Innovation of using Renewable energy resources instead of conventional systems in public libraries of Tehran (An Iranian experience)

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Abstract:

Global warming is one of the most important issues all over the world, extensive use of fossil fuels has caused many difficulties during the past century and it caused many concerns these last years. One of the public buildings which are very important in each city is the public library. Converting libraries into green buildings which can obtain their energy from renewable resources is an important issues that can help the city become greener. In Tehran (Capital of Iran) due to the cheap price of fossil fuels most buildings including public libraries use fossil fuels for their electricity and heating. Because of environmental issues and rising fossil fuels prices in Iran due to subsidies elimination, using renewable energy resources in public libraries becomes a very attractive subject. In this paper, different renewable energy resources which are applicable in public libraries in Tehran such as wind turbines, photovoltaic cells and micro CHP (Combined Heat and Power) systems are studied. The renewable energy resource units are evaluated according to different criteria like capital cost, operation and maintenance cost, CO2 production and electricity cost, using multi attribute decision-making methods such as Analytical Hierarchy Process (AHP) and TOPSIS. Then, the best energy systems for using in public libraries are identified according to these criteria.

The study shows that new energy resources are sustainable sources that help in keeping the environment healthy and pollution free. It also shows that renewable energy units are a reliable alternative for conventional energy units in the long term, and that they can save a lot of money on fuel costs, considering the high price of fossil fuels imposed after subsidies elimination. Due to high capital cost of these units, as their technology is new and expensive,

it is very important for government to support these new technologies through different incentives to make them economically sustainable. In addition, it is inspiring to use green technology in public libraries and it will encourage people to use them in different areas, especially in public buildings.

Keywords: *Renewable energy resources, public libraries, evaluation*

Introduction

During low-carbon economic times, development and utilization of new energies will be a vital means to raise global competitiveness for every country (Cheng, 2011). Many of the popular building energy simulation programs around the world are reaching maturity — some use simulation methods (and even code) that originated in the 1960s. For more than two decades, the US government supported development of two hourly building energy simulation programs, BLAST and DOE-2. Designed in the days of mainframe computers, expanding their capabilities further has become difficult, time-consuming, and expensive. At the same time, the last 30 years have seen significant advances in analysis and computational methods and power — providing an opportunity for significant improvement in these tools.

In 1996, a US federal agency began developing a new building energy simulation tool, EnergyPlus, building on development experience with two existing programs: DOE-2 and BLAST. EnergyPlus includes a number of innovative simulation features — such as variable time steps, user-configurable modular systems that are integrated with a heat and mass balance-based zone simulation — and input and output data structures tailored to facilitate third party module and interface development. Other planned simulation capabilities include multi-zone airflow, and electric power and solar thermal and photovoltaic simulation. Beta testing of EnergyPlus began in late 1999 and the first release was scheduled for early 2001 (Crawley, 2001).

Statement of the problem

Efforts for changing the world by preserving natural resources provide a real opportunity for creating sustainable and lasting growth for the planet and at the same time create jobs and insure a better balance between different parts of the world. Therefore we endeavor to research about the benefits and effectiveness of replacing old by new energy sources in the public libraries of Tehran

Efficient energy consumption became an important requirement and constraint to be considered in many energy systems implementations, especially in public facilities like libraries. In Iran the government pays a lot of money for subsidies. Recently, it decided to cut subsides; therefore, using cheap and clean energy becomes more important. This study is trying to compare different scenarios of energy systems in public libraries in Tehran.

Literature Review

Liu et all (1993), in their paper ”Summary of UTMB O&M Project: Energy Conservation Potential in Five Buildings” offer a summary of five reports (references 1 to 5) which provided detailed descriptions of an O&M (Operation and Maintenance) investigation of the following five buildings on the UTMB campus: 1) John Sealy North Building (JSN); 2)

Clinical Science Building(CSB); 3) Basic Science Building(BSB); 4)Moody Library Building (MLB); and 5) John Sealy South Building (JSS). In these five buildings, the soft tune up (The optimized cold deck set point coordinates the cold deck setting with hot deck setting to minimize the whole system energy consumption) is the major O&M measure identified. The report briefly describes the buildings, summarizes the methodology used and the O&M measures identified for each building, it also presents simulated energy savings, measured savings and conclusions.

Meurer et all (1999) in "PHOEBUS—an autonomous supply system with renewable energy: six years of operational experience and advanced concepts", report on solar-generated electric energy. They explain that:

> "the PHOEBUS demonstration plant has been supplying the Central Library of Forschungs Zentrum Jülich (FZJ) with solar-generated electric energy all year round and independent of the public grid since 1993. The central task was to test the required storage using hydrogen as the energy carrier in conjunction with an electrolyser and a fuel cell under realistic irradiance and consumption conditions and to demonstrate the feasibility of such a zero-emission supply system. The general objective was to determine weak points from the operating experience and measured data obtained, to model the system in a component-oriented manner for simulation, to energetically optimize the plant, to achieve high operational reliability and, above all, to propose and implement cost-reducing and advanced system modifications. With the aid of validated simulation programs, it was possible to carry out optimization analyses for plant".

Mei et all (2003) in a study named "Thermal modeling of a building with an integrated ventilated PV façade" (Photo Voltaic façade) report the changes have been done by the use of air and solar systems in a library". This paper presents a dynamic thermal model based on TRNSYS (Transient System Simulation Tool), for a building with an integrated ventilated PV façade/solar air collector system. The building model that was developed has been validated against experimental data from a 6.5 m high PV façade on the Mataró Library near Barcelona. Preheating of the ventilation air within the façade is through incident solar radiation heating of the PV elements and subsequent heat transmission to the air within the ventilation gap. In winter, the warmed air can be used for building heating. Modeled and measured air temperatures are found to be in good agreement. The heating and cooling loads for the building with and without such a ventilated façade have been calculated and the impact of climatic variations on the performance of such buildings has also been investigated. It was found that the cooling loads are marginally higher with the PV façade for all locations considered, whereas the impact of the façade on the heating load depends critically on location.

Jin et al (2009), in their "Energy efficiency supervision strategy selection of Chinese large-scale public buildings discuss energy consumption " paper, discuss building development and building energy consumption in China, and point out that energy efficiency management and maintenance of large-scale public buildings is the breakthrough point of building energy savings in China. Three obstacles are: lack of basic statistical data, lack of a market for energy saving building services, and lack of effective management measures, which account for the necessity of energy efficiency supervision for large-scale public buildings. Then the

paper introduces the supervision goals, the supervision system and the five basic systems' role in the supervision system, and it analyzes the working mechanisms of the five basic systems. The energy efficiency supervision system of large-scale public buildings takes energy consumption statistics as a data basis, energy auditing as technical support, and energy consumption ration as a benchmark of energy savings and price increases beyond ration as a price lever, and energy efficiency public-noticing as an amplifier. The supervision system promotes energy efficiency operation and maintenance of large-scale public building, and drives comprehensive building energy savings in China.

Loutzenhiser et all (2009), in an energy simulation program named: "An empirical validation of window solar gain models and the associated interactions" report the empirical validation of building energy simulation programs was performed in a test cell on the Swiss Federal Laboratories for Materials Testing and Research (EMPA) campus in Duebendorf, Switzerland. The purpose of this exercise was to evaluate the performances of three building energy simulation programs when simulating energy flows through a window (i.e. glazing unit and window frame). The programs used for this study were EnergyPlus, DOE-2.1E, and IDA-ICE. The inputs to the building energy simulation programs were ascertained through precise measurements and simulations, which are explained in detail in this paper. To assess overall performance, the cooling power measured in the experiment was compared with the programs' predictions. Thorough statistical analyses and comparisons were used to determine the impact of experiment output, input uncertainties and evaluate the programs. The absolute average difference between the experiment and predictions for EnergyPlus, DOE-2.1E, and IDA-ICE were 5.8, 9.9, and 6.0%, respectively.

Escrivá-Escrivá, Álvarez-Bel, Peñalvo-López (2011) in their article "New indices to assess building energy efficiency at the use stage", explain:

> "Numerous computer programs are available to calculate the energy efficiency of buildings. Many are based on the use of a reference building to determine the degree of efficiency. However, this methodology presents a major constraint when assessing a building after construction and during the use stage. To assess the energy efficiency of buildings, this paper proposes new indices based on energy consumption during different periods; as well as other parameters of the buildings such as construction area, number of users, and air-conditioned volume. Results are presented as an application for various buildings on the campus of the Universidad Politécnica de Valencia".

Cheng (2011) in "Factors on new energy development based on cases studies from co-integration and Granger test reports" stated that in order to discover the factors on new energy development, this paper, based on carbon dioxide emission, energy prices and new energy consumption to total energy consumption data from 1990 to 2008, established a regression equation to analyze the factors. Environmental issues and concerns triggered by industrial emission have no impact on new energy sources development, which largely depends upon prices. To develop new energy sources is a useful way to avoid global market risks. By analyzing the costs of new energy sources, we see that the factors influencing their development comprises high production cost and poor technology, so a technical innovation will play a key role in new energy development.

Methodology

A. AHP

The Analytical Hierarchy Process (AHP) is a tool that is used for prioritizing some alternatives based on the criteria of the problem in complex, uncertain, multi criteria problems. This method is a very good method for the mixed evaluation problems which have both quantitative and qualitative criteria. The AHP model divides a complicated evaluation problem into a hierarchical structure to represent the selection. Usually there is a goal of the problem at the top of the hierarchy, criteria and sub-criteria are at the middle level of the hierarchy and alternatives of the problem are at the bottom of the hierarchy structure. The AHP has a top- down structure.

Criteria are weighted considering the final goal, as well as evaluating alternatives regarding criteria and sub-criteria. By using these weights and information, the final decision vector can be calculated.

Pair wise comparison matrices are made in order to evaluate criteria according to the goal and alternatives from the criteria point of view; elements in each level are compared in pairs with elements immediately below, to assess their preferences.

The AHP model uses a verbal scale to compare criteria, which allows stakeholders to use the subjective opinions of experts and personal experiences, which put AHP in the subjective methods group.

Saaty, the founder of AHP has suggested a scale of 1-9 to assess preferences between criteria. A value of 1 shows equal importance, 3 moderately more importance, 5 strong importance, 7 very strong importance and 9 extreme importance, the values of 2, 4, 6, 8 show compromise importance.

TABLE 1
AHP MEASUREMENT SCALE

Importance	DEFINITION	Meaning (A compare B)
1	Equal importance	A equally important to B
3	Moderate importance	A is moderately more important than B
5	Strong importance	A is strongly more important than B
7	Very strong importance	A is very strongly more important than B
9	Extreme importance	A is extremely more important than B

Then, the weights of elements are calculated in each level in respect to elements of the upper level. The composite weight of each alternative is obtained by aggregating the weights through a hierarchy path from the top of the hierarchy to the bottom most level, which is alternatives, and multiplying the weights along each segment in the path.

The result would be the overall weights of the alternatives.

The AHP method uses an inconsistency index to check if the judgments of the decision maker were consistent; an inconsistency index is calculated as a ratio of the decision maker's

inconsistency and a randomly generated index; so this index is important for the decision maker to be sure about the consistency in his judgments. If the judgments are not consistent, judgment matrices should be revised.

B. TOPSIS

The *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS) method developed by Hwang and Yoon, based on the concept that the chosen alternatives should have the shortest distance from the positive ideal solution (ideal point) and the longest distance from the negative ideal solution (nadir point). Formally, for a decision making problem, the ideal point is where the best value for criteria is found among all available alternatives. The nadir point is where the worst value for criteria among all available alternatives appears. The normalized rating vector is then calculated, and by using a weight vector, the weighted normalized rating vector is obtained.

The distance of each alternative for the best point and nadir point is calculated. These distances can be calculated with Euclidian distance or other ways, in this study the Euclidian distance is applied.

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \qquad i = 1, \dots, m \qquad (1)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \qquad i = 1, \dots, m \qquad (2)$$

, Where v_j^+ and v_j^- are the best and nadir points.

Finally the relative closeness for each alternative is calculated; therefore the final ranking of alternatives is obtained through relative closeness.

$$rc_i = \frac{d_i^-}{d_i^+ + d_i^-} \qquad (3)$$

The greater relative closeness leads to the higher rank.

Case study and discussion

In this study, the energy system in the two public libraries is evaluated, to see which kind of energy system is more suitable for public libraries. It is necessary to know detailed information about electricity usage, the cooling and heating systems and the hot water usage of the libraries. The two libraries chosen for the study are two public libraries in Tehran.

These alternatives are already used in some buildings and are capable of meeting the energy demand of a library. There is a wide range of alternatives that can be used in different buildings. In this paper we have tried to choose alternatives that can cover a wide range of available technologies and their combinations (table 5).

Several systems are available and have been studied in this paper, Solar photovoltaic (PV), gas engine (GE), wind turbine (WT), air conditioner (AC), gas boiler (GB), electric boiler (EB), Fuel cell (FC) and the utility grid system that provides just use of grid power (UG).

The specification of these systems is shown in the table 2.

Table 2
Systems specification

System	Capacity (KW (h))	Capital cost ($\times 10^3$ $)	Efficiency/COP	Life time (Year)
Photovoltaic	48	57	12%	30
Gas engine	100	40	35%	15
Wind turbine	64	60	40%	20
Air conditioner	11.2	25	Cool: 5.5; Heat: 6.6	15
Gas boiler	20	29	95%	15
Electric boiler	18	35	5%	15
Fuel cell	50	44	45%	

Different alternatives are chosen from the combination of the available systems that are mentioned above and they are compared with conventional system. They can be seen in table 3.

In order to do an evaluation process, criteria for evaluation should be indicated. The evaluation process used to be done based only on cost, but recently, many other aspects have become important besides financial aspects, especially the environmental aspects. In this study, Capital cost (CC), Operation and maintenance cost (RC), CO2 emission (CO2Em) and Energy consumption (EC) are considered as criteria for evaluation.

Table 3
Alternative systems

Alternatives	Description of the system	combination
A1	Conventional system	UG+AC+GB
A2	Fuel cell	UG+FC(1KWh)+AC
A3	Wind energy	UG+WT (3.2 kW)+AC+EB
A4	PV all electric	UG+PV (3 kW)+AC+EB
A5	PV	UG+PV (3 kW)+AC+GB
A6	Gas engine	UG+GE (1 kW)+AC
A7	All electric	UG+AC+EB
A8	Hybrid system	UG+WT (3.2 kW)+PV (0.2 kW)+AC+EB

Besides criteria themselves, the weights of these criteria in the evaluation process is very important and it affects the answers significantly. The weights are determined by decision makers doing a comparison on a matrix regarding the goal, but in this paper four different scenarios are defined and the sensitivity analysis is done through changing weights of criteria, and its effect on the final ranking is observed.

Electricity and gas prices are also needed to complete the evaluation process.

The price of electricity and gas in Iran is based on the seasons and tariffs are calculated accordingly. Subsidies used to be provided to public libraries, but during last year the government decided to release prices and cut subsidies.

Then the capital cost of each system, operation and maintenance cost, CO2 emission and energy consumption of each system is calculated. Based on experts' opinion, the evaluation is done according to AHP method as well as TOPSIS method.

For Arghavan public library in Tehran the following table is calculated.

Table 4
Evaluation table

	Capital Cost, Thousand $	Operation & maintenance cost, Thousand $	CO2 Emission, ton	Consumption (GJ)
A1	0.74	1.028	17.45	249.5271
A2	2.6	0.69	16.18	233.5558
A3	1.9	0.88	14.08	234.5702
A4	1.75	0.775	12.36	214.8135
A5	1.6	0.921	15.18	228.8963
A6	0.94	0.697	17.98	247.8813
A7	1.2	0.891	14.56	235.5736
A8	1.8	0.872	14.37	234.0181

According to the calculated table, the comparison is carried out, and then in the comparison it is decided that each criterion has the same weight for the evaluation. According to the AHP and TOPSIS methods, the following evaluation is performed.

Table 5
First scenario result

AHP	TOPSIS	Ranking
A4	A6	1
A6	A7	2
A2	A4	3
A7	A1	4
A1	A5	5
A5	A8	6
A8	A2	7
A3	A3	8

With the AHP method, in this scenario the PV all electric system is the best system, followed by the Gas engine system and fuel cell system, but with the TOPSIS method the best systems are the Gas engine, the all electric system and PV all electric system. The complete results for scenario 1 are shown in table 9, which obviously shows that these two methods do not lead to the same ranking but reveal a similar trend.

In the next scenario, we assume that the cost factors have more importance than other factors. This scenario is very important since Iranian government has decided to cut subsidies for energy, making it very important to study this case. Results can be seen in the following table.

In this second scenario, although cost is still paid the most attention, not only initial cost but also running cost are considered (life cycle point of view). By applying the AHP method on one hand, the gas engine and the conventional system appear as the best systems, while the worst system is PV system. On the other hand, when using TOPSIS, the best systems are the gas engine and the all electric system, while the worst system is the hybrid system.

Table 6
Second scenario result

AHP	TOPSIS	Ranking
A6	A6	1
A1	A7	2
A2	A1	3
A4	A4	4
A7	A5	5
A3	A3	6
A8	A2	7
A5	A8	8

It is obvious that although cutting subsidies has led to rising energy costs; at the current price, it is still more economical to use conventional systems rather than renewable energy systems. So in order to encourage library buildings to use renewable energy systems instead of conventional systems it is crucial to help libraries with their costs, or the price of conventional energy systems should be much higher.

Conclusion

In this paper, two different multi criteria evaluation methods have been used in order to evaluate energy systems in the public library in Tehran. This evaluation has been done based on four different criteria and according to different weights for them. These different criteria have included economic, environmental, and energy characteristics. Two scenarios for different weights of criteria are defined and evaluation is done based on them. Multi criteria evaluation methods can provide more information for decision makers and decision makers can be more confident about their decision.

Different methods of multi criteria evaluation lead to different answers although these answers follow the same trend. There's no best multi criteria method for each problem and choosing a proper multi criteria evaluation method can be a multi criteria problem itself.

If economic factors are paid more attention to, the conventional systems are the best system in comparison with renewable energy resources in public libraries, so that for encouraging public libraries to use renewable energy resources it is desirable that the government were to allocate some extra budget to public libraries in order to pay for the expense.

Among the renewable energy resources in both methods, PV systems are more popular than others; this may be due to the sufficient radiation in the area. It is recommended to do this study with fuzzy methods, which may result in more realistic and accurate answers.

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