Comparison of sustainable information technologies for companies

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Abstract

Ensuring the diversity of energy technology and using energy-efficient information technology are the key factors of sustainable energy politics in business. In the present study, we focus especially on choosing the best alternative to improve energy efficiency in business. In this context, this question may be analyzed via a survey method. We compare energy efficiency improvement alternatives of computer use methods in companies by TOPSIS methodology, which is one of the multi-criterion decision-making techniques.

Keywords: information technologies; sustainability; TOPSIS; energy efficiency; survey

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1 INTRODUCTION

Sustainable energy politics have many aspects. One of these aspects is about the kind of energy used: renewable or non-renewable. Today, ∼85% of energy resources used in the world come from fossil fuels. The reserves in the ground are very limited while their use grows significantly every year. In addition to this scarcity problem, burning of fossil fuels releases all manner of pollutants into the air with dangerous effects on human health and into greenhouse gases, which threaten the environment. The main negative impacts of combustion of fossil fuel are air pollution and climate change, along with the major harm coming from the extraction and transport of this kind of energy source. There is widespread consensus that energy policy plays a vital role in potentially mitigating the impacts of global warming and crisis of energy availability. With increasing negative effects of narrow dependence on fossil fuels on the environment, and further depletion of a finite supply, many countries have been forced to inquire into and begin adapting more environmentally friendly energy alternatives. The fact that this type of non-renewable fuels and the problems they cause on both human health and the environment has brought the concept of renewable energy sources and energy efficiency. Sustainable energy politics plays a great role in the development of environment-protecting countries. When considering a country, its level of development in terms of energy can be examined by two key indicators: one is energy consumption per capita and the other energy efficiency. Today, in our world the demand for energy is increasing. Diversifying energy supplies, increasing energy efficiency in the regional and global field, ensuring the diversity of energy technology, adding renewable sources to the energy supply system, protecting the environment and public health in the production of energy, taking into account consumers accessibility to energy in terms of cost and time, and implementing measures for energy efficiency are some of the measures for sustainable energy politics of countries and also for companies.

In the context of this paper, when we especially focus on sustainable information technology (IT), ensuring the diversity of energy technology is the key factor. In this present study, we firstly introduce basic computer application alternatives for improving energy efficiency in business. Secondly, we present TOPSIS method, which is a multi-criterion decision-making technique. Then, we realize our analysis in the aim to choosing the best alternative to improve energy efficiency in business. This question may be analyzed via survey method. Finally, we give our results in the last part of our study and give our remarks for further research.

2 ENERGY EFFICIENCY IN BUSINESS

In our world, because of the increasing energy costs and greenhouse gas emissions produced by the increasing usage of the information and communication technologies, there is an urgent demand for energy-efficient technologies [1]. Using these technologies, a decrease in the overall energy costs, consumption of

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computation, storage and communications is expected. That's why energy efficiency in the future information and communication technologies is considered to be increasingly important. In recent years, many companies are trying to involve sustainable IT by implementing sustainable technologies to make their businesses cost-effective and sustainable. Companies are under increasing pressure from customers and shareholders to make a sustainable business. The development of information and communication technology (ICT)-based businesses and social practices has transformed most of the businesses into e-businesses. On the other hand, global warming and climate change with limited energy reserves and rising cost of energy are posing serious challenges for the sustainability in business. Data centers offer to a company a large variety of services such as Internet, e-commerce, social networking, and more general services such as software as a service, Internet as a service, platform as a service, and grid and cloud computing [2]. Huge amount of computation power is required to provide these large systems. This will result in emissions of greenhouse gases causing global warming and climate change.

For all these reasons, the energy use and environmental impact of data centers has recently become an important issue for companies. The servers consume a lot of energy and emit greenhouse gases like CO_2.

In Figure 1, the large percentage of CO_2 emissions, nearly 40% of the total emissions, produced by personal computers and monitors are shown. Second huge part, 23% of total emissions belong to the servers with cooling. It is estimated that energy consumption and carbon emissions will continue to increase in the future [3]. This estimation realized by SMART 2020 study estimates also that CO_2 emissions from ICT will increase at a rate of 6% per year and will represent 12% of worldwide emissions by 2020.

The environment is affected by IT in different ways. This effect occurs from the beginning of a computer's production until it becomes a waste. Electricity, raw materials, and chemicals are consumed by computers, and the harmful waste is produced at the last stage of a computer's life cycle. Whole issues during this cycle provide many environmental problems. Furthermore, the increase in energy consumption results in increased greenhouse gas emissions as most of the electricity is generated by burning coal, oil, or gas. Old computers, which contain toxic materials, are also an important resource of pollution. Powerful media attention has increased the awareness of people around the world for climate change and greenhouse gas effect on global warming.

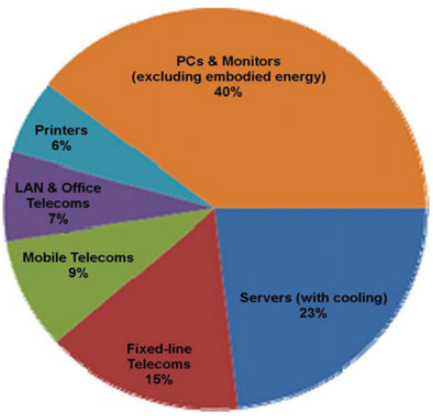


Figure 1. *Estimated ICT CO_2 emissions.*

The data centers not only consume enormous energy but also increase the budget of electricity consumption of the company. There exists a large field of interest about the electricity used for IT equipment since the first Energy Star description for personal computers was published [4]. According to Gartner, if energy costs continue to double every five years, they will considerably increase to 1600% between 2005 and 2025 [5]. On the other side, like the energy costs, energy use in data centers is also doubling every five years [6].

Since recent years, for companies it becomes urgent to develop environmentally sustainable IT, from both an economic and environmental viewpoint. For this reason, using energy efficiently can help the company control the energy costs and preserve the environment. Energy efficiency is the use of technology that requires less energy to perform the same function. In this context, energy sustainability takes a great part of the energy efficiency. The sustainability focuses on long-term energy policies. The aim is to ensure suitable energy to meet today's needs, as well as tomorrow's. Sustainability includes research investment and development of environmental technologies. Sustainability in business proposes major advantages and benefits as mentioned below:

- It reduces IT maintenance activities and costs;
- It reduces companies' overall energy costs;
- It reduces the emission of CO_2, which is the main factor of greenhouse gas emissions;
- It reduces global climate change effects;
- It reduces overall carbon footprints.

Ensuring the sustainability in business may be created by different low-carbon technologies used on IT systems. In this study, we firstly introduce basic computer application alternatives for improving energy efficiency in business. Those alternatives are as follows:

(1) common use of computing resources to provide lower-energy saving computers (cloud computing),
(2) reducing the number of servers by virtualized server,
(3) company computers replaced with energy-efficient components,
(4) using automatic desktop hard disk backup system.

Cloud computing is a style of computing in which scalable and elastic IT-enabled capabilities are delivered as a service using Internet technologies [7]. This technology uses the Internet and central remote servers to maintain data and applications. Cloud computing allows consumers and businesses to use applications without installation and access their personal files at any computer with Internet access [8]. Any transactions by cloud computing users are not carried out on their own computers but

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from cloud computer service providers. By this fact, this cloud computing users are not necessarily high-performance computers. Only cloud-performance computer used to access the Internet access is sufficient to run programs. Thus, energy is saved as lower-energy-consuming computers are realized by performing operations using cloud computing.

The second alternative of our study is reducing the number of servers by virtualized server. Companies have been buying separate server for transactions such e-mail and data storage. The use of virtualized servers for each transaction eliminates the need for a separate server. A single server acts as several servers with the use of virtual machines on a single server. Thus, by reducing the number of servers, savings on the energy used by servers, cooling energy consumed by servers and the purchase cost can be accomplished [9].

The third alternative is replacing company computers with energy-efficient components. The energy efficiency of components of computers is becoming more and more significant. Today, with the development of technology as well as better performance, less energy-consuming processors are being developed. By this way, energy efficiency is provided by changing the parts of existing computers. The development of efficient components is a former charge of suppliers [10].

Using automatic desktop hard disk backup system is the fourth alternative. When employees leave the company if they don't turn off their computer. To prevent this waste of energy, this alternative lead to automatically save the work on the computer.

In this study, we compare these four alternatives by TOPSIS methodology, which is one of the multi-criterion decision-making techniques. By taking into account the qualitative and quantitative information obtained from the results of our interviews with the specialists of the subject, we tried to choose the best alternative for the best energy-efficient technology in computer usage.

3 METHOD

The multi-criterion decision-making (MCDM) problems are widespread in the field of the theory of the decision as mentioned by Triantaphyllou [11]. According to Hwang and Yoon, the problems of MCDM are commonly categorized into two groups, multiple attribute decision-making (MADM) and multiple objectify decision-making (MODM) [12]. MADM, defined as a technique of assistance, has the decision to evaluate and choose the alternatives that are characterized with several attributes of criteria. In this study, we have chosen TOPSIS, which is one of the methods of MADM developed by Hwang and Yoon [13]. Although the other methods have many advantages, TOPSIS is the best method for our study since it has an appropriate structure decreasing the response time for the information obtained from the experts who contributed to our research. TOPSIS is based on the principle where the chosen alternative should be the one that is the closest to ideal alternative and the furthest from the negative-ideal alternative explained by Hung-Chang [14]. TOPSIS uses the following six steps:

(1) Standardization of the data: the standardization of vector is employed to calculate the normal data:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad i = 1, 2, \ldots m; j = 1, 2, \ldots n, \tag{1}$$

where x_{ij} indicates the effective output of the ith alternative with regard to jth criterion.

(2) Calculation of the weighed normal data: the weighted normal data are calculated as follows:

$$v_{ij} = w_j r_{ij} \quad i = 1, 2, \ldots m; j = 1, 2, \ldots n, \tag{2}$$

where w_j is the weight of jth criterion.

(3) Determination of the ideal and anti-ideal solutions: the ideal solution (A^*) and the anti-ideal solution (A^-) are defined in terms of weighed normal values as follows:

$$\begin{aligned} A^* &= \left\{ (\max_i v_{ij} | j \in J), (\min_i v_{ij} | j \in J'), i = 1, 2, \ldots m. \right\} \\ &= \{ v_{j*}, j = 1, 2, \ldots, n \} \\ A^- &= \left\{ (\min_i v_{ij} | j \in J), (\max_i v_{ij} | j \in J'), i = 1, 2, \ldots m. \right\} \\ &= \{ v_{j-}, j = 1, 2, \ldots, n \} \end{aligned} \tag{3}$$

where j is the whole of criteria of profit and i is the whole of criteria of cost.

(4) Calculation of measurements of distance: the Euclidean dimensional distance of n can measure the distance between the alternative solutions. The distance from each alternative ideal and anti-ideal solution is then indicated by:

$$\begin{aligned} D_i^* &= \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j*})^2}, i = 1, 2, \ldots, m, \\ D_i^- &= \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j-})^2}, i = 1, 2, \ldots, m. \end{aligned} \tag{4}$$

(5) Calculation of the proximity to the ideal solution:

$$C_i = \frac{D_i^-}{D_i^* + D_i^-}, i = 1, 2, \ldots, m, \tag{5}$$

(6) where C_i indicates the proximity of the ith alternative to the ideal solution. $0 \leq C_i \leq 1$, where $C_i = 0$ when $A_i = A^-$ and $C_i = 1$ when $A_i = A^*$ Determination of the order of preference: the alternative solutions are arranged in descending order.

The type of data is obtained and formed from the responses given by the experts to the questions of our survey questionnaire.

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These experts are from Netaş information and telecommunication solutions company. In our study, first of all, we determined the sample size of interview by the following formula:

$$n = \frac{z^2 \cdot N \cdot P \cdot Q}{(N \cdot D^2 + Z^2 \cdot P \cdot Q)}, \quad (6)$$

where Z, confidence level for %95; N, total number of population, i.e. 600 engineers; P, the probability of searching attribute. As our study is multi-purpose, we take it as %50; $Q = 1 - P$; $D =$ %10 of sample error.

Table 1. *Types of the criteria*

Main criteria	Sub-criteria
Economical (C1)	Investment cost (SC11)
	Management and maintenance costs (SC12)
	Return period (SC13)
	Annual cost impact (SC14)
	Impact on energy consumption cost (SC15)
Technical (C2)	Security (SC21)
	System sustainability (SC22)
	Improving system maintenance and establishment (SC23)
Environmental (C3)	Impact on CO2 emission reduction (SC31)
	Impact on noise reduction (SC32)
	Impact on reduction of physical area using by energy systems (SC33)
Social (C4)	User-friendliness (SC41)
	Impact on information share speed (SC42)
	Impact on reduction of negative externalities (SC43)

Table 2. *Results concerning the degrees of importance of the criteria*

Criteria	Degrees of importance
C1	0.25
C2	0.31
C3	0.25
C4	0.19

Table 3. *Results of the degrees of importance of the criteria*

Sub-criteria	Degrees of importance
SC11	0.05
SC12	0.05
SC13	0.05
SC14	0.05
SC15	0.05
SC21	0.1116
SC22	0.1116
SC23	0.0868
SC31	0.0825
SC32	0.085
SC33	0.0825
SC41	0.0627
SC42	0.0646
SC43	0.0627

Depending to this formula, we found the sample size as $n = 83$.

4 RESULTS

The comparison of these computer systems depends on many criteria. Hence, we have determined four main criteria in the frame of this study. These are economic, technical, environmental, and social criteria. Each criterion has fourteen sub-criteria and they are shown in Table 1.

After this step, we converted the answers of the surveys from the qualitative form to the quantitative form. Depending on the TOPSIS, we found the degrees of importance of the main criteria by taking the average of the given responses. The values from 1 to 5 were taken as answers: 1 for the answer 'much less important', 2 for 'less important', 3 for 'quite important', 4 for 'important', and 5 for 'very important'. Using these data, we formed Table 2.

In the same way, we got the degrees of importance of the sub-criteria depending on the main criteria shown in Table 3. Then, we used the steps of the TOPSIS method and obtained the ideal and non-ideal solutions for each sub-criterion, Table 4. Table 5 shows the ranking of the possible alternatives for improving energy efficiency in business. In the next part, we give results of our analysis.

Table 4. *Results of the ideal and non-ideal solutions*

Sub-criteria	Ideal solution	Non-ideal solution
SC11	0.0001	0.0499
SC12	0.0001	0.0482
SC13	0.0198	0.0264
SC14	0.0084	0.0329
SC15	0.0198	0.0264
SC21	0.0558	0.0558
SC22	0.0443	0.0591
SC23	0.0397	0.0529
SC31	0.0327	0.0437
SC32	0.0360	0.0480
SC33	0.0377	0.0503
SC41	0.0313	0.03135
SC42	0.0274	0.0365
SC43	0.0249	0.0332

Table 5. *Ranking of the possible alternatives*

	Cloud computing	Reducing the number of servers by virtualized server	Energy-efficient components	Automatic desktop hard disk registration system
Ideal distance	0.02916399	0.04073658	0.07631882	0.013172804
Anti-ideal distance	0.073041678	0.069068094	0.02378916	0.072956837
Proximity to the ideal solution	0.714653886	0.629008691	0.237635003	0.847058412
Ranking	2	3	4	1

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In the next step, we calculated the ideal and non-ideal solutions for each sub-criterion, Table 4. The ranking of the possible alternatives for improving energy efficiency in business is given in Table 5.

5 CONCLUSION

In this study, we focused on the basic computer application alternatives for improving energy efficiency in business. We considered four alternatives, which can reduce energy usage and improve the sustainability in companies: cloud computing; reducing the number of servers by virtualized server; energy-efficient components; and automatic desktop hard disk backup system. We compared these four alternatives using a MADM method, TOPSIS. The data were collected from the survey results. The answers of the NETAŞ company engineers were evaluated. The automatic desktop hard disk backup system gave the best result so that it is considered as the first in the ranking of four alternatives. For the sustainable development of countries and companies, energy use plays a great role. The results obtained from the data used in this study show that automatic desktop hard disk backup system gave the best results compared with other alternatives in the domain of computer applications for energy efficiency.

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REFERENCES

[1] Berl A, De Meer H. An energy consumption model for virtualized office environments. *Future Gener Comp Sy* 2011;**27**:1047–55.
[2] Loper J, Parr S. Energy efficiency in data centers: a new policy frontier. *Environ Qual Manag* 2007;**16**:83–97.
[3] SMART 2020 report http://www.smart2020.org/publications/ (February 2013, date last accessed).
[4] Johnson B, Catherine J, Zoi R. EPA Energy Star computers: the next generation of office equipment. In: *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings*, 1992. p. 6.107–6.114.
[5] Gartner. *Going Green: the CIO's Role in Enterprise Wide Environmental Sustainability*. Gartner EXP premier, 2008.
[6] Kumar R. Media relations. Gartner, 2008 www.gartner.com/it/page.jsp?Id1/4781012 (September 2012, date last accessed).
[7] Gartner glossary http://www.gartner.com/it-glossary/cloud-computing/ (February 2013, date last accessed).
[8] http://www.wikinvest.com/concept/Cloud_Computing. (19 February 2012, date last accessed).
[9] Dasgupta G, Sharma A, Verma A, *et al*. Workload management for power efficiency in virtualized data centers. *Commun ACM* 2011;**54**:7.
[10] Neugebauer R, Wabner M, Rentzsch H, *et al*. Structure principles of energy efficient machine tools. *CIRP J Manuf Sci Tech* 2011;**4**:136–47.
[11] Triantaphyllou E. *Multi-criteria Decision Making Methods: A Comparative Study*. Kluwer Academic Publisher, 2000.
[12] Yoon K, Hwang CL. *Multiple Attribute Decision Making: An introduction*. Sage, 2005.
[13] Hwang CL, Yoon K. *Multiple Attribute Decision Making: Methods and Applications*. Springer Verlag, 1981.
[14] Hung-Chang L. Using PCR-TOPSIS to optimize Taguchi's multi-response problem. *Int J Adv Manuf Technol* 2003;**22**:649–55.

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