Energy efficiency in high performance buildings related strategies and techniques

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Conforming to local trend towards energy consumption, this paper is an attempt to identity the different strategies and technologies related to energy efficiency in buildings. The paper consists of four main parts. The first part is an introduction to what is called “high performance buildings” and their characteristics. This part also gives brief to local awareness towards Energy Efficiency. The second part defines energy efficient & zero energy buildings and discuses the best way to establish a kind of “score” or rating system for energy efficiency in buildings. The third part reviews strategies of energy efficiency and related techniques focusing on the three main strategies and related technologies that can be applied to buildings to achieve energy efficiency and high performance (passive cooling and heating, passive renewable energy, and passive day lighting). This part also demonstrates through examples the main contemporary techniques used in high performance buildings to achieve energy efficiency (trombe walls, solar walls, building-integrated photovoltaics (PV) panels, integrated wind turbines, sidelighting and toplighting, core daylighting, and hybrid lighting system). Finally, in the forth part conclusions are formulated focusing on the most efficient solution to energy efficiency in buildings.

الكفاءة في استهلاك الطاقة من الأمور التي حازت اهتماما على المستوى الدولي والمحلي. وهذا البحث هو محاولة للتعرف على الإستراتيجيات والتقنيات المتعلقة بالكفاءة في استهلاك الطاقة بالمباني. ويتكون البحث من أربعة أجزاء ، الجزء الأول تعريف بخصائص المباني ذات الأداء العالي وهو توجه معاصر من أهم أهدافه تحقيق الكفاءة في استهلاك الطاقة. كما يتناول هذا الجزء السياسات والتوجهات المحلية نحو تطبيق وسائل استغلال الطاقة المتجددة في كافة المجالات ومنها قطاع التشييد والبناء. الجزء الثاني من البحث يعرف مفهوم الكفاءة في استهلاك الطاقة بالمباني كما يناقش وسائل تقييم أداء المباني من منطلق استهلاكها للطاقة. الجزء الثالث يستعرض الإستراتيجيات المختلفة للتبريد والتدفئة والإضاءة بالمباني اعتمادا على الطاقة المتجددة. كما يوضح هذا الجزء من خلال أمثلة التقنيات المختلفة التي منها ما هو تطوير لتطبيقات في مباني تاريخية ومنها ما هو مستحدث. ومن هذه التقنيات الحوائط الحرارية، الخلايا الكهروضوئية المندمجة بالمباني، توربينات توليد الطاقة من الرياح المندمجة بالمباني وتقنيات الإضاءة الطبيعية المختلفة. الجزء الأخير هو استنتاج لافضل الوسائل التقنية التي تحقق الأداء العالي والكفاءة في استهلاك الطاقة بالمباني.

Keywords: High performance buildings, Energy efficiency, Zero energy buildings, Renewable energy, Integrated photovoltaics

1. Introduction

1.1. High performance buildings

Buildings bring a wealth of social and economic benefits to our communities. Yet in evaluating these benefits, one of the main goals is to assess how our buildings directly and indirectly contribute to environmental and human health problems. In Egypt, not so many designers or people involved in the building industry fully consider or realize the extent to which building construction and operation generates material waste and results in energy inefficiencies and pollution. The environment and the society absorb these so-called ‘externalized costs’. Every day, buildings misuse valuable capital by wasting energy, water, natural resources, and human labor. Most of this waste happens incidentally, as a result of following accustomed practices.

Today’s design decisions have local, regional, and global outcomes. According to the Worldwatch Institute, almost 40% of the 7.5 billion tons of raw materials annually extracted from the earth are transformed into the concrete, steel, glass, rubber, and other elements of our built environment. Buildings consume about 40% of the world's energy production. As a result, buildings are involved in producing about 40% of the sulfur dioxide and nitrogen oxides that cause acid rain and contribute to smog formation. Building energy use also produces 33% of all annual carbon dioxide emissions, significantly contributing to the climate changes brought about by the accumulation of this heat-trapping gas [1].

International awareness of the impact of the building industry on the environment has led to adopt cost-effective new technologies, processes, and materials that dramatically reduce environmental impacts while increasing profitability in what is called "High performance buildings". Demonstrating that high-performance buildings make economic sense is crucial for broader local market acceptance. However, to verify the economic benefit of high-performance buildings, there must be a standard method for comparing building energy performance. This information can support the financial arguments required for creating mainstream high-performance commercial buildings. The real value of high performance buildings can be easily be depreciated by traditional accounting methods that do not recognize 'external' local and regional costs and benefits. High performances building cost evaluations address the economic, social, and environmental benefits. Those benefits are obtained in the following four main features of "High performance buildings" fig. 1:

- Energy efficiency/clean energy resources
- Source reduction, pollution prevention and recycling
- Building operations resource management
- Improved Indoor Environment

This paper focuses on the main feature of High Performance Buildings, which is Energy efficiency. In fact measuring building energy performance in a compatible and strict manner will lead to more acceptable comparisons of current practice versus high-performance buildings.

1.2. Local awareness towards energy efficiency

Conforming with international awareness towards Energy Efficiency, Egyptian energy policies have been developed, and included two main aspects:

- Energy conservation and more efficient energy use.
- Promotion of renewable energy utilization.

Energy efficiency is an important strategy that has been adopted and promoted throughout the Egyptian Economy. Several organizations in Egypt are currently conducting energy conservation programs in different sectors of the economy. Having determined the critical energy situation in Egypt, the high level of energy consumption and the limited energy resources, it is important to conserve energy in the various economic sectors. This is an essential part of the integrated energy planning process and policies that the government considered.

The Organization for Energy Planning (OEP) and other concerned agencies that tackle the problem of inefficient energy use in Egypt have moved aggressively in all areas of energy conservation. One of the most important energy conservation activities that have been considered as first priority by various agencies in Egypt is the Industrial Energy Conservation Program. The objective of this program is to plan and implement energy conservation measures in the various economic sectors in Egypt, in order to achieve measurable energy savings at reasonable cost.

In addition to its limited commercial energy resources, Egypt has also good potential renewable resources. Due to its geographic location, Egypt enjoys sunshine all year around. Direct solar intensity ranges between 260 and 710 cal/cm2 [3]. Egyptian Government has launched a program to apply new and renewable energy technologies. A New and Renewable Energy Authority (NREA) was established in 1986. NREA's objectives are to introduce renewable energy technologies to Egypt on a commercial scale. The Egyptian Renewable Energy Development Organization (EREDO) was established in 1992 by mutual financing from Egypt and European Communities; covering renewable energy technologies, testing and endorsing certificates of components [3].

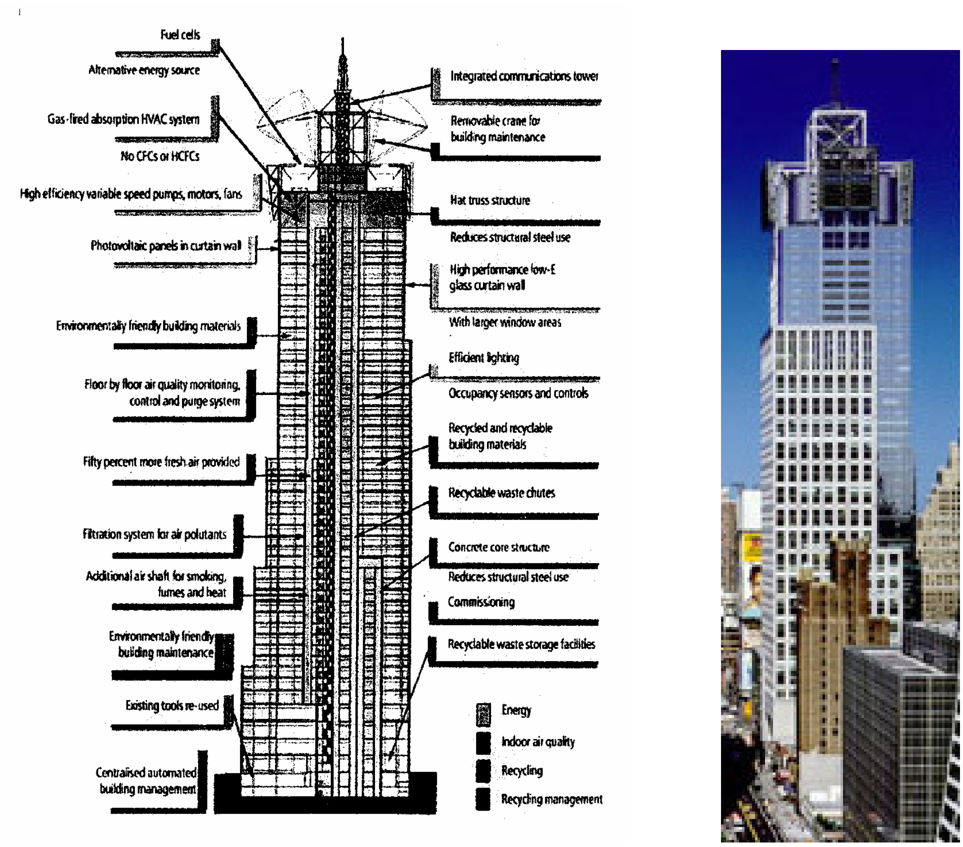

Fig. 1. Four Times Square is an infill high-rise development in the heart of Manhattan [2]. It is the first project of its size to adopt state-of-the-art standards for energy conservation, indoor air quality, recycling systems, and the use of sustainable manufacturing processes which are the main features of High Performance Buildings [2]

In addition, the Support For National Action Plan (snap) study on Greenhouse Gas (Ghg) mitigation and adaptation technology assessment identified a set of seven energy efficiency technologies that have been used in Egypt. The set included the following technologies [3]:

- Fuel Substitution of oil with natural gas in the industrial sector,
- Combined heat and power production, co-generation,
- Combustion control,
- Waste heat recovery,
- Efficient lighting systems,
- Use of renewable energy in electricity production, and
- Steam condensate recovery.

This set has been thoroughly evaluated in terms of costs, effectiveness and socioeconomic impact. Based on the base line scenario for energy and CO2 emissions, the study tried to identify and assess a number of measures /technology for mitigating CO2 emissions. These selected measures and technologies were classified into the following scenarios (fig. 2) [3]:

- Fuel Substitution Scenario (FSS)
- Use of Renewable Energy in electricity production Scenario (RES), and
- Energy Efficiency Scenario, (EES).

In the residential and commercial sector buildings are responsible for about 50 percent

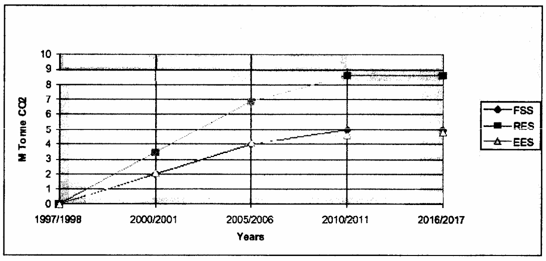

Fig. 2. Expected CO2 reduction in Egypt for the three Scenarios [3].

of total energy used in a country, and the transport needed to get to these buildings and the provision of supplies to them from rural areas account for another half of the remaining energy consumption [4]. Therefore, research projects for energy efficient buildings and buildings that use renewable energy technologies are one of the main areas of research which were identified in the Egyptian climate change action plan.

2. Energy efficiency

2.1. Definition of energy efficient & zero energy buildings

Recently, the concept of Zero Energy Buildings (ZEB) has been promoted. On the face of it, the ZEB would appear to mean:
A building that relied entirely upon energy captured on site to provide all the desired amenities.

But, the United States Department of Energy (DOE) offered the following definition: Cost-effective buildings that have zero net annual need for non-renewable energy.
Later, in the face of various political (and practical needs) the DOE revised the definition to: Any building that demonstrates significant integration and optimization of both energy efficiency and site power generation [5].

Hence, one can consider efficient buildings those that reduce energy use and demand through passive solar techniques and integrated building design. This process looks at optimum siting/orientation and maximizes the thermal efficiency of the building envelope (windows, walls, roof) while considering the interaction of the HVAC, lighting, and control systems. Integrated design uses daylight to reduce electrical demand, and incorporates energy efficient lighting, motors, and equipment. It encourages 'right-sizing' of mechanical systems to avoid higher first costs. Where feasible, renewable energy sources such as photovoltaic cells, solar hot water, and geothermal exchange are used in tandem with other low-emission technologies, such as fuel cells. Consequently, improving building science will strengthen the case for high-performance buildings nationwide and aid in the transformation towards zero energy buildings.

2.2. Rating system for energy efficiency

To establish a kind of "score" or rating system for energy efficiency in buildings a simple performance indicator is a building's total annual energy use divided by its floor area. These values are widely known and are appropriate for comparisons of similar buildings (such as schools in the same city). However, it is easy to confuse a low-energy building with an energy-efficient building (and a high-energy building with an inefficient building). A low-energy building is not efficient if the low energy use is achieved by providing reduced amenities, such as lower ventilation rates, uncomfortable inside temperatures, or shorter occupancy schedules. At the other end, a building with a high-energy consumption is not necessarily inefficient if it is operating 24 hours per day or contains unusual, energy-intensive, activity [6].

Standard methods for measuring energy performance will help indicate when a building is not performing as expected. Metrics is required to characterize building energy performance. The benefits of such metrics are summarized as follows:

- Increasing building energy performance by providing improved measurement tools.

Strengthening the arguments for constructing and operating high-performance buildings by helping to demonstrate that these buildings usually have lower life-cycle costs than conventional buildings.

Establishing energy metrics for high-performance commercial buildings can be achieved by completing three primary activities:

- Determine what to measure in buildings. This activity involves determining specifically what aspects of energy performance should be measured, such as the details of energy consumption, environmental impacts, and economic factors. For example, should the asset value of making a building more energy efficient be included? Should life-cycle costs of resource consumption (e.g., the extracting and burning of fossil fuels to produce electricity for buildings) be included when measuring a building's energy use? What returns will developers and communities realize by investing in high-performance buildings?
- Determine how to measure the aspects of energy performance defined in the first step. Replicable procedures must be developed for gathering, retrieving, organizing, and storing these data [7].
- Determine how to apply the metrics by establishing methods for evaluating total life-cycle costs and other benefits of high-performance building investments, particularly related to energy performance, to be used by owners, occupants, and communities.

3. Strategies of energy efficiency and related techniques

Three main strategies can be applied to buildings to achieve energy efficiency and high performance:

- Passive cooling and heating
- Passive renewable energy
- Passive day lighting

Passive solar design is the technology of heating, cooling, and lighting a building naturally with sunlight rather than with mechanical systems. Basic design principles are large south-facing windows with proper overhangs, as well as tile, brick, or other thermal mass material used in flooring or walls to store the sun's heat during the day and release it back into the building at night or when the temperature drops. Passive solar also takes advantage of energy efficient materials, improved insulation, airtight construction, natural landscaping, and proper building orientation to take advantage of the sun, shade, and wind. Passive solar designs can also include natural ventilation for cooling. Related Technologies include trombe walls, evaporative cooling towers, photovoltaic cells, and daylighting technologies.

It is worth mentioning that several high performance characteristics are found in many historic buildings. Historic buildings often demonstrate integrated design by achieving satisfaction with an economy of means and without reliance on sophisticated mechanical and electrical systems. They have thermally efficient masonry walls, large built-in ventilation shafts, and courtyards. These features control temperature, maximize daylighting, and encourage cross-ventilation.

3.1. Passive cooling and heating techniques

3.1.1. Trombe walls

Since ancient times, people have used thick walls of brick or stone to trap the sun's heat during the day and release it at night. Today's this ancient technique is being improved by incorporating a thermal storage and delivery system called a Trombe wall. Named after French inventor Felix Trombe in the late 1950s [8], the Trombe wall continues to serve as an effective feature of passive solar design.

A typical Trombe wall consists of a 20- to 40-cm-thick masonry wall coated with a dark, heat absorbing material and faced with a single or double layer of glass. The glass is placed 5 cm from the masonry wall to create a small airspace. Heat from sunlight passing through the glass is absorbed by the dark surface, stored in the wall, and conducted slowly inward through the masonry.

Applying a selective surface to a Trombe wall improves its performance by reducing the amount of infrared energy radiated back through the glass. The selective surface consists of a sheet of metal foil glued to the outside surface of the wall. It absorbs almost all the radiation in the visible portion of the solar spectrum and emits very little in the infrared range. High absorbency turns the light into heat at the wall's surface, and low emittance prevents the heat from radiating back towards the glass. Although not as effective as a selective surface, painting the wall with black, absorptive paint will also help the wall to absorb the sun's heat [8].

For a 20 cm-thick Trombe wall, heat will take about 8 to 10 hours to reach the interior of the building (heat travels through a concrete wall at rate of about 2.5 cm per hour)[8]. This means that rooms remain comfortable through the day and receive slow, even heating for many hours after the sunsets, greatly reducing the need for conventional heating. Rooms heated by a Trombe wall often feel more comfortable than those heated by forced-air furnaces because of the radiantly warm surface of the wall, even at lower air temperatures.

Properly sized overhangs shade the Trombe wall during the summer when the sun is high in the sky. Shading the Trombe wall prevents the wall from getting hot during the time of the year when heating is not needed.

The Dan Schaefer Federal Building, or Visitors Center, located in Golden, Colorado, has an innovative Trombe wall —the building's most striking architectural feature —lights and heats the exhibit hall. The south-facing wall has five sections; each angled in a "V" shape. Windows on the southeast side of the "V" provide natural daylighting and early morning heat. Facing south and southwest are thick concrete walls coated with black paint and faced with glass. A small airspace separates the wall from the glass. Direct solar radiation is absorbed by the wall, trapped by the glass, and conducted inward to gradually heat the exhibit hall later in the day. Horizontal beams on the Trombe wall were engineered to shade the wall during summer when the sun is high in the sky. During winter the beams, allowing heat to penetrate into the Trombe wall do not block the sun (fig. 3).

The technique of trombe walls was applied in Egypt since the eighties of the twenties century. However it was not wide spread in Egypt's new towns in spite of its' correspondence to hot arid zones and its numerous objectives in passive heating and cooling systems (fig. 4).

3.1.2. Solar walls

Unlike trombe walls, solar walls (fig. 5), which are transpired air collector systems for space heating, require no expensive glazing with associated energy loss to reflection. Transpired air collector systems essentially consist of a dark-colored, perforated façade installed on a building's south-facing wall. An added fan system draws ventilation air into the building through the perforated absorber plate on the façade and up the plenum (the air space between the absorber and the south wall). Solar energy absorbed by the dark absorber and transferred to the air flowing through it can preheat the intake air by as much as 22°C [10].

3.1.3. Downdraft evaporative cooling

Passive Downdraft Evaporative Cooling (PDEC) is a technique that has been used for many centuries in Islamic architecture. In this tradition, wind-catchers guide outside air over water-filled porous pots, causing evaporation and bringing about a remarkable drop in temperature before the air enters the interior. Contemporary natural downdraft evaporative coolers are towers-like devices supplied with wetted pads and sprays at the top, which provide cool air by gravity flow. In arid regions, these devices can be used for cooling residential and commercial buildings, as well as outdoors private and public areas.

These towers are often described as reverse chimneys; just as the column of warm air in a chimney rises, the column of cool air, in this instance, falls. The air flow rate depends on the efficiency of the evaporative cooling device, tower height and cross section, as well as the resistance to air flow in the cooling device, tower and structure into which it discharges [11].

More recent applications for such technique achieved lower capital, energy and maintenance costs when compared with mechanical systems for cooling. On the other hand, the use of PDEC needs a transitional space required to promote the distribution of cool air within the building. A high performance example of such PDEC is the design proposed by Mario Cucinella Architects for the new office in Italy (fig. 6). The Design evolved from a building with a large atrium at its core to a design with a 'distributed' approach to PDEC. The extensive application of passive cooling, in opposition to current mechanical systems, involved a low energy strategy. This meant that the small quantities of energy that the building could produce 'passively' must be fully exploited and concentrated where cooling is needed without any dispersion.

A building with a central atrium acting as a fresh air reservoir requires energy to cool the big volume of air and to distribute it into each floor. This energy is in most cases too high to be fully 'passive'. For this reason Mario Cucinella Architects decided first to reduce the size of the atrium, and second to define a shape that could better respond to downdraft distribution.

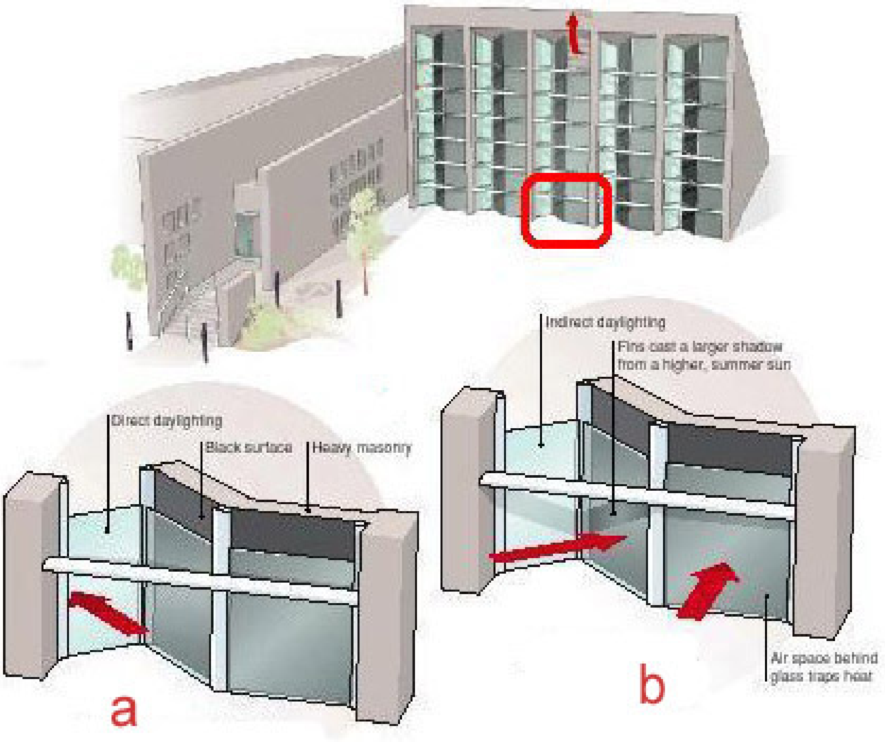

Fig. 3. Innovative Trombe wall in Visitors Center, Located in Golden, Colorado. (a) Morning sun pours in window providing natural light. (b) Afternoon sun warms Trombe Wall, storing heat for release in evening [8].

Fig. 4. Maxi project: a private residence in South Tahrir designed by Samir Bayoumi ,1987. Cross-ventilation, wind tunnels humidifying the air, Trombe walls and the planted patio constitute the main passive cooling systems, while direct and indirect heat gain through glazed windows and Trombe walls are used for passive heating [9].

The main idea was to create a number of PDEC towers that passed through the building vertically. Each tower cooled the air in the adjacent area when needed. The towers were also used for night ventilation and to bring daylight into a deep plan space [12].

This approach is energy efficient for the following reasons:

- The possibility of different cool areas of the building responding to demand.
- The possibility of distributing natural lighting and therefore increasing the floor depth without reducing visual comfort.

3.2. Passive renewable energy techniques

3.2.1. Building-integrated photovoltaics panels

PhotoVoltaic (PV) cells are direct means to transform sunlight into electricity. The evolution of photovoltaic system technology started with applications of solar cells in space. Functional considerations, and in particular efficiency, dictated research and development. Medium- to large-scale ground-mounted systems were intended to compete with conventional electricity generation. PV cells were either circular or rectangular, blue (polycrystalline cells) or black (monocrystalline cells) and they were assembled into PV modules in rectangular-shaped aluminum or stainless-steel frames, leaving almost no scope for aesthetic considerations to be taken into account [13].

When building integration of photovoltaics started in the 1980s a conflict arose between scientists and engineers, who were aiming at maximizing the energy output, and architects, who were concerned about a building's aesthetics. However, in the 1990s, when PV was gaining greater acceptance, the aesthetic limitations of PV technology were identified as one of the major obstacles to general acceptance by architects and the public. Since this problem has been identified, significant attempts have been made to improve the aesthetics of photovoltaic systems [13].

Although the costs of PV energy generation have become significantly lower in recent years, PV is still considered to be an (economically) expensive method of electricity production [14].

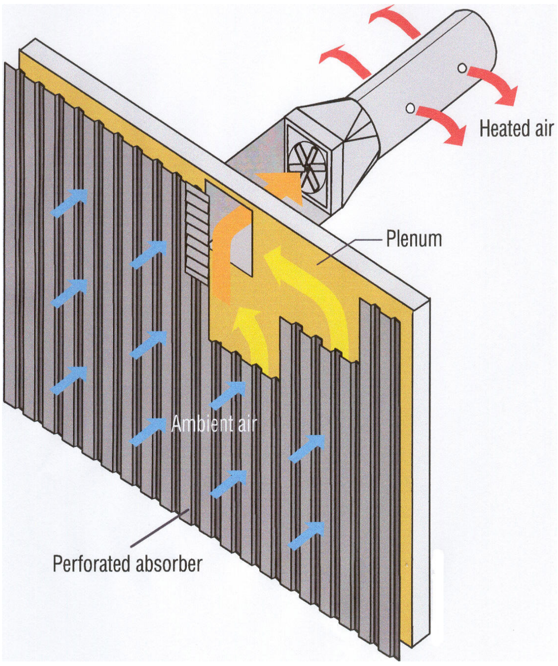

Fig. 5. Transpired air collectors preheat building ventilation air by using the building's ventilation fan to draw fresh air through the system. The intake air is heated as it passes through the perforated absorber plate and up the plenum between the absorber and the south wall of the building [10].

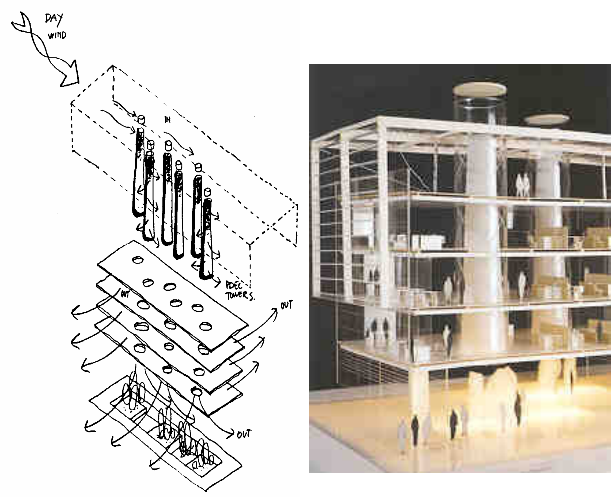

Fig. 6. The new office Building in Catania, Italy by Mario Cucinella Architects: Passive Cooling and downdraft ventilation for energy efficiency [12].

A solution to this problem is to replace convention elements of the building envelope (roof tiles, roof cladding, facade elements, windows, shading devices etc.) with PV modules. This replacement leads to a dual function at the PV system: as a building element and in electricity generation. If the costs of the conventional building element are deducted from the overall PV system costs, the specific costs of electricity generation (in /kWh) can be significantly reduced. However, before making the decision to utilize photovoltaic panels, rather than stone or any other conventional materials, the following considerations are essential:

- The orientation of the structure,
- Possible shadow effects,
- The correct inclination of the panels,
- The sum of available surface, and
- The amount of electrical energy that needs to be generated

Researches on integrated PV panels are being carried out all over the world to enhance efficiency and appearance and to reduce initial cost. NREL's Solar Energy Research Facility (SERF) is a state-of-the-art research facility used to develop technologies for converting sunlight into electricity (fig. 7). Completed in October 1993, SERF houses includes 42 laboratories that conduct research on photovoltaic (PV) technology or solar-electricity, superconductivity, and related material sciences. It was designed and constructed to meet or exceed all applicable environmental, safety, and health codes and standards for the three adjoining modules. Each module has two pods: a laboratory pod in the back and an office pod in the front. SERF's annual energy costs are 40% lower than a similar building designed to meet energy standards. Ten photovoltaic panels have been installed on top of SERF's east and west office pods to study the performance of integrated PV systems on commercial buildings. The panels generate as much as 12 kilowatts of electricity that is fed into the power grid [8].

An example of Integrated PV panels in residential buildings is the Energy Efficient and Zero-Energy project In the Netherlands. The project in the city of Harderwijk consists of 31 houses (fig. 8). The houses are divided in one row of one-family terrace houses and two rows of houses for the elderly (so called senior houses). The senior houses have the living, kitchen, bed- and bathroom on the ground floor and a spare room on the first floor.

The energy use of the houses has to be 60% below the 'reference' use of energy at that time, which is now 40% below the standard of the government. To achieve the low energy consumption, the houses have a very high isolation standard and very low U-values of windows. The houses also have a heat recovery system. To reduce energy loss the (hot) water-supply lines and the heating lines are as short as possible. Integrated in the roof of each house are a solar collector for domestic hot water, and a foursquare meter photo voltaic-system [15].

The advantages of solar PV modules and solar thermal technologies are obvious. First, PV modules require no moving parts, and they can be conveniently used for any electrically powered end use. In addition, climatic conditions in Egypt encourages the application of PVs, Egypt enjoys a high solar radiation intensity of 1.900-2.600kWh/ m2/ year. Further intensity up to about 2.400 kWh/m2/year is observed when moving from the sea towards the desert [3].

Unfortunately, these advantages come with a penalty in terms of overall efficiency. For example, commercial PV modules typically have a total conversion efficiency of <15%, and only a small portion of the visible light into electricity. Further, losses attributed to electric power transmission/ distribution (approx. 8%) and dc-ac power conversion (10-15%) further reduce the overall effectiveness of conventional solar technologies [16]. Because of these and other reasons, conventional solar technologies have not displaced significant quantities of non-renewable energy and a great deal of work is needed to persuade firms and people to adopt photovoltaic technology, a problem that Egypt shares with the rest of the world.

3.2.2. Integrated wind turbines

Natural ventilation which is often achieved through the use of wind scoops or various designs of wind-tower which are mainly, extractor devices using a low pressure effect from the wind, having a major limitation that they cannot generate a driving pressure much

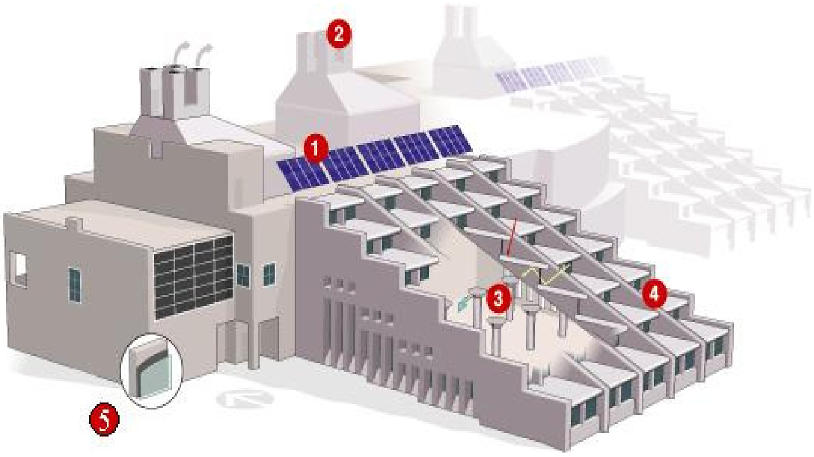

Fig. 7. NREL's Solar Energy Research Facility (SERF) [8]
1. PV panels 2. cooling towers 3. ventilation tower 4. low-e window 5. Trombe wall.

Fig. 8. Energy efficient and zero-energy building in the netherlands, to reduce energy loss the (hot) water-supply lines and the heating lines are as short as possible. Integrated in the roof of each house are a solar collector for domestic hot water, and a foursquare meters photo voltaic-system [15].

more than the dynamic head of the wind. Therefore wind turbines offer a means of enhancing natural ventilation by capturing power at low density over a relatively large area and concentrating it to provide higher power over the smaller area of a typical ventilation inlet or exhaust. Energy capture is enhanced when turbines can be sited in a “gap” between tall building blocks [17].

Key findings of energy studies concerning integrated wind turbines showed that:

- Optimum performance is obtained for smooth, rounded, fully 3-D building forms,
- Towers with ‘Kidney’ or ‘Boomerang’ footprints produce the best wind enhancement (fig. 9) [18].

Examples of integration in the urban environment, closer to prime consumers of energy such as buildings, remain scarce. Successful integration will require developers to fully address the concerns of planners, pressure groups and the public as to the necessity and environmental impacts of such schemes. Turbines should (be sized to) produce a significant proportion of the annual electricity demand of the building in which they are housed or of neighbouring buildings. Three generic integration techniques are available in the urban environment:

- Full integration, such that the wind turbines (WTs) drive the architectural form,

- Retrofitting wind turbines onto existing buildings, and
- Siting (landscaping) stand-alone wind turbines in urban locations [18].

In Egypt one of the energy supply mitigation Actions is to promote renewable energy in electricity generation using wind and solar energy: These renewable energy sources may be either used directly, or to complement traditional electric energy production. In that regard, it is possible to increase the dependence on PV systems. However, the application of wind turbines in Egypt sited on a building can only make a small contribution to its energy requirements because of the limited wind conditions and its' speed on major cities all over the year.

On the contrary, stand alone wind turbines have good potentials in Egypt. Egypt's Climate is characterized by particularly good wind regimes with excellent sites along the Red Sea and Mediterranean coasts. Sites with an annual average of 8.0-10.0m/sec have been identified along the Red Sea coast and about 6.0-6.5m/sec along the Mediterranean coast [3]. Today a wind farm of 6 MW is operative on the Red Sea Coast. In the power sector, a prominent role was given to renewable energy resources particularly wind energy, where more than 16 TWh need to be produced by the year 2020 [3].

3.3. Passive day lighting

Although artificial light has given architects new opportunities to define their forms, architecture had evolved for thousands of years in response to the contribution of light from the sun. During the summer or in consistently warm climates, day lighting can increase the cooling load on one hand and can reduce the energy consumption of a building substantially on the other hand; heat comes directly from daylight and Indirectly from electric lights posing impact on cooling

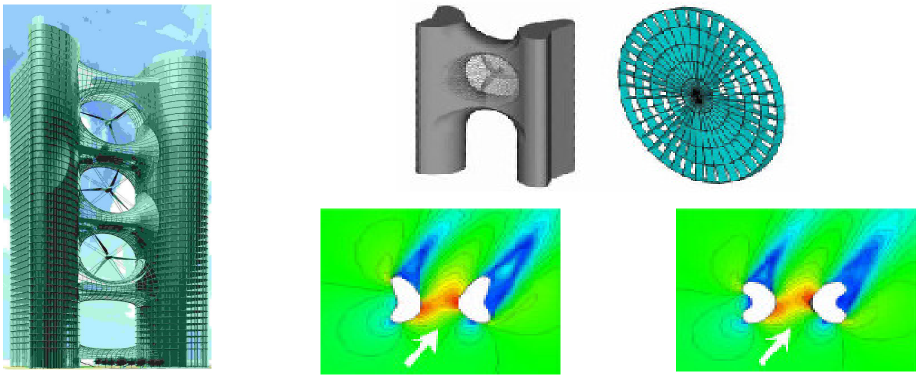

Fig. 9. (Left) Architects at the University of Stuttgart have created a prototype design for a two-tower 200-metre tall building with three integrated turbines. Each turbine would need to be 30 metres in diameter to generate a minimum of 20 percent of the energy needed by a building of this size. (Upper right) illustration of the design and deployment of a prototype Urban Wind Energy Conversion Systems' (UWECS) safety device (Lower right) Wind enhancement for boomerang‘ and ‚kidney‘ twin towers [18].

Fig. 10. Passive light-shelf (left) and light- pipe (right) designs can introduce adequate ambient daylight for office tasks in a 4.6 m to 9.1 m zone of a deep perimeter space [20].

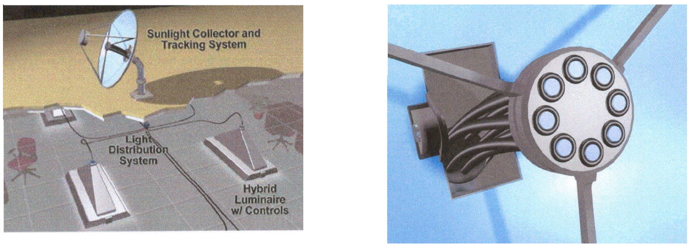

Fig. 11. An overview of the Hybrid Lighting System with collector, light guides and luminairs (left). A close-up of the eight fiber ends (SOE) placed in the center of the collector dish (right) [21].

equipment. Apparently, as a rule of thumb, each unit of electric light contributes to an additional 1/2 unit of electricity for space conditioning [19]. Therefore, daylight, which is a free source of illumination, can be used to complement electric illumination. In high performance lighting systems photocells that determine the ambient light level are placed in buildings. Information gathered is then relayed to a control device that adjusts the luminaire output to keep the desired illumination level constant.

The amount of energy savings that can be realized through daylighting is affected by factors such as:

- Building shape,
- Building orientation,
- Building materials used ,
- The orientation of work areas in relation to windows, and
- The use of window coverings such as drapes, shades and blinds .

Tranditional daylight designs can provide adequate daylight within about 4.6 metres of the conventional-height window [4]. The use of larger windows and higher transmittance glazings to provide sufficient levels of daylight at distances further from the window has proven to be ineffective [4]. Daylight levels increase asymptotically with distance from the window, so that a disproportionate amount of daylight/solar radiation must be introduced into the front of the room to achieve small gains in daylight levels at the back of the room.

There are a number of experimental perimeter daylighting systems that passively redirect beam sunlight further from the window using special optical films, optimizing geometry and using special glass, 'articulated light shelves' and 'light pipes'. The objectives of these systems are:

- Increasing daylight illuminance levels with minimum solar heat gains,
- Improving the uniformity of the daylight luminance gradient across the room under variable solar conditions throughout the year.

3.3.1. Sidelighting and toplighting strategies

Skylights and windows incorporates daylighting into the building as the preferred mode of interior illumination, reduces lighting load and saves electricity, which is the most expensive form of energy. Windows are sidelighting strategies and Skylights are toplighting strategies that provides the opportunity to illuminate a space completely differently than with windows. Its effects range from a uniform light to a more dramatic and strategic lighting of certain spaces. One disadvantage of toplighting is the access to it. In order to control the light coming in, one has to have access to the aperture itself. Another disadvantage is the fact that toplighting usually effects only the uppermost levels. Skylights are simply defined as "horizontal glazed roof apertures that are parallel to the roof. Large skylights are usually the most economical to install but produce a situation where it is harder to control light coming in. Smaller more tightly spaced skylights are more costly to install but tend to give more uniform light and greater energy savings. "The general rule of thumb is to space skylights at 1.0 to 1.5 times the ceiling height." [20]

The use of a horizontal Skylight provides approximately three times the amount of daylight as a vertical window of the same size [20]. Skylights can be placed closer to the centre of an area and therefore offer more uniform light distribution throughout the space. Prismatic or angular Skylights have the advantage over flat alternatives in that they can be selective about the light they transmit. They can be designed so that they only allow the passage of lower level light. This provides daylighting without overheating, particularly in summer [20].

3.3.2. Core daylighting

Core daylighting is a process that brings sunlight inside a building though different "indirect" strategies. One of the oldest examples is that of the Egyptian cultures that managed to bring light deep inside tombs with a system of mirrors. The modern versions are not that different, in principle and include Light shelves and Light ducts.

Light shelves are horizontal reflectors designed to modify daylight distribution by bouncing light deep into a room from the window wall rather than to directly admit daylight. They do this by reducing the direct daylight component and increasing reflection from ceilings, etc. This results in a more uniform distribution of daylight throughout a room. As a result, light shelves are more efficient in rejecting sunlight than displacing diffuse light deep into the interior of a building. Their major benefit is thus derived from increases in thermal comfort, particularly in summer.

A light duct (also known as a light pipe or light tunnel) is a rigid device designed to transmit daylight deep into the interior of a building. Light ducts offer considerable advantages, although significantly more complex than most daylighting systems. Daylight can be transmitted to any space throughout the building, regardless of the proximity to, or access to, the exterior. Light ducts also transmit light without transmitting heat. They provide interior light by collecting sunlight through heliostats, concentrating the light through mirrors or lenses, and directing it to the interior of the building through shafts. Shafts are traditionally lined with highly reflective polished metal, but newer and more effective alternatives are now being developed which transmit far more light than their metallic counterparts, allowing for longer pipes without optical loss [20].

Passive light-shelf and light- pipe designs, fig. 10 can introduce adequate ambient daylight for office tasks in a 4.6 m to 9.1 m zone of a deep perimeter space under most sunny conditions with a relatively small inlet area; the light-pipe has been shown to perform more efficiently throughout the year than the light shelf [4].

The advanced core daylighting systems are based on the following concepts [4]:

- By reflecting sunlight to the ceiling plane, daylight can be delivered to the workplace at depths greater than those achieved with conventional windows or skylights, and without significant increases in daylight levels near the window. This redirection improves visual comfort by increasing the uniformity of wall and ceiling illumination levels across the depth of the room.
- By using a relatively small inlet glazing area and transporting the daylight efficiently, lighting energy savings can be attained without severe cooling-load penalties from solar radiation.
- By carefully designing the system to block direct sun, direct source glare and thermal discomfort can be diminished. The challenge of the design stems from the large variation in solar position and daylight availability throughout the day and year.

However, Previous attempts to use sunlight directly for interior lighting via lens collectors, reflective light-pipes and light shelves has the following disadvantages:

- Significant losses in the collection and distribution system,
- Ineffective use of non-visible solar radiation, and
- A lack of integration with electric lighting systems required supplementing solar lighting on cloudy days and at night.

3.3.3. The hybrid lighting

The hybrid lighting is a systems-level strategy to solve the key problems discussed above. It is a strategy to improve the electrical power efficiency of solar energy by integrating two solar technologies into multi-use hybrid systems that better utilize the entire solar energy spectrum. The entire solar spectrum is concentrated by a primary mirror and the visible portion of the solar spectrum separated from the ultraviolet and near infrared portions at a secondary optical element. The two energy streams are used for different purposes, interior lighting and electricity generation [16]. The system constitutes Light collection and electricity generation, Light transmission, and Luminaires (fig. 11).

- *Light collection and electricity generation*: Hybrid Lighting sun collector is a 2-axis sun-tracking collector. It is designed as a parabolic mirror (the primary mirror) that reflects direct non-diffuse sun light onto a Secondary Optical Element (SOE), placed in focus of the parabola. The SOE is a spectrally selective cold mirror, which separates the visible portion of the solar spectra from the near infrared spectra [21]. It reflects the visible portion of the sunlight onto number of large-core optical fibers placed in the centre of the dish. The infrared rays are transmitted through the cold mirror and are utilized by a photovoltaic cell to generate electricity. This solar cell is especially sensitive to the near infrared wavelengths.
- *Light transmission :* The SOB is divided into eight sections that reflect the light onto eight fiber ends placed in a circle, 54 mm in diameter, in the centre of the dish fig. 10. The fibers are large-core plastic fibers with a diameter of 18 mm. The number of fibers used and their size is dictated by the size of the primary mirror [21].
- *Luminaires:* The system is called "hybrid lighting" since it requires an alternative light source in cloudy weather or when the sun is below the horizon. The alternative light source is planned to be some kind of electrical lamp mounted together with dispersers for the sunlight in hybrid luminaires. This dual system will have a control system that ensures that the illumination remains constant even if the sun is temporarily hidden behind cloud. The control system employs ballast dimmers that adjust the electrical light according to how much natural light is available. In this way electrical energy is saved. It will also be possible to dim both the natural and electrical light based on preference and to switch it on and off.

4. Conclusions

Buildings consume energy before their construction; starting from the extraction of raw materials from natural resources, manufacturing of such materials, and their transportation to different construction sites. Then buildings consume energy during construction through the assembly of materials in addition to the continual process of material transportation from areas of production to construction sites. Finally buildings consume energy after construction through the different operational systems to maintain the internal environmental conditions. Therefore, any policy for energy conservation has to formulate strategies that give a major priority to reduce energy consumption before, during and after the construction of buildings.

Metrics is required to characterize building energy performance. Establishing energy metrics for high-performance commercial buildings can be achieved by completing three primary activities:

- Determine what to measure in buildings.
- Determine how to measure the aspects of energy performance.
- Determine how to apply the metrics.
- Three main strategies can be applied to buildings to achieve energy efficiency and high performance:
- Passive cooling and heating,
- Passive renewable energy , and
- Passive day lighting.

Although the costs of PV energy generation have become significantly lower in recent years, PV is still considered to be an (economically) expensive method of electricity production. A solution to this problem is to replace convention elements of the building envelope (roof tiles, roof cladding, facade elements, windows, shading devices etc.) with PV modules. The advantages of solar PV modules and solar thermal technologies are obvious. Unfortunately, these advantages come with a penalty in terms of overall efficiency. Therefore, conventional solar technologies have not displaced significant quantities of non-renewable energy and a great deal of work is needed to persuade firms and people to adopt photovoltaic technology, a problem that Egypt shares with the rest of the world. The application of wind turbines in Egypt sited on a building can only make a small contribution to its energy requirements because of the limited wind conditions in major cities and its' speed all over the year.

Strategies using sunlight directly for interior lighting via lens collectors, reflective light-pipes and light shelves has the following disadvantages:

- Significant losses in the collection and distribution system,
- Ineffective use of non-visible solar radiation, and
- A lack of integration with electric lighting systems required supplementing solar lighting on cloudy days and at night

Hybrid lighting system has the potential to become more cost-effective than the most efficient traditional daylighting system. Hybrid lighting would likely compete favorably with other solar technologies used in commercial buildings.

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