Solar energy potentials in Egypt

Solar energy applications as integral multi-functional systems

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Abstract: *It well known since many decades that, the concentration of urban population on the precious very limited cultivated land is the greatest problem faced Egyptian government. Redistribution population of dense urban regions, therefore, was and still the most important aim for all strategic development plans in Egypt. Many development corridors and axes have been initiated, outwards the Nile valley towards the adjacent desert lands, to realization those planes. New urban settlements were built in desert to absorb the pressure of growing the urban population outside the valley. Many studies and researches concluded that renewable energy especially solar energy has great potentiality in developing process of new communities and should plays a key factor in implementation these plans. To date, this potential has gone largely untapped, owing to a series of policy decisions favoring conventional energy.Many reasons have led to this situation for examples:*

1. *Lack of series strategy to encourage the investment in renewable energy systems.*
2. *Limited capacity, high prices and Lack of common awareness of available systems.*
3. *Finally, lack of series scientific research strategy to evaluate the national experience of utilization renewable energy and its potentialities & limitations according to the conditions of local context.*

The main purpose of this paper is critically analyses the potentialities and limitations of utilization solar energy in Egypt. Also, introduce some applicable solutions for integrating micro renewable energy supply systems as multi-functional elements in architectural design as examples for sustainable and green building approach.

However, the prevailing Egyptian desert conditions also result in extreme summer temperatures and high dust levels, both of which have a negative impact, which lead to rapidly deterioration of recent solar energy appliances. Therefore, it needs more researches to tackle these technological challenges.

Keywords: Renewable energy, Remote areas, strategic development, sustainable approach.

1. INTRODUCTION

Main urbanization Problem in Egypt is considering the concentration of population (98%) in Nile valley and Delta, which presents only 4% of the total area of Egypt. The rest of the land is vast desert adjust the valley along east and west Nile River. Only 2% of population lives on remote settlements dispread on about 2% of these deserts. This situation makes clear, why main development strategy of Egypt is the redistribution of the population. Thus was planned to achieve through creation many developments axis outwards from Nile valley to adjacent deserts, and initiates new urban settlements away from the precious cultivated land. Renewable energy resources especially solar energy has great potentiality in the near future to play a considerable role by the implementation of development programs and plans in those remote areas and new urban settlements. To date, this potential has gone largely untapped, owing to a series of policy decisions favouring conventional energy. Many reasons have led to this situation for examples:

- Lack of knowhow, professional experiences and availability of appropriate local products in local market.
- Lack of ambitious marketing policies, which encourage private investments in the renewable energy micro-supply systems.
- High prices of available systems comparable with their limited capacities.
- Lack of awareness about these systems among the normal building professions and users.

Considering the new demand for power driven by economic growth and swelling populations, policymakers will have to seek new sources of supply. However, investments in clean energy continued to fluctuate along with oil prices as the 21st century began. (see figure 1)

The current global boom in renewable is characterized by four major trends:*"Global concerns over accelerating climate change, Energy security, Supply and demand fundamentals, Technological improvements,"* (Booz & c, 2009) that are likely to make it a sustainable trend rather than a temporary bubble.

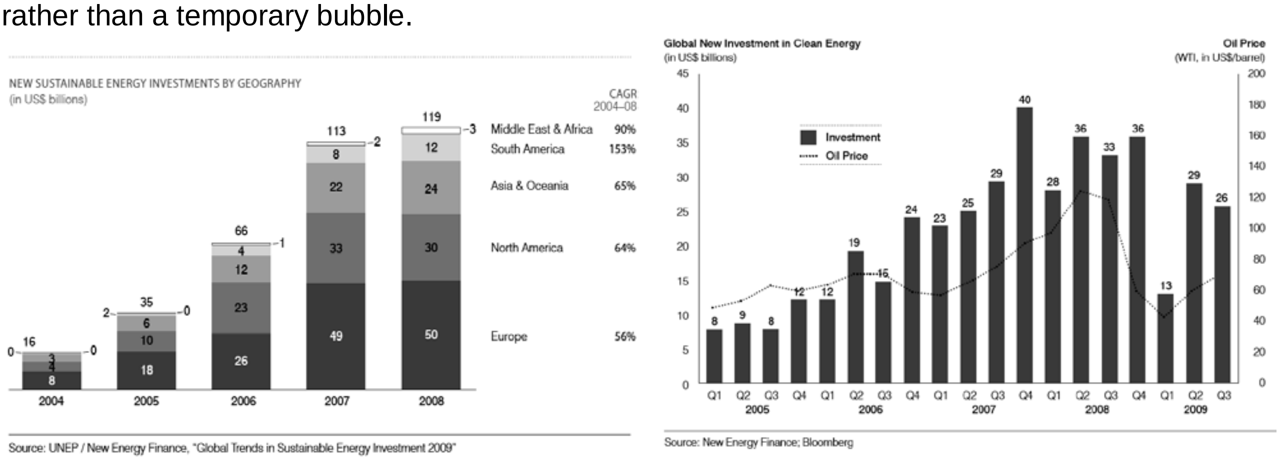

Figure 1: Clean energy global Investments trends and its depending on Oil Prices (Booz, 2009)

2. OBJECTIVE & METHODOLOGY

The aim of this paper is to give as possible a broad overview for the future opportunities of utilization solar energy in Egypt; as a source for clean sustainable energy, and why should be a favorite target in its strategic developing plans.

The methodological approach based on analytical and empirical study. The main purpose of analytical part is critically analyzed the potentialities and limitations of utilization solar energy in Egypt according to its geophysical context. The empirical study introduce some exemplar projects present the integration of renewable energy supply systems as multi-functional elements in project design as sustainable applicable examples for green building concepts.

3. FEASIBLE FUTURE OF RENEWABLE ENERGY IN MENA REGION

The MENA (Middle East and North Africa) region has huge potentiality to become one of the world's foremost producers of renewable energy. The use of renewable energy would have numerous benefits: decreased pollution levels; reduced carbon emissions; create self-sustaining industries; better advantage of oil and gas resources for higher-value industries such as petrochemicals and creation of new, skilled-labor jobs. These considerations should encourage the governments of this region to undertake a full review of their renewable energy opportunities. Yet, there are at least six reasons that the MENA region should be a world leader in renewable energy:

1. The region has an advantageous geography and climate.
2. The region's current energy supply may not be sufficient to meet future demand.
3. Renewable energy could help address the region's environmental problems. (see fig. 2)
4. Renewable energy could generate value in their own right, as well as freeing oil and gas for more profitable uses.
5. Renewable energy could enhance the export value of the region's traditional energy assets.
6. The renewable energy industry could drive economic diversification and create jobs.

Unfortunately, the lack of renewable energy acquisition activities is rooted to some extent in the region's abundant supplies of fossil fuels. The recent economic crisis has not helped matters: Cheaper oil has made renewable energy relatively less cost-effective, and a global lack of liquidity has made financing of renewable projects more costly. Countries will need to analyze which technologies are best suited for their geographic characteristics, power needs, and financial resources.

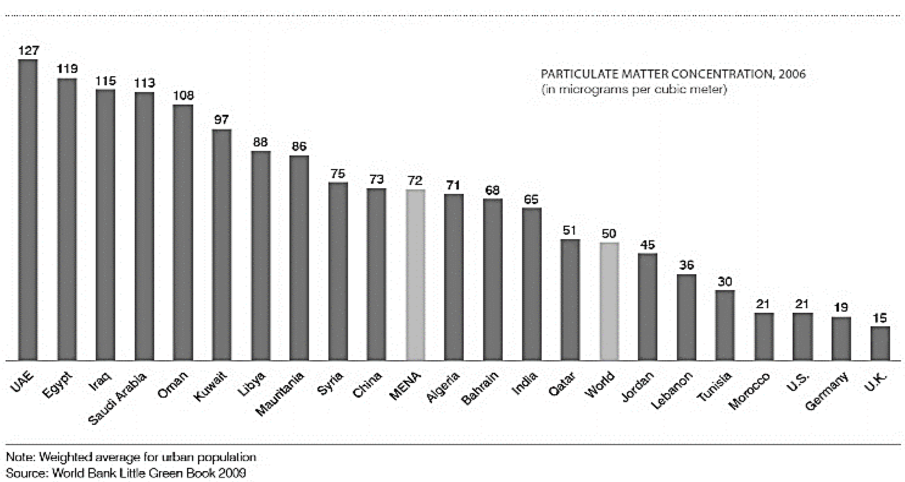

Figure 2: Increasing pollution rates as a national scourge (Booz, 2009)

However, not all renewable energy technologies will be viable for the MENA region. Wind and solar offer the greatest potential (see figure 3). Other forms of renewable energy including geothermal and biomass may be promising, but most MENA countries do not have the natural resources to make them viable.

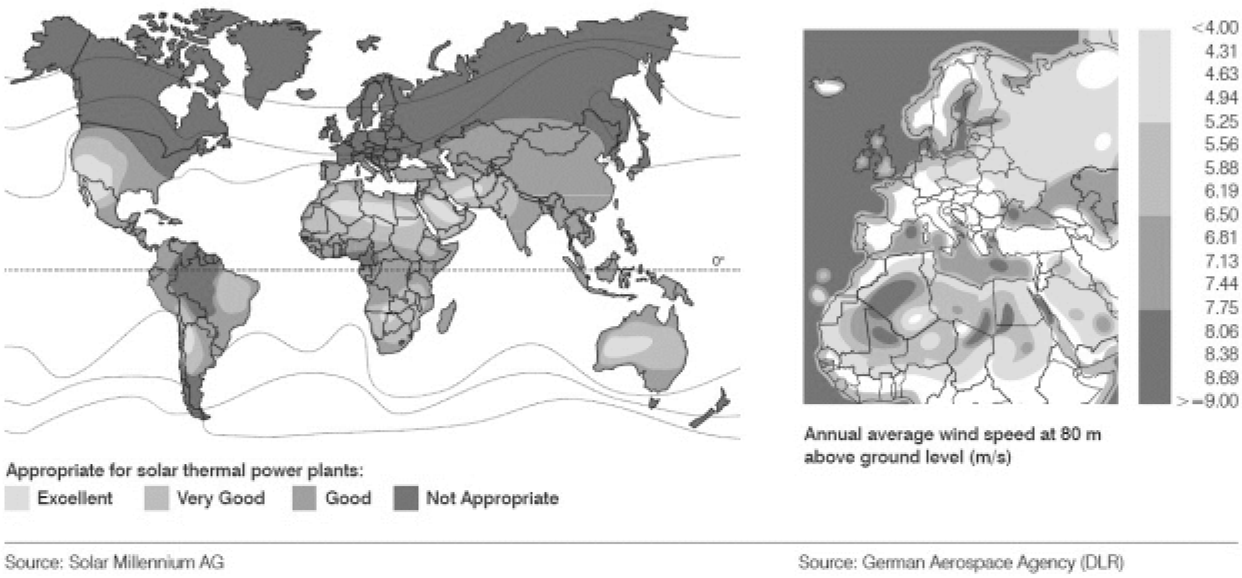

Figure 3: Natural advantages for both solar and wind as renewable energy resources (DLR, 2005)

3.1. Solar Energy Potentials & Limitations in Egypt

The key ingredient for any solar technology -solar radiation- is abundant in Egypt. However, the prevailing desert conditions also result in extreme summer temperatures and high dust levels, both of which have a negative impact on solar energy. Therefore, Egyptian governments should carry out intensive researches to tackle these technological challenges. Despite these difficulties solar technologies could be deployed widely throughout the country (see figure 4).

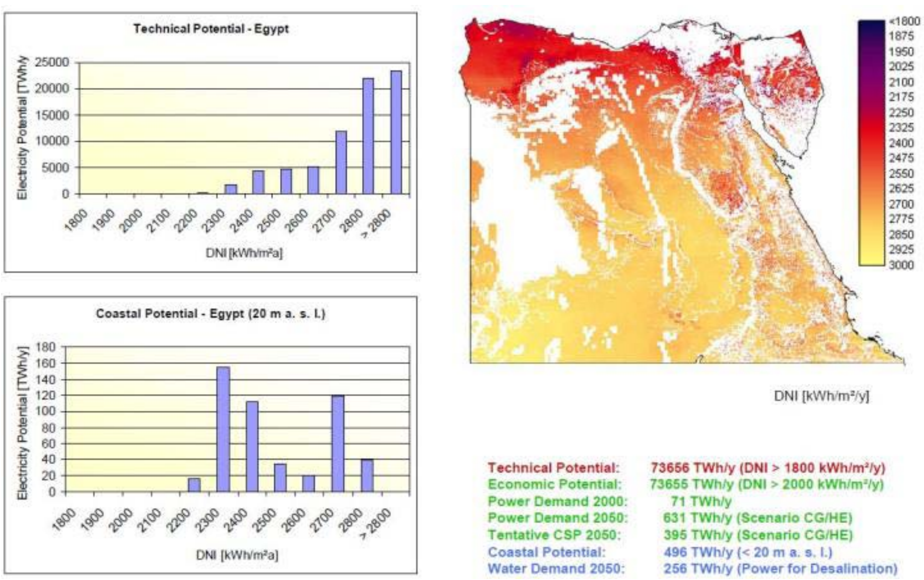

Figure 4: Solar Thermal Electricity generating potential in Egypt (DLR, 2005)

3.2. Utilization of solar energy in Egypt and the future ambitions

In 2011, Egypt has witnessed two important events: Revolution of 25th of January and the first achievements of utilization of renewable energy resource, which was the completion of the first 140 MW solar thermal plants in Kuraymat, and connecting it with the national grid at the end of June 2011. The government planned by with multi international help and support to implement large-scale development of Egypt's renewable resources with the goal of having 20% of its installed generation capacity in the form of renewable by 2020 (including existing hydropower).Proposed project to implement 20 MW solar Plant in Hurghada in co-operation with JICA: Tokyo Electric Power Service Company (TEPSCO) was selected toconduct the project feasibility study. The solar radiation measurement equipment was supplied beside the supply of two modules to measure the sand effect in the site according to solar cell performance has been erected since October 2011. The duration of the project is 18 month started from 18 January. Also was proposed to implement 20 MW solar plants in Komombo in co-operation with French development agency (AFD). Feasibility study will be prepared through a grant presented from AFD with an amount of 800 thousand Euros; grant agreement to be signed between The Ministry of International Cooperation & AFD is under study.

In spite of being an expensive technology, Photovoltaic systems are considered the most appropriate energy application for rural and remote areas of small-scattered loads, which are far away from national grid. The total set-up capacity of PV systems in Egypt is around 10 MW, which is mainly used for lighting, water pumping, wireless communications, and commercial advertisements on highways. The Egyptian "NREA" signed a protocol for cooperation with the Italian Ministry of Environment, Land and Sea to electrify two remote settlements in Matrouh Governorate by PV systems. The project consists of electrifying of 100 houses and 40 street light units, one school, three mosques and two medical clinic units. This project has been - supposed to be - completed and operated since December 2010.

4. APPLICABLE FORMS OF SOLAR-GENERATED POWER

There are two major forms of solar-generated power:

- Concentrating Solar Power (CSP) uses mirrors and lenses to concentrate solar energy within plants that are utility-scale generators.
- Photovoltaic (PV) solar power directly converts sunlight into electricity using semiconductors, and is often used on a smaller scale.

4.1. Concentrating solar thermal power technologies CSP

Concentrating solar thermal power technologies (CSP) based on the concept of concentrating solar radiation to be used for electricity generation within conventional power cycles using steam turbines, gas turbines or Stirling engines. For concentration, most systems use glass mirrors that continuously track the position of the sun. The concentrated sunlight is absorbed on a receiver that is specially designed to reduce heat losses. A fluid flowing through the receiver takes the heat away towards the power cycle, where e.g. high pressure, high temperature steam is generated to drive a turbine. Air, water, oil and molten salt are used as heat transfer fluids. (See figure 5)

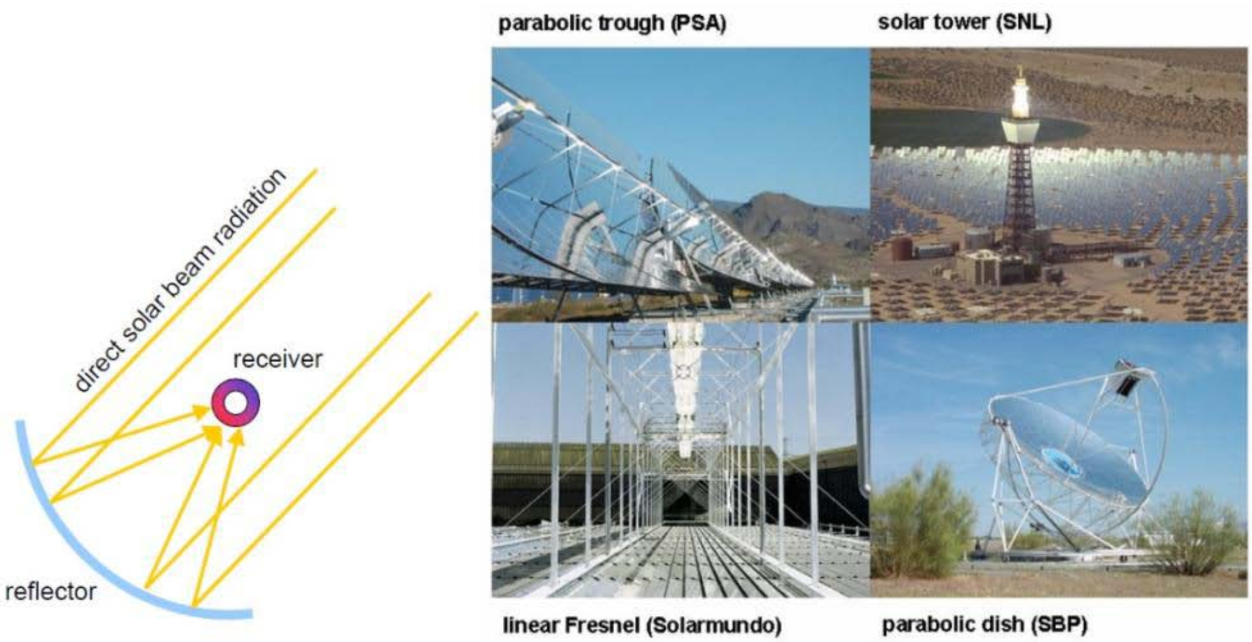

Figure 5: Different forms of concentrating solar thermal power technologies (DLR, 2005)

Each of these technologies can be operated with fossil fuel as well as solar energy. This hybrid operation has the potential to increase the value of CSP technology by increasing its power availability and decreasing its cost by making more effective use of the power block. Solar heat collected during the daytime can be stored in concrete, molten salt, ceramics or phase-change media. At night, it can be extracted from the storage to run the power block. Fossil and renewable fuels like oil, gas, coal and biomass can be used for co-firing the plant, thus providing power capacity whenever required (see figure 6). This is a key advantage since it addresses the intermittency of solar power and permits power generation even after sunset.

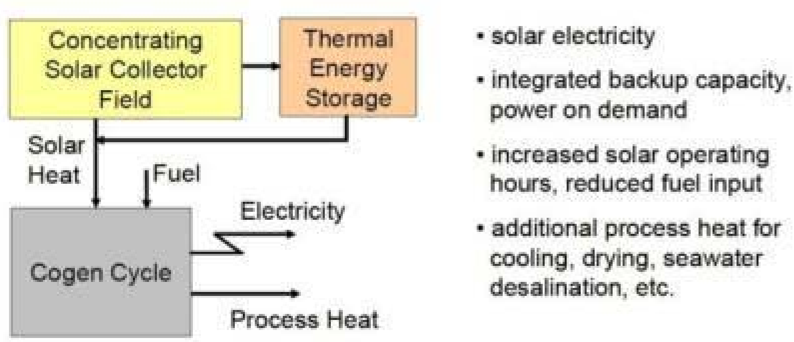

Figure 6: Principle of solar thermal co-generation of heat and power (DLR, 2005)

Possible applications cover the combined production of industrial heat, district cooling and seawater desalination. All concepts have the perspective to expand their time of solar operation

to base load using thermal energy storage and larger collector fields. To generate one Megawatt-hour of solar electricity per year, a land area of only 4 to 12 m² is required. This means, that one km2 of arid land can continuously and indefinitely generate as much electricity as any conventional50 MW coal - or gas fired power station.
Thus, two main characteristics make concentrating solar power a key technology in a future renewable energy supply mix in Egypt:

- it can deliver secured power as requested by demand
- its natural resource is very abundant and practically unlimited

Solar chimneys are also considered as solar thermal power plants, though not concentrating. They consist of a very large glass or plastic roof with a chimney in its centre. The air underneath the glass roof is heat and by its lower weight forced into the chimney, where it activates a wind turbine for power generation. They can be built in the range of 100 - 200 MW capacity. Heat can be stored in the soil and in water storage below the collector for night-time operation. They cannot be used for co-generation of electricity and heat. Hybrid operation with fuels is not possible. There availability and capacity credit is considered 90 %. They are suited for base load and intermediate power. Solar chimney potentials are considered part of the solar thermal power potential and are not quantified separately.

4.1.1 Integrated Systems and Multipurpose Plants

The collectors of some CSP systems provide shaded areas that could be used for purposes like greenhouse, chicken farm, parking etc. Integrated systems that use power, desalted water and shade for generating a new environment for farming in desert regions could become feasible in the future as countermeasure to desertification and loss of arable land (see figure 7). This requires more investigation on the possibilities and restrictions of such systems.

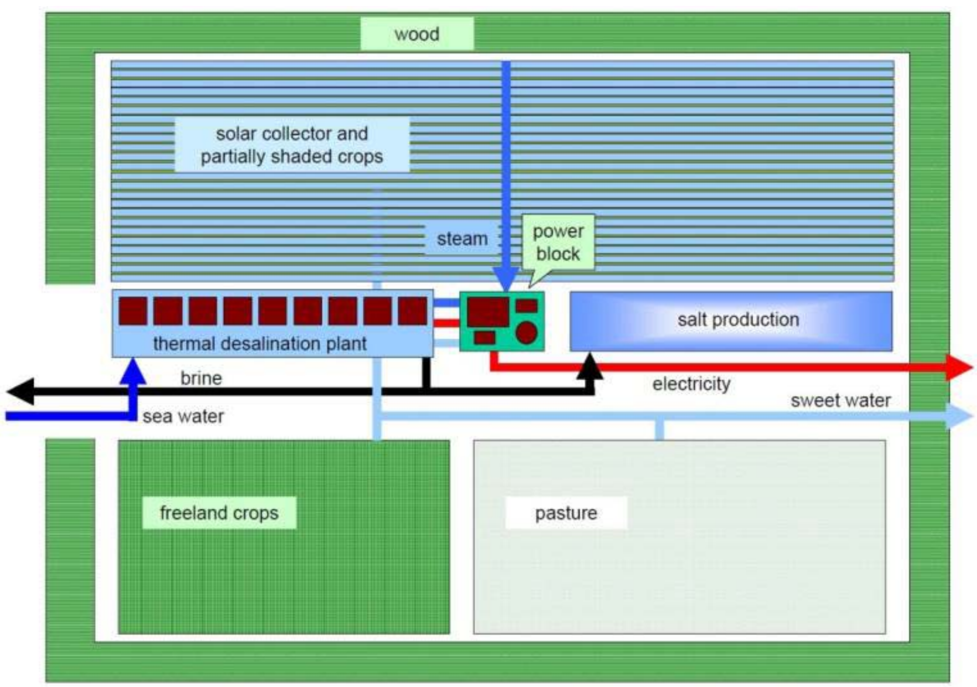

Figure 7: Multipurpose plant scheme for the development of arid regions (DLR, 2005)

4.2. Photovoltaic Applications

Photovoltaic applications are in principal unlimited and can be used for distributed or remote power systems with or without connection to the utility grid. There are no criteria for site exclusion for PV systems, as they can be installed almost everywhere. Their capacity ranges from a few Watt to several MW. Batteries are usually applied in smaller decentralized supply systems to store the solar energy over the night. Energy from very large PV could be stored in pump storage systems. PV cannot offer any secured capacity. Backup capacity must be provided by other technologies within the grid. However, PV applications expansion is still limited by their high investment cost. Using present growth rates and scenarios for very large PV systems and distributed applications, PV potentials were assessed in a relatively intuitive way. The global irradiance on a surface tilted according to the latitude was used as performance indicator. PV suggest that this technology will become competitive by the middle of this century under the irradiance conditions of the MENA region(see figure 8& 9).PV systems, may be, are especially suited for decentralized small scale applications in remote regions, where they often are already competitive to conventional Diesel motor-generator power supply schemes.

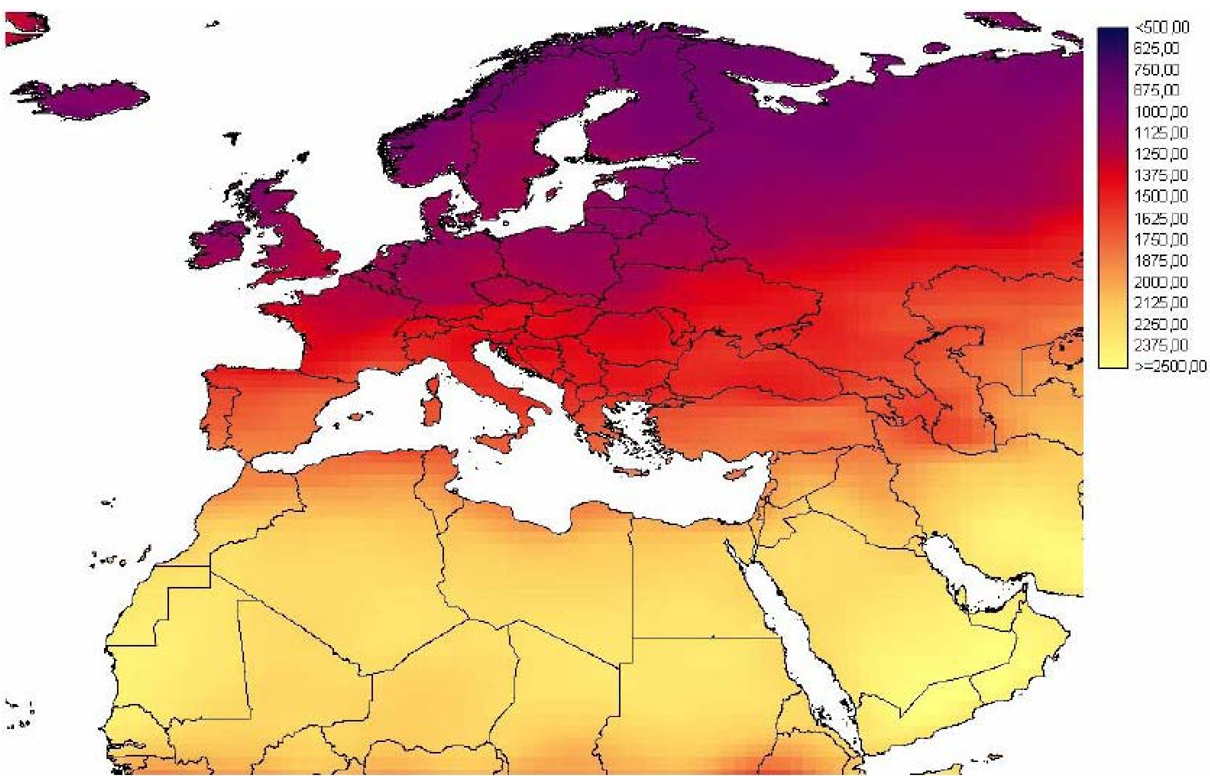

Figure 8: Annual global irradiation, in MENA region, on surfaces tilted south with latitude angle in kWh/m^2/year (DLR, 2005, with data from /ECMWF 2002/ for / WBGU 2003)

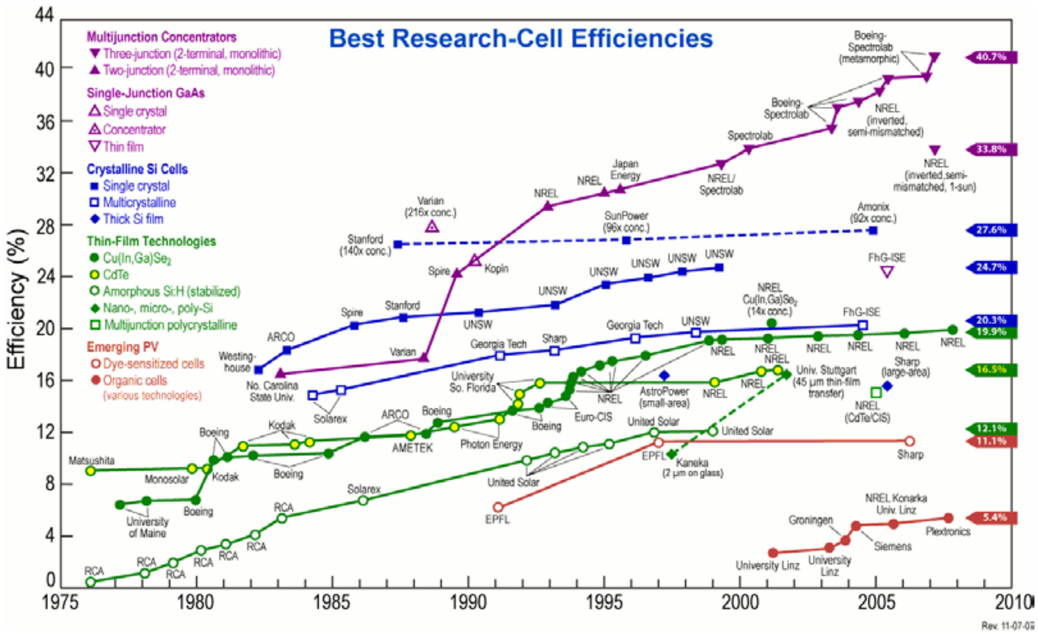

Figure 9: Timeline of solar cell energy conversion efficiencies
(from: National Renewable Energy Laboratory, US Department of Energy, Wikipedia, 2013)

4.2.1. PV panels systems as integrative building elements

Because their relatively high cost and limited capacity utilization of PV panels as a power systems in buildings constructions is very limited. Hover Therefore if the designer can employ them as multi-function elements and utilizing these panels as parts of faced envelop, shades on top of flat roofs, canopies in open spaces, or ceilings for atriums and courts (see figure 10 &11). PV panels in that way can gain more engineering values, which can overcome their problematic by reduction of building initial costs.

Figure 10: Photovoltaic wall at MNACTEC Terrassa in Spain (Chixoy, Wikipedia, 2013)

PV units as a part of external shade, new Labs building in 6th Oct. city (1st prize competition, 2008)

PV units as shade above the roof terraces, primary school in remote region (1st prize competition, 2009)

Figure 11: Utilizing PV units as shading elements in building design

"In 2010, more than four-fifths of the 9,000 MW of solar PV operating in Germany were installed on rooftops"(Wikipedia, 2013).Building-integrated photovoltaic (BIPV) units are increasingly incorporated into new domestic and industrial buildings as a principal or ancillary source of electrical power. Typically, an array is incorporated into the roof or walls of a building. Roof tiles with integrated PV cells are also common. A 2011 study using thermal imaging has shown that solar panels provided an open gap in which air can circulate between them and the roof, provide a passive cooling effect on buildings during the day and keep accumulated heat in at night.

4.3. Preferences and choice criteria among solar energy applications systems

CSP and PV applicationsboth have its own advantages also limitations due to the local context circumstances and the best approach for many countries will likely be to use some combination of the two. In determining whether CSP or PV is the better fit for a particular need, planners must consider the location and kinds of applications. The major differences between the two lie in scale, infrastructure requirements, and consistency of power output.

CSP technologies generally require significant infrastructure investment and support. Since their power conventional generation blocks, such as gas or steam turbines in the multi-megawatt range, their operation and maintenance costs are much higher than those of PV technologies are and require specialists to build and operate. In addition, most CSP plants require significant volumes of water for operation. Even though CSP plants have significant drawbacks, utilities prefer them because of their more consistent power output. In addition, CSP plants can be coupled with thermal storage units or backup fossil-fuel burners to maintain smooth operations. Thus, utilities can depend on CSP plants for power output and do not have to keep other power plants in reserve.

For remote and small-wattage needs, which less than 50 megawatts, PV may be a better and more economical choice than CSP (2009 Booz & C). The primary advantages of PV systems rest in their scalability. Systems can generate as little as a few watts at a time or reach several megawatts. PV systems can be deployed with a single panel, delivering a few hundred watts of peak output. Further maintenance is generally limited to occasional cleaning of the panels, which does not require specialized expertise. In regions without access to the electricity grid, PV in combination with storage can offer a way to replace or complement expensive diesel generators without extending the grid into remote areas.Cost calculations assume average local conditions in terms of solar radiation, temperatures, and other technical factors. "Based on cost assumptions, the unsubsidized cost of solar PV power in the Egypt could become competitive, with that of natural gas between 2015 and 2025, depending on the prices of gas and carbon" (El-Husseini 2009).

Table 1: Some different characteristics of contemporary power technologies (adapted, DLR, 2005)

	Unit Capacity	**Capacity credit**	**Capacity factor**	**resource**	**applications**	**comment**
Photovoltaic	1 W – 5 MW	0 %	15 – 25 %	Direct and diffuse irradiance on a fixed surface tilted with latitude angle	electricity	Fluctuating, supply defined by resource
Solar Chimney	100 W – 200 MW	10 to 70 % depending on storage	20 to 70 %	Direct and diffuse irradiance on a horizontal plane	electricity	Seasonal fluctuation, good storability, base load power
Concentrating Solar Thermal Power	10 kW – 200 MW	0 to 90 % depending on storage and hybridization	20 to 90 %	Direct irradiance on a surface tracking the sun	Electricity and heat	Fluctuations are compensated by thermal storage and fuel, power on demand

5. CONCLUSIONS - Findings & Results -

- Considering the new demand for power driven by economic growth and swelling populations in Egypt, policymakers should have to seek new sources of energy supply.
- The use of renewable energy would reduce air pollution levels and create self-sustaining industries that would diversify regional economies. These considerations should encourage the government to undertake a full review of their renewable energy opportunities.
- Due to the developing renewable energy sector, oil and gas could be used to generate value as high-margin inputs into industries such as petrochemicals.
- Thanks natural geographical feature, both solar technologies CSP plants and PV systems could be utilized widely throughout Egypt. In determining whether CSP or PV is the better fit for a particular need, planners must consider the location and the application.
- Architectural design can play an important role to encourage and convince private developers and clients to invest in utilization micro renewable energy supply systems in their building. They can integrate these systems in design as multi-functional elements to reduce the cost implications on total building budget. They can also explore to them, how they can benefit from these systems on long run and have their own contribution by reduction CO2 emission.
- Finally, Egypt must make substantial changes in the regulatory framework to create incentives that would kick-start renewable energy investments.

6. REFERENCES

El-Husseini, I. & Fayad, W. & El Sayed, T. & Zywietz D. (2009). A New Source of Power - The Potential for Renewable Energy in the MENA Region. Booz & Company Inc. http://www.booz.com/global/home/what we think / reports and white papers

German Aerospace Center (DLR), Institute of Technical Thermodynamics, Section Systems Analysis and Technology Assessment (2005). MED-CSP. Concentrating Solar Power for the Mediterranean Region Final Report. Commissioned by Federal Ministry for the Environment, Nature Conservation and Nuclear Safety Germany Stuttgart. http://www.medemip.eu/WebPages / Common / showpage.aspx? page id=46

Ministry of Electricity & Energy New & Renewable Energy Authority, Annual Report 2010/ 2011 http://www.nrea.gov.eg/ english1.html

Ministry of Information, yearbook 2009, State Information service. http://www.us.sis.gov.eg/en/ Last Page. aspx? Category ID=1067

Ministry of state for Environment Affaire, (2010), Egypt State of the Environment, Report 2009& 2006, Egypt State of the Environment, Report 2005. Egyptian Environment Affaire Agency http://www.eeaa.gov.eg/English/info/report search.asp

Mohamed. A. R., (2008), HBRC New Labs Building, 1st prize competition, report.

Mohamed. A. R., (2009), School Prototypes, 1st prize competition, poster.

The free encyclopaedia, Photovoltaic, last modified on 16 June 2013 http://en.wikipedia.org/wiki/Photovoltaics