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The Integration of Stand Alone Photovoltaic Systems in the Development of the Residential Buildings in Al Burullus Graduates Villages

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The Integration of Stand Alone Photovoltaic Systems in the Development of the Residential Buildings in Al Burullus Graduates Villages.

تكامل أنظمة الخلايا الكهروضوئية المستقلة ذاتيا فى تطوير المبانى السكنية بقرى الخريجين بالبرلس

Mokhtar H. Akl and Sherif A. Sheta

KEYWORDS:
Al-Burullus, Solar Energy, Stand-alone photovoltaic (SAPV), PVSYST

الملخص العربي:- تقترح هذه الدراسة منهجية مرتكزة على التقنيات البيئية للعمارة والتصميم العمراني لإعادة تأهيل قرى الخريجين المصرية ببحيرة البرلس كمجاورات سكنية مستدامة. حيث تهدف الورقة البحثية لتطوير التصميم المعماري والتجمعات العمرانية لوحدات الاسكان كي تحقق الاكتفاء الذاتى للطاقة من خلال دراسة تطبيق نظام الخلايا الكهروضوئية المستقل بذاته باستخدام برنامج PVSYST على قرى الخريجين ببحيرة البرلس في شمال الدلتا بمصر، كأحد تطبيقات تكامل نظم الطاقة المتجددة في العمارة والعمران. ويقوم البرنامج باستنتاج مساحة ومكونات النظام الشمسى بناء على تحديد الاستخدامات المختلفة للسكان من الطاقة داخل الوحدة السكنية ودراسة كمية الطاقة الكهربية التى ينتجها النظام الشمسى والفقد المتوقع من الطاقة. وتخلص الدراسة إلى أهمية تطبيق هذا النموذج من خلال استعراض مقترح لآليات التنفيذ فى البلدان النامية وكيفية مشاركة كل الأطراف المعنية ودور كل من البحث العلمى والتعليم والمجتمع والصناعة والقطاعات الحكومية في مصر.

***Abstract*— This paper suggests a technical methodology to regenerate the Egyptian Hinterlands of the Graduates' villages at Al-Burullus Lake into sustainable neighborhoods. The aim of the research is to develop self-sufficient economic housing prototype. The study defines energy potentials and examines the future feasibility for renewable energy integration into rural communities. It aims to develop reliable Stand-Alone Photovoltaic (SAPV) system to residential buildings. The study uses simulation software to develop the reliable SAPV system as well as predicting the yearly energy output. The simulation of the SAPV system configuration is presented using the PVSYST tools software. The simulation defines the total amount of electrical energy generated by PV array supplied to the determined load by users, the various types of power losses, the optimal size of SAPV system configuration, and the total energy flow through the whole year.**

The study recommends the implementation stages of PV systems in developing countries and addresses their impact on research, education, community, industry, and other governmental sectors in Egypt.

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I. INTRODUCTION

BUILDING-Integrated Photovoltaic (BIPV) is now a part of architect's Knowledge, as the installation of PV panels on roofs is the main practical method for cutting the investment cost facilitating and supporting the transition to solar technologies in dense cities and rural communities than is likely to occur at the utility scale [1].

Egypt's energy sector is currently facing a variety of conflicting and overlapping challenges. The National goal as stated in Egypt vision 2030 is "to develop an integrated energy strategy for medium and long-term and maximize the efficient use of various traditional and renewable resources contributing to economic growth, competitiveness, achieving social justice, and preserving the environment"[2]

The research aims to extend the coverage of electricity demand and contribute feasible conditions for the investments and regulatory framework in energy sector in countries located within the solar belt. The case study is selected as an example for urban regeneration of urban/rural areas at the international coastal road at Al-Burullus Lake in Egypt (Fig.1). It is connected to the international coastal road and located into the solar belt [3].

It introduces a part of a research project named" "Combined Renewable Energy Techniques, for the Development of the Egyptian Hinterlands," funded by the Competitive Funding Program (CFP), postgraduate, research and cultural affairs sector at Mansoura University. The project aims to develop self-sufficient economic housing prototype for Al-Burullus Housing units to achieve sustainability of the northern coastal communities in Egypt and examine the future feasibility for renewable energy integration [4].

The research objectives are to analyze the current situation of case study and to study the feasibility of electricity power production using PV cells using simulation methods. It focuses on examining the ability of using integrated VLS-PV systems in the recent and future urban contexts, to improve energy efficiency, and renewable energy use.

Fig. 1 The case Study location
(authors processed by Google Earth)

II. Research Methodology

The Methodology could be organized into 2 main steps:

1) The analysis of current residential units and performing some design modification to be suitable for residents' needs based on field study.

2) The design and installation of PV systems are examined using simulation tools for estimating the average performance of PV system in different positions of the built environment. The results have been complied into performance graphs.

The study uses PV-SYST as the simulation tool to form and examine the PV system and determine its accurate performance. The program defines PV system specifications and calculations- simulation of PV system hourly, daily, and annual performance – calculation of the seasonal needs of electricity per dwelling.

III. Study Model Design

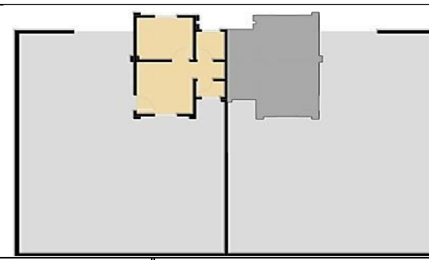
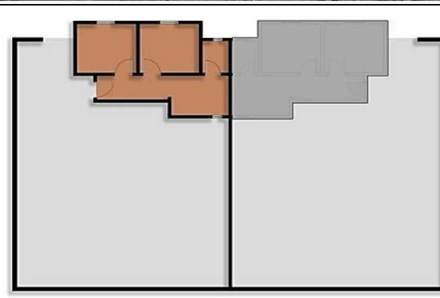
The area is divided into 3 locations named by SidiTalha, El-Said El-Badawy, and Ebrahim El-Desouky villages as shown consequently from right to left in figure 2. They are located at Sidi Salem center at Kafr el-Sheikh Governorate on the north of El-Burullus Lake [4].

Fig. 2 Al Burullus 3 Graduates villages location
[authors processed by Google Earth]

A. Residential Units Modifications

The residential buildings are classified into 2 Types each of them is semi-attached one story building which are: (1) Type A with built area 34 m^2 and 17.5% from total plot area; and (2) Type B with built area 44 m^2 and 23% from total plot area. Table 1 shows the 2 residential building types and design, built area ratio [6].

TABLE 1
Residential building types [authors]

Type A	Built area = 34 m^2 (Flat roofs) About 17.5% from total unit area
	
	
Type B	Built area = 44 m^2 (Flat roofs) About 23% from total unit area
	
	

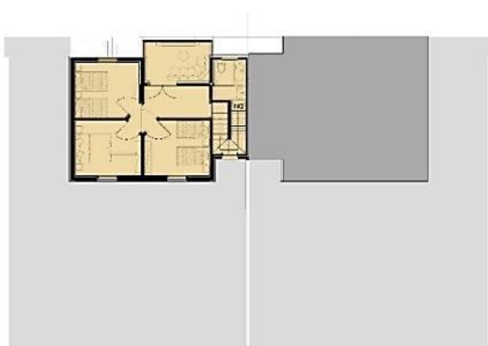
Most of residents made many modifications on the building form and its design expanding its spaces to be suitable for their needs. Other interventions are done by reconstructing new buildings on the whole area with different structure to be further extended vertically without any regulations to control and optimize the building form or design character as shown in figure 3 [6].

Fig. 3. Resident’s interventions [authors]

The research suggests some modifications to the residential units based on residents. Each unit could be extended on the existing bearing walls structure horizontally or vertically to accommodate a family that consists of about 4-6 persons as shown in table 2 and figure 4. So, the total floor areas will be 130 m^2.

TABLE 2
RESIDENTIAL UNITS MODIFICATIONS [AUTHORS]

Residential units Modifications

Ground floor Extension design

Typical floors Extension design

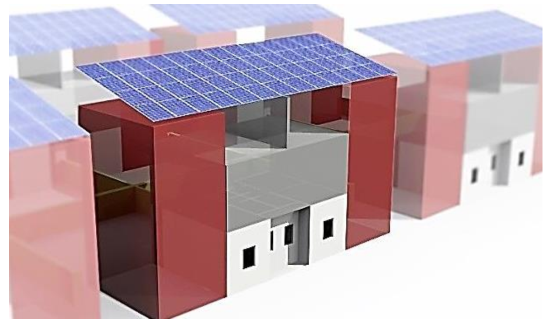


Fig. 4. Extensions potentials and PV Integration [authors]

To perform the simulation of SAPV system, it is important to determine the important inputs which have affected the performance of the system as follows:

B. Geographical of Site Location

The site is located by 31.45°N latitude and 30.62° E longitude. This location has a good potential for solar radiation as shown in figure 5.

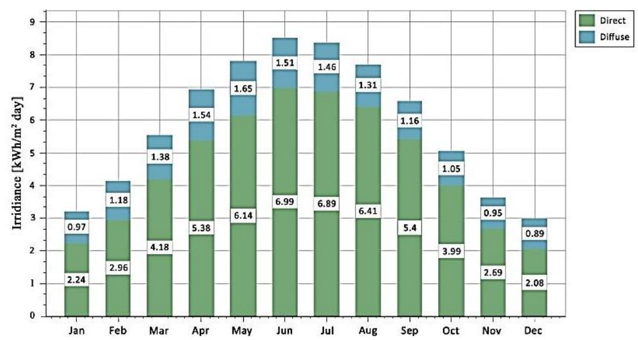


Fig. 5. Solar irradiance for case study site [authors processed by PVSYST]

C. Energy Demand Consumption

In SAPV system, the energy demand is determined according to users’ needs and consumption. The energy demand is determined by the amount of electricity needed, appliances used, and their operating time.

Having fulfilled the data and information needed for the average dwelling consumption though study visits and field surveys, the energy demand for case study is determined and processed by the PVSYST tool as shown in figure 6 and table 3. The average estimation of daily energy is assumed to be 16.5kWh/day according to the energy load requirement.

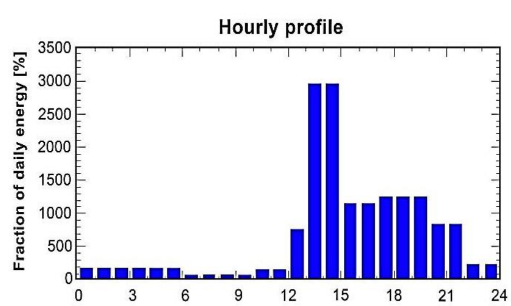


Fig. 6. Energy demand hourly profile [Authors processed by PVSYST]

TABLE 3
APPLIANCES ENERGY DEMAND CONSUMPTION
[AUTHORS PROCESSED BY PVSYST]

	Number	**Power**	**Use**	**Energy**
Lamps (LED or fluo)	10	9 W/lamp	13 h/day	1170 Wh/day
TV / PC / Mobile	5	120 W/app	10 h/day	6000 Wh/day
Domestic application	2	200 W/app	5 h/day	2000 Wh/day
Fridge / Deep-freeze	1		24 Wh/day	1200 Wh/day
Dish- & Cloth-washers	1		2 Wh/day	4400 Wh/day
Fans	3	25 W tot	14 h/day	1050 Wh/day
Stand-by consumers			24 h/day	720 Wh/day
Total daily energy	16540 Wh/day			

D. PV Type and Orientation

The PV system type is selected to be stand alone, fixed at a tilted plane or seasonal tilt adjustment according to the site conditions, performance, and cost preferences as shown in figure 7. In case of fixed PV array the PV array needs to be placed at a certain angle 30° to receive the maximum amount of solar radiation. Typically, the array needs to be oriented to face south in the Northern hemisphere [7].

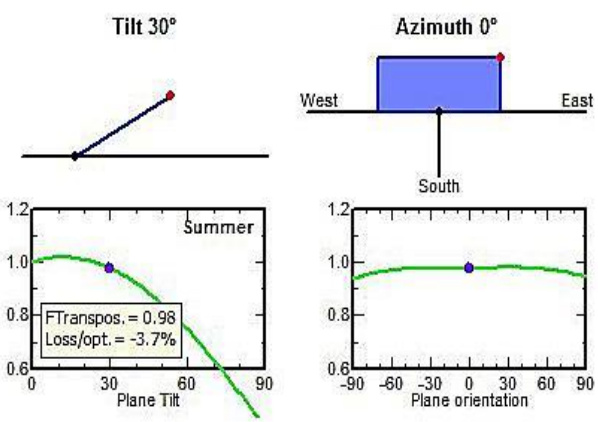


Fig. 7. PV field type: Fixed tilted plane [authors processed by PVSYST]

E. PV System Details

The PV system details is chosen and resulted through simulation from PVSYST. Table 4 shows PV array characteristics and parameters.

TABLE 4
PV ARRAY CHARACTERISTICS AND PARAMETERS
[AUTHORS PROCESSED BY PVSYST]

PV array parameters			
System type		Stand Alone System	
PV module		Si-poly	
Model		Poly 60 Wp 36 cells	
Number of PV modules	*In series*	4 modules	
	In parallel	19 strings	
Total number of PV modules		76	
Module area		42.3 m2	
Battery	*Model*	S-460	
	Voltage	48 V	
	Nominal Capacity	1746 Ah	
	Nb. of units	In series	8
		In parallel	6
	Temperature	Average between fixed (28oC) and External	

IV. SIMULATION RESULTS

The energy produced by PV array is summarized in the following figure 8 and table 5. Some losses occur according to module quality loss and ohmic wiring loss as in figure 9.

The SAPV system failed to generate 100% the energy delivered from the sun because of some losses. The overall system loss diagram for the system is illustrated in Fig. 12. Hence, the actual energy supplied to the load can be calculated by cutting down the energy losses of the regulator and battery storage [8]. The resultant simulation from June to December shows the following:

- The available solar energy (E Avail.) reached to the PV array for the whole year is 4214.216 kWh`
- The total energy supplied to the user (E User) is 3428.5 kWh for the whole year.
- The total energy needed of the user (E load) is 3539.6 kWh for the whole year.
- Performance ratio PR is 57.36 %
- Excess (unused) energy is 924 kwh/kwp
- Energy losses are 111 kwh

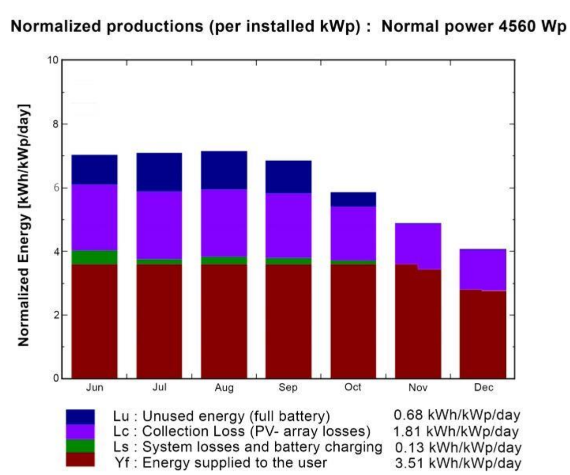


Fig. 8. The energy production of the SAPV system
[Authors processed by PVSYST]

TABLE 5
THE ENERGY PRODUCTION OF THE SAPV SYSTEM [AUTHORS PROCESSED BY PVSYST]

	GlobHor kWh/m²	GlopEff kWh/m²	E Avail kWh	EUnused kWh	E Miss kWh	E User kWh	E Load kWh	SolFrac
June	235.1	203.8	678.171	124.5	0.0	496.2	496.2	1.000
July	240.8	212.6	705.075	168.7	0.0	512.8	512.8	1.000
August	221.7	215.2	712.695	167.8	0.0	512.8	512.8	1.000
September	183.2	199.9	662.177	138.8	0.0	496.2	496.2	1.000
October	143.4	176.9	588.472	59.7	0.0	512.8	512.8	1.000
November	101.1	142.5	471.253	0.0	0.0	496.2	496.2	1.000
December	83.9	122.9	396.373	0.0	111.056	401.7	512.8	0.783
Period	1209.2	1274.0	4212.216	659.4	111.056	3428.5	3539.6	0.969

Legends
GlobHor Horizontal global irradiation
GlobEff Effective Global, corr for IAM and shading
E Avail Available Solar Energy
E Unused Unused energy (full battery) loss
E Miss Missing energy
E User Energy supplied to the user
E Load Energy need of the user (Load)
SolFrac Solar fraction (EUsed / ELoad)

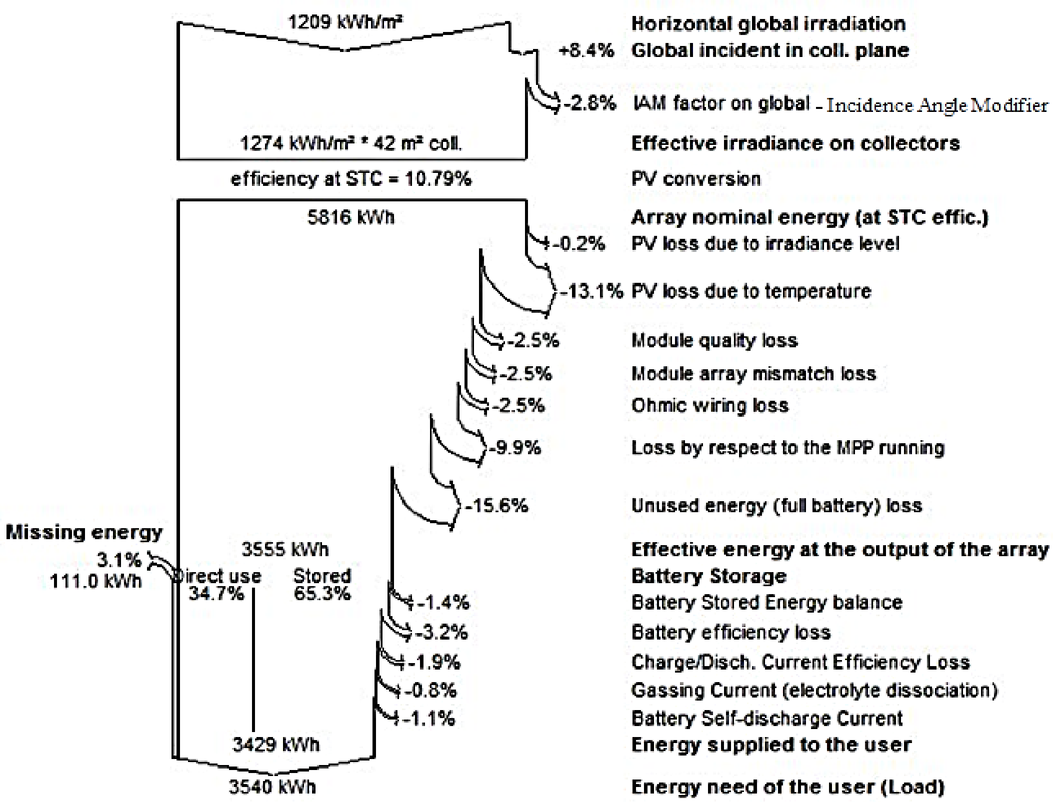


Fig. 9. Loss diagram over the whole year [authors processed by PVSYST]

V. RECOMMENDATIONS

The research project studies both the technical aspects of using PV technologies for an Egyptian hinterland. From the technical part tackled in this paper, the study examined the ability to install reliable SAPV system, followed by a numerical assessment of the proposed system by PVSYST simulation tool. The PVSYST software helped define the installed system configuration, determined PV sizing and simulated energy loads, and calculated the production and loss according to geographical site location.

The Implementation of PV systems in developing countries is expected to have an impact on research, education, community, industry, and other governmental sectors in Egypt as the following:

- Research, to develop methodologies of the implementation phases, new technology, materials and tools needed.
- Education, to provide real-life cases to be practiced at the architectural and planning studios into real-time projects.
- Community, directly touched at its specific characteristics and opportunities with a great socio-economic potential impact.
- Government, where the impact will mainly be done over the management capacity and its realization at decision making stages, housing option and infrastructure management.
- Industry, realized on the market: should be in a way that proposes a new approach of the industry.
- Management, to drive clear benefits for energy efficient technologies.

Successful implementation requires the identification of neighborhood energy plan to minimize the need for artificial heating and cooling with appropriate solar orientation and natural ventilation and integrate renewable energy systems.

As a conclusion of the above, the authors recommend a four phase energy plan for the prototype model examined at the case study that could be applied extensively on similar cases with special emphasis on the socioeconomic aspect. This plan is formulated in accordance with the guidelines issued by Barton et al. [9] into the following core stages:

- Stage 1 - stakeholders engagement

Engage partners and potential users in a briefing workshop; define the scope, objectives and broad strategy.

- Stage 2 - Baseline survey

Assemble basic local information. Conduct a demand and user survey; a site and energy source survey; and an institutional management and stakeholders' survey. Connect the neighborhood with its surrounding context. The stakeholders target groups may need to be extended following this strategic issue for the area.

- Stage 3 - Develop alternatives

Generate basic proposals and alternatives with key actors. All proposals and options will be reviewed at a second briefing workshop with stakeholders. Include proposals for delivering user advice/training and support during and after implementation.

- Stage 4 - Refining solutions and implementation

Integrate the energy criteria into the main spatial framework for the neighborhood. The later steps of this stage will be derived by technical consultants.

VI. CONCLUSION

Available photovoltaic technologies are not uniformly applicable especially in developing countries because of the lack of information, lack of technical or commercial skills, inaccessibility of technology, and the high risk associated with high initial cost admissions. However, most forms of renewable energy still have a significant way to go before they become competitive with fossil fuel technologies, especially for power generation. This would require intensive research & development effort, especially in the developing countries.

The study focused on the SAPV system applied to a modified residential unit. The examined unit consists of a single dwelling according to the users' needs at the graduates' villages at Al-Burullus Lake. The results show that the needed system would consist of 76 modules (4 in series – 19 strings in parallel) with each rating power of 60-watt p, and (8 in series x 6 in parallel) units of batteries with nominal capacity 1746 Ah. To generate 4560 Wp, the system should receive an amount of 4214.216 kWh solar power from June to December. According to the system losses such those from module quality and ohmic wiring loss, the energy supplied to the user is 3429 kwh, while the energy need of the user (load) is 3540 kwh with total losses of 111 kwh (Solar fraction SF 96.86%). The area needed for one module is 42.3 m2 which can be installed on the modified house roof, with an optimized orientation to face the south with a tilt angle of 30 degrees.

The study promotes and examines the ability of renewable energy integration into rural communities through application of simulation tools in design and evaluation phases.

VII. ACKNOWLEDGMENTS

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REFERENCES

[1] M. U. (Combined Renewable Energy Techniques for the development of the Egyptian Hinterlands), Postgraduate, Research and cultural Affairs Sector, Mansoura university, 2012.

[2] SDSEgypt2030. (2018, 04 10). Energy Pillar. Retrieved from Sustainable Development Strategy: Egypt Vision 2030: http://sdsegypt2030.com/economic-dimension/energy-pillar/?lang=en&lang=en

[3] El-Sudany, M. M. (Integrating of VLS-PV systems within development scenarios for the Egyptian desert), Kuwait, 2009.

[4] Akl M. H. (Towards Sustainable Neighborhood design in Egypt), Master thesis, Architectural Engineering Department, Mansoura University, 2015.

[5] GOPP (General Organization for physical planning), from http://gopp.gov.eg/eg-map/delta-map/, Retrieved 05 01, 2016.

[6] Akl M. H., Sheta S. A. and Hegazy I. R. (Population Density and Solar Radiation Effect on the Residential Buildings Forms: Case Study of the

Graduates Villages at El -Burullus Lake), Mansoura Engineering Journal, vol. 40, no.1, March 2015

[7] Irwan Y. M., Amelia A. R., Irwantoa M., Fareq M., Leow W. Z., Gomesh N. and Safwati I. (Stand-Alone Photovoltaic System Assessment using PVSYST Software), International Conference on Alternative Energy in Developing Countries and Emerging Economies, Bangkok, Thailand, Energy Procedia, vol.79, pp. 596 – 603, 2015.

[8] Idris N., Omar A. M. and Shaari S., (Stand-alone photovoltaic power system application in Malaysia), The 4th International Power Engineering and Optimization Conference, PEOCO2010, Shah Alam, Selangor, Malaysia, 23-24 June 2010.

[9] Barton H., Grant M. and Guise R., (Shaping neighborhoods a guide for health, sustainability and vitality), Spon press: Taylor and Francis group, London, 2003.

[10] Coluccia A., and Horvata M., (Making Toronto solar ready: Proposing urban forms for the integration of solar strategies), Energy Procedia, pp.1090 – 1098, 2012.