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# RECENT DATA (2013) OF THE EXPERIMENTAL MODEL HOUSE FOR ZERO ENERGY DEMAND AND ZERO EMISSIONS (ZED-KIM)

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## ABSTRACT

This paper concerns the description and the recent data achieved in 2013 regarding ZED – KIM (Zero Energy Demand -Kimmeria) which is a small prefabricated model house situated at the D.U.Th. Campus (Xanthi) aiming at the research regarding the energy production of Photovoltaic panels and wind generators in the difficult climatic conditions in Northern Greece.

There are multiple tasks in this project:

a. to investigate whether R.E.S. and particularly Photovoltaics and Wind Generators may contribute to the energy demands of a middle family house in northern Greece

b. to help students, postgraduates and professionals of the area comprehend what R.E.S. may produce in the specific area and under several weather conditions, all year round.

c. to present an example for an experimental proposal when a need for urgent or emergency housing arises in places where no energy supply exists.

The results from monitoring the R.E.S applications in ZED – KIM mentioned in this paper are very fruitful and promising. It seems that a large part of the energy demand of a house even in northern Greece, may be covered from P/V and W/G, and at the same time, reducing the emissions of CO2 to the environment.

Keywords: Zero Energy demand, zero emissions, Photovoltaics, Wind Generator, Off-Grid, emergency housing

## 1. INTRODUCTION

Both our civilizations and world economy, for all history of mankind, have been depended upon hydrocarbons (HC). This has led to “growth”. “flourishment” and the globalization of the economy, and the hyper consuming society. But, on the other hand, this has led also to the depletion of fossil fuels, global warming, pollution of the environment, nuclear reactors and radioactive waste, and an absolute dependence from HCs (oil, natural gas) and of course, from the system that controls them. However, an increased interest towards the Renewable Energy Sources has arisen, together with

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an intense concern about the environment (Huang and Wu 2007), (Kosmopoulos 2004), (Rifkin 2002).

At the same time while energy requirements are increasing continually due to technological development and the overpopulation of the planet, there is a concern over the adequacy of energy sources and the rising of the cost of energy, which play a catalytic role in the economic crisis which permeates the world community at the present time (world financial crisis). Over the last years prices of oil, natural gas and uranium have almost tripled (http://www.iea.org), while the cost of carbon dioxide emissions has increased almost by 25% (Zerefos 2008).

Thus, the fact that fossil fuels have decreased alarmingly, the harm to the natural environment, while the demand for electrical energy ever increases, has lead many governments and international organizations to research and discuss towards the search for the use of alternative sources of energy. The basic idea of these sources is the sustainable development which consists of a more optimistic policy on a worldwide level to end the economic crisis. According to some calculations, by 2025 the number of large city inhabitants and therefore energy consumers, will have exceeded 60% all over the world and it will be close to 85% in developed countries (Kellis 2008).

The general trend is towards renewable sources of energy (R.E.S), which is 'clean', inexhaustible and with no hazardous emissions. It's a matter of a favorable energy option, whose main challenge is the reduction of the cost of the energy produced at a competitive level. As a solution to that problem, state support of R.E.S. must be combined with the application of relevant grants and at the same time penalties regarding traditional sources of energy and for the non- fulfillment of social aims (Lund 2008).

With world support R.E.S. are fitting, with research and development and with the expansion of their technology, developing into competitive forms of energy, with extensive use and reliability with the economic viability of R.E.S., it's possible that a quicker, cheaper, long term sustainable development (Leijon 2010, a), (Leijon 2010, b), with almost no harm to the environment may be attained on a Life Cycle level according to Valverde et all (Valverde 2009).

In this direction, an autonomous experimental house by the name of ZED-KIM (Zero Energy Demand) has been developed at the Laboratory of Environmental and Energy Efficient Design of Buildings and Settlements. The aforementioned house is located in the region of Kimmeria, 4 kilometers east of the town of Xanthi.

The aim of this research effort is the practical efficiency of R.E.S. systems and more specifically that of photovoltaic and wind generators as well as their contribution to the coverage of energy demands which may be attained by the installment of similar provisions in a mean household in Northern Greece, together with the prevailing climatic conditions and seasonal fluctuations throughout the year.

## 2. METHODOLOGY: DESCRIPTION OF ZED-KIM (Zero Energy Demands - Kimmeria)

The prefabricated experimental house ZED-KIM, which consists of an imitation of an average household on a scale of 1:5, the general image of which is presented in picture 1, has been constructed in such a way so as to conform to bioclimatic design principles

(Kosmopoulos, 2006). Its ground plan is rectangular and 20 $m^2$ in total, the house faces south with an azimuth angle of $0^o$. It has two windows, one on the south and one on the east side, which allow sun light to enter, thus increasing thermal energy. On the south and west sides (the most significant winds) evergreen trees have been planted for shade in the summer and protection in winter. At this point it is worth mentioning that this pilot house is very well insulated, its roof provides additional thermal insulation and sound proofing (Kosmopoulos 2004), (Papadopoulos 2000). The roof is tilted at $42^o$ which is considered the most appropriate slant for the latitude of the city of Xanthi, in order to exploit the greatest levels and intensity of solar radiation during the sunny months (Hussein 2004), (Kosmopoulos 2000). Six photovoltaic panels of multi-crystalline silicon (total area 6,4 $m^2$ and 1.020 W ) have been installed on the roof (Kosmopoulos 2008).

Figure 1: The prefabricated house ZED-KIM.

According to the climatic and techno-economic studies which were carried out in the region of Kimmeria, aiming at installing an ideal R.E.S. system for the area in order to cover the energy requirements of the application, which will exploit harmoniously both the solar and wind power of the area, an autonomous photovoltaic hybrid system which is also linked to the PPC Grid to line was installed. The whole system is a pilot one as its functioning may be either autonomous or connected to the central grid. More specifically, when the total stores from the renewable energy sources (R.E.S.) are insufficient to cover the needs of the household, then they are covered by the central network. On the other hand when there is a surplus (which happens most of the time) this is fed into the central grid, thus maintaining a reciprocal relationship autonomous grid connected (Grigoriadis 2010).

Besides the photovoltaic array (1.020W) as was mentioned before, another photovoltaic panel is installed with a two axis tracker (920 watt) with the potential of autonomous and off – feeding electrical rotation $120^{o}$ in the direction of east – west every 20 minutes. This rotation is determined by a solar monitor (Figure 2).

Figure 2: PV array with a two axis tracker (920W). Figure 3: Wind generator (900W).

The afore-mentioned array consists of two photovoltaic panels of multi-crystalline silicon and two of mono-crystalline silicon, each of the same power. Each of these systems and their different technologies are compared through experimental investigation of their thermal and electric characteristics.

On the west side of the house a wind generator has been installed, which has been carefully studied in order to function alongside the hybrid system in connection with the photovoltaic modules and to help considerably in the production of energy during seasonal fluctuations (wattage 900watt with wind speed rotation 2.7 m/s) (Fig. 3).

The total production of the installed R.E.S. (3kW) contributes to a complete system, consisting of 3 inverters (DC/AC), 1 charge controller linked to a storage cell system (200Ah – 12V) and 1 control unit which records data which communicate with the computer.

Figure 4: Recording and storage cell system.

Finally it is worth noting that in the ZED-KIM a complete system has been installed to follow and record meteorological conditions, which can be seen on the left and right side of the house (Fig. 1). This system consists of a wind cup anemometer, rain gauge, temperature and humidity gauge, barometer, two pyranometers to measure total solar radiation and one pyranometer with a shadow ring to measure the intensity of diffuse solar radiation.

## 3. RESULTS AND DISCUSSION

According to the data collected, which are the results of yearly measurements, Table 1 presents an analytical monthly and yearly production of energy, a total figure and a figure for each renewable source of energy installed in the ZED-KIM house.

Table 1: Monthly and yearly production of electrical energy.

| Month | Rotating PV (1kW) (Kw) | Steady PV (1kW) | PV production (kWh) | W/G (kWh) | Total production (kWh) |
|---|---|---|---|---|---|
| January | 70,0 | 56,4 | 126,4 | 106,8 | 233,2 |
| February | 89,7 | 68,6 | 158,3 | 91,7 | 250,0 |
| March | 120,9 | 90,4 | 211,3 | 76,8 | 288,1 |
| April | 139,8 | 100,7 | 240,5 | 61,6 | 302,1 |
| May | 158,6 | 109,0 | 267,6 | 45,4 | 312,9 |
| June | 171,9 | 113,8 | 285,7 | 35,1 | 320,8 |
| July | 189,1 | 120,8 | 309,9 | 29,8 | 339,7 |
| August | 178,7 | 115,6 | 294,3 | 38,2 | 332,5 |
| September | 148,9 | 103,6 | 252,5 | 61,4 | 313,9 |
| October | 121,6 | 87,9 | 209,5 | 77,8 | 287,4 |
| November | 79,8 | 61,6 | 141,4 | 89,4 | 230,8 |
| December | 59,1 | 49,8 | 108,9 | 100,2 | 209,1 |
| **Yearly production:** | **1528,1** | **1078,2** | **2606,3** | **814,2** | **3420,5** |

The total electrical energy which is collected and used by the system yearly is in the range of 3420,5 kWh, within which the rotating two axis photovoltaic tracker produces 1528,1kWh, the photovoltaic array on the roof produces 1078,2 kWh while the wind generator produces 814 kWh.

In Fig. 5 there is an association of the total produced energy of the system per month, with the corresponding total of the photovoltaics and wind generator.

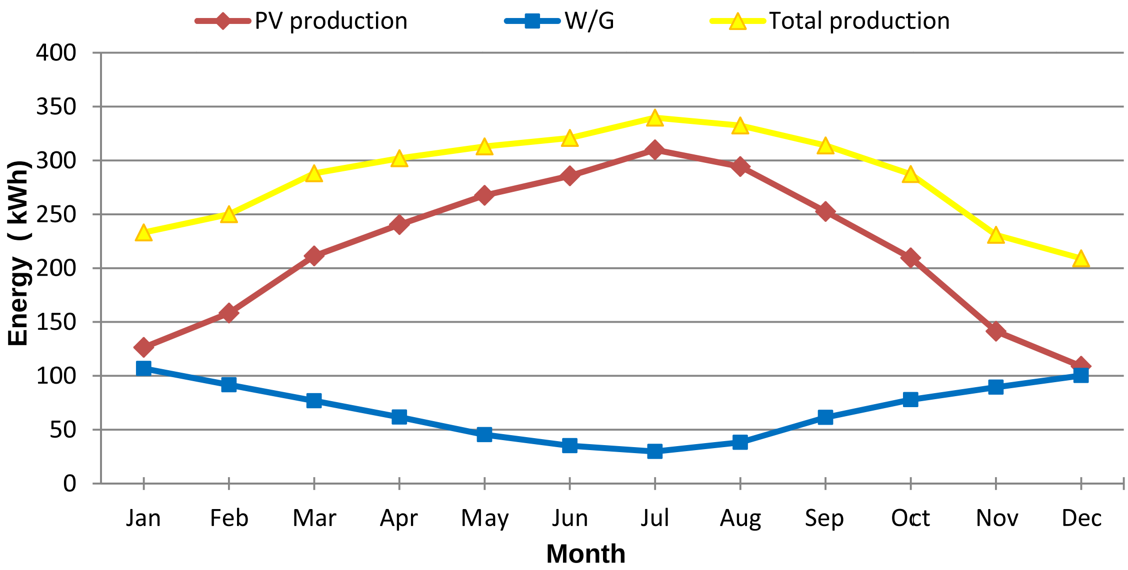


Figure 5: Monthly production of electrical energy

In Fig.6 the total electrical energy from the installed R.E.S. is presented per month.

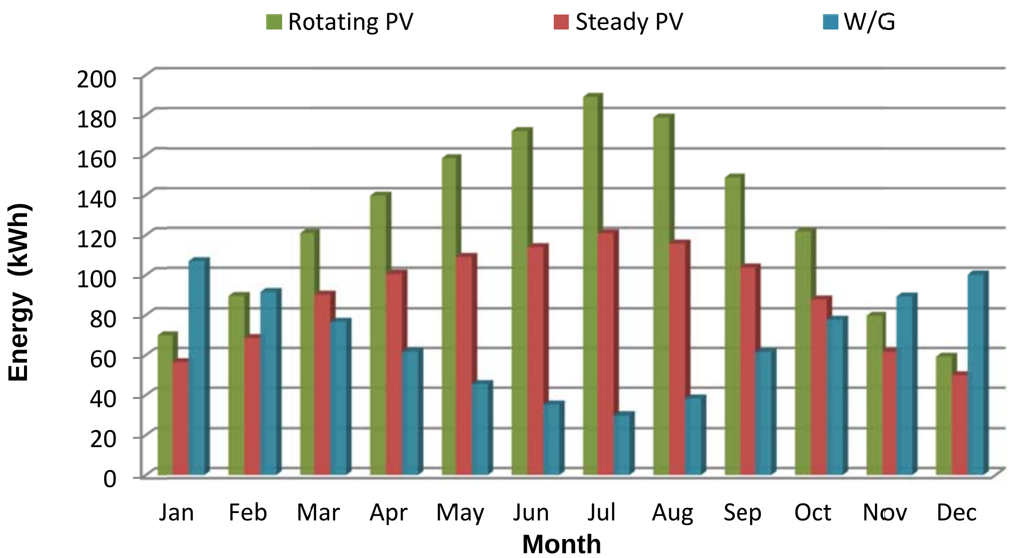


Figure 6: Monthly production of electrical energy of each R.E.S.

As presented in Table 2 which follows, the minimum average total energy produced by the system per day ranges between 7 to 8 kWh during the winter, while the largest amount ever recorded reaches 15 kWh during the autumn period on days with a high level of solar radiation and strong winds.

Table 2: Daily produced electrical energy

| Month | Rotating PV (1kW) (kWh) | Steady PV (1kW) (kWh) | PV production (kWh) | W/G (kWh) | Total production (kWh) |
|---|---|---|---|---|---|
| January | 2,3 | 1,8 | 4,1 | 3,4 | 7,5 |
| February | 3,2 | 2,5 | 5,7 | 3,3 | 8,9 |
| March | 3,9 | 2,9 | 6,8 | 2,5 | 9,3 |
| April | 4,7 | 3,4 | 8,0 | 2,0 | 10,0 |
| May | 5,1 | 3,5 | 8,6 | 1,5 | 10,1 |
| June | 5,7 | 3,8 | 9,5 | 1,2 | 10,7 |
| July | 6,1 | 3,9 | 10,0 | 1,0 | 11,0 |
| August | 5,8 | 3,7 | 9,5 | 1,2 | 10,7 |
| September | 5,0 | 3,5 | 8,4 | 2,0 | 10,5 |
| October | 3,9 | 2,8 | 6,8 | 2,5 | 9,3 |
| November | 2,7 | 2,1 | 4,7 | 3,0 | 7,7 |
| December | 1,9 | 1,6 | 3,5 | 3,2 | 7,0 |

In Table 3 which follows, the percentages of total energy as well as the energy produced by each installed R.E.S. system in the ZED-KIM house are presented on a monthly and yearly basis.

Table 3 Percentage of produced electrical energy

| Month | Rotating PV (1kW) (%) | Steady PV (1kW) (%) | PV production (%) | W/G (%) |
|---|---|---|---|---|
| January | 30,0 | 24,2 | 54,2 | 45,8 |
| February | 35,9 | 27,5 | 63,3 | 36,7 |
| March | 42,0 | 31,4 | 73,3 | 26,7 |
| April | 46,3 | 33,3 | 79,6 | 20,4 |
| May | 50,7 | 34,8 | 85,5 | 14,5 |
| June | 53,6 | 35,5 | 89,1 | 10,9 |
| July | 55,7 | 35,6 | 91,2 | 8,8 |
| August | 53,7 | 34,8 | 88,5 | 11,5 |
| September | 47,4 | 33,0 | 80,4 | 19,6 |
| October | 42,3 | 30,6 | 72,9 | 27,1 |
| November | 34,6 | 26,7 | 61,3 | 38,7 |
| December | 28,3 | 23,8 | 52,1 | 47,9 |
| Yearly production: | 44,7 | 31,5 | 76,2 | 23,8 |

Of the total electrical production approximately 76% stems from the installed photovoltaic systems (45% rotating PV, 31% steady PV) while 24% is from the wind generator. During the winter period when it is very cloudy or when there are strong winds, the contribution to the production of electrical energy made by the photovoltaics is reduced to 52%. A significant merit of electrical energy during this period, comes from the wind generator (48%). During the summer, however, the afore mentioned situation is more intense, and the photovoltaics produce 91% of the energy, limiting the contribution of the wind generator to an amount of 9%. The above results are presented in Fig. 7.

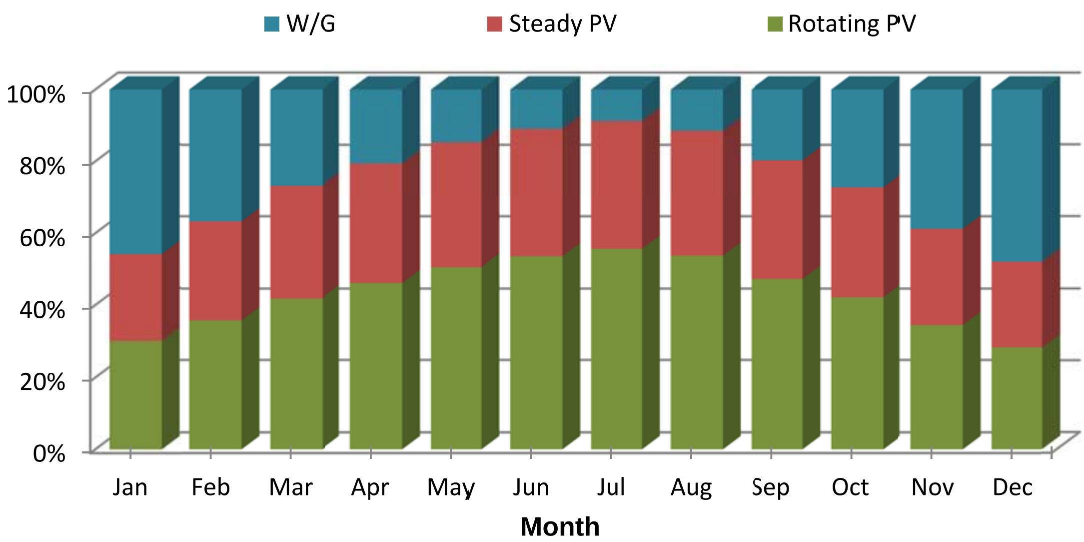


Figure 7: Percentage production of electrical energy from each R.E.S.

At this point, it is worth mentioning and analyzing the difference in the levels of electrical production of the rotating and fixed photovoltaic arrays. During the summer months when the two systems are exposed to high levels of solar energy, a dominance of the rotating PV array is noted, against the amount of the fixed PV array (19%) which corresponds to about 63 kWh a month production of electrical energy (www.cres.gr), (Kalapodas 2011). The above phenomenon is noted in a smaller scale during low levels of solar radiation (the winter period) where the rotating photovoltaic array contributes more (19%), from the steady PV array on the energy production. This is due to the fact that the produced wattage from each photovoltaic cell, depends significantly on the produced intense of electrical current which relates directly to solar radiation. In contrast, voltage increases with the slightest exposure to low level solar radiation (Nikou 2010). Thus, due to the fact that during the winter months diffuse solar radiation dominates to a great extent, which falls upon the two photovoltaic systems at the same level independent of the azimuth angle from the south, it has been noted that the percentage of energy production (19%) between the rotating PV array and the steady PV array installed in the ZED-KIM is smaller than in the summer period (35%).

Finally, the results referred to an analogous system, consisting of a wind generator of 1 kW and a rotating photovoltaic array of 1kW is presented, according to our research data: (both systems of electrical energy have the potential to rotate according to the natural source which drives them towards electrical production. Thus the energy expected to be produced by this system, according to our data, and the energy accumulated and conclusions reached relating to the comparison of solar and wind power in the city of Xanthi are presented in table 4.

On Table 4 we may see that the wind generator (1kW) may produce 905 kWh yearly while the rotating photovoltaic array of the same power, presents almost 0.7 times more energy production (1528,1 kWh), reflecting the rich solar and wind power of the area.

Table 4 Results referred to a system of a total wattage 2kW.

| Month | Rotating PV (1kW) (kWh) | W/G (1kW) (kWh) | Total production (kWh) |
|---|---|---|---|
| January | 70,0 | 118,7 | 188,7 |
| February | 89,7 | 101,9 | 191,6 |
| March | 120,9 | 85,3 | 206,2 |
| April | 139,8 | 68,4 | 208,2 |
| May | 158,6 | 50,4 | 209,0 |
| June | 171,9 | 39,0 | 210,9 |
| July | 189,1 | 33,1 | 222,2 |
| August | 178,7 | 42,4 | 221,1 |
| September | 148,9 | 68,2 | 217,1 |
| October | 121,6 | 86,5 | 208,1 |
| November | 79,8 | 99,4 | 179,2 |
| December | 59,1 | 111,3 | 170,4 |
| Yearly production: | 1528,1 | 904,6 | 2432,7 |

## 4. CONCLUSIONS

According to the data presented in this research it can be stated that if the results of the pilot house (scale 1:5) are transferred into reality and photovoltaic arrays 5 times more (~10kW) and wind generator of 0.5 times more (~1.5 kW), the power are installed, with a yearly total production of 3420,5 kWh the following will occur: In an average household of 4-5 people with a house of 100 $m^2$ and appropriate insulation, in difficult climatic conditions such as in Northern Greece, 14.250 kWh of energy are expected to be produced yearly. This will exceed the needs of an average household and the surplus energy may be sold back to the PPC (0,45 €/kWh). From the above it can be easily acknowledgment that for the covering of the aforementioned needs 5000 kWh yearly are required (Rifkin 2002), a system's payback period is of 6 years, with today's market prices and no tax-free purchase, with considerable reduction in the forthcoming years as R.E.S. technology develops and improves.

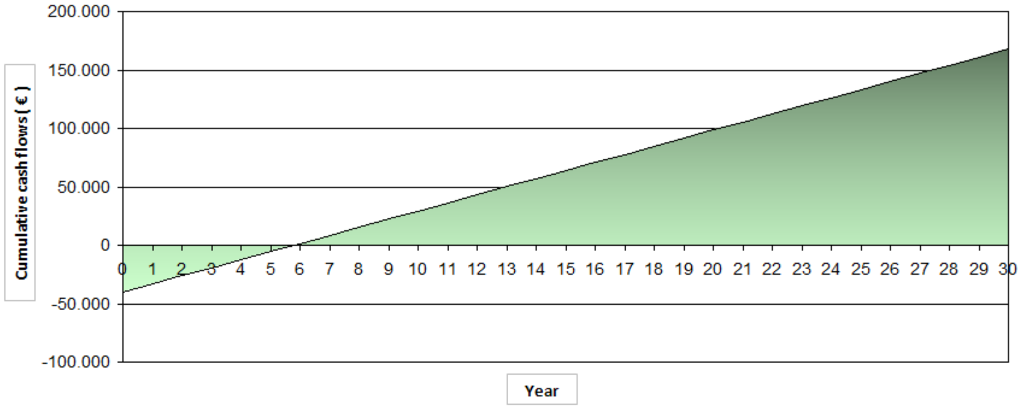


**Figure 8:** Cumulative cash flows graph.

In figure 8 which follows, the cumulative cash flows and the payback period are presented in a 30 year basis.

Furthermore it has been shown that the city of Xanthi which is located in Northern Greece, has high solar and wind potential which makes it suitable for the installation of hybrid systems. These systems can exploit the north-eastern Greece wind and solar potential towards satisfactory electrical production throughout the unstable weather patterns yearly.

Finally, it has been proved that photovoltaic arrays in two axis tracker, increase the yearly electrical production by 29% compared to those that are placed at a steady angle, equal to the latitude of the place. This percentage exceeds 35% during the summer months.

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