENA countries for the last decades; high subsidies on retail energy prices covered this fact for years, however as the oil prices shrunk, this was no longer possible due to reduced revenues. The combination of those two reasons led since the early 2010s some MENA countries to develop energy efficiency (EE) policies, whilst others are trying to catch up. Egypt is the most populous country, facing many challenges: a further significant growth of population and an expected high annual economic growth on the one hand, the need for new infrastructure and the scarcity of water on the other. The present paper focuses on the situation of Egyptian building sector with respect to prevailing energy efficiency regulations and their implantation, as well as on the elaboration of proposals for a viable and effective strategy to improve conditions.

Keywords. Energy efficiency; building sector; Egypt; strategy; policies

1. Introduction

Egypt is the country with the biggest Arab population, located strategically in the crossroads between Europe, Africa and the Middle East and between the Mediterranean and the Red Sea. The country’s population is growing at exponential rates: Within 25 years, from 1990 till 2015, it grew from 52 to 90 mn people, of which 43% live in urban areas, in Cairo alone are estimated to live 15 mn people [1]. Presenting adequate housing to the population is a challenge, with approximately 700.000 new dwellings needed annually just to cope with the population increase, without considering the renewal of the building stock. Considering final energy consumption, it rose from 23.2 Mtoe in 1990 to 55.5 Mtoe in 2015. The building sector, including services, accounts for 38% of the total energy consumption, while with respect to energy sources used, it accounts for more than 52% of the country’s electricity consumption and more than 17% of the fuel oil consumption [2]. It is therefore evident, that the energy efficiency of the building sector affects directly the life of the country’s population and the competitiveness of the tourism and other services, especially in the big urban areas [3]. It has to be noted, that the residential sector alone accounts for 42% of the electricity consumption, with an average annual consumption of 3.200 kWh per household, although there are very significant differences between urban and rural and lower and higher income groups of population [4]. The necessity to improve the building stock’s energy performance is becoming peremptory in the light of this demographic, economic and social changes taking place in
Egypt. However, the phenomenon is neither new nor one-dimensional. In the recent, but deceptively easily forgotten first half of the 20th century, drastic energy conservation measures were applied affecting the economic and social life in most European countries. It is therefore only reasonable to capitalize on experience and expertise obtained all over Europe, and especially in regions close to Egypt, like Greece and Cyprus but also Israel, where the implementation of energy efficiency policies lead to reduction in the consumption between 40 and 60%. As experience showed, the way towards increased energy efficiency passes through the reduction of air-conditioning, ventilation, domestic hot water production and lighting requirements, whilst at the same time trying to raise the living standards of the day. [5, 6, 7]

At the same time, one has to keep in mind, that if any energy efficiency policy intends to be successful, it cannot be limited to new constructions, but has to be extended to the refurbishment of the existing building stock. Coming to the energy performance of the Egyptian building stock, one has to notice that there are certain uncertainties considering the number and surfaces of building, especially of governmental and other public ones.

Considering the residential building stock, the data available from the Egyptian Central Agency for Public Mobilization and Statistics authority (CAPMAS) mention nearly 18 mn dwellings in 2015 [1]. With respect to the average surface per dwelling on national average, this accrues to 75 m$^2$. On the other hand, given the fact that urban residences have the stronger impact on energy consumption, due to higher living standards, one can use figures mentioned by other studies, which approximate the surface of typical urban dwellings to be 125 m$^2$ [8].

![Figure 1. Partially completed residential apartment block in Cairo.](image)

A further uncertainty factor has to do with the so-called informal settlements, i.e. residential areas where constructions are not formally authorized and no building permits exist. The number of dwellings
and residents is difficult to assess, but it is worth mentioning that it accounts for more than 62% of the Greater Cairo Area alone, with an estimated 5 - 7 mn people living there, as compared to the formal population of some 10 mn [9, 1]. Still, even in formal settlements, the reality is sometimes difficult to assess, as the image of a, quite typical, unfinished multifamily apartment block depicted in Figure 1, shows.

2. Energy use in the building sector: Setting the goals

2.1. Analysis of the situation

As already mentioned, the building sector, including the residential and the tertiary subsectors, accounts for about one third of final energy consumption in the country. Final energy consumption of buildings in Egypt has increased from 157.000 million GWh in 2009 to about 223.000 GWh in 2017, with an average annual growth rate of 4.2 % [10].

![Figure 2. Final energy consumption in the building sector.](image)

As shown in Figure 2 thermal energy represented 59% of the total energy consumption, whereas electricity consumption 41% in the reference year 2012, values that changed rather insignificantly to 57% and 43% in 2017. Considering the qualitative features of energy consumption, following points should be taken into consideration [11, 12]:

- Gas, both natural gas but in particular liquefied petroleum gas (LPG) is used mostly for cooking and water heating. It does not greatly change seasonally, and does not scale with dwelling size as electricity consumption does. Natural Gas is more and more displacing LPG.
- Consumption of natural gas is nearly constant over a period of time, while that of electricity varies significantly. The greatest growth in power demand is on electricity to lighting, running new appliances, as well as for ventilation, air conditioning and heating.
- Although there are recent initiatives for using natural gas in cooling in commercial building, this technology has not yet become widespread in Egypt.
- LPG presents a substantial amount of energy consumption in the residential sector. Unlike natural gas and electricity, no meters are installed for measuring LPG consumption in households and the existing data are underestimating the total consumption.
2.2. A forecast

A statistical analysis of the Egyptian building stock was carried out, with respect to the energy efficiency of the residential and non-residential sector developments up to 2035. As reference year was considered 2015 and as mid-term horizon 2025. As there are rather few available data on the detailed breakdown of energy consumption, a model was developed within the TARES project in order to correlate energy consumption and estimate basic benchmarks per building type [13, 14]. For the calculation model, the Egyptian building stock was divided into three major categories that coincide with the typology the Egyptian Ministry of Planning and International Cooperation uses for the forecasts of the annual growth of the residential buildings.

The estimation of the numbers of buildings and the average energy consumption per building category was based on the available data of the Egyptian Electricity Holding Company (EEHC). According to CAPMAS 2015 data, 99.1% of the households and 98.6% of the population are connected to electric energy. Estimations were made correlating the number of households per power tariff category for 2015 and the average power and thermal energy consumption. Power consumption was estimated as the average monthly consumption of the tariff category whereas thermal energy consumption as a percentage of power consumption, according the correlation of the total power to thermal energy ratio. Taking into consideration the annual increase of the residential buildings rate and the rise of demand, the percentage of unoccupied buildings was re-estimated at 10%, thus concluding in the following Table, describing the overall energy consumption per building category.

| Buildings' Categorization | Average monthly energy consumption (kWh/month) | Specific annual energy consumption (kWh/m²/year) | Total annual energy cons. (GWh/year) |
|---------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------|
| 1 Housing units for low-income class | 86 | 21,83 | 3.633 |
| 2 Housing units for middle classes | 398 | 52,83 | 73.022 |
| 3 Housing units for upper middle and high classes | 1232 | 105,56 | 42.187 |
| Total | | | 118.842 |

Not surprisingly, 61.45% of the total energy consumption is used by middle classes housing units whereas the upper middle and high-income classes although 13% of the building stock (in terms of housing units) are responsible for 35.50% of the total energy use. The relative small percentage of energy use of the low classes housing sector (3.05%) combined to the very low specific energy consumption indicate that priority should be given to the refurbishment and energy upgrade mainly of the middle classes units and secondary to the upper middles and high ones. A target of an average refurbishment percentage of 10% of the existing building stock until 2025 is considered realistic and feasible [13].

The measures proposed, and the expected energy savings compared to the base case, are depicted in Table 2. They were chosen on the base of being technically possible, feasible and with a pay-back period that is less than one third of their expected life time. In all cases, developments in the technologies use were considered linear, without drastic changes, whilst the country’s energy mixture and the prevailing price policies were adopted from the IRENA and USEIA outlook reports [14, 15].

For the development and quantification of the targets and results of the Energy Efficiency Strategy in the Residential Sector the outlook considered two periods: the ongoing, short-term one, from 2014 to 2025, for which following assumptions were taken into consideration:
• Percentage of old buildings being renovated until 2025: 10%
• Annual demolition rate until 2025: 1%

Based on the data, a forecast was elaborated, predicting that the total energy consumption is due to increase by 11.08 % until year 2025 whereas the specific energy consumption in the residential buildings’ sector will decrease by 7.033 % due to the transformation of the building stock, with 21% representing new energy efficient residences, 7% refurbished housing units and 72% existing, non-refurbished buildings.

Table 2 Energy efficiency measures

| Energy use                  | Technology to be used                                                                 | Energy Saving Potential compared to present (%) |
|-----------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------|
| Lighting                    | Replacement of existing with efficient lamps (LED)                                   | 60                                            |
| Refrigerators               | Replacement of existing with efficient refrigerators (A++ class)                     | 20                                            |
| Washing Machines            | Replacement of existing with efficient refrigerators (A++ class)                     | 20                                            |
| Air Conditioning            | Replacement of existing with efficient refrigerators (A++ class)                     | 10                                            |
| Insulation of the envelope & double glazing | Retrospective thermal insulation, especially of the flat roofs. Use of cool materials |                                               |
| Use of Solar Water Heaters  | Introduction of solar water heaters                                                  | 100                                           |

For the development and quantification of the targets and results for the mid-term future, namely the period 2026 – 2035, following assumptions were taken into consideration:
• Percentage of old buildings being renovated until 2035: 12%
• Annual demolition rate until 2035: 1%

The annual growth of the residential building stock and the respective energy efficiency of the new and refurbished buildings were similar to the rates taken for the 2015 – 2025 period. According to the simulation the building stock in 2035 is due to consist of:
• New energy efficient buildings: 36%
• Refurbished energy efficient buildings: 12%
• Existing – old non-refurbished buildings: 52%

Hence, in the Business as Usual scenario, considered for the whole of the Energy Efficiency Strategy period 2015 – 2035, although the building stock is likely to increase by nearly 48% in terms of buildings units, the overall energy consumption for the building sector will increase by only 24.5 % (152.350 GWh), whereas the specific energy consumption will decrease by 12.08%.

One can consider an Optimistic Scenario, with alternative assumptions on the energy efficiency improvement rate of the new and refurbished buildings, namely Energy efficiency of new buildings improving by 20% - 40% and of refurbished buildings by 10% - 30% in comparison to the existing ones. In this optimistic case, the total energy demand would increase by nearly 10% until 2035, whereas the specific energy consumption will decrease significantly by 22.4%.

3. Developing a strategy
Energy trends in the buildings sector vary significantly from country to country depending on a number of factors ranging from climate, population, income, economic development and household sizes. Immediate priorities and future goals therefore need to reflect a country’s energy system’s features and also societal attitudes. There are many technology options and policy recommendations which are
applicable to all countries either immediately or in the future. The most suitable for the Egyptian climatic, economic, technical and social conditions should include:

3.1. Institutional capacities for planning, policy making, monitoring and evaluating
Experience has shown, that it is important to have an administrative unit that will be able to act as a focal point for all the activities including, but not limited to:
- Monitoring and keeping records of the current situation of the building stock.
- Utilization of all the statistical data available and implementation of an energy information system that will provide decision support analysis.
- Monitoring of the effectiveness of legislation, evaluation of the legislative and regulatory acts in power and proposal for new / revised ones.
- Elaboration of financing schemes and tools.
- Overview of training and certification processes.
- Elaboration and implementation of specific programs and/or action plans, which may include energy audits, demonstration projects, information campaigns etc.
- Maintaining contacts and networking with energy efficiency agencies and bodies all around the world.

3.2. Selection of best available technologies
It is necessary to select the most suitable, best available technologies, amongst those available on the global market, taking into consideration the potential for energy efficiency and the ways in which it can be utilized, as those are determined by the climatic conditions of Egypt, the patterns and preferences of the construction sector, the way in which cost-effectiveness is appreciated by the market and the behavioural aspects of the final consumers, as the acceptance of technologies is in some aspects subject to non-technical factors [15].

The major groups of technologies that fulfill those criteria can be summarized as follows:
a) Advanced envelope technologies to reduce the cooling loads and the small heating loads that occur. This can be achieved primarily by:
- Using cool materials on the buildings’ roofs and facades.
- Introducing sun-protection devices
- Using high energy efficiency, low emissivity glazing in windows and glass-facades
- Utilizing night time ventilation and the thermal storage capacity of the buildings’ envelopes
- Providing thermal insulation on the building envelopes’ opaque elements, in particular of the roof.

Thermal insulation materials, energy efficient glazings and facades, cool paints and cladding materials, in general hence the envelope of the buildings, are the most important contributors and also the most cost effective way to achieve a reduction of the energy demand. This approach has to some extent already been adopted by the Egyptian regulation in an effective way, as thermal insulation is mandatory since 2005. It should therefore be implemented in a consequent way in practice [16].

Improvement of the thermal properties of building materials, and of its utilization, has a strong impact in the energy demand of the buildings, as this has been achieved by adding coatings, by utilizing nanotechnologies, etc. Furthermore, new or adapted products and techniques are available, and can be utilized by the local industry, in order to increase energy efficiency of transparent and opaque building materials, which is of particular importance for the high solar radiation values in Egypt.

In order to use the best suitable technologies in an optimum way, the gap between theory and practice needs to be filled, by means of applied research on the one hand and of training the other. The architects and engineers need to get acquainted to new modeling and simulation approaches, as those are necessary for considering the overall energy behaviour of the envelope, both in new designs and in refurbishments.
b) Using high efficiency air-conditioning systems, in line with the tighter requirements foreseen by international standards, both for room air-conditioners (split and window units), VRVs and central units. The adoption and implementation of EU Regulations 626/2011 and 206/2012, on the Ecodesign and energy labelling of Air Conditioners and comfort fans, can provide the framework for gradually improving the efficiency of the equipment.

Given the nature and the breakdown of energy consumption in residential and non-residential buildings, this is perhaps the most cost-effective measure that can be implemented, as air-conditioning presents the most important single energy consumption factor. Furthermore, it is an issue that affects both new and existing buildings and can therefore be an ideal measure also for improving the performance of existing buildings, especially if a tailor-made incentive for the replacement of the old, existing A/C units (especially the window-type ones) can be provided.

Using high efficiency motors for circulator pumps, but also for ventilation systems, elevators, escalators etc.

c) Fostering the use of solar water heaters.

d) Introducing Building Automation and Control systems for establishing effective energy management

Apart from current state of art Building Automation and Control systems (as described by EN 15232) new methods and procedures can be utilized to integrate ICT tools (e.g. low-cost monitoring systems, building information models, embedded wireless devices, new user interfaces, new processing algorithms, etc.) into building projects, to achieve energy efficiency, productivity and security. Web based control platforms that allow the remote monitoring and control of a building’s energy systems provide an excellent tool for effective energy management of big, complex buildings (like governmental and private office buildings, hospitals etc.) or of many, similar buildings run by one authority (like schools).

As the increasing complexity of buildings makes it necessary to have real-time access and monitoring of the building’s performance, these tools will also help to support new models for performance-based service contracts, like those provided by Energy Service Companies.

e) Promoting integrated renewable energy systems

- Geothermal energy for cooling
- Building integrated photovoltaics
- High efficiency biomass systems

f) Promoting Combined Heat and Power systems

g) Promoting high efficiency household appliances

h) Promoting high efficiency office equipment

3.3. Reinforcement of the national expertise in energy efficiency

The successful implementation of any of the aforementioned technologies presupposes the vocational training and the continuous education of the engineers, technical and managerial staff, so as to build up capacities on an adequate level of expertise. This includes amongst other:

- Training energy auditors for buildings, also in conjunction with training to energy managers – on the base of the ISO 50001. A critical issue to be considered is that, as the experience shows, developing audits and disseminating information is not sufficient, if there is no proper energy management system, which will allow taking advantage of the results.

- Training of national auditors, which goes along with the creation of a certification scheme for the auditors.

- Continual training of professionals, designers, installers, maintenance on state of the art technologies.

- On the long term, developing specific courses in the syllabi of the Schools of Engineering. As experience in Europe showed, a continuous assessment is needed, followed by a revision and/or
adaptation of the courses’ syllabi, so that they mirror the truly interdisciplinary nature of the energy design of buildings’ scientific field. Such a syllabus may include amongst other elements of: Architectural design, Building construction, Thermodynamics, Heating, Ventilation, Air-Conditioning, Automation and control, Investment appraisals and financing etc. In order to achieve this, the training of future engineers and architects has to become as interdisciplinary as possible, considering traditional elements of architectural design (for the engineers) and thermodynamics (for architects), but also more fields like materials’ science (nanotechnologies), production management (lean production techniques) and logistics to improve the efficiency and cost effectiveness of systems for everyone.

3.4. Incentives and financial tools

It is more than evident, that incentives are needed to promote EE in buildings. Providing incentives, especially in terms of economic and financial support, is one amongst many tools to achieve this, probably the most effective at least on a short term. Those incentives can be provided to three beneficiary groups (in reality stakeholders), namely (a) the final consumers, (b) the developers and/or constructors and (c) the manufacturers of building materials and systems.

Developing viable incentives is an exercise based on the balance between making the promoted technology feasible, and ideally attractive, to the investor/consumer, whilst at the same time cost of this measure is paying dividends, or at least is not burdening, the financing body, which is a rule the government. Designing therefore an incentives’ framework for the promotion of EE in Egypt presupposes a clear set of goals, a quantification of the expected costs and a safe estimate of the expected benefits both for the state and the recipient of the incentive, in our case the final consumer.

It is clear that this is a task that has to be undertaken in co-ordination of the policy-makers and the stakeholders, as part of dedicated work-plan.

4. Conclusions

It is fairly clear, that the aim of improving the energy performance of the Egyptian building stock, is much more complicated than being solely a technical one: Designing and constructing high energy efficiency buildings, and ensuring their efficiency and durability over time, is not easy; it calls for meticulous design, careful construction and appropriate maintenance. The economics of such buildings are, when considered as investments, also complicated: They depend on their cost –and on the incremental cost they represent- with respect to the purchasing power of the final consumer, but also to the cost of energy conserved.

As long as energy prices are not mirroring the real cost of energy for the user, little can be done to visualize the problem and to convince on the feasibility of energy efficiency. In the residential sector the problem is even manifold, as it is not only an issue of low energy prices, but also of low energy demand for the typical low and middle-income Egyptian household, whilst for the high-income household the problem is not a matter of energy costs anyway. It is therefore only to reasonable to design and promote a long term strategy, based on the assumption that retail energy prices will be significantly higher than they currently are.
Delivering more energy efficient buildings is a complex problem in more ways than one: It calls for reasonable capital cost rates for the investor and on the existence of specific financing tools. The banking system has to provide the capital needed; as a rule it is reluctant to do so for energy saving measures, as they pay no direct dividend. The developers, have to face the aforementioned principal agent problem, but also the prospective owners’ and users’ unwillingness to accept novel technologies. The authorities supervising the building sector, are asked to supervise the implementation of new, more demanding regulations and codes. Finally, the building industry, that has to provide improved materials and to train the personnel in using those appropriately. This complex interdependence is depicted in Figure 3.

Eventually, one cannot neglect the socio-economic parameter: The changes in the energy market may affect the living standards of a good part of Egypt’s population. Achieving energy efficiency in the building sector is the most effective way to offset this.

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