AHP Based Decision Making Process for Zero Energy House Building

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***Abstract*—Zero energy house topic is important because of high energy savings, ecological balance issues, low requirement of energy resources etc. A net-zero energy (NZE) building is one that relies on renewable sources to produce as much energy as it uses, usually as measured over the course of a year. In this study, the goal was determining the best "zero energy house" building strategy by selecting the right components such as solar panels, wind turbine, hybrid systems by using Analytic Hierarchy Process method.**

***Index Terms*—renewable energy, solar panels, wind turbine, hybrid systems, AHP**

I. Introduction

Energy is the most important resource for humanity. Nowadays, civilizations start war for absent energy sources. As a result renewable energy systems attract more interest. In this study, a prefabricated house in Antalya has been selected and a decision has been made on which renewable energy is going to be chosen (solar system, wind turbine, hybrid system) with Analytic Hierarchy Process (AHP) method.

Zero Energy Building in the dedicated literature writers often 'zero' to highlight the lack of common understanding of what should be equal [1]. This issue is common, but the question is discussed in several publications: "zero" energy, refer to energy or CO2 emissions or energy costs, perhaps, has not been clearly still need answers. In the report, the Torcellini, *et al.* [2], the authors can use the general definition for Zeb issued by the US Department of Energy (DOE) Building Technologies Program: "net zero energy building (ZEB) greatly reduced a residential or commercial building needs through such productivity increases with energy. Balance of energy needs renewable can be achieved with technologies "But they clearly undefined 'zero' pointed out:" phrases Despite the excitement created on a "zero energy", we have a common definition of deficiency, even if a common understanding of what it means. "Furthermore, the paper authors investor's intentions, finally concerns about climate change and greenhouse gas emissions or energy, depending on the project objectives, definition of zero energy buildings can be constructed in various ways shows costs. Torcellini [2] to all scenarios described above, taking into account distinguish the advantages and disadvantages of the four most commonly used definition of the mark:

Net Zero Site Energy: When was responsible for on-site, a site ZEB produces at least as much energy it uses in a year.

Net Zero Source Energy: It was also responsible for resource use over the years as a source ZEB produces at least as much energy [3]. Means to generate energy for the primary energy used to power the site. To calculate the total source energy of a building, imported and exported energy is multiplied by the appropriate site-source conversion factors.

Net Zero Energy Costs: In a cost of zero energy building, at least the building owner pays the year for the amount of money equal amount of energy that help with the program pays for energy services and energy used over export network building. [4]

Net Zero Energy Emissions: The emissions generate a net-zero emissions building at least as many emissions using renewable energy sources produce free energy.

Some technical specifications' of wind turbines and solar panels are giving below [5];

a) In a wind turbine system wind causes rotation of the rotor (like an airplane wing) passes over the blades creating lift. Knives turning the low speed shaft inside the nacelle: Gears connect the low-speed shaft with a high-speed rotor shaft, which drives the generator. Here, the slow rotation of the blades revolution speed generator is upgraded to higher speeds. Some wind turbines to produce power from the generator and comprising a transmission instead of using a direct drive mechanism. Rapidly rotating shaft drives the generator to produce electricity and converts electricity from the generator to the correct mains voltage transformer expenses. Electricity is then transmitted via the mains.

b) Solar panels convert light into electricity are devices. Often, the most powerful source of light available is the sun, called Sol by astronomers as "solar" panels are called. Some scientists call them photovoltaic basically

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means "light-electricity." A solar concentrator to take over a large area of sunlight and light rays bending and focusing of the lens directing them to a certain point, it uses the so-called Fresnel lens. They're using a magnifying lens to focus the Sun's rays on a pile of kindling or papers to start the fire some people use the same principles.

A solar panel is a collection of solar cells. Small solar cells spread over a large area can work together to provide enough power to be useful for many applications. Depending on the functional and operational requirements of the system, the necessary specific key components of components such as a DC-AC power converter, the battery bank, the system and the battery controller, the auxiliary energy source, and sometimes marked electrical load (equipment) as appropriate.

In this study, Analytic Hierarchy Process (AHP) methodology was used. AHP is a decision-making method in case of problems in terms of the factors affecting the decision point used in the decision-making can be identified, so that the distribution of decision-making and estimation method. Although this wide application, AHP axiomatic basis of carefully problem environment [6] limits the scope.

This method is an array of features to some criteria was selected to determine the relative importance. AHP process of possible concrete quantitative criteria as well as on intangible qualitative criteria included that the judgment easier. AHP method is based on three principles, the structure of the model used in comparative multi-criteria decision making problems. Also AHP is used in various decision-making problems. This is a well-defined mathematical structure of consistent and accurate or approximate weight matrix [7] to create, based on the associated right eigenvector talent.

II. Methodology

Using AHP, as can be seen from the following materials on hand to judge the decision involves a large number of problems associated with mathematical synthesis. It is not uncommon for dozens or even hundreds of numbers to this decision. While the math can be done by hand or with a calculator, use one of the various computerized method for entering the judgment and synthesis is much more common. Powered by the most sophisticated use of special devices to achieve the decisions of decision-makers often proprietary, convened a meeting room these simple contains standard spreadsheet software.

Using AHP procedure can be summarized as [8]:

Step-1: Decision goal, modeling the problem as a hierarchy containing alternatives and criteria to evaluate alternatives to achieve.

Step-2: elements of judgment to set priorities based on pairwise comparisons between elements of the hierarchy by making a series. Comparing potential commercial real estate purchases example, investors might say preferred position on the timing of the price and price.

Step-3: to synthesize these judgments to obtain a general list of priorities for the hierarchy. It features into the overall priorities for each feature, B, C, and D locations; you want to combine the investors' decisions about the price and timing.

Step-4: Check the consistency of the decision.

Step-5: Evaluate the final decision based on the results of this process.

Modelling the problem, as a first step in the analytic hierarchy process is hierarchy. In doing so, participants then explore detailed aspects of the problem in general refers to the level that requires a multi-level AHP [9]. They are trying to create a hierarchy, in their context, to improve their understanding of the problem and both of their thoughts and feelings about each other.

III. Application

There are several different types of solar panel in the world. Six different type of solar panel have been found suitable for this project and according to their properties one of them has been selected for %100 solar panel feature because of this project fixed daily production limit at 10 kwh/day with a cost of € 3, 966.

Also four different type of wind turbine have been found suitable for this project and a %100 wind turbine system has been selected for this study with a 10 kwh/day capacity and a cost of € 3,897.

3 hybrid systems were created with this data and this system shown at the following tables. These systems have 10 kwh/day and their cost is showed in the Table I, Table II, and Table III respectively.

TABLE I. Cost and Power of Hybrid System 1

Solar Panel & Wind Turbine (%50 solar-%50 wind)			
Hybrid 1	Solar Panel	Wind Turbine	Total
Cost (€)	2489	2429	4918
Energy (kwh/day)	5,5	5	10,5

TABLE II. Cost and Power of Hybrid System 2

Solar Panel & Wind Turbine (%30 Solar Panel %70 Wind Turbine)			
Hybrid 2	Solar Panel	Wind Turbine	Wind Turbine
Cost (€)	915	2429	1610
Energy (kwh/day)	2,8	5	2,5

TABLE III. Cost and Power of Hybrid System 3

Solar Panel 4 & Wind Turbine 1 + 3 (%70 Solar Panel %30 Wind Turbine)			
Hybrid 3	Solar Panel	Solar Panel	Wind Turbine
Cost (€)	2489	459	1611
Energy (kwh/day)	5,5	1,4	2,5

In this study, 5 different systems (Solar Panel, Wind Turbine and Hybrid System 1, 2, 3) are compared with AHP method (with 3 experts analyzes). All of the system have same daily production (10 kwh/day), same location (Antalya) and using standard battery (200 AH – €360) and same house (duplex-prefabricated house). Summary of Cost of Renewable energy systems have been given at Table IV.

TABLE IV. COST OF RENEWABLE ENERGY SYSTEMS

LIGHTING + TV+ REFRIGERATOR + WASH. MACHINE +DISHWASHING + WATER PUMP (10KW DAILY- STANDARD BATTERY)					
	100s	100w	50s-50w	30s-70w	70s-30w
	Solar	Wind	H1	H2	H3
investment cost	€ 3.966	€ 3.897	€ 4.918	€ 4.954	€ 4.559
battery cost	€ 2.857	€ 2.857	€ 2.857	€ 3.571	€ 4.643
total cost	€ 6.823	€ 6.754	€ 7.775	€ 8.525	€ 9.202
maintenance operating cost/year	€ 952	€ 952	€ 952	€ 1.190	€ 1.548

These 5 alternatives have been evaluated according to 4 criteria which are economic, environmental, technical, and social. Each criterion has some sub evaluation criteria that can be summarized as below:

Economic: Investment cost, maintenance and operating cost.

Environmental: Visual impact, noise.

Technical: Lifetime, efficiency, min capacity, max capacity, battery demand, energy sustainability.

Social: People's acceptability, quality of life.

After determining these criteria, importance of these has been evaluated by 3 different experts by the help of AHP. For expert 1 environmental criteria is more important than the other criteria with weight 0,394, and he give more importance for noise than visual impact. For expert 2 Technical criteria is more important than the other criteria with weight 0,434 and he give more importance for efficient with 0,357 than the other sub-criteria. For expert 3 economic criteria is more important than the other criteria with weight 0,523 and he give more importance for maintenance and operating cost than investment cost. After calculating individual weights of each criterion for each expert; group decision weights have been calculated as given on Fig. 1. For experts 1, 2, 3 economic criteria is more important than the other criteria with weight 0,411 and they give more importance for maintenance and operating cost than investment cost

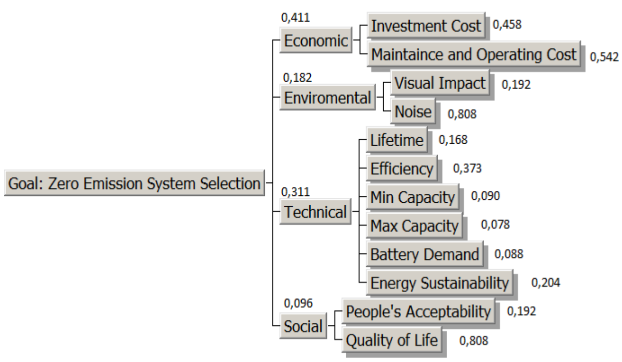

Figure 1. Group-decision making weights for criteria.

After weighting the criteria, at the second phase of AHP alternatives have been compared according to weights given in Fig. 1. Expert 1 selected Solar System with weight 0,303 because of the high importance of environmental criteria. Expert 2 selected Hybrid system 2 with weight 0,232 because of the high importance of technical criteria. Finally, expert 3 selected Solar System with weight 0,215 because of the high importance of economic criteria.

According to group-decision making rules final evaluation has been carried out. Results of this final analysis have been given in Table V.

TABLE V. FINAL DECISION WEIGHTS

System	Weight
Solar System	0,233
Wind System	0,172
Hybrid System 1	0,196
Hybrid System 2	0,211
Hybrid System 3	0,188

In this study, 3 experts' opinions are evaluated via AHP method and then Solar System has been chosen. Solar system's cost is shown at Table VI with duplex prefabricated house.

TABLE VI. TOTAL COST AFTER AHP RESULT

	Solar Panel 10kwh/day
Investment cost	€ 3.966,29
Battery cost	€ 2.857,14
Sub-Total cost	€ 6.823,43
Duplex Prefabricated House Cost	€ 20.000,00
Total Cost	€ 26.823,43

This study showed that Zero Emission System can be setup for €26825 in Antalya. There are several types of prefabricated house but for this project this type of (duplex-prefabricated house) house selected because of cost and has more roofs for solar panels. There are 1 lounge with 24 m^2 and one kitchen with 15 m^2 and one bathroom with 6 m^2 and an entrance with 21 m^2 and veranda with 20 m^2 at first floor. There are 2 bedrooms with 10 m^2 and one bedroom with 15 m^2 and there are 2 bathrooms one of them is 6 m^2 and other bathroom is 3 m^2, a balcony with 6 m^2 and hall with 17 m^2 at second floor.

IV. CONCLUSION

In this study, zero energy house building strategies has been evaluated with the AHP method with the assistance of several experts. Best cost effective, efficient strategy has been defined as a result of series of analysis. Findings of this study would shed light into selection of green energy options to use at house building stage. Data used in this study consist of Turkish market information. There may be some difference in the results of application in different countries which may result in interesting findings. Criteria used for the evaluation of alternatives can be generalized for different applications on different countries.

Solar panel system is not on-grid system because of the high battery costs and taxes. Government may support people more to use this kind of renewable energy source by decreasing taxes. For instance; in Turkey people buy electricity for 28kr/watt and promise that buy back from consumer for only 14kr/watt for 5 years. Maybe government can increase buyback price and promise 10 or 15 year deals for it. Then it is more profitable and importance of location decreases. So that other locations can be chosen with more cold weather for zero emissions house, not only southern city like Antalya as in this study.

Further research can be incorporated into this study with different hierarchical and detailed objectives with sub-factors. Other mathematical models (i.e. Fuzzy AHP) can be integrated to obtain final ranking. This method other than a fuzzy hybrid method (e.g. fuzzy and TOPSIS) is used the assessment of alternative tent cities participating in field evaluation with this system suggested as future work. There are not exact information, when it is doing with other expert opinions can be obtained different results.

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