SUSTAINABLE ENERGY MANAGEMENT STRATEGIES IN HOSPITALS: EXAMINATION AND ANALYSIS

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ABSTRACT

Background: Sustainable development is often defined as the process of change by which the current needs of society are without hindering the capacity of future generations to meet their needs. Hospitals and medical centers are among the most vital organizations in any society and are among the largest consumers of water and energy and producers of waste.
Objective: The purpose of this study was to identify and rank sustainable energy management strategies in Farabi Hospital.
Method: The present study is applied in terms of purpose and descriptive in terms of methodology. For collecting data, a researcher-made questionnaire based on multi-attribute decision-making methods used in this study (test and evaluation decision method, network analysis method, simple weight total, and Linmap) was used, which were completed by ten experts familiar with the topic of sustainable energy management with at least ten years of experience in Farabi Hospital in Bastak city in Hormozgan province.
Result: The results of data analysis indicated that reduction of fossil energy consumption, waste recycling, and renewable energy are respectively the most significant criteria for sustainable energy management in hospitals while employing equipment for reducing water consumption, installing automatic doors, and utilization of rainwater collection system are respectively the most important criteria for optimized, sustainable development
Conclusion: According to the study results, the hospital managers are required to adopt combined solutions for energy management in the water and electricity sectors to focus on reducing energy waste and the use of new energy sources such as solar and rainwater.

INTRODUCTION

Development has been the primary concern of humanity for attaining superior standards of life (Mohammadi De Cheshmeh, Mustafa, 2014). Sustainable development is called the main challenge facing humanity in the present century (Maleki S, 2014). It is defined as the progress by which the current generation's needs are met without compromising the ability of future generations to meet their needs (Keshtkar GA, 2010). Sustainable development is an extensive field that has been raised by scientists to respond to the economic, social, and environmental problems of the modern world and has been acknowledged by governments, academia, centralized national and international programs (Bilgen S, 2008).

Furthermore, health and hygiene have long been of utmost significance to all societies. One of the essential issues in this field is providing quality services and efficient decision-making to increase patient satisfaction (Beheshtinia MA, 2017). Health is the right and need of all human beings, and the development of any community is often assessed by the quality of health therein (Gostin LO, 2017). Hospitals and medical centers are considered one of the most pivotal establishments of any society, as their strategic position in the face of critical disasters and their role in increasing the country's level of health and well-being has further highlighted their significance. The ability of these establishments to control current costs and spend the profits obtained from optimizations is of particular importance to the main objective of these centers, which is to provide appropriate medical services to patients (Jabbarvand M, 2011). Therefore, as one of the essential components of the health system, hospitals are heavily featured in plans for sustainable development (Kolokotsa D, 2012).

The World Health Organization (WHO) estimates that approximately three-quarters of all health care budgets in developing countries are assigned to hospital expenditures (Sadrizadeh F, 2002). In our country, public hospitals are among important yet high-cost public centers. However, energy consumption in Iran is far from optimal, which has increased significantly in recent years (Fattah H R, 2011).

In a study aimed at ranking the solutions to reduce energy consumption in hospitals, the solutions in water consumption were determined to have the highest weight, followed by measures to reduce consumption in the fields of electricity, gas, and utilities (Jabari O, 2018). Another study sought to identify and rank improvement projects focusing on energy consumption management in the hospital, which showed that energy consumption has a high percentage of hospital costs (Ostadi B, 2016). Another study on energy efficiency methods in hospitals showed that energy supply problems in hospitals include

low efficiency of electricity production in the country, instability and security in electricity supply, emergency generators, and hospital management problems (Abbasi F, 2015).

The results of a study on the management of energy consumption conservation in hospitals showed that corrective and cost-effective maintenance measures could reduce energy consumption (García-Sanz-Calcedo J, 2017). The results of a study on the health sector revealed the optimality of a hybrid system in which the strengths of a renewable energy source using efficient batteries are combined with a diesel generator for sustainable energy management (A.Franco A, 2017). The results of a similar study indicated that the use of renewable energy compared to conventional energy significantly reduces carbon emissions and diesel consumption (B. Alotaibi DM, 2019).

A review of previous studies reveals that sustainable energy management in hospitals has garnered much attention among research, while more local studies should be conducted given the distinct economic and climatic features of our country. Therefore, this study aimed to identify and rank sustainable energy management strategies in Farabi Hospital in Bastak city in Hormozgan province using a mixed multi-attribute decision-making approach.

METHODS

The present study is a cross-sectional applied which uses descriptive methods, including multi-attribute decision making. In decision-making studies, the panel of experts usually consists of 5 to 15 people. The panel of experts in this consisted of 10 experts of sustainable energy management with at least ten years of experience in Farabi Hospital in Bastak. A minimum of 10 years was considered to guarantee the familiarity of the experts with the hospital environment. After obtaining the necessary licenses, some of the qualified members were purposively selected, which was continued using snowball sampling until all the organization's experts were identified. In the first step, criteria and strategies for sustainable energy management were identified from the research literature.

For this purpose, related articles were queried from Google Scholar, Science Direct, and Springer from 2015 to 2020 using the keywords “Criteria and strategies for sustainable development, sustainable energy management, and hospitals.” Based on the results of review studies, 31 strategies and 22 criteria related to sustainable energy management were identified. Data were collected by a group of experts using three researcher-made questionnaires based on the research method. In the first questionnaire based on the DEMATEL method, experts were asked to determine the effect of criteria on each other.

Data analysis using this method led to the identification of causal and latent relationships between the criteria. In the next step, the relationships above were employed to draw a network of criteria related to sustainable energy management. A questionnaire of criteria pairwise comparisons was designed to determine their weight using the Analytic Network Process (ANP) method; the outputs were then recorded.

To rank sustainable energy management solutions, the score of each option was calculated according to each criterion. The score of the solutions of quantitative criteria was determined based on the hospital documentation, while the score of the qualitative criteria was determined based on the average opinions of the experts in the relevant questionnaire. The final ranking of the solutions was determined using the LINMAP method. This method first determines the optimal point and then determines the option that has the shortest distance to the optimal point (Azar A, 2014). It should be noted that the LINMAP method requires pairwise comparisons to function. In the present study, these comparisons were extracted from the Simple Additive Weighted (SAW) method. Figure 1 shows the research methodology.

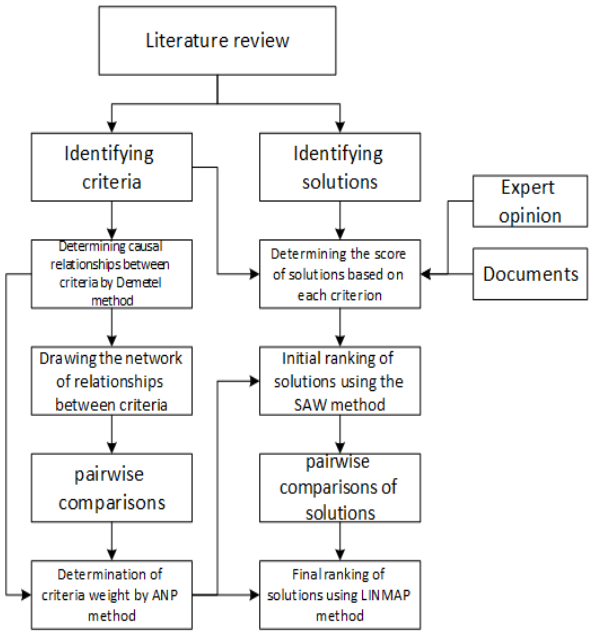

Figure 1: Research steps

RESULTS

In the first phase of this study, the previous literature was revealed to identify the criteria related to sustainable energy management in hospitals and the corresponding optimization strategies. Accordingly, 22 criteria related to sustainable energy management were classified into three economic, social, and environmental dimensions.

After drawing the network of criteria based on the Decision-Making Trial and Evaluation Laboratory (DEMATEL) output, the collected data were analyzed to determine the weights of the criteria based on the opinions of experts using the analytic network process (ANP) in Super Decisions software. In order to ensure the reliability of the results, the inconsistency ratio was calculated. In general, inconsistency ratios less than 0.1 are

considered relatively acceptable (Saaty TL, 2008), which was the case for all of the present study matrices, indicating the reliability of the results. The criteria, along with the weights obtained from the ANP method, are listed in Table 1.

Table 1
Weight And Rank Of Criteria Related To Sustainable Energy Management In Hospitals

Rank	Criterion	Cluster	Weight in cluster	Total weight	Source
1	Reduction of fossil energy consumption	Environmental	0.1905	0.1326	Ostadi B, 2016
2	Waste recycling	Environmental	0.1784	0.1242	Keshtkar Ghalat AR, 2010
3	Renewable energy	Environmental	0.1718	0.1195	Wang JJ, 2008
4	Environmental effects	Environmental	0.1702	0.1184	Wang JJ, 2008
5	Cost of energy	Economical	0.375	0.0877	Zheng G, 2010
6	Water consumption	Environmental	0.1153	0.0803	Jabari O, 2018
7	Electricity consumption	Environmental	0.0989	0.0688	Jabari O, 2018
8	Service lifespan versus cost	Economical	0.2457	0.0574	Wang JJ, 2008
9	Staff training	Social	0.7549	0.0528	Saeedpour J, 2013.
10	Return on investment	Economical	0.1064	0.0248	Wang JJ, 2008
11	Investment cost	Economical	0.079	0.0184	Taheri S, 2015
12	Employing local people	Economical	0.0753	0.0176	Wang JJ, 2008
13	Risk	Economical	0.075	0.0175	Jabari O, 2018
14	Consumption of fossil fuels	Environmental	0.0229	0.0159	Jabari O, 2018
15	Vocal noise	Environmental	0.0222	0.0155	Wang JJ, 200
16	Emissions of greenhouse gases	Environmental	0.0152	0.0106	Wang JJ, 2008
17	Wastage	Environmental	0.0146	0.0099	Jabari O, 2018
18	Social acceptance	Social	0.1196	0.0083	Mirsafian HR, 2018
19	Government grants	Economical	0.0269	0.0063	Mohebbifar R, 2012
20	Solidarity and public participation	Social	0.0757	0.0052	Keshtkar GA, 2008
21	Cost of operation, maintenance	Economical	0.0167	0.0048	Wang JJ, 2008
22	The impact of operations on local communities	Social	0.0498	0.0035	Wang JJ, 2008

In the next phase, strategies for optimizing sustainable energy management were ranked based on the results of previous steps. Table 2 shows the sources and ranking of solutions using simple additive weighted (SAW) and LINMAP methods.

Table 2
Ranking Of Sustainable Energy Management Strategies In Hospitals

Solution	Source	Rank based on	
		LINMAP	SAW
LED and photocell lamps	(11,13,23)	15	13
Intelligent lighting system	(11,13)	16	11
Intelligent engine room control	(11,13,28)	20	7
Thermostatic and vent valves	(8,29)	18	6
Double glazed windows	(23,31,30)	14	16
Automatic doors	(28,31)	2	2
Nano insulation paints	(23,30)	23	24
Sealing tapes	(11,13)	17	5
Water reducing equipment	(11,12)	1	3
Thermal insulation of pipes in the engine room	(28)	6	8
Equipment file	(35)	11	10
Smart adjustment of curtains	(28)	24	23
Disposable vegetable dishes	(35)	26	27
Solar Energy	(11,33)	4	20
Intelligent programming system	(28,29)	12	19
Energy Supervisor	(26,29)	8	17
green roof	(28)	22	22
Electrical protector	(23)	19	21
Ventilation system intelligence	(29)	13	18
Decreased activity during peak hours	(28,29)	25	25
Education and culture	(12,23)	9	4
Solar battery	(33,32)	5	9
Equipment repair	(10)	21	12
Rainwater collection system	(12,34)	3	15

Separation of wastes	(33)	7	14
Suitable for air conditioners	(35)	29	29
Electrical appliances with energy label A.	(13)	31	31
Improving cooling systems	(12)	27	28
LED monitors	(12)	30	26
Maintenance of engine room equipment	(36)	10	1
Insulated flooring	(36)	28	30

DISCUSSION

This research aimed to identify and rank sustainable energy management improvement strategies based on relevant criteria. The ranking of criteria affecting sustainable energy management indicated that measures to reduce fossil energy consumption, waste recycling, and renewable energy were the most important criteria for sustainable energy management in Farabi Hospital.

The study's findings also reveal that, in general, environmental criteria are more significant in sustainable energy management of the hospital than economic and social criteria and hence require more consideration. This finding is consistent with that of previous studies (Roulet CA, 2012), (Janjic A, 2012).

Based on the ranking of sustainable energy management solutions, employing water-reducing equipment, automatic gates, rainwater collection system installation, and solar energy were the most important criteria. The results from ranking criteria and strategies for sustainable energy management suggest the simultaneous attention to renewable energy sources with less environmental pollution and attention to solutions more consistent with the hospital's climate. As such, employing technologies that are best fitted to optimize energy consumption is essential to designing sustainable medical centers (Sahamir SR, 2014). The importance of this issue becomes more pronounced when hospitals are considered a significant source of energy consumption and hence have a high potential for energy saving (Madadi S, 2010).

Previous studies on energy efficiency show that using renewable energy sources leads to promising results (Cavallaro, F, 2005), as for instance, a hospital in Italy reported that it could provide up to 76% of its electricity using fuel cells (Bizzarri G, 2006). Correspondingly, Solar energy can be heavily involved in clean energy supply. A study conducted at a hospital in Mexico revealed that up to 60% of the required heat energy could be obtained from solar sources (Errera, A.,2003). The use of modern, clean energy sources to control environmental issues like controlling carbon dioxide emissions is of paramount importance (Bizzarri G, 2006).

The use of other solutions presented in this study has resulted in promising outputs. For example, a hospital in Greece reported reducing the energy requirement for lighting by up to 50 percent. Moreover, in another case

study, awnings and ceiling fans reduced the need for electricity consumption to cool the environment by 68% (8). A study in a Spanish hospital found that an average annual increase of 6% in the time spent on preventive maintenance operations led to an average annual reduction of 500 MWh in energy consumption (García-Sanz-Calcedo J, 2017).

The present study was performed in Farabi Hospital in Hormozgan and is cross-sectional in terms of time, and hence the results should be approached with care. Also, the methods used in the present study cannot predict the effects of managerial decisions.

CONCLUSION

According to the results of the study, the hospital managers are required to adopt combined solutions for energy management in the water and electricity sectors to focus on reducing energy waste and the use of new energy sources such as solar and rainwater to consider environmental, economic, and social criteria in assessing solutions.

Based on the research results, managers and decision-makers of medical centers are recommended to use solutions such as rainwater collection systems, thermostatic and ventilation valves, and automatic doors to optimize energy consumption and develop sustainable plans. Establishing energy and environmental supervisory post with tasks such as administration of waste segregation and educational and cultural activities is also recommended.

It is recommended that mothers during pregnancy consume a balanced diet so that the mother and fetus are well-nourished during pregnancy so that the baby is born with a normal weight. Pregnant women carry out ANC (Antenatal Care) at nearest Community Health Center or posyandu. Complete, the mother give exclusive breast milk to her baby, as well as, the mother pay attention to the toddler's personal hygene to avoid infectious disease and actively carries out basic complete immunization before the age of 1 year.

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