Developing the Egyptian Desert by Photovoltaic Technology

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ABSTRACT

Settling the desert has long been an Egyptian dream. Dictated by the population needs, future hopes, and a broader vision for a better life, desert development has widely been considered a national goal. Numerous studies have discussed the future of the Egyptian desert development as “Egypt 2020” by Rageh, and the “Development Corridor” by Farouk El-Baz. Studying the international trends related to sustainable development and renewable energies utilization has shown a gap between the entire national trends and the relevant international strategies that call for an optimum utilization of the “Very Large Scale Photovoltaics” (VLS-PV) in the world’s desert. Such new visions may help create new productive sustainable communities in the desert while providing for a new desert development scenarios.

The research suggests an integrated approach to practical utilization of VLS-PV guided with the national visions of the future of prospected desert communities in Egypt. It further presents the main database required to formalize a guideline to the utilization of Photovoltaics in new desert communities, through a proposal titled ‘Green Mines Community’.

The proposal presents a model for the integration of photovoltaic system with the new supposed future communities in the Egyptian desert, whether through the “development corridor” project, or desert development framework in general. The dwelling unit and its energy system are focused through diagrams and models. The proposal findings illustrate the recommended targets that may possibly make the recent development projects more adaptive with the use of solar energy applications; mainly with the VLS-PV systems.

Keywords: Egyptian Desert- Solar Energy- Sustainable Community- VLS-PV systems.

INTRODUCTION

Egypt covers an extremely arid area (about 1,000,000 km²), of which only 5% is inhabited. According to census estimates, the Egyptian population almost tripled during the last 50 years to become about 74 x 10⁶ inhabitants in 2008. By the year 2025, it is estimated to become 95 x 10⁶ people, of whom almost 99% may concentrate in the Nile Valley and Delta (SIS 2009)¹. Therefore, redistributing the population over a larger area has increasingly become a necessity. To facilitate this process, it is essential to reclaim new lands for agriculture use, create new industrial regions, build adequate services and plants, create new job opportunities, and provide adequate food for emerging communities. Meanwhile, the problem of climate change put new constrains to the
anticipated development, of which desertification is considered a major threat to the bio-productive systems in the country and the entire world.

Eco-development strategies along with urban and desert development have become crucial issues in achieving the national strategies. In this sense, numerous studies have discussed the future scenarios. Partially addressed as part of these studies scenarios, the desert has been focused and its obstacles analysed; raising the following couple of questions: (1) could Egypt grow in the old valley alone; leaving 95% of its total area unexploited? and (2) what would happen after a quarter-century without heading towards the desert? Essentially, the answers will emphasize the importance of conducting R&D along with applicable studies. Recently, the vision and proposal of the “Developmental Corridor,” introduced by Dr. Farouk El-Baz, has emerged as a developmental ideology, that looked at the Egyptian western desert as a potential, and celebrated science and youth as the way to achieve the goals. (Rashed, 2009).

Dr. Rashed, chair of the Architectural Engineering Department in Mansoura University from 2005 to 2008, had guided the academic effort within the educational programs to contribute to this framework and follow up with Dr. El-Baz proposal. “Egypt, the Future” was the main theme under which numerous graduation projects have been produced since the Academic Year 2005/2006. As a parallel effort in R&D, the ESU 95% Lab (Egyptian 95% Sustainable Urbanism Laboratory) was launched as a scientific research group. They helped develop the findings and data and share the results and outputs with interested governmental parties and private sectors that showed interest in Dr. El-Baz proposal.

As part of the “ESU 95% Lab” effort, this paper is meant to discuss and demonstrate the abilities for developing the Egyptian Desert with the utilization of solar energy. The “Very Large Scale Photovoltaics” (VLS-PV) application is particularly addressed as a clean renewable potential that might help create new productive and sustainable urban communities in the Egyptian desert.

AIMS OF THE RESEARCH

This study aims at approaching the following:

- Discussion, analysis, and development of the existing scenarios dealing with the developmental concepts for the Egyptian desert and creation of new urban communities.

- Emphasizing the role of renewable energies (solar energy in particular), handling the implementation of self-sufficient/productive housing units, and fostering the effective role of architecture in disseminating and developing sustainability strategies for desert settlements and regional communities at large.

- Promoting the major governmental projects, implemented in desert hinterlands by expanding the body of knowledge to a larger scale of stainable photovoltaic application in the local urban communities.

- Proposing some urban and architectural design guidelines for discussion, debate, and further input.

METHODOLOGY

This paper is determined to study the major potential approaches for developing the Egyptian desert. In collaborative effort with authors two and three, this study mainly stems from theoretical studies carried out by the first author through his Masters Thesis.
in progress, conducted academic research, and submitted entries at several environmental architectural competitions. Through all these contributions, solar energy applications in urban development have been mainly focused, and major international experiments studied to draw out practical criteria to pave the way for the Egyptian desert to be home to new communities and future generations.

RENEWABLE ENERGY (RE): PHOTOVOLTAIC TECHNOLOGY

Egypt RE Policy and Potentials
Fossil fuels, in addition to hydropower and non-commercial fuels, are considered as the main energy resources in Egypt. The Supreme Council of Energy (SCE) consists of the ministers of electricity and petroleum. The Egyptian energy policy focuses mainly on promoting RE utilization, enhancement of natural gas, adjustment of energy prices, removal of subsidies, and energy efficiency and conservation. The Renewable Energy (RE) resource development has attracted strong interest with strategy targets to supply 3% of electricity generation by 2010. In addition, the old strategy of Renewable Energy Technologies (RETs) has been developed by focusing on: (1) research and transfer; (2) technology demonstration; (3) establishing testing and certification facilities; (4) increasing awareness; and (5) promotion of environmental considerations. (Pracad. Fenmann 2002 & SIS Egypt 2008)³.

Within this framework, the main areas of activity are wind farms, solar water heaters, and photovoltaic cells for special applications. Egypt has plenty of sunshine; there are over 3400 hours/year of solar availability in the north and 3900 hours in the south. The average annual solar radiation varies between 1900 and 2600 kWh/m²/y, from the northern to the southern parts of the country, Figure 1-a.⁴

Fig. 1: a-Solar Insolation Rates Graph.-b- Al-Kuraymat, Solar thermal Electricity project (New & Renewable Energy Authority NREA 2007)

Solar Energy Technology Feasibility in Egypt
The Studies carried out by national organizations, such as (NREA), Egyptian Solar Research Centre, Nokraschy Engineers, and international associations as GEF and MEDA, have outlined the feasibility of local solar technologies, both for thermal and electrical applications, Figure 1-b. These applications are outlined in the following.

Proposed Thermal Technologies
Of the numerous solar thermal applications, the Egyptian government promoted the following selected technologies; identified as “the feasible applicable systems”:
a. Solar water heating for domestic and commercial use;

b. Solar Systems for industrial heating processes; and

c. Solar thermal Electricity.

In cooperation with international firms and Nokraschy Engineers for solar thermal applications, the effective utilizing of an integrated solar combined-cycle electricity projects on the Egyptian desert has been demonstrated. The government promoted the project, with assistance from the Global Environment Facility (GEF) and the European Union’s Mediterranean Assistance (MEDA) program. This was supported by (NREA), to be implemented as a private sector power project sited in Al-Kuraymat region.6.7 (ESMAP, 2005, El-Zalabany 2007)

**Proposed Electrical Technologies**

a. Solar photovoltaic for rural and remote areas. The government promoted the use of photovoltaics in electrification systems and groundwater pumping in rural area with no access to the grid.8

b. Very large-scale photovoltaic systems (VLS-PV). A practical proposal for generating energy from the world’s desert by utilizing of large-scale PV plants and creation of developmental vision of the desert regions. This project provides a significant relation between the required sustainable urban development in the Egyptian desert and the desired generation of an EU-MINA renewable energy links, Fig. 2 (Kurokawa, et al. 2007, Mediterranean Union 2008)9.10

![Image](image.png)

**Fig. 2:** a- Modelling of VLS-PV system in agriculture community - b- The map of EU-MINA-RE Energy link (Kurokawa, 2007, Mediterranean Union, 2008).

**THE DEVELOPMENT OF EGYPTIAN DESERT: THE NECESSITY**

Climate change poses significant risks on Egypt’s population, land-use and agriculture, as well as the economic activity. Throughout history, the development has been constrained along a narrow Y-shaped strip of land along the Nile and the deltaic coast. Sea level rise on the costal zone, desertification, temperature increase, and scarcity of rails call for immediate shift of national development trends, population map, and national resources, Figure 3-a. As mentioned above, the re-distribution of Egypt’s population is an urgent need, while desert development and scenarios promotion will further require R&D, new innovative concepts, and social consciousness.

**Proposed Developmental Scenarios**

The following demonstrates the proposed highlighted scenarios of developing the Egyptian desert.
Rageh Scenarios (Egypt 2020)

Integrated with strategic governmental plans, this scenario depends on the historical reading of the Egyptian reality and its social, economic, and urban political transformation through the last 30 years. The scenario has a holistic, national perspective through the Grid Developmental Form (GDF). The GDF combines the targeted development regions, segments, and poles of growth to create – in alignment with the strategic goals of the old valley – a holistic socio-economic and environmental development of future communities. Yet, this scenario lacks the proper use of new sustainable processes, social engagement, utilization of new sustainable technologies; while still built-up on exploiting the exhausted infrastructure of the old valley, Fig 3-b.

![Map of Egypt with coastal inundation and Rageh proposal](image)

**Fig. 3:** *a-* Coastal inundation in the Nile delta under sea level rise, and *b-* Rageh proposal Egypt 2020 developmental axes (Otto et al. 2007, Rageh 2007)\(^{11}\) - \(^{12}\)

El-Baz Scenario (Developmental Corridor)

This scenario is considered a sub-detailed project, associated with more specific and innovative concepts. It argues the potential mitigation of continued overloads on the old valley by creating the Development Corridor parallel to the Nile path. It consists of north-south super highway, modern railway, water pipeline, and electric line. The main highway oriented in a roughly east-west direction would connect it to the main centres of population to create new productive communities in the hinterlands and deserts (El-Baz, 2007)\(^{13}\). The following illustrates the adaptability and feasibility of El-Baz scenario, backed with sustainable development visions of the world’s deserts.

VLS-PV Feasibility, and Relevance to Desert Development

**VLS-PV & BIPV –vs- Urban Development and Architecture**

The term ‘Building-Integrated Photovoltaics (BIPV)’ is now a part of every architect's vocabulary (Addington, Schodek, 2005)\(^{14}\). Installation of PV panels on roofs is the main practical method for distributing the investment cost and immediate the transition to solar technologies in dense cities, than is likely to occur at the utility scale.

![Diagram of VLS-PV and BIPV](image)

**Fig. 4:** Developing the Desert by use of BIPV and VLS-PV, a proposed scenario.

Dissemination of BIPV systems – extended with the use of VLS-PV – is hypothesized to form the combined strategic vision for developing the Egyptian desert, Figure 4.
DEVELOPMENTAL CORRIDOR USING VLS-PV: PROPOSED SCENARIO

Developmental Corridor & VLS-PV Desert Developmental Scenario

The concept, presented by the significant geological scientist Prof. El Baz, would provide numerous opportunities for the development of new communities, agriculture, industry, trade, and tourism around a 2,000 km strip of the Western Desert, Table 1-a

Tab.1: Identical issues of the proposed VLS-PV project in Mangole Desert and Developmental Corridor in Egypt (developed from VLS-PV, 2007 and El-Baz 2008)

| Desert Nature | Consists of multi-type of deserts (plain- depression-valleys- Great sandy desert) |
| Climate | Formed multi-type of climates (Mediterranean zone- semi-arid – arid – desert zone) |
| Population | Prospected to attract 25% of the Egypt’s population; approximately 17-20 million |
| Transmission line | Through railway or North-south highway; the main feed for the corridor developmental axes |
| Activities (GDP) | Studied activities: Agricultural expansion and domestic animals production, Urban development, military activities, Medical valley, Construction materials Industry, urban Development, International tourism, fishing resources |
| Energy | Electrification: the proposed expansion of North-South national grid, natural gas resources, and renewable energies. |
| Rural Areas | Rural areas not connected with these energy systems have publicly operated diesel power stations |
| Agricultural land | Viability of 1.6 million acre for reclamation and agricultural activities |

The Egyptian government has studied the project, which was then carried out by the Ministry of Economic Development, with the shared participation of Ministries of Housing, Development, and Urban Development; Tourism; Culture; and Irrigation. The studies gained preliminary acceptance for the project’s feasibility with some modifications, emphasizing the feasibility of numerous industrial, agricultural activities with estimated investment of LE243.8 billion, in addition to the viability of 1.6 million acre for agricultural activities, Table 2. (MED, 2008)\(^5\)

Table 1, discusses the identical components of the Egyptian Development Corridor and the structure of recent VLS-PV utilization in magnolia desert (Table 1-b). This experiment indicates the feasibility of the Egyptian strategic vision of combining the VLS-PV concept with methodology for developing the proposed agriculture desert regions in the Development Corridor.
The Proposed Combined Concept

VLS-PV Provides Egyptian Desert Development

Fortunately, the abundant of agriculture regions emphasize the integration with studies carried out by Tokyo University of agriculture and Technology. The main concern was the investigation for developing and constructing a new concept of integrated RE technologies and VLS-PV within the agriculture community in arid regions.

Tab. 2: Developmental Corridor axes and the studied developmental activities in 2050.

<table>
<thead>
<tr>
<th>AXES NAME</th>
<th>Industry</th>
<th>Agricultural &amp; Reclamation</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexandria Axis</td>
<td>20,4</td>
<td>3,5</td>
<td>23,9</td>
</tr>
<tr>
<td>Tanta (Delta) Axis</td>
<td>7,2</td>
<td>9,3</td>
<td>16,5</td>
</tr>
<tr>
<td>Al-Faiyum Axis</td>
<td>20,5</td>
<td>-</td>
<td>20,5</td>
</tr>
<tr>
<td>Cairo Axis</td>
<td>12,0</td>
<td>3,1</td>
<td>15,1</td>
</tr>
<tr>
<td>El Wahat El Bahariya</td>
<td>28,2</td>
<td>0,7</td>
<td>28,9</td>
</tr>
<tr>
<td>Al Minya Axis</td>
<td>10,8</td>
<td>-</td>
<td>10,8</td>
</tr>
<tr>
<td>Assuit Axis</td>
<td>20,7</td>
<td>1,9</td>
<td>22,6</td>
</tr>
<tr>
<td>Qena Axis</td>
<td>17,5</td>
<td>1,4</td>
<td>18,9</td>
</tr>
<tr>
<td>Luxor Axis</td>
<td>10,7</td>
<td>-</td>
<td>10,7</td>
</tr>
<tr>
<td>Kom Ombu-Aswan</td>
<td>21,3</td>
<td>10,3</td>
<td>31,6</td>
</tr>
<tr>
<td>Toshka Axis</td>
<td>11,0</td>
<td>11,0</td>
<td>22,0</td>
</tr>
<tr>
<td>Abo-Simple -Nasser</td>
<td>22,3</td>
<td>-</td>
<td>22,3</td>
</tr>
<tr>
<td>Total</td>
<td>202,6</td>
<td>41,2</td>
<td>243,8</td>
</tr>
<tr>
<td>Percentage</td>
<td>83 %</td>
<td>17 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Based on national studies conducted to determine the successful community models for Egypt, numerous types of proposed community that are able to collaborate on agriculture and technology have been recommended. The following types are particularly recommended by the VLS-PV Research Group for the Egyptian desert: (1) collaborating on agriculture and technology; (2) economically sustainable community; and (3) self-supporting community (Kurokawa, et al. 2007). In the following, the study introduces the “Green Mines Community;” a proposal to deal with the national strategic vision discussed above. It illustrates the developed model for promoting community constituents, units, forms, and their related studies, Figure 5.

Fig.5: GrMC’s Framework adapted to VLS-PV research studies. (Kurokawa, et al. 2007)
PROPOSAL STRUCTURE, STUDIES, AND FORM

The Proposal Structure
This proposal discusses the development of the desert by utilizing the potentials for reclamation regions on the Delta’s borders and the fertile lands in the desert areas (Figure. 6). The concept was built upon the following themes; (1) development in reclamation regions in the desert; (2) agricultural-based development; (3) combined utilization of renewable energy like bio-fuels and solar energy in particular; (4) adoption of VLS-PV systems in the holistic design; and (5) creation of new self-sufficient community in the desert with electrical export potentials by using VLS-PV systems. (Sudany- GrMC, 2008)

Fig. 6: Targeted points for achieving sustainability within the GrMC proposal.

Project’s Proposed Unit,
The proposed name “Green Mine Unit” - inspired from the Mine Unit expression used in Word War II – is determined to serve newly reclaimed regions by working as a wide-range dwelling in the centre of agriculture pivotal unit system. The unit is recognized as a dwelling and initial storage for the daily agricultural activities. It has a biomass sub-tank, recycle system, technical room for PV batteries, and other services. Figure 8

Fig. 7: Studies for PV tracking system with time, installed on units (El-Sudany, 2008)

Solar energy and biogas are the main energy sources for the unit. Solar tracking system is used to provide shadows for the unit’s south-facing surface (Fig. 7), decrease the direct solar gain, and convert it into electricity. Besides, agriculture residues are utilized to draw bio-fuels. Earth-sheltered building techniques are used to keep the integration between the unit and harsh climatic conditions in the desert, and creation of trained local inhabitants to manufacture their own materials and build their own units.

Fig. 8: Plans of the GrMC unit, illustrating the dwelling components. (El-Sudany, 2008)
Community Form,

With bringing forth aggregated units in hundreds and thousands, a small self-sufficient community will be created, where electrical energy and bio-fuels for the daily human and agricultural activities will be locally produced. The uniform shape category will be dictated by specific urban planning criteria, the irrigated agricultural landscape, the social structure, and the aesthetic value to be determined. The planning is neatly structured to ensure the most efficient use of land; using simple natural materials and the earth sheltering technique to provide comfort in a thermal and physical sense. (Sheta, 2000)17

![Fig. 9: a- GrMC form as visioned -b- Installation of PV cells on the Units.](image)

CONCLUSION AND RECOMMENDATIONS

This paper presents a cohesive concept that combines the international visions for developing the desert with the corresponding national strategic plan. GrMC is a versional and feasible community still through R&D stage; the model that embodied our vision structure and outlines. Finding and recommendation of the research paper can be summarized in the following:

- Utilization of renewable energy and solar energy in particular, whether in large or small scale, provides sustainable frame for the new urban communities in the desert.
- Developing the desert needs more innovative visions, studies, and developing of creative thoughts and concepts to make it possible.
- The integration between architectural and developmental visions is a necessity to create sustainable communities in desert regions.
- Obstacles for developing the Egyptian desert can be overcome by fulfilment of the scientific methodology, developmental; not conquering thinking, and national, provincial, political, economic, commercial, cultural and societal ambitions.
- The importance of achieving the vision of VLS-PV system within the overall developmental, urban, and architectural framework, to insure the feasibility and dissemination of PV technology; especially for desert communities.
- Sustaining VLS-PV vision with urban and architectural studies will make the proposal more available to as many architects and developers as possible. Therefore, they will be able to pose sustainable and futuristic visions of VLS-PV upon the future designated communities.
ACKNOWLEDGMENT

This paper is derived in part from the Masters’ thesis and concurrent research project developed by the authors through the ESU95% lab. We would like to thank our colleagues Eng. Mahmoud Ramadan and Ahmed Helmy for the effort they have contributed in the lab initiation and activities, and acknowledge the inspiration and experience of the scientists Prof. Farouk El-Baz and Kosuke Kurokawa, whose perspectives and thoughts of developing the world’s desert helped formulate our own.

Conducting Research
GrMC planning & Infrastructure – GrMC’s Unit Details and Materials

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7 El-Zalabany, A., “The First Solar Thermal Power Plant in Egypt; solar thermal power and desalination symposium” New & Renewable Energy Authority ( Cairo; Cairo University, 2007).


10 VLS-PV (Very large Scale Photovoltaic): the project is based, under the umbrella of the international Energy Agency (IEA) Photovoltaic Power System Program (PVPS) Task 6 in 1998. The new Task 8-VLS-PV power generation Utilizing Desert Areas- was established in 1999.

11 Otto S., UNEP/GRID; G. Sestini, F.; Remote Sensing Center, Cairo; DIERCKE Weltwirtschaftsatlas


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BIOGRAPHY

Moamen El Sudany is an assistant teacher and researcher in the Dept. of Architectural Engineering at Mansoura University. He was a founder member of the ESU 95% lab- a scientific research group- for studying the sustainable urbanism of Egypt’s 95% of land. Moamen is involved in the integration of architectural studies with the glocal issues, and he is interested in the architectural competitions, academic, and scientific activities.

Ahmed Rashed is a professor of urban and Architecture in British University in Egypt, and previously, Chair of Mansoura Architectural Dept., he carried out leading initiative for adopting, studying, and discussing the national issues as “Egypt the future” and “Developmental Corridor” in the architectural education. He is the founder of - ESU 95% Lab.; in Mansoura University, and Centre for Sustainability and Futuristic Studies; in British University.

Sherief A. Sheta is an associate professor and BSc in Architectural Engineering, Department of Architectural Engineering, Faculty of Engineering, Mansoura University, where he’s taught since 1993. Sheta received both his PhD and MSc from Mansoura University in Egypt, and BSc from the Department of Architectural Engineering, Faculty of Engineering, Alexandria University in 1991. He worked as a visiting Assistant Professor in the Department of Technology Systems, East Carolina University in August 2007 thru May 2008. His research focuses on sustainable architecture (planning and design) with particular stress on design development theories and technique; interrelated socio-economic fields; and human-related issues.