

Evaluating the Economic and Environmental Impacts of Smart Management Systems for Cooling and Heating Systems in Building: Case study of Office Building in Tehran

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ABSTRACT

Considering the increasing rate of energy consumption and its environmental detrimental effects, as well as considering the use of non-renewable energy sources such as fossil fuels, energy management issues have become more important. Given the 40% share of the building industry's total energy consumption, as well as the 80% share of energy consumed during the operation period, attention to the areas of energy management and optimization during the operation period of the buildings can have a major impact on buildings' energy performance. In this research, through identifying building energy management tools and studying previous studies and assessing the effects of building energy management systems, the economic and environmental impacts of using building energy management systems on the annual energy consumption in an office building in Tehran as a case study has been investigated. The results indicate a 32 percent reduction in energy consumption and a significant reduction in the release of the environmental pollutants in smart mode compared to the base mode. Moreover, considering the social costs associated with the emitted pollutants as well as the return period, it has been attempted to identify the factors contributing to the economic justification of using smart heating and cooling systems. According to the results, the use of smart energy management systems can be considered as an effective step in optimizing and managing energy consumption in the construction sector.

KEYWORDS

Building management system, Smart building, Energy consumption management, Demand response management, Energy consumption optimization

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1- Introduction

Increasing energy consumption, globally, in addition to making economic challenges, has led to detrimental environmental impacts, especially in developing countries [1]. In most of developing countries such as Iran, due to the high share of non-renewable energy sources such as fossil fuels, addressing the issue of energy management is so critical based on its destructive environmental impacts [2]. Moreover, in Iran, the building sector is one of the primary sources of energy consumption. As a result, it is crucial to address energy management strategies, such as the development of smart heating and cooling systems in the building sector [3].

In recent years, due to the growing use of smart energy management systems in the building sector, some studies are conducted to assess the impact of using smart energy management systems. King and Morgan (2007) showed that the productivity of the building energy consumption, as well as the energy consumption costs, are significantly affected by smart building energy management systems such as smart heating and cooling systems [4]. Rocha et al. (2014) examined the effects of energy pricing policies on the development of smart energy management systems in the building sector [5]. Furthermore, Aslam et al. (2017) investigated the capabilities of reducing energy consumption in smart buildings using genetic algorithms and different energy pricing scenarios [6].

In the present study, it is tried to evaluate the environmental and economic effects of smart heating and cooling systems in a non-residential building as a case study. In addition to evaluating the environmental and economic impacts, by calculating the social costs of pollutant emissions and evaluating the payback period, it is attempted to identify and evaluate the factors affecting the economic feasibility of using smart heating and cooling systems in the building sector.

2- Methodology

The methodology of this research is comprising of the following stages:

1. *Library studies and identifying smart heating and cooling systems components:* at this stage, it is tried to review the recently conducted studies in the field of using smart energy management systems in the building sector. Moreover, based on the current infrastructural and economic conditions of Iran, it is tried to identify the available components for smart heating and cooling systems.

2. *Case study:* in order to identify the economic and environmental impacts of using smart heating and cooling systems, a two-story building with an area of 6700 m² is studied in Tehran, the capital and largest city of Iran.
3. *Evaluating the economic and environmental impacts:* At this stage, considering the average reduction in the annual energy consumption, the economic and environmental impacts of using smart heating and cooling equipment are evaluated. The use of smart devices will have direct and indirect economic effects that are addressed in the current study.
4. *Interpreting the results:* at this stage, it is tried to evaluate the challenges and obstacles toward the use of smart heating and cooling systems and identify the possible solutions for their development.

3- Discussion

After developing the smart heating and cooling systems on a non-residential building, the annual energy and water consumption in both base and smart modes are shown in Table 1.

Table 1 – Annual water and energy consumption in the base and smart modes

Energy source	Base mode	Smart mode	Improvement (%)
Natural gas (m ³)	140,040	94,894	32.2
Electricity (KWh)	660,067	626,656	5.1
Water (m ³)	3,572	3,139	12.1

Based on the results of implementing smart heating and cooling systems (Table 1), in the first step, the economic effects are evaluated (Table 2).

Table 2 – The economic effects of using smart technologies

Energy source	Base mode (million Rials)	Smart mode (Million Rials)	Improvement (%)
Natural gas	490	332	32
Electricity	660	627	5
Water	1150	959	17

In addition to identifying the economic impacts of developing smart heating and cooling system (Table 2), it is tried to evaluate the environmental impacts. In this regard, it is tried to identify the emission units for both natural gas and electricity consumption (Table 3).

Table 3 – Pollutant emission of natural gas and electricity consumption [7]

Pollution	NO _x	SO _x	CO ₂	CO	CH	SPM
Natural gas (gr/m ³)	2.05	0.04	560.2	0.33	0.12	0.29
Electricity (gr/KWh)	0.906	0.906	598.3	0.001	0.024	0.088

Based on Tables 2 and 3, the environmental impacts of using smart heating and cooling systems are shown in Table 4.

Table 4 – Environmental effects of using smart technologies in Iran

Different modes	NO _x	SO _x	CO ₂	CO	CH	SPM
Base mode (kg)	885	603	473,368	47	33	99
Smart mode (kg)	762	571	428,087	32	26	83
Improvement (%)	14	6	10	32	22	16

As shown in Table 4, using smart heating and cooling the pollutant emission reduced significantly.

In addition to evaluating the environmental impact of using smart heating and cooling systems, it is tried to identify the impact of using smart heating and cooling systems on the social costs of pollutant emissions (Table 5).

Table 5 – Social costs saving of the pollutant emissions [8]

Pollution type	NO _x	SO _x	CO ₂	CO	CH	SPM
Cost unit ¹	885	603	473,368	47	33	99
Social saving ²	762	571	428,087	32	26	83

1) Thousands of Rials/ton 2) Thousands of Rials

Based on Table 5, considering the social costs of pollutant emissions, the annual cost savings of using smart heating and cooling systems increased by about 30%.

After identifying the direct and indirect economic effects of using smart heating and cooling systems, through calculating Net Present Value (NPV), the payback period is calculated (Eq. 1).

$$NPV = \frac{CF_i}{(1+i)^t} \quad (1)$$

Where, CF_i is the annual cost saving, i is the interest rate, and t is the year number. The payback period is about three years, based on the calculated NPV.

The most critical challenges toward the use of smart heating and cooling systems are (1) additional initial costs, (2) low energy tariffs, and (3) uncertainties about the environmental and economic effects of using smart heating and cooling systems.

As a result, the possible solutions for the development of smart heating and cooling systems could be categorized into (1) using domestic products, (2) considering the social costs of pollutant emissions, (3) replacing the current energy tariffs with real tariffs (eliminating the energy subsidies).

4- Conclusions

In sum, it can be concluded that using smart heating and cooling systems, in addition to reducing the total energy consumption, maximum energy demand, and costs of energy consumption, by reducing the repair and maintenance costs, it leads to a justifiable process for returning the initial required investments. This issue could solve one of the major challenges of using smart heating and cooling systems.

Considering the challenges, obstacles, and identifying possible solutions for the development of smart heating and cooling systems could lead to a practical solution toward achieving sustainability in the building sector during the operational period in Iran.

5- References

- [1] L. Pérez-Lombard, J. Ortiz, C. Pout, A review on buildings energy consumption information, *Energy and buildings*, 40(3) (2008) 394-398.
- [2] F. Barbir, T.N. Veziroğlu, H.J. Plass Jr, Environmental damage due to fossil fuels use, *International journal of hydrogen energy*, 15(10) (1990) 739-749.
- [3] M. Rostami, A. Khademvatani, M. Omidali, Forecasting Electricity Demand in Iran: The application of a Hybrid Dynamic Partial Adjustment and ARIMA Model, *Journal of Applied Economics Studies in Iran (AESI)*7(25) (2018) 177-199.
- [4] D.E. King, M.G. Morgan, Customer-focused assessment of electric power microgrids, *Journal of Energy Engineering*, 133(3) (2007) 150-164.
- [5] P. Rocha, A. Siddiqui, M. Stadler, Improving energy efficiency via smart building energy management systems: A comparison with policy measures, *Energy and Buildings*, 88 (2015) 203-213.
- [6] S. Aslam, Z. Iqbal, N. Javaid, Z.A. Khan, K. Aurangzeb, S.I. Haider, Towards efficient energy management of smart buildings exploiting heuristic optimization with real time and critical peak pricing schemes, *Energies*, 10(12) (2017) 2065.
- [7] M.o.E.o.I.R.o. Iran, Detailed statistics of Iran's power industry, in, 2018, December 12.
- [8] Khodadad, F., Akaberi, M., Mousavi, Y., Khosravinejad, A., 2016. Calculating the Social Costs of Carbon Dioxide Emissions in Different Provinces of Iran. *eprjournal*.