FEASIBILITY OF USING VLS-PV SYSTEMS IN FUTURE EGYPTIAN CITIES

Case Study "Suez Canal Region"

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Abstract— *The international project, Very Large Scale Photovoltaic (VLS-PV), is considered one of the international promising projects that discuss the potentials for developing the world's desert by using large scale Photovoltaic plants. Urban-scale photovoltaic applications have been sponsored by the International Energy Agency (IEA) and discussed through Photovoltaic Power System Program (PVPS) through "Task 10" in 2004, in addition studying the use of "photovoltaic services for developing countries" through "Task 9" started in 1999. The tasks aim to improve the utilization of PV systems in the urban environment, as part of the global trends for maximizing building energy efficiency by using renewable energy systems. Studying the feasibility of VLS-PV projects for developing the deserts in Egypt and other Middle-East countries, has a wide interest in research activities through the last years, specially studying of the urban and architectural infrastructure for the proposed VLS-PV community and feasibility in the Egyptian desert, beside studying of socio-economic, energy, and developmental constituents of desert communities. Through the studies, VLS-PV project has been introduced as the most promising project that may combine the international trends regarding renewable energy and sustainable development, with the recent national developmental trends and proposed scenarios.*

In this context, the research paper presents the ability of using building integrated PV systems 'BIPV' to improve energy efficiency in the Egyptian' cities, throughout presenting case study of "El-Mostakbal city" in Suez Canal region, as a part of studying the feasibility of implementing VLS-PV stages. The research findings and recommendations are forwarded to the development of urban and architectural design strategy for the recent and future Egyptian cities, to be more adapted to use renewable energy integrated systems.

Keywords: *VLS-PV, Energy from the desert, Egyptian Cities, PV System simulation.*

INTRODUCTION

There are wide prospects that fossil fuel horizon is relatively short, as 40 years left for oil and 65 years for gas; the fact that calls for immediate humanity needs to move away from the use of greenhouse gas producing fossil fuels towards a greater dependence on clean renewable energy. For instance, in industrialized countries, building sector is the biggest single indirect source of carbon emissions generated by burning fossil fuels, largely through buildings, in use or construction, account for over 50% of total emissions.

Studies have demonstrated that, reducing carbon intensity (carbon per unit of energy) can occur independently of a reduction in energy intensity (energy per unit of economic activity). In this regard, the use of energy efficiency measures can contribute to reduce carbon emissions from houses by 60% or more, while it is possible to reach the 90% level of reductions required by using renewable energy technologies. In UK, for instance, research demonstrated that it is technically possible to meet the 60% target with a combination of energy efficiency measures and new low-carbon technologies there.

It is noteworthy that there are international competitive efforts to promote the use of renewable energy systems (RE) in built environment, to work as main source energy sooner rather than later, and shifting away from conventional fossil fuel energy systems. So, in recent years, we explored rapid development in grid-connected building-integrated photovoltaic (BIPV) systems, based on the government-initiated renewable energy programs, aiming at the development of renewable energy applications and reduction of greenhouse gas emissions.

Here, the research studies the feasibility to attach renewable energy system into built environment in the Middle-East and North-Africa regions, to contribute achieving sustainable development of recent and future communities, studying the feasibility of using Very Large Scale Photovoltaic project's framework and strategy in future Egyptian cities.

AIMS OF THE RESEARCH

The paper aims at approaching the following issues:

- Studying, analyzing and development of the existing urban and architectural strategies in Egypt, to contribute to the future new sustainable settlements located in the Egyptian hinterlands and desert areas.
- 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.
- Studying the feasibility for using integrated solar energy technologies into the recent and future Egyptian cities, through examining the capacity for integrated PV system, to contribute the cities' energy efficiency and enhancing cities sustainability.
- Promoting the recent and future strategies related to urban and architectural design in the Egyptian governmental projects, implemented in desert and hinterlands, by expanding the body of knowledge to a larger scale of sustainable photovoltaic application in local urban communities.
- Enriching urban and architectural design guidelines with the criteria of installing solar energy system in built environment.

METHODOLOGY

The research is determined to examine the major potentials for integrating renewable energy technologies, using electrical solar energy applications in specific, into the Egyptian built environment in hinterlands and desert areas. As part of author's research studies related to examining the feasibility for using VLS-PV project and methodology for developing the Egyptian desert, using sustainable framework. In collaborative effort with the second author, the study stems from former theoretical studies, in Suez Canal region, using (Mostakbal City) as a case study, as it has an optimal and suitable infrastructure for the research, and using examining grid-connected PV systems into the urban context.

Through the Case study, different numbers of parameters are considered requested to design and installing of PV systems, using simulation tools for estimating the average performance of PV system in different positions in the built environment. The results have been complied into performance graphs. The introduced graphs are mainly focused on:

a. Relation of annual energy performance versus PV panel feasible angels and area for different dwelling blocks.

b. Energy output of PV systems based on panel's tilt and azimuth angles.

Simulation Tools,

The Author uses the following modeling and simulation programs to form and examine the PV system accurate performance, as follows;

Modeling tools;

- *AutoCad* (2D-3D); for calculating the effective and suitable roof area for PV panels, and modeling building blocks by shape type.
- *ECOTECT*; for determining the annual range of self-shading, and ambient shading of PV Panels installed on different types of roofs.

Simulation tools;

- *PV-SYST*; for PV system specifications and calculations- simulation of PV system hourly, daily, and annual performance – calculation of the seasonal needs of electricity per dwelling.

VLS-PV; THE INTERNATIONAL PROJECT

VLS-PV project, as mentioned above, is introduced as one of the recent international promising projects that aim at contributing substantially to global energy needs by using very large-scale photovoltaic plants located in the world's desert. Large-scale photovoltaic applications have been sponsored by the International Energy Agency (IEA). It discussed Photovoltaic Power System Program (PVPS) through a research project called 'TASKS' which has been divided into numerous sub-tasks. The project - started since 1999 to date - has introduced promising ideas aiming mainly to contribute to the following sides;

- *Global environmental protection, and renewable energy utilization in the long term;*
- *Economical and technological feasibility; and*
-
- *Socio-economic development, especially for developing countries with large desert areas.*

The research project (Task 7) titled "Photovoltaic power systems in the built environment", started in 1997 and was concluded in end 2001, is considered one of PVPs' important tasks, as it is related to the built environment and enhancing the architectural quality, the technical quality and the economic viability of PV, which contribute directly to energy efficiency strategies in urban and architectural building context. It involves the creative contribution of architects, urban planner, and building engineers.

In addition, the research project "Task 7" is a part of three approaches considered to encourage the spread of PV systems, which open the door for implementing the holistic proposal of VLS-PV stages, as shown in the following steps.

c. **Establish small scale independent PV systems** into **two scales**:
   - *installing stand-alone,* **several *hundred watt-class PV*** *systems for private dwellings,* and *installing 2 to 10 kW-class systems on the roofs of dwellings, 'used in developing countries, as the solar home system (SHS)',*
   - *and* ***10 - 100 kW****-class systems on office buildings and schools. ' used in industrialized countries'*

d. **Establish 100 to 1000 kW-class mid-scale PV systems** *on unused land on the outskirts of urban areas, as germinated by PVPS/Task 6-8, and their number is expected to increase rapidly in the early 21st century to multi-megawatt size.*

e. **Establish *PV systems larger than 10 MW*** *on vast barren, unused lands that enjoy extensive exposure to sunlight. In such areas, a total of even more than 1 GW of PV system aggregation can be realized.*

- **VLS-PV & BIPV: Integration in Urban Development and Architecture:**

Building-Integrated Photovoltaic (BIPV) is now a part of every architect's vocabulary. 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.

Dissemination of BIPV systems – extended with the use of VLS-PV – is hypothesized to form the combined strategic vision for developing the Egyptian cities and contributes desert development, and as part of the proposed cooperation between Euro region and North African for renewable energy links, so-called "EU-MENA renewable Energy links (TREC)". (Figure 1)

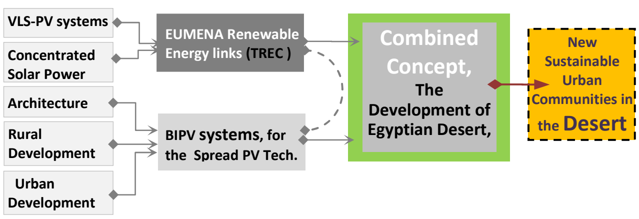


FIGURE 1

DEVELOPING THE DESERT BY USEING BIPV AND VLS-PV, THE PROPOSED SCENARIO FOR EGYPTIAN DESERT DEVELOPMENT.

INTERNATIONAL EXAMPLES; USING RE- SYSTEMS;

The international project and initiatives provided numerous contributions to urban and architectural research and knowledge related to renewable energy integration in built environment, and achieving principles of sustainability in world's recent and future built environment. In this context, it is noteworthy to refer to IEA PVPS Task 10, the project which aims to enhance the opportunities for wide-scale, solution-oriented application of photovoltaic power electricity production in the urban environment as part of an integrated approach that maximizes building energy efficiency and solar thermal and photovoltaic usage. It considers numerous sides such as value analysis, policy incentives, as well as system design and integration that have proven successful in the IEA' participating countries.

The research discusses the main objects, used energy system, and installation type of solar applications in three international leading urban projects; examines large scale applications of PV system as a main source of energy; and ends with the an analysis of the most recent zero-Energy project "Masdar City" initiated at Abo-Dhabi, UAE, designed by architect Norman Foster and partners, Table 1.

TABLE 1

COMPARISON BETWEEN THREE MAIN EXAMPLES OF SOLAR CITIES.

Solar City- Linz Pichling – Austria	
	- To create a base for the **future social residential housing project**. - Achieving pillars of Sustainability; (economic growth- ecological balance- social progress) and Achieving the principles of **sustainable Architecture**.
System	- **GRID-CONNECTED** - Energy conservation & Energy supplying - High utilization of **solar thermal systems** (**passive systems**). - Utilizing of solar electrical systems (**Active systems**).
installation	- **Roof Case**; (BIPV) Fixing solar thermal collectors and PV cells , - **Façade Case**; Intelligent utilization of passive systems and high thermal capacity materials - **Passive systems**; Uses of centralized servicing, in vertical cores, with integrated heat
Solar Village Amersfoort-Netherland	
	- **Reducing of CO2** emissions and strategy for supplying 3.2% of electricity form RE sources. - To examine the **impact of using solar power at district level.** - Demonstrating the **technological** and **architectural** potential of **BIPV.**
System	- **GRID-CONNECTED** - **Achieving of 1MW energy generation** from: - Solar Photovoltaic systems - Solar / Gas combination unit has been installed in each house.
installation	- **Roof Case; (BIPV)** Fixing solar thermal collectors and Photovoltaic cells , - **Façade Case;** Intelligent utilization of passive façade systems . - **Other cases;** installing PV panels in Urban Tools as garages and shades.
Masdar City Abu-Dhabi- UAE	
	- New sustainable city in abu-Dhabi to imitate a new sample for **future cities**. And to achieve a **Zero Carbon** and **Zero waste Community.** - To develop the utilization of **Renewable energy**, especially **solar energy systems.**
System	- **GRID-CONNECTED** - Using of **Photovoltaics plants** outside the city to generate energy and Installing **Photovoltaic cells on city's roofs**. - In combined with other renewable types like (Wind, Geothermal, Biofuels), to generate energy for the city and connected to grid.
Install-ation	- **Very large-Scale Photovoltaic** power plant. - **BIPV**; installing PV panels in building roofs. - Using of Passive systems.

REGION OF STUDY; Ismailia Governorate,

Ismailia is the middle of three governorates located by the Suez Canal strip, **(Latitude: 30.6053 - Longitude: 32.2772).** The importance of Ismailia is built upon its central location and significant increase of different activities such as; social structure, industrial, and agricultural development, such case that gives it remarkable potentials to sit an integrated technological industrial zone, based on the former infrastructure located in Ismailia eastern bank. The project's first stage started in 1994 by the Egyptian government to develop high technological and electronics industry, similar to the technology valley "Silicon valley" in USA, China, and India.

In this context, added to other educational and physical infrastructure, Ismailia has been select as one of the optimal locations to study the future of renewable energy integration into built environment, especially the western bank of the governorate where numerous industrial developmental activities are located. As a recent development, the new expansion of Ismailia city called "El-**Moastakbal city**", has been established as a new residential complex for youth and employments in the industrial zone. (Figure 2)

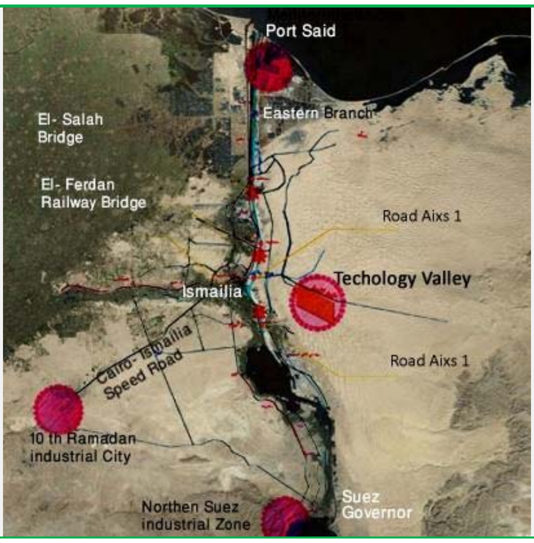


FIGURE 2
SUEZ CANAL REGION MAIN PROJECTS AND TRANSPORTATION NETWORK.

CASE STUDY; (El Mostakbal City)

The objective of this study is to examine the ability of using PV cells to fulfill the electricity needs in the near future — 20-50 year— when most of the world cities are expected to use solar energy as a main or secondary source of energy after the depletionof fossil fuels, and when cost analysis of PV system will be far more competitive.

(Figure 3), illustrates the site components and the ambient and main circulation routes connected to the site. The new implementation provided an extension to the dense city center of Ismailia City to serve the new industrial and free zones located around the site.

Site' Advantages:

The city considered a suitable site for studying solar energy application as new urban community, and an example for the governmental housing models of the industrial communities in Egypt.

Field Trip;

Field trip to site provides clear understand to the urban and architectural context of the city, and surveying on social and economical, and technical sides and the economical infrastructure also.

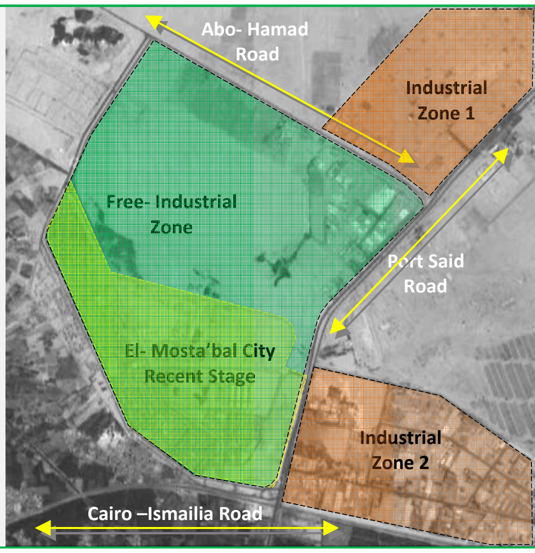


FIGURE 3
EL-MOSTA'BAL CITY BORDERS.

Social Context

1- The new community consists of educated inhabitants, between **good and medium education levels**.
2- There is a **technical group** from the community that will be responsible for **maintenances processes** and checking the **system performance**. (Figure 4)

The city contains the following Components:

1-	Economic Housing – level (2)	- **Zone A**
2-	Housing – level (2)	- **Zone A"**
3-	Economic Housing – level (3)	- **Zone B**
4-	Housing – level (2)	- **Zone B"**
5-	Housing – High level (1)	- **Zone C**
6-	Economic Housing – level (3)	- **Zone E**
7-	The Main wholesale Center	- **Zone D**

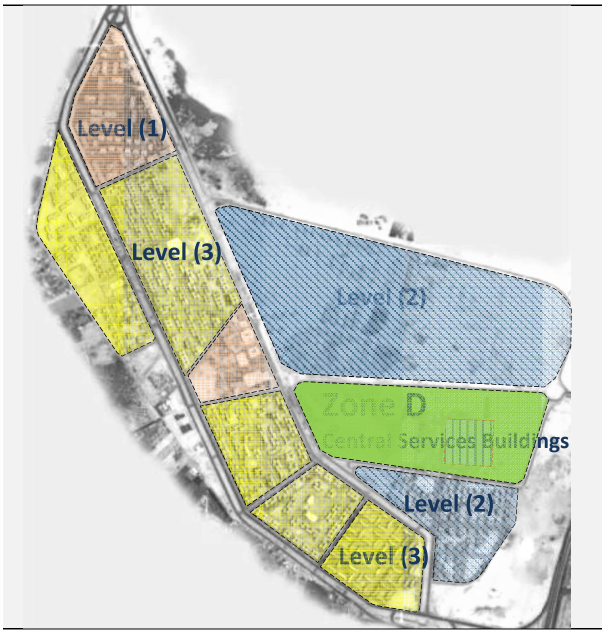


FIGURE 4
CLASSIFICATION OF EL-MOSTA'BAL ZONES BY LIFE-LEVEL.

Study Assumptions

The examination of site for installation of photovoltaic cells depends on the following assumptions and requirements:

- **System Assumptions**

a. Using **Grid-Connected** system**;** as the city is already connected to grid, and to avoid the extra costs of Batteries. (Figure 5)

b. Using of **high or medium efficiency** *(Mono crystalline 24 %- or - poly crystalline 13%)* of Solar cells for producing maximum electrical power, and injecting surplus electricity into national grid.

c. **Subtracting (25%) of the roof total area —specified into the Egyptian Building standard Code—** for other inhabitants' uses and equipment (e.g. antennas, water tanks…etc).

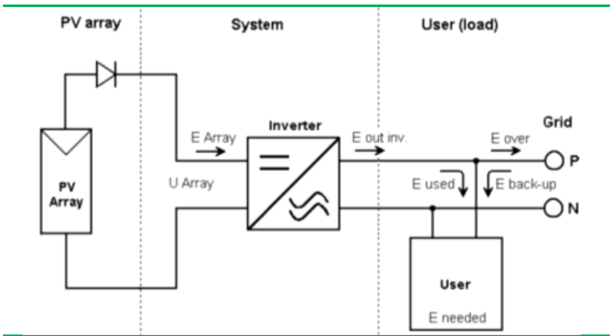


FIGURE 5
GRID CONNECTED; SYSTEM SCHEMA

- **Effective Roof Areas by the Block Shape,**

Studying the effective roof area for installing PV system is important to determine the available net areas for determining the structural system, as well as predicting the effective distribution of PV panels on roof, while subtracting maintenance paths and panels' self and physical shadows yearly range to emphasis more accuracy of the study, Figure 6, analyzed through Table 2.

FIGURE 6
BUILDING SIMULATION FOR ANNUAL SHADOW, AND PV POSITIONS.

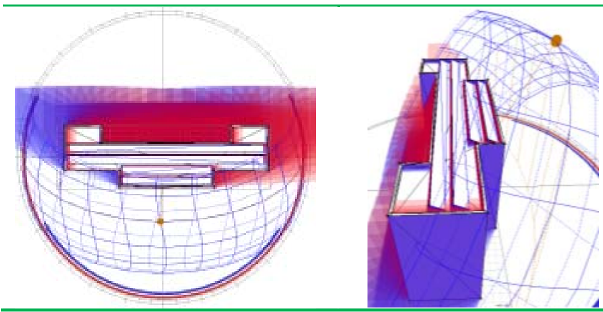
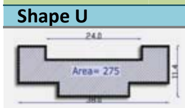
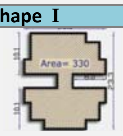
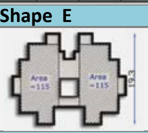
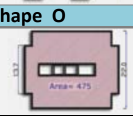


TABLE 2
ANALYTICAL STUDY FOR PV SYSTEM AREA PER BLOCK ROOF AREA.

El-Mostakbal City Units / Units Shapes	Total Numbers	Orientation	Net Roof Area- PV	Total PV Area	Covered U.	Un-Covered units	Evaluation
Shape U 	60 block Zone **E**	55^{0}/axis **N-S**	206 m^2	12375 m^2	8	8	51 %
Shape I 	45 block Zone **A"** / 20 block Zone **B"**	24^{0} /axis **N-S** / 24^{0} axis **N-S**	248 m^2	16088 m^2	12	4	77 %
Shape Z 	30 block Zone **E** / 156 block Zone **B"**	24^{0} /axis **N-S** / 24^{0} /axis **N-S**	248 m^2	46035 m^2	12	4	62 %
Shape H 	97 Block Zone **A** / 30 block Zone **A"**	12^{0} axis **N-S** / 12^{0} /axis **N-S**	206 m^2	26194 m^2 + 5400	10	6	77 %
Shape II 	75 block Zone **B/ 30 Unit** Zone **E**	24^{0} /axis **N-S/ 55^{0}** Axis **N-S**	203 m^2	21263 m^2	8	8	64 %
Shape E 	84 block Zone **C**	24^{0} /axis **N-S**	173 m^2	14490 m^2	7	9	51 %
Shape O 	28 block Zone **B"**	24^{0} /axis **N-S**	356 m^2	9975 m^2	18	6	41.5 %

PV System Specifications,

- **Energy consumption, based dwelling types,**

In Egypt, the difference between seasonal consumptions is significant, especially in terms of using ceiling fans in summer. Consequently, ***Seasonal modulation*** and ***hourly energy distribution*** are essentially used for determining the specific energy consumption of occupants is based mainly on life standards. In this sense, the calculations are classified into types related to soci-economic dwelling categories. (Table 3)

Increasing of daily energy fraction to the peak are considered also into calculations, through 4h at night times, 1.5h in morning times, and 1h in evening times, as they represent the main critical times for dwelling activities and consequently, for the direct energy used form PV modules' production duration.

TABLE 3

ELECTRICAL TOOLS & ENERGY CONSUMPTION PER DWELLING LEVEL

INSTALLED TOOLS	No.	Power	Use	Energy
Fluorescent lamps	5	30 W/lamp	2 h/day	300 Wh/day
TV / Video-tape. / PC	1	75 W/app	3 h/day	225 Wh/day
Domestic app. (Fans)	3	45 W/app	8 h/day	1080 Wh/day
Fridge / Deep-freeze	1	3000 Wh/d.	3000 Wh/d.	3000 Wh/day
Dish /Cloth-washer	1		860 h/day	860 Wh/day
Other uses	1	1500 W tot	0 h/day	450 Wh/day
Stand-by consumers	-	6 W tot	24 h/day	144 Wh/day
Total daily energy				6059 Wh/day
Average per year	Seasonal modulation global			2120 kWh/year
LEVEL (3) Blocks	Without (Heater/ Dishwasher)			6066 W/h/day
LEVEL (2) Blocks	With (Heater)			7478 W/h/day
High LEVEL (1)	All Utilities (Dishwasher)			7935 W/h/day

- **Azimuth angles, by Blocks Zone.**

By studying the urban context for the city in general, it has been observed that four main groups of residential blocks are arranged in three main angles: first group, with deviation angle approx. (zero^{o} from axis E-W), second group with deviation angle (-24^{o} form axis E-W), and third group with deviation angle (35 ^{o} from axis E-W), and finally, the wholesale center (zero^{o} from axis E-W), Figure 7.

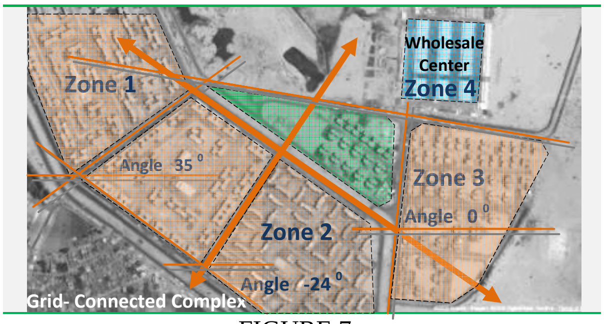


FIGURE 7

ANALYTICAL STUDY OF BLOCK ORIENTATION PER URBAN ZONE

- **PV System Performance, Based Azimuth Angles.**

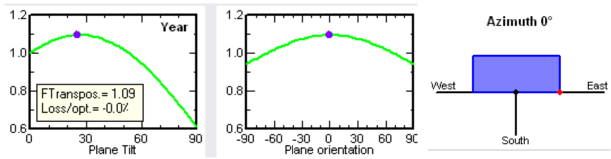
Tilt angles of the three cases are fixed as an optimal orientation for the system over the year, while Azimuth angles of three residential groups are considered in calculations for installing PV system. Table 13, illustrates the predicted loss of energy generations of PV panels through the different panel positions. The first case emphasizes the optimal orientation of PV panels and minimum energy losses, while the second and third indicate gradual increasing losses with respect to optimum orientation. (Table 4)

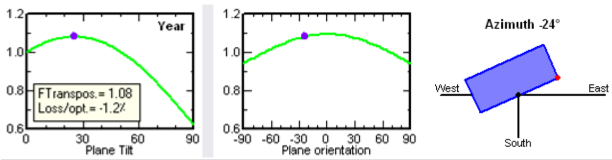
Note: Though the optimal orientation of the Wholesale center is considered, the case is neglected as the roof is folded from the center point of shape, a case which requires installing specific structure to fix PV panels and thus conflicts with the building form and function.

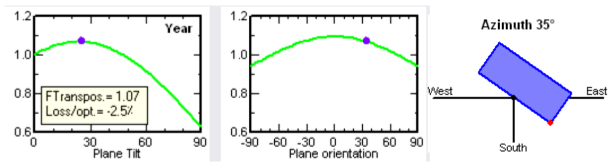
TABLE 4

STUDYING THREE AZIMUTH ANGLES CASES OF THE PV PANELS

PREDICTED PERFORMANCE OF PV	Simulation variant
- Transposition factor FT = 1.08 - Loss by respect to optimum = 0.0 % - Global on Collector Plane = 2284 kwh/m2	Tilt 25° azimuth 0°
- Transposition factor FT = 1.08 - Loss by respect to optimum = - 1.2 % - Global on Collector Plane = 2257 kwh/m2	Tilt 25° azimuth -24°
- Transposition factor FT = 1.07 - Loss by respect to optimum = - 2.5 % - Global on Collector Plane = 2228 kwh/m2	Tilt 25° azimuth 35°







- **PV system analysis and specifications.**

Table 13, illustrates the examined adapted tools of PV panels and inverters used, and classifies the specifications of PV's modules' type, number, and area per dwelling's needed energy in worse cases where stand-Alone system is activated. Inverters' specifications are also studied to invert DC current into AC. PV modules area is app. 23 m^2 (to cover 2.3 kWp, the annual average of energy used), the number which will play an important role in determining the stockholder of each dwelling with the available roof area. (Table 5)

TABLE 5

SPECIFICATIONS OF PV MODULES AND INVERTERS USED FOR SYSTEM

Near **Shadings**	-	Average Height		**1.4 C**
PV Array Characteristics				
PV module	Si-poly	Model	PQ40K	
Number of PV modules	In series 2 modules		In parallel 23 strings	
Total number of PV modules	Nb. Modules	46	Unit Nom. Power	50 Wp
Array global power	**Nominal-(STC)**	**2.30 kWp**	At operating conditions	2.10kWp (45°C)
Array operating chart. (50°C)	U mpp	33V	I mpp	63 A
Total	**Module area**	**22.9 m2**	Cell area	18.4m2
Inverter Characteristics				
Inverter Model	M 19072 208	**Manufacturer >>**		Enphase
Characteristics	Operating Voltage	22-40 V	Unit Nom. Power	0.19 kWAC
Inverter pack	Number of Inverter	11 units	Total Power	2.09 kW AC

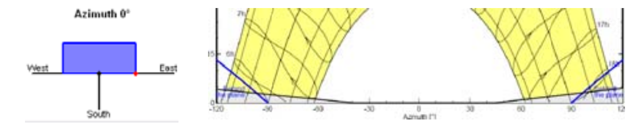
- **Energy Output.**

For Analyzing and comparing of PV system performance in the three planned cases, *PV-SYST* simulation program has been used, based on comparing four sides, *first*, azimuth angle and parameters effects on horizon line, *Second*, PV's produced and specific energy, and system performance ratio, *third*, yearly energy average, and normalized production per month, and *finally*, the energy distribution to user grid and from grid. **Table 6** illustrates the results of PV system performance in the three cases of study.

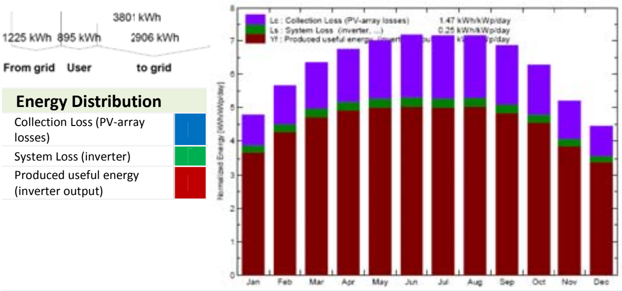
TABLE 6

COMPARISON OF PV SYSTEM PERFORMANCE

MAIN DATA	**PV system Performance**
Tilt 25° azimuth 0°	

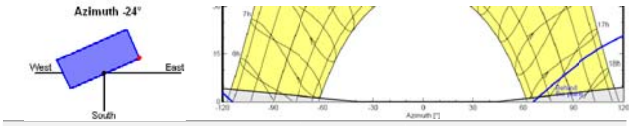


Produced Energy	**3801** kWh/year
Specific production	**1653** kWh/kWp/year
Performance Ratio	**72.5** %
Effective energy at the output of the array (E-Array)	**4009.1** kWh/year
Energy injected into grid (E-Grid)	**3801.2** kWh/year

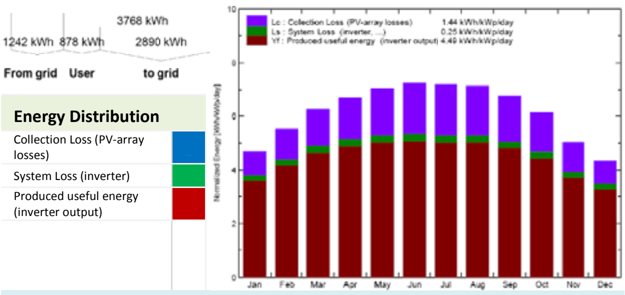


Normalized productions (per installed kWp): Nominal power 2.30 kWp

Tilt 25° azimuth -24°

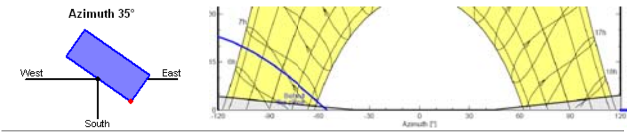


Produced Energy	**3768** kWh/year
Specific production	**1638** kWh/kWp/year
Performance Ratio	**72.7** %
Effective energy at the output of the array (E-Array)	**3975.0** kWh/year
Energy injected into grid (E-Grid)	**3767.9** kWh/year

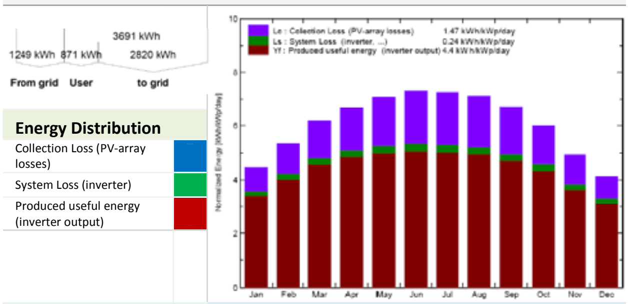


Normalized productions (per installed kWp): Nominal power 2.30 kWp

Tilt 25° azimuth 35°



Produced Energy	**3691** kWh/year
Specific production	**1605** kWh/kWp/year
Performance Ratio	**72.0** %
Effective energy at the output of the array (E-Array)	**3893.9** kWh/year
Energy injected into grid (E-Grid)	**3690.7** kWh/year



Normalized productions (per installed kWp): Nominal power 2.30 kWp

- **Accumulation of Energy:**

The difference of energy output of single dwelling for the three cases of PV installation was somewhat small. However, by using simple calculation, and multiply yearly energy output of block (shape U) with the total number of blocks in (zone 2) for the different cases, it will be, (zero^{o}-Azimuth- 104,5275 kWh/year), (-24^{o} –Azimuth- 103,6200 kWh/year), and (35^{o} –Azimuth- 101,5025 kWh/year); the numbers that demonstrate a wide gap of energy production between the first and final case of PV installation.

STUDY FINDINGS

The study carried out on El-Mostakbal City in Ismailia Governorate helped understand the potentials for installing PV system on roof in medium and long-term periods, and the capacity to cover dwelling's needs of electricity. In addition, it helped determining the available areas for installing PV panels on roof per block, and calculating the number of dwellings covered by system in case of utilizing PV Cells as a main source of energy (Stand Alone system).

The fieldtrip and simulation processes, numerous data, charts, and calculations have helped constitute the research findings, which can be classified in the following (Figure 8):

- **Urban and Architectural Design**

Urban and architectural design has significant impacts on PV system's orientation, area for installation, design, and energy output as follows:

a. Urban design and orientation effects on the orientation on PV system in general.
b. Different urban orientation affects directly the distribution of PV panels on roof as a result of the shortage of panels' number.
c. The architectural design of roofs has negative effect on panels' number.
d. In cases where shadow range was large, the extended battery core of building exceeding roof levels would have a large effect on the number of panels.
e. In other cases, the architectural design of roof caused failure of selected PV panels and structure. Such a case requires alternative solutions of PV type that might be unavailable, expensive, or resulting in inadequate efficiency.

- **Orientation;**

The orientation of PV panels has direct effects on the following parameters:

f. The efficiency of yearly PV cells production,
g. Shadow range of panels, casted on each other panels,
h. Effective capacity of roof's area for installing panels,
i. Although the optimal orientation of (Zero^o-Azimuth) with performance ratio (72.5%) has been generally concluded, the performance ratio of (-24^o -Azimuth) was higher (72.7 %).

- **Energy Output**

The orientation of PV panels consequently affects the energy output of panels. The main findings are summarized in the following;

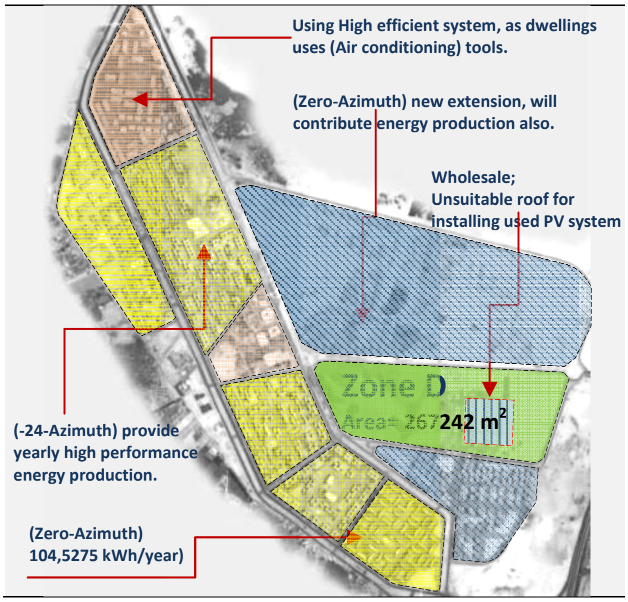
a. The accumulated energy output of the city complex in general will be highly different and effective for every azimuth angle (Zero^o- 24^o- 35^o), although the difference of energy output for single dwelling was somewhat small,
b. The distribution of energy (User - from Grid- injected to Grid), was optimal for the first case (Zero^o-Azimuth), and highly suitable to hourly energy used by occupants, to utilize direct PV' clear energy,
c. Planned PV system (Panels type- inverters) was optimal for all cases, as the energy loss was minimum,

- **Significant Notes**

The following notes discuss other issues that may have not been highly tackled in the study, but still of considerable importance:

a. The extended battery core of building will cause numerous problems for PV system orientation.
b. Orientation angles of more than (-24^o -Azimuth) will cause design problems for PV area and distribution.
c. PV Cells will contribute in providing yearly maintenance for the roof fabrication.
d. The governmental dwelling blocks of El-Mostakbal city will provide a good opportunity for installing PV cells in the future.

FIGURE 7
ILLUSTRATION OF STUDY FINDINGS AND NOTES ON THE CITY.



CONCLUSION AND RECOMMENDATIONS

Simulation results on the performance of the proposed grid-connected BIPV system have been reported. The performance ratio of the optimal case (Zero^o-Azimuth) of this system was found as 72.5%. The study results have shown that the production of PV system produces sufficient electricity for the 50- 60% of dwellings per block unit. The optimal case was (Zero^o-Azimuth) angle, which panels produce more power compared with the same surface area of PV panels with angle (-24° -Azimuth), while the angle (35° - Azimuth) is not recommended.

The project VLS-PV is considered a promising project for the developing countries, although the recent evidence of the economical issues. Technology however should be promoted due to its potentials in terms of environmental protection and contributed to the future sustainable development. Solar energy application for electricity generation using CSP technology is also considered a promising application in Egypt. It is anticipated that renewable energy, especially solar energy and wind energy, will be developed commercially in Egypt in the near future.

Based on the PVPS research programs, world's best practice experiments, and the case study discussed above, there are numerous points of recommendation for upgrading the recent and future Egyptian use of renewable energy technologies, particularly PV system applications. These points can be summarized in three main scales of design as follows:

Urban framework:

The following considerations are required;

- Using optimal orientation — North-south Facing — as possible for reducing the shortage of Electricity output, efficient system installation, and providing flexible adaptation with the building.
- Installing Extra-area of PV cells on roof for un-covered units may need urban modification of building clusters using **Possible Density of Blocks**, without neglecting the minimum distance between blocks in new urban cities in Egypt.

Architectural framework:

- The advantage of using more **number of Block shape** (**O- H- Z-I**) for its high efficient architectural design of roof.
- The architectural design and location of battery core extended upon roof level, must be taking into account, to avoid casted shadow on roof and shortage of PV panels number.
- Possibility of neglecting **Roof Services** area — (**25%**) for Dish and water tanks, and replacing the area by **Using Central Services**, and maximizing the roof area for installing PV panels on roof.

FURTHER RESEARCH

More research and information outreach is needed to add power and dimensionality to VLS-PV studies and techniques for the Egyptian case studies, especially in considering energy efficiency techniques in recent and future urban design of cities. So, we have intents to develop and conduct other research plans forwarded to social, economical, environmental issues through developing an advanced computerized based model, which will contribute to the decision making process of such project in the future.

ACKNOWLEDGMENT

The authors wish to thank the teamwork of the International Energy Agency (IEA), Photovoltaic Power System Program (PVPS), University of Geneva (*PV-SYST program's developer)*, and the national institutions and governmental organizations for providing valuable database and programs that helped in the research processes and outcomes.

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