# Analysis of Load Demand and Economic Assessment Based on Weather Forecasting in Green Buildings

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*Abstract* - **This study is concerned with the efficient integration of the power management system from a microgrid with the power generation by using renewable resources and the green buildings concept. The software BIM was employed in order to study the effects of climate and other external factors on energy consumptions and related costs. Two sites, highly different with respect to the climate conditions and cost of electric power (Bagdad from Iraq and Craiova from Romania) were addressed in order to evaluate the volume of CO2 emissions and respectively the effectiveness of power generation by using solar and wind energies. Two identical weather forecast buildings from the same sites were also studied. The results of studies over the monthly power consumptions structures for one year were discussed. The conclusions of an analysis concerned with the performances (power consumption and costs) for 3 scenarios (with BIM, without BIM and respectively "high performance") were presented as well. A study on the cost efficiency of photovoltaic cells arrays in different contexts was made, addressing the same geographic locations. General aspects of the influence of environment conditions (solar irradiance and temperature) over the performances of the studied PV array were approached for this aim. The seasonal Pay Back indices were evaluated for both locations, concluding that for any of them the use of the solar energy represents a cost effective solution for a "green" power supply.**

**Cuvinte cheie:** *sisteme de management energetic, microgrid, cladiri verzi, software pentru optimizare.*

**Keywords:** *energy management systems, microgrid, green buildings, optimization software.*

## I. INTRODUCTION

This paper represents an improved version of the paper [1]. Its main contribution consists of a study on the cost efficiency of photovoltaic cells arrays in both sites addressed in [1], considering the differences relative to climate and power related costs.

Despite the fact that there are many issues and factors that have contributed towards the occurrence of the phenomenon of climate changes, the absence of effective strategies for energy and power management represents a problem that needs urgent solutions. Some of the strategies related to power generation by using renewable energy did not have the intended implications, especially when it comes to power consumptions efficiency. A holistic approach that is strongly aligned towards modern platforms of Electrical Engineering is needed. This study aims to evaluate the distinctive ways in which the energy management in microgrid systems can be correlated to the efficient use of renewable energy resources. Considering the numerous problems and challenges associated to the energy management, it is vitally important to make sure that an efficient design addressing this issue is conceived [2]. The possibility to implement microgrid systems within the framework of green buildings is also discussed. This is essential in terms of enhancing the extent to which costs of energy and accessibility are enhanced for consumers.

## II. GREEN BUILDINGS

This section is focused on the distinctive role played by green building towards the attainment of efficiency in power and energy management. The energy management is multidimensional in that it is impacted and influenced by many factors.

While some factors are influential in the short-term, others apply in the long-term. Green building is a concept and approach that encompasses emphasizing on sustainability of the building process such as to avert or prevent undesirable environmental implications such as pollution [3]. In order for power and energy management to be adequately implemented, there is always the need to ensure that a multidimensional approach is used. The role of green building must be clearly identified. For instance, it is notable that such building strategies can enhance the manner in which the structures' construction process is modified such as to allow for a minimal environmental pollution. Despite the fact that some of the existing trends in green technology are beneficial, others are associated with implications that are more or less undesirable [4].

The framework of the specific objectives of this research also encompasses the evaluation of the existing trends in green technology as pertains to the microgrid systems. Green technology is dynamic in that it not only promotes efficiency, but also the optimization of the extent to which existing resources are used in the short-term as well as in the long-term. Therefore it means that the existing trends in green technology have to be evaluated in order to find possibilities to align them into microgrid systems such as to improve the implementation process.

For this aim, a systematic analysis is required, because such an approach goes a long way towards enhancing the decision making process as far as the implementation of microgrid systems is concerned.

## III. Microgrid Architecture

One of the major drawbacks of using thermal energy is related to the significant costs involved by it [5]. They may represent a major problem when it comes to the assimilation of a microgrid into the energy management system (EMS).

Renewable sources represent the other notable source of energy when the local generation within a microgrid is addressed. Solar energy or turbines that are powered by wind can be involved. They can be defined as sustainable and reliable, especially when compared to other sources.

Fig.1 depicts the main components of a microgrid, which are connected to the point of common coupling (PCC). The flows of information and communication, respectively of energy are also represented. The Microgrid Central Controller (MCC) is used for the centralized control, the flows being realized through local connections (LC).

The functionality of any power system is always significantly influenced by the manner in which it facilitates energy saving. Unless a system promotes the extent to which energy is saved, it can be complex for the intended outcomes to be attained. This accentuates why the use of microgrid is beneficial. In essence, it is notable that there are various ways in which the use of microgrid system helps in saving energy [6].

## IV. Economic and Reliability Analysis Based on Weather Forecasts

Each major component of a microgrid is characterized by specific functions [7].The overall effectiveness of the entire microgrid is influenced by the efficiency of individual components. Maximum generated power, minimum power losses and less energy consumptions, these are the main factors addressed by the reliability and economic analysis of the microgrid (MG). The weather forecast (WF) have has a direct impact over the estimation of the power to be generated whilst considering the smaller power consumptions when Green Buildings are addressed.

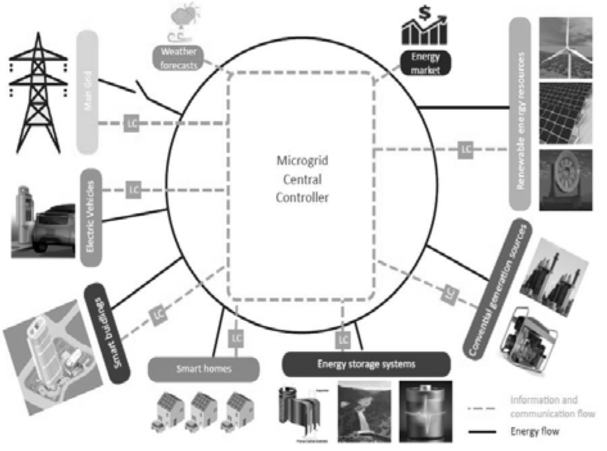


Fig. 1. Microgrid components

For the photovoltaic (PV) arrays of cell as those studied in this paper, the model of the solar irradiance considers that the solar irradiance can be evaluated as a sum between *Br*, *Dr* and *Rr*, where *Br* represents the beam radiation, *Dr* represents the diffused radiation and *Rr* represents the reflected radiation.

This model was used when running the BIM software (Building Information Modeling by Rivet auto desk software) in 2 sites: Baghdad (Iraq) and Craiova (Romania).

The microgrid reliability was evaluated considering that for a time interval [0 …*T*], the loss of power probability (LPSP) can be evaluated with Eqs. (1) and (2):

$$\sum_{t=0}^{T} \mathrm{Time}\ (P_{available}(t) < P_{needed}(t)) \quad (1)$$

$$P_{needed}(t) = \frac{P_{ACload}(t)}{\eta_{Inverter}(t)} + P_{DCload}\ (t) \quad (2)$$

Eq. 1 makes use of the power generated by using renewable energy resources ($P_{available}$) and the power absorbed by loads ($P_{needed}$) through a specific time. Eq. (2) provides the modality to compute the power absorbed by loads considering distinct contributions for the AC and DC loads, along with the inverter efficiency.

## V. Results Yielded by the Building Information Modeling Software

One of the main reasons for which the microgrid provides emergency energy supply is that it is characterized by the component of energy regulation [8]. This is essential because it supports "on demand" energy generation. Moreover, microgrids are also aligned towards the issue of diversified sources [9].

A BIM based study concerned with the evaluation of $CO_2$ emissions addressed 2 identical very small areas, one from Bagdad (Iraq) and the other one from Craiova (Romania) [1]. More emissions could be noticed for Bagdad for the same area per year (almost 7 tons versus 4.5 tons), but in both cases it was proven that one of the important factor to be considered when building smart grids or smart cities consists in reducing the negative environmental effect. Therefore "$CO_2$ free" power generating solutions have to be considered.

The potential for PV cells and wind turbines based generation of power was studied for the same 2 geographical locations mentioned above with BIM. Table I [1] presents the simulation results. In all cases, higher powers were associated to both solar and wind based systems in Bagdad.

BIM software was also used to collect, analyze and perform real time simulations based on remote sensing of weather using the two weather stations mentioned above.

This software allowed for the quantification of the environmental pollution and for conceiving possible solutions to reduce it.

Table II [1] reveal some differences, mainly explained by the highly different specific climate characteristics.

Different average lighting powers were noticed (Bagdad has more shiny days and a different distribution of number of daylight hours) and more people were needed to develop WF activities in the WF station from Craiova (where there are 4 seasons and the weather exhibits more and faster variations).

TABLE I.

ESTIMATIONS ON POWERS PROVIDED BY PV SYSTEMS AND WIND TURBINES PER YEAR

| Evaluated quantity | Bagdad | Craiova |
|---|---|---|
| Roof mounted PV system (5% efficiency) | 12,377 kWh/yr | 9,009 kWh/yr |
| Roof mounted PV system (10% efficiency) | 24,755 kWh/yr | 18,017 kWh/yr |
| Roof mounted PV system (15% efficiency) | 36,132 kWh/yr | 27,026 kWh/yr |
| Single 15' wind turbine potential | 1,956 kWh/yr | 691 kWh/yr |

TABLE II.

CHARACTERIZATION OF THE ANALYZED WEATHER STATIONS AND ELECTRICAL POWER/FUEL COSTS

| Parameter/Type of costs | Location of the weather station | |
|---|---|---|
| | Craiova | Bagdad |
| Outdoor temperature | [-16…36] $^0$C | [-8…41] $^0$C |
| Floor area | 269 m$^2$ | 269 m$^2$ |
| Exterior wall area | 197 m$^2$ | 197 m$^2$ |
| Average lighting power | 10.66 W/ m$^2$ | 4.84 W/ m$^2$ |
| Number of people | 53 | 2 |
| Exterior window atio | 1.13 | 1.13 |
| Electricity cost | 0.09 $/kWh | 0.14 $/kWh |
| Fuel cost | 0.78 $/Therm | 0.14 $/Therm |

The electricity costs are lower in Craiova whilst the fuel costs (considering the natural resources from Iraq) are lower in Bagdad. All information was analyzed in order to select the best renewable resources depending on them.

Table III gathers estimations of the electricity and fuel consumptions in both analyzed WF, based on the data processed by BIM. 30 year life cycles and 6.1% discount rates for costs were considered. Different consumptions were revealed: the WF station from Craiova uses more electricity, in direct relations to the increased number of personnel, whilst the fuel consumption in Bagdad is supposed to be higher. The estimations for energy costs are a little bit higher for Craiova.

Figs. 2 and 3 [1] illustrate predicted annual energy consumptions (in MJ), represented across the 12 months, for all components (Bagdad versus Craiova). Whilst almost zero energy consumptions were noticed for 4 months in Iraq, in direct relations to the number of sunny days, only the month of July was „close to zero energy consumptions" in Craiova (probably due to the summer vacation). This is also reflected by the energy consumptions with the personnel (significantly higher in all months for Craiova).

TABLE III.

ESTIMATIONS ON ELECTRICITY AND FUEL CONSUMPTIONS ALONG WITH COSTS, COMPUTED BY BIM

| Evaluated quantity | Bagdad | Craiova |
|---|---|---|
| Life cycle electricity consumption | 1499.634 MWh | 1573.769 MWh |
| Life cycle fuel consumption | 4164264 MJ | 2606453 MJ |
| Life cycle energy cost | $78723 | $99797 |

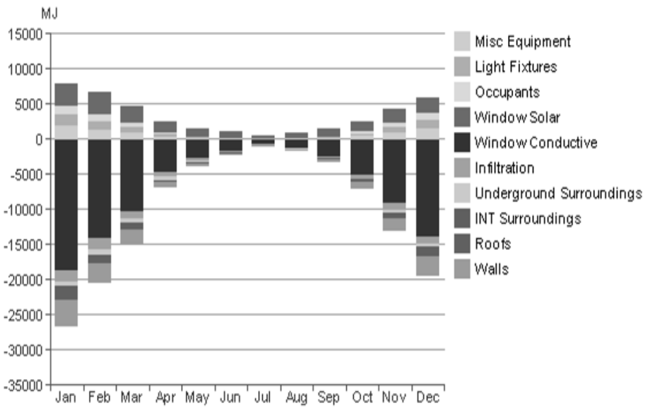


Fig. 2.Evolution of annual energy consumptions (Craiova).

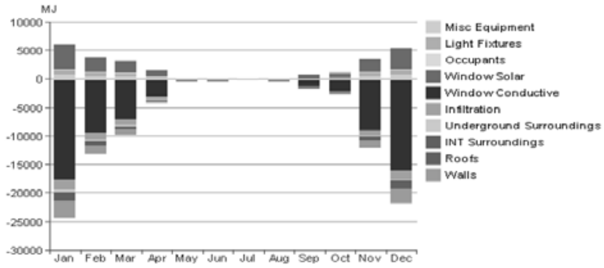


Fig. 3. Evolution of annual energy consumptions (Bagdad).

In both stations the highest consumptions are associated to the month of January, followed clearly by December in Bagdad and by February in Craiova (which is slightly higher than December). A correlation to the average temperatures in winter is obvious. The energy transfer through windows is more significant in Craiova, the solar energy being more effective in Iraq. The differences between consecutive months are more visible in Iraq, where the spring and summers are characterized by significantly higher temperatures. The power transfer through walls is one of the parameters most affected by the current month.

In correlation with the data from Table II, the overall energy consumptions in Craiova are higher than those from Bagdad.

## VI. ANALYSIS OF PERFORMANCES (POWER CONSUMPTIONS AND COSTS) FOR 3 SCENARIOS

When a system is not adequately cost-effective, then its overall implementation blueprint is significantly compromised. On the other hand, a system that is adequately cost-effective is characterized by an implementation blueprint that is seamless over a given period [7].

The BIM insight 360 software contains 26 factors to increase the performance and decrease the cost of energy and fuel depending on the location of the building and analysis of the green building by using the Rivet Autodesk software. It allows for a comparison between 3 scenarios: without BIM, with BIM and respectively the so-called "high performance" scenario.

The diagram from Fig. 4 (left) [1] represents the performance analysis relative to the energy consumptions in terms of kWh/m3/year for 3 different buildings for which the climate conditions are known and whose constructive

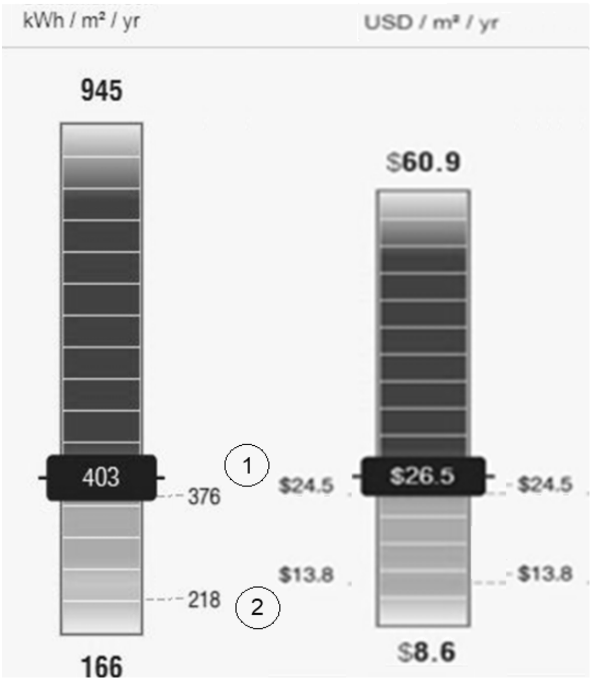


Fig.4.Performance analysis . Left - energy consumption. Right – costs. 1 – regular building and 2 – green building

parameters/energy management system are established in each of the above mentioned scenarios. Fig. 4 (right) [1] represents the counterpart performance analysis, but relative to costs instead of energy consumptions.

One can notice the decrease of electrical energy consumption from 376 kwh/m3/year (the regular case) to 218 kwh/m3/year (the green building case). This results into a cost saving of $11.5/ m3/year (due to the reduction from $24.5/m3/year to $13/m3/year).

The engineering vision of analyzing and constructing green buildings is a foundation for energy management such as to guarantee the achieving of great economical benefits [8, 9]. Fig.5 [1], built for a building from Bagdad, proves that, when weather conditions are considered, the energy management can directly decrease electrical energy consumptions by building a system that smartly reacts to external environmental effects.

In Fig. 5, 3 prototypes of buildings were addressed. The 1-st building (leftmost) has a conventional energy consumption system and is characterized by an electrical energy consumption of 400 kWh/m3/year. The 2-nd one (middle position) was designed by using Green Building and BIM such as to have an energy consumption of 310 kWh/m3/year. The rightmost bar illustrates an advanced system of construction, maintenance and consumption, taking into consideration all the factors that lead to lower energy consumption (124 were considered for Fig. 5). A consumption of 120 kWh/m3/year was achieved with this last system.

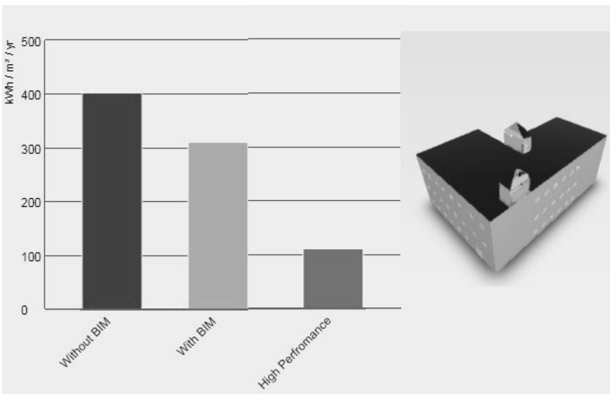


Fig.5. Performance comparison

## VII. Evaluating the Cost Efficiency of Photovoltaic Cells Arrays in Different Contexts

### *A. General aspects of the influence of environment conditions over the performances of a PV array*

When designing a green building, taking advantage of the environment conditions along with other factors (e.g. building properties and materials) represent an essential technique to be applied for cost savings while maintaining a high quality.

Reducing the losses resulting from the power generation or consumption has a great economic impact. Depending on the environment conditions and other country-specific costs with the power generation, the use of PV arrays may represent more or less a cost saving solution for a green building supplying.

The weather effect is one of most important factor to be considered for the calculation of the period associated to the “return of investment” based on the energy costs.

Table IV shows the estimation of the environmental impact on the PV energy output (for example irradiance, temperature etc.). The following quantities were addressed:

- *Tc*= panel cell temperature ;
- *Ta* = ambient temperature ;
- *MPP*= maximum power output from PV.

### *B. Influence of sollar irradiance*

Figs. 6 and 7 illustrate the “power versus voltage” and “current versus voltage” characteristic curves of a PV array of type TALEV for variable levels of irradiance and a constant temperature of 25C$^{o}$. They reflect that an irradiance increasing results into an increase of the power provided by the PV array.

### *C. Influence of temperature*

Fig. 8 depicts the family of “power generated by PV cells versus voltage” characteristic curves while considering variable temperatures from the set {25, 40, 50, 60, 75}$^{o}$C whilst Fig. 9 is dedicated to the current-voltage

TABLE IV.

ENVIRONMENTAL PARAMETERS AND ENERGY OUTPUT FROM PV

| Generation category | Irradiance [W/m$^2$] | Ta [$^o$C] | Tc [$^o$C] | MPP [kW] |
|---|---|---|---|---|
| Design | 964 | 30 | 60.1 | 5.78 |
| Normal | 900 | 30 | 58.1 | 5.4 |
| Emergency | 700 | 30 | 55 | 4.8 |
| Standby | 600 | 30 | 48.8 | 4.2 |
| Startup | 500 | 30 | 48.6 | 3.6 |

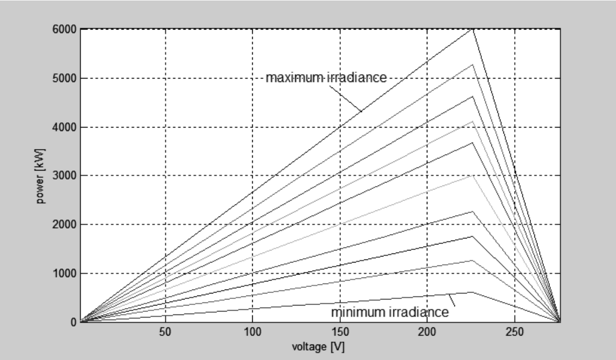


Fig. 6. P-V characteristics curves based on variable irradiance.

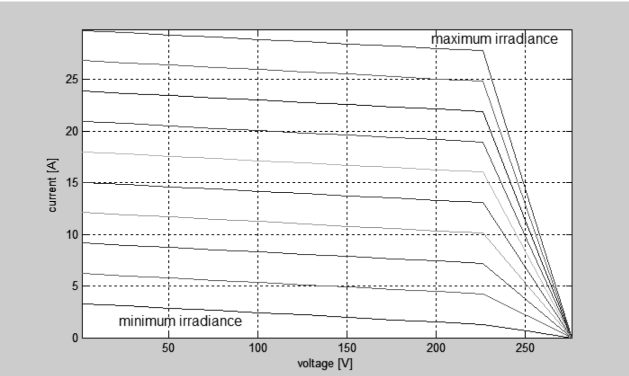


Fig. 7. I-V characteristic curves based on variable irradiance.

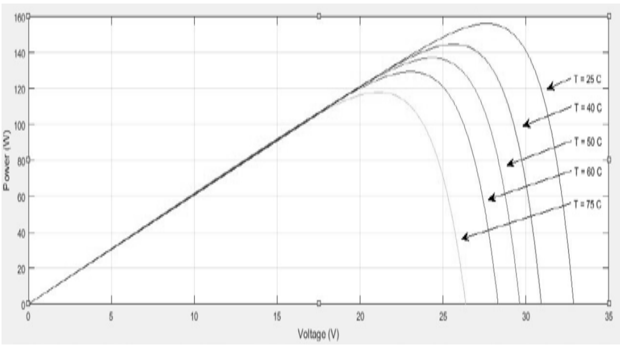


Fig. 8. P-V characteristic curves based on variable temperatures.

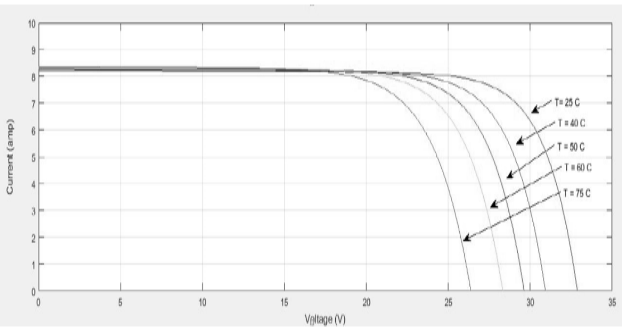


Fig.9. I-V characteristic curves based on variable temperatures.

characteristic curves depending on the same set of temperatures.

The diagrams with family of curves determined by temperature variation reveal that high temperatures significantly affect the power generation by arrays of PV cells: a temperature of 25C$^o$ is associated to the maximum generated power, whilst a temperature of 75C$^o$ is associated to the minimum generated power.

Similar results to those depicted by Figs. 6…9 were presented in [10]. All of them prove that the environmental conditions significantly affect the performances of PV cells.

### *D. Calculation of Pay Back associated to the use of PV array in Bagdad and Craiova*

In order to calculate the Pay Back (*PB*) associated to the use of a PV array, which represents the number of years in which the cost of the investment needed by the acquiring, installation and exploiting of a PV array is recovered from the incomes, the following formula was used:

$$PB = C/Y \tag{3}$$

where *C* represents the costs required by PV array installation and exploiting and *Y* represents the yearly incomes due to PV array exploiting.

From this point on, the following assumptions will be made relative to the studied PV array:

- The PV array supplies power approximately 8 hours in winter and 12 hours in summer;
- the overall costs related to the installation and exploitation of the PV array which supplies 6 kW (including the voltage source converter, cables, connections, UPS, control and measurement) is around 35000 $ in Bagdad;
- the factor denoted by PCG (power cost gain, which is associated to the hourly cost savings associated to power generation due to the installation of the PV array used to supply a green building when compared to the supplying of a normal building), is equal to 16.64$ per hour;
- the energy costs in Bagdad is around 0.32$/kWh.

In these conditions and considering the winter/summer environmental conditions in Baghdad, one can apply the formula:

$$\text{Pay Back} = \frac{35000}{52 * x * 16.64} \tag{4}$$

where *x* can be either 8 (in winter) , or 12 (in summer) and an estimation of 52 weeks per year is made.

The PB computed for winter conditions in Bagdad is equal to 5.05 years whilst the one computed for summer conditions in Bagdad is equal to 3.5 years.

When evaluating the PB in Craiova for the same PV array, one should consider that:
- the sun irradiance is the same;
- the temperatures are lower than those from Bagdad;
- the electricity cost is lower (representing around 40% from the electricity cost in Bagdad);
- the energy consumptions are different.

Under these circumstances, the same method of calculation as the one used for Bagdad yielded a "winter" PB equal to 7.7 years and a "summer" PB equal to 5.65 years.

Both season dependent PBs from Craiova are higher than those from Bagdad, mainly due to the differences between the electricity costs and energy consumptions.

Considering the above, one can conclude that all values of PBs for both analyzed sites are small enough to recommend the utilization of the PV arrays instead of classical systems for power generation on cost-related considerations.

These calculations recommend the implementation of PV arrays which proved to be an economically efficient solution to supply the green buildings from both analyzed geographical places.

## CONCLUSION

The information on weather (short term) and environment conditions (long term) can be used such as to get significant savings in terms of both energy consumptions and costs.

BIM software can yield the best green building model based on the cost and energy effectiveness (reliability and economy). It considers the effect of all significant parameters (such as building materials, constructive parameters, sun orientation, wind characteristics, heating, ventilation, air conditioning etc).

The main advantage of using the BIM and Green building software consists in the possibility to perform the performances analysis quite since the building designing stage while considering the impact of environment, energy consumption, renewable energy resources, infiltration, physical materials etc.

The green building concept represents the first step for the creation of a new system as a microgrid with new technology.

Depending on the environment conditions and other country-specific costs with the power generation, the use of PV arrays may represent more or less a cost saving solution for a green building supplying.

The weather effect is one of most important factor to be considered for the calculation of the period associated to the "return of investment" based on the energy costs. This measure of cost-effectiveness can be strongly influenced by the environment conditions as well as by the local cost of classic electric power generation and electrical consumptions respectively.

All values computed for the Pay Back index, for both analyzed sites, are small enough to recommend the utilization of the PV arrays instead of classical systems for power generation on cost-related considerations.

These calculations recommend the implementation of PV arrays which proved to be an economically efficient solution to supply the green buildings from both analyzed geographical places.

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