Journal of International Scientific Publications:
Materials, Methods & Technologies, Volume 6, Part 1

ENERGY EFFICIENCY, COMFORT AND COST ANALYSES IN BUILDINGS WITH AUTOMATION SYSTEMS

Semiha Öztuna[1], Seyhan Özkan[1], Kamil Kahveci[1]

[1]Mechanical Engineering Department, Trakya University, 22180 Edirne, Turkey

Abstract

One of the most important challenges today is to sustain energy supply and demand balance. Therefore, it is needed to improve the energy efficiency of the heating, cooling and lighting systems in buildings, which are some of the most energy demanding sectors. In this regard, automation systems used in the buildings are worth investigating because they provide comfort and are easy to use apart from their advantageous in energy saving. Heating-cooling, lighting and security systems for five types of building are investigated in this study. The building types considered are: mall, hotel, operating room, convention center and villa. The amount of prospective energy saving rate, cost and amortization time due to the usage of these systems were specified. The results show that the usage of these systems provides significant energy saving rates. The results also show that amortization times are relatively short.

Key words: *energy efficiency, comfort analysis, cost analysis, building, automation system*

1. INTRODUCTION

Nowadays, energy saving and energy efficiency constitute some of the most important subjects in all around the world. The building automation offers wide opportunities to the operator and a functional building to the user since it can control the device and components of heating-cooling-ventilation, air conditioning, lighting, fire call and security systems. The user can operate all systems in a building from one center via adaptable softwares, can receive malfunction warning, can make capacity control, and can archive incoming and outgoing commands.

The aim of building automation is to provide central operation and supervision, energy saving, comfort and security control. With its developing skills, building automation systems become the most important tools in energy management in buildings (ABB, 2009). With their ability of adjustment to the dynamic changes, building automation systems have led to the improvement of European norm EN15232 in 2007 and has become systems that can offer live realization of the optimum solutions to the possible changes in behavior of a building (load, fullness, synchronization, malfunction of equipment etc.) (Ercan, 2009). Automation is one of the most important applications in timely determination of the malfunctions of equipment in heating, ventilation and air conditioning systems and in energy management and optimization (Siemens, 2010). Developments in building automation systems have provided various systems to operate integrated to each other and the information collected further provided systems to operate in an unexpected high efficiency with instant or previous record assessments. In the energy usage in the buildings, smart buildings, building automation, automation systems in heating-cooling and energy efficiency stand out.

In the literature, there are many researches on automation systems and energy efficiency. Yumurtacı and Keçebaş (2009), Küçükbakırcı (2006), Baysal (2008) and Göksu (2010) investigated smart buildings and automation applications in smart buildings in their works. Lin et al. (2007), Maro (1995), Ercan(2009), Çimen (2008), Atabaş et al (2007), Yakut et al. (2008), Bayer (1993) and

Çilingir (2011) studied the building automation and automation applications in heating-cooling systems.

In this work, 5 different types of building have been taken into consideration and automation (automatic control) systems used for energy observation and management in these buildings have been investigated in terms of energy efficiency, comfort and cost. The influence of the differences from the usage purpose of the buildings on heating-cooling, lighting and security systems has been evaluated and comparisons have been made. The important factors for the selection of the systems have also been reviewed in order to get an opinion for an efficient building automation system.

2. AUTOMATION SYSTEMS AND BUILDING AUTOMATION

Automation is system activities in relation with its environment within the scope of the information supplied to it. The activities are performed according to the inputted or calculated information or according to a certain procedure with previously determined parameters. The usage areas of the automation systems can be divided into two groups: industrial automation systems and building automation systems. Building automation systems are the systems that enable to monitor, command and control the systems in buildings by computers (ASHRAE, 2007).

2.1. Influence of Automation Systems on Energy Efficiency

The most important problem in energy efficiency applications is the sustainability of the system. Systems that are efficient within a certain time frame but inefficient in general can be seen in practice. For the sustainable energy efficiency, the energy measurements should be made firstly, then application or process components should be examined and the basic factors affecting the efficiency should be determined. After the determination of basic factors, control-management systems (automation) are installed. Finally the operation data of the installed system is monitored and the application is supervised. The steps to be followed are given in Figure 1.

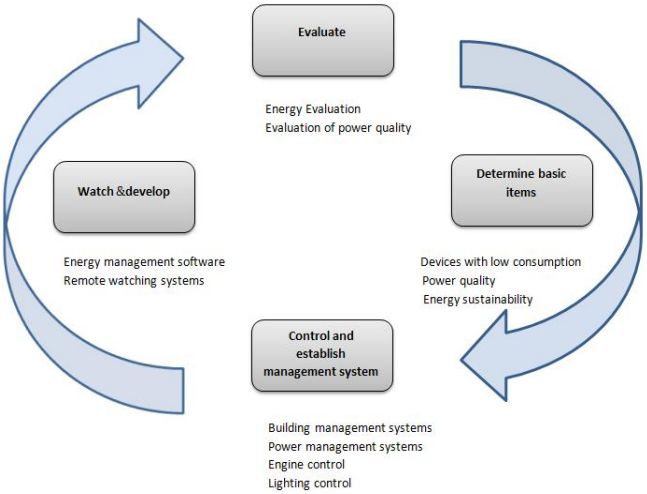


Fig. 1. Necessary steps for sustainable energy efficiency (Çilingir, 2011).

It is without question that automatic control and management systems are an important factors in energy saving. The energy consumed in buildings is electrical or fuel energy. The highest ratio in

consumption of electrical energy belongs to lighting, cooling and ventilation. The highest ratio belongs to the heating in usage of fuel energy. It is possible to obtain a saving between 10% and 40% with the control of heating-cooling systems, lighting systems, and security systems (Çilingir, 2011).

2.2. Systems in buildings which can be applied automation

Application areas of building automation systems are as the following: fire (function control, detector control, fire and life safety), security (doors, PIR (movement), integrity work), access (doors, buildings, fullness ratio), energy (consumption (electricity, water, gas, fuel), customer consumption, air/water, lighting and the usage of alternative energy sources), lighting (timeline, occupation), elevators (malfunction, maintenance), communication (voice, video, data), 24/8 monitoring (failure detection, settings of devices, conditioned observation, parking lot usage), HVAC (air conditioning units, boilers, pumps, fans, energy control, variable air flow rate, air quality). Air conditioning is a process in which the properties of air in a place such as temperature, moisture, and purity are brought to an optimum level for human health and comfort or for the industrial process. Security systems are generally used for environmental safety. They are applied to the surrounding environment of the residence or business office. They mostly function with security detectors. Besides, camera systems, window and door monitoring detectors, barrier detectors functioning with invisible laser rays or pressure sensible fiber cable systems mounted at the garden or neighboring of the house are used. Security systems can easily function in an integrated manner with the other building automation systems. Security measures are generally taken against gas, fire and water flood. The system is activated via smoke sensor, heat sensor and water sensor in cases of fire, gas leakage and water flood. Lighting systems are systems that determine and regulate the light need inside a dwelling by a central computer system as in the heating-cooling systems.

2.3. Energy monitoring and management systems

Energy monitoring and management systems are necessary for efficient automation solutions. Energy data of the process or building should be analyzed carefully. It should be acted according to the results of this analysis.

Automation systems applied by collecting multiple systems under a single roof provide easiness both in application and in management. With the integration provided by the software, tens of independent systems such as HVAC, lighting, energy monitoring and control, engine control, entrance-exit control, security, energy distribution can be controlled when requested. Besides control, an efficient and productive operation of all these systems should also be provided.

3. ANALYSIS OF SAMPLE BUILDINGS WITH AUTOMATION SYSTEMS

In this study, 5 different types of building have been taken into consideration and analyzed. At the end of these analyses, investment and operating costs, energy saving rate, amortization time have been obtained separately for each building and a comparison has been made.

3.1. Mall automation

Malls are structures with large closed areas that host a lot of people at different hours of a day. As the density of people is high, air conditioning, lighting and especially security automations carry high importance. The mall considered in this study has a 10.000m^2 closed area and 4 floors and it also has a closed parking garage. There are approximately 20 shops at each floor and there is a foyer area on the top of the building for general purposes. The analysis results for the mall are given in Table 1.

For the other analyzed buildings, results for automated and non-automated building have been obtained in the same manner.

3.2. Hotel automation

Hotels are complex structures that should be designed carefully by taking into account the security issues and are expected to offer different comfort opportunities with many locations used for different purposes. The hotel considered in this study has an 8.000m^2 closed area and 8 floors.

Table 1. A comparison of the systems with automation and without automation for a mall.

		Without Automation			With Automation			
		Heating	Cooling	Total	Heating	Cooling	Total	Diff.
Investment Cost (TL)		263.200			365.400			% 28
Operating Cost in Summer (TL)			10.584	52.920		8.316	41.580	
Operating Cost in Winter (TL		15.540		108.780	12.200		85.400	
Energy Saving	Electricity	50.400 KW/Month			39.600 KW/Month			% 22
	Natural Gas	21.000 Nm^3/Month			16.500 Nm^3/Month			
Amortization Time		Operating Cost in Summer	Operating Cost in Winter		Operating Cost in Summer	Operating Cost in Winter		
		10.584TL/Month	15.540TL/Month		8.316TL/ Month	12.200TL/Month		36 Months

(Note: Summer is assumed as 5 months and winter is assumed as 7 months)

3.3. Operating room automation

Operating room automation should be applied in a more careful, detailed and precise way than all other building automations. Since the hygiene of the environment is very important for the patient health, all details should be taken into consideration.

3.4. Convention center automation

The convention center considered in this study has a conference hall with a 5135m^2 closed area for 1.000 people. The management and other buildings in the convention center have a 7850m^2 closed area.

3.5. Villa automation

The villa automation has been examined in a more detailed manner as they are the most common structures. Heat loss is 63kW in the sample villa and it is assumed to be heated with a boiler. The heat gain is 161 Btu/h and air cooling is assumed to be provided with a VRF air conditioning unit.

4. RESULTS AND DISCUSSION

In this study, heating-cooling, lighting and security systems with and without automation have been taken into consideration for 5 different types of building. The results of cost, energy saving rate and amortization time analyses are given in Table 2 for 5 different buildings considered in this study.

In the mall, VAV (variable air volume) automation system has been assumed to be used due to the fact that it keeps most of the zone at a stable temperature range and it meets clean and fresh air need. As the malls are used intensely for seven days of the week, it is seen that a high rate of efficiency can be obtained with automation. Even though the cost of air conditioning unit constitutes 28% of the total investment cost, it provides amortization in approximately 36 months by increasing the energy efficiency at 23% level. Lighting system is assumed to consist of LED armatures due to their durability. Security system consists of doorstep detectors, fire sensors and CCTV cameras.

In the hotel, four pipe fan coil system automation is assumed to be used due to its heating-cooling capability with high precision in different zones. There is no continuous usage of the hotel rooms. This fact is also taken into consideration in the automation. The automation activates the systems when the person enters the room and they operate in basal mode in predetermined set values when the person exits the room. The hotel air conditioning system automation includes unit automations in the number of rooms. Although its investment cost constitutes 35% of the total investment cost, it provides amortization in approximately 49 months by the increase in the energy efficiency at 25% level. The usage of lighting and security systems is also important factors and they are also activated when a person enters the room. Lighting armatures are checked with dimmers and lighting is provided as much as it is necessary. CCTV cameras cannot be used in hotel rooms.

Another building type considered in this study is an operating room. In operating rooms, mostly single zoned air conditioning system automation is used as the necessary air flow rate and positive pressure can easily be provided with this system, the other rooms aren't influenced from any problems in the air conditioning unit and half volumetric flow rate working principle is easier to apply. Even though operating room air conditioning system automation constitutes 43% of total investment cost, it provides amortization in approximately 42 months by the increase in the energy efficiency at 25% level. In operating rooms priority is given to the hygiene and comfort instead of the efficiency. Hygiene is achieved by a three phases filtering, and quality, gas, and particle sensors in the room and linear air flow achieved through positive pressure. The most important thing in the automation of this type of rooms is the quick and efficient control of very sensitive comfort conditions and hygiene from a single station.

Convention center is one of the examples of public buildings considered in this study. Heating is provided by a four pipe fan coil system in this structure. There is also an air conditioning unit. As the usage hours are known in the public buildings, the frequency inverters used in the automation systems provide an efficiency increase. Even though convention center air conditioning automation constitutes 24% of total investment cost, it increases energy efficiency at 34% level and provides an amortization within approximately 43 months. In lighting system, compact fluorescent bulbs have been assumed to be used due to their low consumption. Closed circuit camera systems and sound systems are assumed to be used in security automation.

The last building type considered in this study is a villa. The villa is assumed to be heated by a central heating boiler and to be cooled by an air conditioning unit. An automation system which can be integrated to the heating-cooling system is assumed to be used. The investment cost of automation system constitutes 37% of total investment cost. The amortization time is found as approximately 82 months. With the automation, energy efficiency shows an increase of 22- 24%. Villa automation system provides its user a comfortable environment due to its positive features such as remote control capabilities, security means, precision, timing options, ability to control multiple devices from a single location.

In this study, an energy efficiency, comfort and cost comparison for the automation systems used in 5 different buildings has also been made. The results are given in Table 3.

5. CONCLUSION

Energy efficiency rate, investment cost ratio and amortization time of the automation systems applied to the five types of building have been found as: energy saving rate 22%-25%, investment cost ratio, 20%-43%, amortization time, 36-68 months.

Significant points in the application of automation to the buildings are given below:

- Selection of building automation system should be made during the planning of architectural and fitting projects if possible.
- The followings are the most important parameters in the energy efficiency of the automation systems: daily or monthly air conditioning periods, heating-cooling-ventilation loads and the dimensions of air conditioned locations.
- In the selection of each automation system, priority should be given to the meeting of expectations. The building might necessitate different automation applications according to its location, type of use and structure.
- Cost and efficiency balance should be considered in the selection of automation systems. There is also a connection between the technological scope of the automation system to be applied and the energy efficiency and comfort.
- Maintenance and repair activities are very important expense items for the automation systems.
- Applications of the automation system are as much important as the selection of the system.
- The advantageous of building automation systems is limited when the building is not well isolated, not located well and whose fittings have not been planned or installed properly.

Table 2. Results of cost, energy saving rate and amortization time analyses for buildings with automation systems (Özkan, 2011).

	Investment Cost Ratio (%)	Energy Saving Rate (%)	Amortization Time (Month)
MALL	28	22	36
HOTEL	35	25	45
OPERATING ROOM	43	24	47
CONVENTION CENTER	24	25	62
VILLA	20	23	68

Table 3. A Comparison for the automation systems used for five different buildings (Özkan, 2011).

TYPE	ENERGY EFFICIENCY	COMFORT	COST
MALL	►Instant control of heating, cooling and ventilating load by measurements of temperature ►Improvement of efficiency by the control of fullness ratio ►Energy saving rate of 22% by automation systems	►Easy and quick use with central control panel ►Temperature and malfunction monitoring by computer	►An investment cost ratio of 28% in total investment cost ►Amortization in 36 months
HOTEL	►Stopping air-conditioning and lighting systems in rooms out of use ►25% energy saving rate by automation systems	►Flexible use according to personal comfort demand ►Sensitive temperature and humidity control and easy reach to control systems	►An investment cost ratio of 35% in total investment cost ►Amortization in 45 months
OPERATING ROOM	►Sensitive air-conditioning with computer controlled sensors ►Energy saving rate of 24%e by automation systems	►Control of systems such as heating, cooling, humidity, particle, gas, pressure, lighting from a single centre ►Fast adjustment to the sensitive comfort and hygiene conditions	►An investment cost ratio of 43% in total investment cost ►Amortization in 47 months
CONVENTION CENTER	►Preventing unnecessary use of air-conditioning and lighting systems ►Controlling fluid conditioning units by inverters ►Saving from labor work due to the automations ► Energy saving rate of 25% by automation systems	►Effective use and maintenance of air-conditioning system ►High performance in lighting and sound systems	►An investment cost ratio of 24% in total investment cost ►Amortization in 62 months
VILLA	►Efficiency increase because of preventing losses from doors, windows and lighting caused by user's fault ►The optimum start-stop control of equipment ►Energy saving rate of 23% by automation systems	►Easy integration to the widely used heating, cooling and lighting systems ►Easy and efficient use	►An investment cost ratio of 20% in total investment cost ►Amortization in 68 months (only heating and cooling automation), amortization is 109 months (only lighting automation), amortization time in 82 months (both automations)

REFERENCES

ABB (2009) Smart Home and Intelligent Building Controls, Technical Handbooks ,Heidelberg Germany , Page 1-23.

ASHRAE Fundamentals of HVAC Control Systems, (2007) Technical Workshop, Hong Kong, China, pp :1-53.

Atabaş İ., M. Arslan, İ. Uzun, (2007) Isıtma Sistemlerinin Otomasyonu ve İnternet Üzerinden Kontrolü, Akademik Bilişim, Kütahya, Türkiye.

Bayer S. (1993) Isıtma, Havalandırma Klima Sistemlerinde Genel Otomatik Kontrol Uygulamaları, Teskon Bildirisi, Ankara, Türkiye.

Baysal R. (2008) Akıllı Binalarda Enerji Yönetimi ve Kontrolü, Yüksek Lisans Tezi, Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü, Isparta, Türkiye.

Çilingir Ü. (2011) Binalarda Enerji Verimliliği ve Otomasyon Çözümleri, Schneider Electric, İstanbul, Türkiye.

Çimen L. (2008) Bina Otomasyon Sistemleri, Türkiye Tesisat Mühendisleri Odası Dergisi, No: 33.

Ercan S. M. (2009) Bina Otomasyon Sistemi ile Devreye Alma İşlemleri ve Diğer Sistemlerle Bilgi Alışverişi, IX. Ulusal Tesisat Mühendisliği Kongresi, Türkiye, pp. 1121-1127.

Göksu S. (2010) Akıllı Bina Uygulamalarında Maliyet Artışının Geri Kazanım Süreç Analizi, Yüksek Lisans Tezi, Sakarya Üniversitesi Fen Bilimleri Enstitüsü, Sakarya, Türkiye.

Küçükbakırcı C. (2006) Bir Mikro Denetleyici Tabanlı Akıllı Ev Sıcaklık ve Aydınlatma Otomasyonu Uygulaması, Yüksek Lisans Tezi, Gebze İleri teknoloji Üniversitesi Mühendislik ve Fen Bilimleri Enstitüsü, Gebze, Türkiye.

Lin C., C. Fiderspiel, D. Auslander, (2007) Multi-Sensor Single-Actuator Control of HVAC Systems, University of California, Berkeley, National Science Foundation, Grant No: 0088648.

Maro O. (1995) Bina otomasyonu, II Ulusal Tesisat Mühendisleri Kongresi Bildirisi, İzmir.

Özkan S. (2011) Bina Isıtma- Soğutmasında Otomasyon Sistemlerinin Konfor ve Enerji Verimliliği Yönünden İncelenmesi, Yüksek Lisans Tezi, Trakya Üniversitesi, Fen Bilimleri Enstitüsü, Türkiye.

Siemens Belgium (2010) Realization and Content of Standart EN 15232 Bulding Technologies.

Yakut K., M. Koru, A. Şencan, (2008) HVAC Sistemlerinde Kontrol Sistemleri ve Enerji Tasarrufu, Tesisat Mühendisliği Dergisi, İstanbul, Türkiye.

Yumurtacı M., A. Keçebaş, (2009) Akıllı Ev Teknolojileri ve Otomasyon Sistemleri, 5. Uluslararası İleri Teknolojiler Sempozyumu (IATS'09), Karabük, Türkiye.