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Calculating Payback Periods for Energy Efficiency Improvement Applications at a University Hospital

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Abstract

The increasing demand for energy and the depletion of existing fossil fuel based resources have forced the countries to realize the efficient use of energy, energy saving applications and searching alternative energy sources. Using the energy efficiently and performing energy saving studies have great importance for developing countries like ours that are dependent on other countries to meet their energy needs. Hospitals generally consume 6% of total energy in the buildings. Heating, Ventilation and Air Conditioning (HVAC) systems are the significant part of electrical energy consumption at the hospitals. The air-conditioning system is responsible for around 70% of total electricity consumption. Electric motors and lighting systems in a hospital represent approximately 19-21% of the total energy consumption. In this study, according to the detailed analysis on the lighting devices, electric motors and HVAC systems, the energy saving potentials and payback periods of these systems are estimated for a University Hospital.

Keywords: University hospital, Energy efficiency, Energy saving, Energy management.

Bir Üniversite Hastanesinde Enerji Verimliliğini Artıran Uygulamaların Geri Dönüşüm Sürelerinin Hesaplanması

Özet

Artan enerji talebi ve mevcut fosil yakıt tabanlı kaynaklarının hızla tükenmesi, ülkelerin enerjiyi verimli kullanmasına, enerji tasarrufu yapmasına ve alternatif enerji kaynaklarını aramasına zorlamıştır. Enerji ihtiyaçlarını karşılamada başka ülkelere bağımlı olan bizim gibi gelişmekte olan ülkelerde, mevcut enerjiyi verimli kullanmak ve tasarruf çalışmaları yapmak daha büyük önem taşımaktadır. Hastaneler binalarda kullanılan toplam enerjinin yaklaşık olarak %6'sını tüketmektedir. Isıtma, Havalandırma ve İklimlendirme sistemleri (IHİS), hastanede tüketilen elektrik enerjisinin büyük bir kısmını oluşturmaktadır. İklimlendirme sistemleri toplam tüketilen yaklaşık olarak %70'inden sorumludur. Hastanedeki elektrik motorları ve aydınlatma sistemleri yaklaşık olarak toplam enerjinin %19-21'lik kısmını harcamaktadırlar. Bu çalışmada, aydınlatma cihazları, elektrik motorları ve IHİS sistemleri üzerine yapılan detaylı çalışmalar sonucunda, bir üniversite hastanesinde bu cihazların enerji tasarruf potansiyelleri ve geri dönüşüm süreleri tahmin edilmiştir.

Anahtar Kelimeler: Üniversite hastanesi, Enerji verimliliği, Enerji tasarrufu, Enerji yönetimi.

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1. INTRODUCTION

Hospitals account for a remarkable ratio of the total energy consumption in the utility buildings sector, due in large part to the very high energy intensity levels of hospitals and other inpatient care facilities [1]. Energy efficiency studies can be divided into four main categories in the hospitals. These categories are lighting, electric motors, HVAC and other systems. 20% of total world electricity consumption is approximately consumed by lighting. Energy efficient lighting is one of the best and most cost effective way to reduce total energy consumption in the world. It is very important to evaluate and change current lighting system to satisfy energy efficient lighting. Lighting systems consist of four physical components namely lamp, fixture, ballast and control system. Each component affects energy use and annual cost of the lighting system. The energy consumption of each component is very important for the energy efficiency researches. The selection of more efficient material and equipment will reduce the electricity consumption and increase the energy efficiency. For energy saving in lighting, lamp types and their characteristics should be known in detail [2-3]. Old or inefficient lamp types should be changed with new and efficient lamp types. In the new installed buildings, LED lamps should be preferred by calculating payback time.

Approximately 65% of total electricity consumption is consumed by electric motors in Turkey [4]. In addition, about 35% of total energy is used in the industrial sector in Turkey [5]. In the world, an industrial sector uses more energy than any other end-use sectors and currently this sector is consuming about 37% of the world's total delivered energy [6]. Electric motors in a hospital represent approximately 19% of the total energy consumption. More than 95% of all motors in the industry are AC induction motors. In Turkey, the most of electricity energy in industry sector is consumed by AC motors as elsewhere in the other countries. Motor electricity consumption by end-use in industrial sector are 22% fan, 29% pump, 7% compressor and 42% others devices [7-8]. HVAC systems are the single largest energy consumer in these types of buildings. It accounts for almost 60% of total energy cost in a building [9]. The energy consumption distribution of a hospital can be classified by electrical energy consumption types. HVAC (especially cooling and ventilating) systems are the major part of electrical energy consumption. If the absorption chiller is not in use, then the air-conditioning system is responsible for around 70% of total electricity consumption. Among them, the chillers, the chilled water pumps and the fan of the cooling towers would need 43.94% of the total electricity [10]. The use of energy efficient electric motors and variable speed (frequency) drive (VSD) systems are the best and most cost effective ways to reduce total electrical energy consumption especially in HVAC system at the hospitals [10], [11]. What appears as a problem in most papers is the lack of evaluation of savings opportunities and payback period calculations; in other words, even in the research results where it is indicated how much energy can be saved by using the energy saving studies discussed [12]. In this study, the energy saving potentials are investigated by calculating payback times at a university hospital in Turkey.

2. ENERGY EFFICIENCY and ENERGY SAVING OPPORTUNITIES at UNIVERSITY HOSPITAL

Energy efficiency improvement projects can reduce the utility bill costs and operations and maintenance costs. There are numbers of energy efficiency improvement applications for lighting, motors, VSDs and HVAC systems. Some energy-efficiency improvement projects may not be economically feasible. Simple payback method is preferred for payback period calculations. This method uses a period of time in which a project's energy savings should equal the amount of money invested [3, 13].

2.1. Implemented and Suggested Projects for Lighting Systems

Lighting systems can be investigated as exterior lighting and interior lighting systems. Especially, at the exterior lighting, expensive and high density luminance lamps (mercury vapor or metal halide lamps) are used for environmental and road lighting. These lamps are consumed electric energy more than new lamps led or compact fluorescent. Most of the lamps used for interior lighting of hospital are CFLs with magnetic ballast. CFLs with electronic ballast should be preferred instead of old type magnetic ballast.

2.1.1. Exterior Lighting at University Hospital

The lamps used for the exterior lighting at University Hospital are as shown in Table 1.

Table 1. Exterior lighting at University Hospital

Place/Pcs.	Mercury vapor (125 W)	Mercury vapor (250 W)	Metal halide (750W)	CFL (23W)	Fluorescent (18W)
Back side of parking	20	20	8	-	-
Front side of parking	16	-	-	-	-
Refectory exit under the viaduct	-	-	2	50	-
Viaducts of Blood center	34	-		-	-
Emergency exit	9	-	8	-	
Cafeteria under the viaduct	-	-	-	-	72
Total number	**79**	**20**	**18**	**50**	**72**
Consumption of lamps	9,875	5,000	13,500	1,150	1,296
Total Cons.	**30,821**				

▪ **Replacement 40-pcs 125 W mercury lamps with 40-pcs 2x23 W CFL lamps:** At the exterior lighting, there are 40-pcs 125 W mercury lamps in front of blood center. Mercury lamps have 10% ballast losses and CFL lamps have 8% ballast losses (electronic-type). 2-pcs 23 W fluorescent lamps and armature cost are 110 TL including all taxes as illustrated in Table 2.

The saving kWh in a year can be calculated as 13,908 and saving TL can be calculated 4,451 TL. Installed cost of new armature and lamps labor included price are 40x110=4,400 TL. As a result, payback period can be calculated 0.99 year.

▪ **Replacement mercury lamps with the CFL and LED:** In the hospital, the total installed capacity of mercury lamps for exterior lighting is approximately 5 kW at the back side of the parking. Table 3 shows the total energy savings in a year when the 250W mercury lamps are replaced with 45 W CFL lamps. Mercury lamps have 10% ballast losses and CFL lamps have 8% electronic ballast losses. The running time of exterior lighting lamps is 11 hours in a day. According to peak and night time period, the average electricity unit price for kWh is approximately 0.32 TL. A year will be taken 360 days. If total 20-pcs of mercury lamps are replaced with 45 W CFL, total saving kWh can be calculated as 17,931 kWh and total saving TL can be found 5,738 TL. As a result, payback period is calculated as 0.17 year = 2.04 months.

Calculations:

Total consumption of 250 W Mercury lamp	=	20 x250/1,000x11x360x1.1
	=	21,780 kW
Total consumption of 45 W CFL	=	20x45/1,000x11x360x1.08
	=	3,849.12 approx. 3,849
Saving kWh in a year	=	21,780-3,849
	=	17,931 kWh
Saving TL in a year	=	Saving kWh x Electricity unit price
	=	17,931x0.32 TL = 5,738 TL.
Payback time (year)	=	Total installed cost / Total saving TL.
	=	(Lamp cost x # of lamp) / Total saving TL.
	=	(50x20) / 5,738 = 0.17 year
Payback time (month)	=	7 x 12 = 2.04 months

Table 2. The implemented project for exterior lighting system

Lamp type	Energy consumption (W)	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
125 W Mercury lamp	137.5 W	40	11	360	21,780	-	-	-	-	-
2x23 W CFL	49.7 W	40	11	360	7,872	110	4,400	13,908	4,451	0.99

Table 3. The planned project_1a for exterior lighting system

Lamp type	Energy consumption (W)	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
250 W mercury lamp	275	20	11	360	21,780	-	-	-	-	-
45 W CFL	48.6	20	11	360	3,849	50	1,000	17,931	5,738	0.17

Table 4. The planned project_1b for exterior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
250 W mercury lamp	275 W	20	11	360	21,780	-	-	-	-	-
65 W LED	68.9 W	20	11	360	5,457	472	9,440	16,323	5,223	1.81

Table 5. The planned project_2 for exterior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
23 W CFL	24,84 W	50	11	360	4,918	-	-	-	-	-
7.5 W LED	7,95 W	50	11	360	1,574	35,4	1,770	3,344	1,070	1.65

Table 6. The planned project_3a for exterior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
18 W Fluorescent	23,4 W	72	11	360	6,671	-	-	-	-	-
7.5 W LED	7.95 W	72	11	360	2,267	35,4	2,549	4,404	1,409	1.8

As shown in Table 4, if the 20-pcs of mercury lamps are replaced by 65 W LED armature. The cost of a LED armature is 472 TL. LED lamps have approximately 6% losses. As shown in Table 4, payback time will be found 1.81 years as a result of this replacement. The replacement of the mercury lamp with the CFL is more feasible than the replacement of the mercury lamp with the LED armatures.

- **Replacement CFL with LED lamps:** At the exterior lighting, there are 50-pcs 23 W CFLs at the refectory exit under the viaduct. CFL lamps have 8% losses and LED lamps have 6% losses. As shown in Table 5, when 23 W CFLs are replaced with 7.5 W LED lamps, saving TL in a year can be found 1,070TL and payback are found 1.65 year.

Replacement Fluorescent Lamp with LED lamps: At the exterior lighting, there are 72-pcs 18 W fluorescent lamps with old type magnetic ballast at the cafeteria under the viaduct. 18 W fluorescent lamps with the magnetic ballast have 30% ballast losses and LED lamps have 6% losses. As shown in Table 6, when 72-pcs 18 W fluorescent lamps with the conventional magnetic ballast are replaced with the 72-pcs 7.5 W LED lamps, 1,409 TL will be saved in a year and payback time will be found 1.8 year.

- **Replacement of conventional fluorescent lamp with fluorescent lamp with electromagnetic ballast**: At the exterior lighting, there are 72-pcs 18 W fluorescent lamps with magnetic ballast at the cafeteria. 18 W fluorescent lamps with old type magnetic ballast have 30% ballast losses and 18 W fluorescent lamps with electronic ballast have 8% ballast losses. While the conventional fluorescent lamps are converted to fluorescent lamps with electronic ballast for 18W system, it is enough to change ballasts. Approximately medium quality electronic ballast cost is 7 TL (All taxes are included to this price). After the calculations, payback time will be found 3.6 years as shown in Table 7.

- **Replacement 750 W metal halide lamps with LED lamps:** At the exterior lighting, there are 18-pcs metal halide lamps. 24 number 120 W LED lamps will be used instead of 18-pcs 750W metal halide lamps. Metal halide lamps have 14% losses and LED lamps have 6% losses. As shown in Table 8, energy saving in a year can be calculated 48,924 kWh and period time can be calculated 1.04 years. At the hospital, the most of the exterior lighting armatures are controlled by the day light sensor with the time relay. The using of these automatic controlled systems is more efficient than manual controlled systems. The total estimated energy saving as kWh for exterior lighting is 75,630 kWh. Total investment for these projects is 21,639 TL. The payback periods of feasible projects is changed between 0.17 and 2.35 as shown in Table 9.

2.1.2. Interior Lighting at University Hospital

Most of the interior lightings armatures at University Hospital are conventional fluorescent lamps with the magnetic ballast. Fluorescent lamps with electronic ballast have been only used in old intensive care and there are 220-pcs 2x40 W fluorescent lamps with electronic ballast. Total capacities of them are 17,600 W. At the some units of the hospital such as in the air conditioner center, different types of lamps are used. But this situation

Table 7. The planned project_3b for exterior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
18 W Fluorescent	23.4 W	72	11	360	6,671	-	-	-	-	-
18 W Fluorescent with electronic ballast	19.4 W	72	11	360	5,531	7	504	1,140	364	1.4

Table 8. The planned project_4 for exterior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
750 W Metal Halide	855W	18	11	360	60,994	-	-	-	-	-
120 W LED lamps	127W	24	11	360	12,070	680	16,320	48,924	15,656	1.04

Table 9. Feasible projects for exterior lighting

Project number	Energy saving kWh/year	Energy saving TL	Investment TL	Payback period year
1a	**17,931**	**5,738**	**1,000**	**0.17**
1b	16,323	5,223	9,440	1.81
2	**3,344**	**1,070**	**1,770**	**1.65**
3a	**3,378**	**1,081**	**2,549**	**2.35**
3b	315	100	360	3.6
4	**48,924**	**15,656**	**16,320**	**1.04**
Feasible projects	73,577	23,545	21,639	

is a small part of total lamp number. For example, in the air conditioner center, 16-pcs 250W mercury lamps were used. Conventional fluorescent lamps

can be changed with CFL or LED lamps for saving energy.

- **Replacement mercury lamps with the CFL and LED:** During this research period, 250 W mercury lamps in the air conditioner center of Emergency Unit were replaced with 45 W compact fluorescent lamps. Same electrical socket can be used for two types of system. Because of this, there is no requirement for new armatures. As shown in Table 10, 250 W mercury lamps have 10% ballast losses and 45 W CFL lamps have 8% losses. 16 lamps operate 24 hours in a day for 360 days in a year. Electricity unit price for kWh can be taken approximately 0.32 TL according to average value of day, peak and night time (All taxes are included to this price). Lamp cost is 50 TL including all taxes.

Calculations:

Total consumption of 250 W mercury lamp	=	16x250/1,000x24x360x1.1
	=	38,016 kW
Total consumption of 45 W CFL	=	16x45/1,000x24x360x1.08
	=	6,718
Saving kWh in a year	=	38,016-6,718
	=	31,298 kWh
Saving TL in a year	=	Saving kWh x Electricity Unit Price

Table 10. The implemented project for interior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
250 W mercury lamp	275 W	16	24	360	38,016	-	-	-	-	-
45 W CFL	48.6 W	16	24	360	6,718	50	800	31,298	9,389	0.09

	=	31,298 * 0.3 TL = 10,015 TL.
Payback time (year)	=	Total Installed Cost / Total Saving TL.
	=	(Lamp Cost x # of Lamp) / Total Saving TL.
	=	(50x16) / 10,015 = 0.08 year
Payback time (month)	=	0.08 x 12 = 0.95 month

- **Replacement of 18W conventional fluorescent lamps by fluorescent lamp with electronic ballast in interior lighting systems:** Because interior lighting system has large installed capacity and serves wide range of areas, local applications are more suitable. The values which are calculated at local area can be generalized for total areas.

Archive, radiation oncology and nuclear medicine building are taken as example areas. There are 92-pcs 4x18W armatures in the nuclear medicine building, 5-pcs 2x18W armatures in the archive building and 97-pcs 4x18W armatures in the radiation oncology building. In addition, there are 24 pcs 2x36 W armatures in nuclear medicine, 152-pcs 2x36W armatures in archive and 25-pcs 2x36 W armatures in the radiation oncology. Total number of 18 W lamps is 766-pcs and total number of 36 W fluorescent lamps is 402-pcs. The working time of this buildings are between 08:00 and 17:00 in a day. The unit electricity cost is 0.32 TL for this period (All taxes are included). While the conventional fluorescent lamps are converted to fluorescent lamps with electronic ballast for 18W system, it is enough to change only ballasts. Medium quality electronic ballast price in market is approximately 7 TL (All taxes are included to this price). 18W and 36 W electronic ballast prices are almost same.

As shown in Table 11 and Table 12, payback period is more than 1 year. Otherwise, the demounting of old lamp and mounting of the new lamps are difficult and taken a long time. Because of this, this replacement operation is not feasible for the hospital. When a new building is installing or old buildings are reconstructing, electronic ballast can be preferred instead of magnetic ballast.

- **Replacement 18W conventional fluorescent lamps with 7.5 W fluorescent LED lamps:** 7.5 W fluorescent LED lamps can be used instead of 18 W conventional fluorescent lamps. According to previous mentioned losses and prices, payback period and other saving values are calculated as shown in Table 13. When a new installation or restoration, LED lamps are preferred instead of fluorescent lamps electromagnetic ballast. LED lamps are more feasible than the FLs with electronic ballast.

When the lamps of these three building are examined for generalization, kWh per m^2 can be calculated as shown in Table 14. By using kWh/m^2, energy saving values and saved money as TL are calculated for all area of the hospital. Total area of University Hospital is 128,536 m^2 closed area. Total installed capacity of all hospital for interior lighting can be found 128,536 x 9,73 = 1,250,655.28 W = 1251 kW. If all the lamps are considered as 18 W fluorescent lamps, the total capacity of 69,481-pcs 18 W conventional

Table 11. The planned project_1 for interior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
250 W mercury lamp	275 W	16	24	360	38,016	-	-	-	-	-
45 W CFL	48.6 W	16	24	360	6,718	50	800	31,298	9,389	0.09

Table 12. The planned project_2 for interior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
36 W conventional FL with magnetic ballast	46.8W	402	9	360	60,956	-	-	-	-	-
36 W FL with electronic ballast	38.8W	402	9	360	50,536	7	2,814	10,420	3,334	0.85

Table 13. The planned project_3 for interior lighting system

Lamp type	Energy consumption	# of lamps	hours/day	days/year	kWh/year	Unit cost (TL)	Investment cost (TL)	Savings/year (kWh)	Savings/year (TL)	Payback period (year)
18W conventional FL with magnetic ballast	23.4W	766	9	360	58,075	-	-	-	-	-
7.5 W FL LED	7.95W	766	9	360	19,731	35.4	27,116	38,344	12,270	2.2

Table 14. The calculation of unit W per square meter (W/m^2)

Building	Installed lamp capacity (W)	Total areas (m^2)
Nuclear Medicine Building	8,352	1,200
Archive	11,124	1,135
Radiation Oncology	8,784	570
Total	28,260	2,905
Unit W per square meter (W/m^2)		9.73

fluorescent lamps are calculated easily. If 4-lamp fixture with 18 W FL is used, 17,370-pcs 4-lamp fixture can be calculated. As shown in Table 15, installed cost of LED system is 2,459,627 TL which is very expensive. Because of this reason and limited numbers of technical personnel, LED lamps are preferred instead of conventional fluorescent lamps when the new installation or restoration. Local areas can be designed by LED step by step.

Table 15. Energy saving potentials for replacement of all 18 W FL lamps

Lamp type	18 W conv. FL ballast	7.5W LED FL	18W FL with electronic ballast (ballasts are changed)
Energy consumption (W)	23.4 W	7.95 W	19.4
# of lamps	69,481	69,481	69,481
Hours/day	9	9	9
Days/year	360	360	360
kWh	5,267,771	1,789,692	4,367,297
Unit cost (TL)	-	35.4	7
Total cost (TL)	-	2,459,627	486,367
Savings/year (kWh)	-	3,478,079	900,474
Savings/year (TL)	-	1,112,985	288,151
Payback period (year)	-	2.2 years	1.68 years

In Table 17, all projects for interior lighting are compared with each others and the most feasible project is project 4 with occupancy sensors. The total investment and energy saving potential for exterior and interior lighting are summarized in Table 18.

2.2. Implemented and Suggested Projects on the Electrical Motors and VSDs

There is a few aspirator motor controlled by VSD in the hospital. The practical measurement of 30 kW aspirator motor in the kitchen is shown in Table 19. Reducing the speed of the motor 15% of its nominal speed, 36% of energy saving can be provided by VSD.

2.2.1. Energy Saving with VSD

The total capacity of motors in the hospital greater than 5.5 kW is given in Table 20. In practice, it is very difficult to use VSDs in condenser and chiller motors. All elevator motors have VSDs. Other motors operate at 60-70% of loading factor. The total capacity of motors which can be controlled by VSDs is 7,829.7 kW. The compressor motors in chiller groups, cooling tower fan motors operate nearly 120 days in a year and ventilator motors and aspirator motors operate nearly 240 days in a year. Other motors operate nearly 360 days in a year. The average loading factor of the motors is nearly 60% of full load capacity.

Planned Project_1 is energy saving with VSD. The annual electrical energy consumption of these motors is nearly 15,495,667 kWh. The estimated energy saving potential by using VSDs is 22% of total capacity which equals to 3,409,046 kWh. This saving equals to 1,022,714 TL/year. The total estimated investment for this project is nearly 930,636 TL. The payback period is approximately 0.91 years. All motors in Table 20 are suitable for the VSD control. Some motors such as chiller and conderser motors are different mechanical structures but they have same features as a simple asynchronous motor. The most important point to take into consideration is required capacity.

When the motor runs at maximum capacity and this condition is not enough for comfort quality, there will be no need a VSD device. At the all other conditions, VSD should be used for energy efficiency.

2.2.2. New Purchase of Energy Efficient Motor

The numbers of motors (except elevator, condenser and chiller motors) greater than 5.5 kW is 234. The total capacity of these motors in the hospital is 7,829.7 kW. These motors are IE1 type

Table 16. The planned project_4 for interior lighting system

Total area of suitable corridors	Energy consumption (kWh)	Estimated energy savings (30%) (kWh)	Estimated energy savings (TL)	Unit cost (TL)	Investment cost (TL)	Payback period (year)
7,500 m^2	326,825	98,047	29,414	16.5	12,375	0.42

Table 17. Feasible projects for interior lighting

Project number	Energy saving kWh/year	Energy saving (TL)	Investment (TL)	Payback period (year)
1	10,672	3,400	5,362	1.6
2	10,420	3,334	2,814	0.85
3	38,344	12,270	27,116	2.2
4	98,047	29,414	12,375	0.42
Feasible projects	98,047	29,414	12,375	0.42

Table 18. Energy saving potentials for overall lighting system

Lighting System	Energy saving kWh/year	Energy Saving (TL)	Investment (TL)
Feasible projects for interior lighting	98,047	29,414	12,375
Feasible projects for exterior lighting	73,577	23,545	21,639
TOTAL	**171,624**	**52,959**	**34,014**

Table 19. Measurement results of 30 kW aspirator motor in the kitchen

30 kW Aspirator Motor in kitchen				
Without VSD	Phase	*R*	*S*	*T*
	Power (kW)	8	7.8	7.9
	Current (A)	40	37	40
With VSD	Phase	*R*	*S*	*T*
	Power (kW)	4.9	5.2	5.1
	Current (A)	23	24	23

Table 20. Existing motors greater than 5.5 kW

Motor Types		Total Capacity (kW)
HVAC motors	Compressor	6,196.5
	Condenser	582
	Chiller	875
	Cooling tower fan motor	327
	Ventilator	806.4
	Aspirator	260.3
Other motors	Boosters	142
	Elevators	219.7
	Compressors	97.5

Table 21. The planned project_2 for electrical motor and VSD systems

Motor type	Energy consumption kWh/year	Energy saving kWh/year	Energy saving (TL)	Investment (TL)
Existing motors	15,495,667	-	-	-
New IE3 motors	15,077,284	418,383	125,514	672,345

Table 22. Energy saving potentials for overall motor and VSD systems

Motor system	Saving kWh/year	Saving (TL)	Investment (TL)
Project 1: with VSD	**3,409,046**	**1,022,714**	**930,636**
Project 2: purchase of energy efficient motor	418,383	125,514	672,345
TOTAL	3,827,283	1,148,184	1,602,981

and operate nearly at 60-70% of loading factor. If these motors are replaced by IE3 type motors, the efficiency of the overall system can be increased 2.7% existing efficiency as shown in Table 21. The total investment for this project is 672,345 TL. Energy saving TL is 125,514. As a result, payback period can be calculated as 5.36 years which is not feasible for the hospital. Energy saving potentials for overall motor and VSD systems are shown in Table 22. Bold color project is feasible for the hospital.

2.3. Implemented and Suggested Projects on the HVAC Systems

As calculated in [14], a capacity rating of 2.145 MW was chosen for payback analyzes of both cogeneration and trigeneration plants. For this rating, cogeneration plant with a steam boiler has an investment cost of 1,400,000 $, annual revenue of 928,135 $ and calculated payback time of the investment is 1.51 years. For trigeneration plant with double-effect absorption chiller, system cost is 2,050,000 $, annual revenue of the system is 900,405 $ and payback time of the system cost is 2.27 years [14]. Other implemented and suggested projects on the HVAC systems are presented in below sub-sections.

2.3.1. Heat Saving

The total capacity of motors in the hospital greater than 5.5 kW is given in Table 20. In practice, it is very difficult to use VSDs in condenser and chiller motors. All elevator motors have VSDs. Other motors operate at 60-70% of loading factor. The total capacity of motors which can be controlled by VSDs is 7,829.7 kW. Steam leaks consist because of inadequacy insulation of heat center. For fuel saving and obtaining efficiency at desired values, the steam lines should be renewed and its insulation should be performed. However, for renew of this line, galleries should be also renewed. In galleries there is no enough space for these renewal processes.

Automatic blow-down system and degasser devices are required on the steam boilers which are used in the heat centers. These changes should be performed on boilers in heat center while transition to natural gas. This point was reported to the Department of Construction and Technical Works.

In university hospital building the existing heat exchangers should be replaced with plate heat exchangers when they are broken or out of run. All pipes in hospital air conditioning room are required to be renewed by checking their insulations for the purpose of heat leakages. The valves existing in heat center and air conditioning room should be insulated.
Thermostatic valves should be used on radiators because the polyclinic blocks are heated by radiator system. The old pipelines of central heating system should be renewed and radiators should be replaced by the efficient ones. But, if renovating of polyclinic will be performed, this system should be completely removed and central air conditioning system Variable Refrigerant Volume-Variable Refrigerant Flow (VRV-VRF) should be applied and fresh air heat recovery devices should be designed. The elimination of radiators will satisfy fuel-oil saving.

The fuel system in heat center will be changed to natural gas system because of that there is no need for investment in improvement of fuel currently.

- **Air Curtains:** Air curtains should be placed on the doors opening to the outside in the hospital. This will prevent the inside conditioned air to escape and outside air from entering. Arranging the non-automatic and always left open outer doors as automatic doors with air curtains will be useful to keep conditioned air inside the building. The approximate cost of an automatic doors and its air curtain is around maximum 7,000 TL. The polyclinic parts of ground floor exits and the both of exits which are between morgue-kitchen need to be reorganized.

- **Use of Chemicals in Heating and Cooling Systems:** Energy saving can be satisfied with the use of chemicals which make the transfer of heat without loss by preventing calcification in all insulation for heating and cooling system (1 mm calcification in the installation causes approximately 1-2% energy loss). Total energy consumption of the University Hospital for last 12 months is 4,749.40 TOE (23,960,320 kWh electrical energy (2,060.58 TOE) and 2,727 tonnes fuel oil (2,688.82 TOE)). Annual estimated gain from this investment is **47.49 TOE.**
The lifetime of installations will be longer and getting resistance against corrosion and abrasion will be satisfied.
Its annual cost is 40,000 TL.

- **Valve insulation jacket application:** Due to non-isolated control devices (steam traps, check valves, etc.) used in heating and cooling systems, energy losses occur in the heat center and hospital. For example, heat loss of a 40 mm steam valve is measured as 1,344 kcal/h without insulation and 166 kcal/h with insulation using the heat thermal imaging cameras. The loss difference is 1,178 kcal/h. The annual saving from these control devices is approximately 10,177,920 kcal. There are 1,250 numbers of control devices with different diameters in the hospital. To minimize this losses, as a result of providing insulation with heat-insulating jacket of control elements of the installation. A sample of measurements is shown in Figure 1 and Figure 2.

10,177,920 kcal×1250-pcs=**1,272,240,000 kcal** can be saved. **(127.22 TOE)**
Financial gain of this insulation is approximately 1,272,240,000 kcal / 1,785 = 712,739,000 kg steam × 0.121TL = 862,414TL/year.

Heating and cooling process continue for an average 8 months in a year. In this case, the annual saving is 862,414× (8/12) = 574,942TL/year.

The insulation cost of 1,250 control devices is approximately 90,000 TL. The investment pays for itself in 2-3 months. The lifetime of thermal insulation material is considered as 5-10 years.

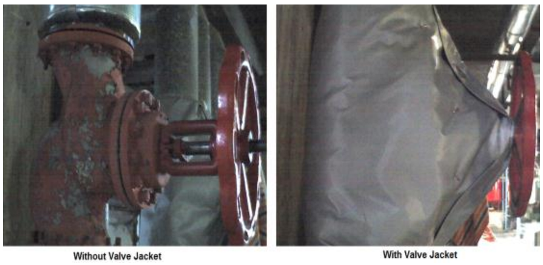

Figure 1. Steam valves with/without valve jacket

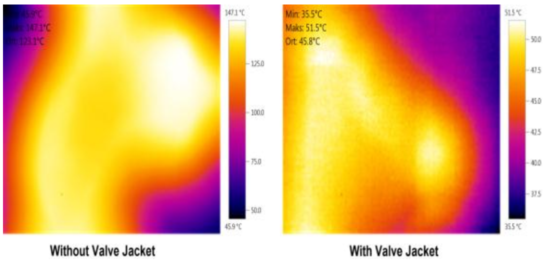

Figure 2. The measurement of the steam valves with thermal camera

2.3.2. Cooling Systems

- **Split Air Conditioners:** The energy classes of split air conditioners at polyclinic blocks are generally C or D. electric energy savings will be provided with the installation of central air conditioning system by eliminating the current split air conditioners. This structuring will be useful and long term system by preventing environmental pollution and also providing inside desired ergonomic values. All 777-pcs of split air conditioners used in the hospital are classes C or D. These air conditioners consume 20-30% more energy than class A. If the air conditioners have inverter system energy saving will be 20-40%. Air conditioners should be chosen A+++ energy class or inverter system from now. The total installed capacity of air conditioners is 1,157.4 kWh. If these air conditioners are accepted to operate on average 8 hours per day they will consume energy 264 days of a year from 22 work days per month. From here, the annual energy consumption per day is calculated as 9,559.2kW × 264 day = 2,444,428.8 kWh annual consumption. Its cost is 733,328.64TL/year.

[15] shows that the energy saving rate of air conditioning in hall is 19.7–49.3%. Similarly at [16] and its investigated studies show that, VRV system improves the energy efficiency and reduces cooling energy consumption for part load conditions lower than 50%. Because of this and similar situation, after installing to inverter system (central air-conditioning system or VRV system can be) average saving will be **40%** generally**.** 2,444,428.8kW×0.40=977,771.52kWh×0.32TL =312,886.88 TL annual savings would be achieved. Approximately 1,450,000TL investment is required for the all air conditioners. The investment will pay for itself over 4.63 years which is not feasible for the hospital.

- **Central Air Conditioners:** The burn unit, emergency, intermediate intensive care units (neurology, cardiovascular, newborn 2), Floors 2-3-4, centrals of floors 1-4-5-6 (heating and cooling) have inverter system. Some of other air conditioner centrals of hospital have to be changed by the air conditioner centrals which are new generation and with automation system, meanwhile centrals are being changed hygienic centrals have to be designed for required places. As a result, energy saving potentials for overall HVAC systems and feasible project are summarized in Table 23. The projects with bold color are feasible.

2.4. Implemented and Suggested Projects for Other Systems

Exterior Wall Insulation and Covering:

Regulation on increasing efficiency for energy resources and in the use of energy was published on 25.10.2008 and energy performance of building regulation was published on 05.12.2008. Energy efficiency strategy paper of 2012-2023 was

Table 23. Energy saving potentials for overall HVAC systems

HVAC System	Saving electricity kWh / year (TOE)	Saving others TOE	Total savings TOE	Saving (TL)	Investment (TL)
Valve insulation jacket application	-	**127.22**	**127.22**	**574,942**	**90,000**
Use of chemicals		**47.49**	**47.49**	**95,145**	**40,000**
Installation of VRV systems instead of split AC system	977,771.52 (84.09)	-	84.09	312,886.88	1,450,000

published on 25.02.2012 by the high planning council and measures were taken to improve the efficiency which were planned to perform until 2023. According to regulation with law number 27035 related with increasing efficiency for energy resources and in the use of energy, the public section buildings which have total construction area at least 10,000m^2 or the total annual energy consumption is greater or equal to 250 TEP (tonnes of oil equivalent) have to employ an energy manager or take the service of energy management (250 TOE equals to 2,907,500 kWh).
Total annual electric energy consumption of our hospital in 2012 was 21,303,600.00 kWh. It is estimated that the total consumption will be 25,000,000.00 kWh with the new plants, loads and transformer putting into use in 2013. The regulation of energy performance on buildings published in the official gazette no 27075 on 05.12.2008 legally obliges to take Energy Performance Certificate (EKB) for the existing buildings which are new and with a floor area greater than 1,000m^2.

Energy performance certificate have to be arranged for the existing buildings and for buildings under construction and not yet received permission to use the building in ten years from the date of publication of the Law on Energy Efficiency (before 02.05.2017).

It is required to perform insulation and jacketing to facade of our buildings until the date 02.05.2017 according to the related regulations. Insulation will provide to reach the desired heat inside fast and minimize losses so it will prevent to operate motors of heating or cooling systems at full capacity. At the same time it will provide the fuel-saving and comfortable room temperature. However, the coating is required to protect heat insulation materials from damage. This process will eliminate the cost of painting and maintenance of the facades and will be used without any operation to exterior facade as the lifetime of the used coating material. The paint and plaster on the exterior facade are blistering and the rips occurred in the rainy weather over time when expose to sun and rain can be totally prevented. 26-48% of the heat lost from a building is sourced from windows. Changing all used glasses with double glazing glasses or with drawling of double-sided film to glasses will save most of the energy. This process will prevent both the escape of heat such and the entering inside of cold or warm air. The insulation of the rooftop and basement of the building should be performed.

Total external facade: 35,000m^2
The cost of insulation and jacketing: 150 TL/m^2
Total investment cost (approximately): 5,250,000 TL

The total annual energy cost of hospital last 12 months is approximately 12,000,000 TL (5,000,000 TL (price of electricity without lighting and other equipment expenditures) + 7,000,000 TL fuel-oil). If minimum 30% of consumed energy is saved only from exterior insulation and jacketing;
Energy consumed for cooling 3 MVA during 4 months (instantaneous consumption). Saving potential for electricity consumption is 5,000,000×0.32=1,600,000×4/12=533,333.00 TL.
Annual fuel-oil consumption in stokehole is 7,000,000 TL. 80% of fuel-oil consumption is used for heating. Saving from there will be 7,000,000×0.80×0.32= 1,792,000 TL.

Most of the energy cost is related with heating and cooling (fuel-oil and electric energy). In addition the cost of painting for every 5 years will be eliminated with the exterior painting of the building. Annul saving from the exterior painting will be approximately 250,000 TL. In this case, the total savings become 1,792,000 + 533,333+250,000= 2,575,333 TL. The total investment is considered as 5,250,000.Investment will take to pay for itself in 2.03 years (5,250,000/2,575,333). Because the total installation cost of this project is very high, this project is not easy to implement.

- **Personals and end Users' Education:** It is important to keep windows and doors closed for cooling and heating. The lamps that are not needed to operate should be turned off. Personal should turn off the electrical devices which are not needed except drug box, refrigerator etc. at the end of the working hours. Especially split air conditioners, computers and printers should be closed. At only the Hospital Information and Management System Department, more than 800 computers and 500 printers have been used approximately. Even if a device consumes electricity one thousandth of normal consumption, when considering the total number of devices, their effect will be large.

- **UPS Efficiency:** New technology 3-level (3-L) UPSs of ENEL Company are 6% more efficient than traditional transformer based UPSs for 100% of full load capacity. The efficiency difference is 10% for 50% of full load capacity. For example, 100 kVA 3-L UPS saves $8,760 (50,265 kWh) a year in electricity costs than transformer based UPS. The payback period for this replacement is approximately 2 or 3 years. At the hospital, all UPSs are transformer based type. The loading capacity of the UPSs is approximately 25%.

The efficiency difference for this loading factor is approximately 10%. The total capacity of UPSs is 2,030 kVA. The energy saving for this replacement is nearly kWh.
$(2030/4) \times 0.1 \times 0.32 \times 24 \times 360 = 140{,}313$ kWh.

- **Transformer Losses:** According to technical specification for MV/LV distribution power transformers, a standard 1000 kVA step-down transformer has 10.5 kW load losses and 2 kW no-load losses. Type-A 1000 kVA step-down transformer has 8.9 kW load losses and 1.45 kW no-load losses. Type-A 1000 kVA high efficiency transformer consumes 2.15 kW less energy than a standard 1000 kVA transformer. The annual loss difference can be calculated as 2.15x24x360= 18,576 kWh. In Turkey, the unit price of electricity is a 0.16$ (All taxes are included to this price). Annual saving is 2,973 $. The purchase price of Type-A 1000 kVA transformer is 2,400$ more expensive than a standard one. The payback period of this investment is nearly 10 months.

3. CONCLUSIONS

In this research paper, the best energy saving approaches and energy efficiency improvement methods for University Hospital giving the payback periods of the suggestions were developed. Approximately up to 10% energy saving without any charges can be achieved by using simple precautions. The findings of this research study help the engineers and managers in the hospitals for reducing energy consumption while maintaining the quality of service.
This paper proves that applying the energy efficiency and saving practices will save considerable amounts in the electrical bills and fuel. In this paper, new energy consumption rates by suggesting energy improvement applications and energy saving methods are compared with the present energy consumption rates in the hospital. As a result of the detailed analysis on the existing system, 20-40% of energy saving potential is estimated at the University Hospital.

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- Project title/number: Developing a software program to determine the optimal capacity rating of cogeneration and trigeneration plants driven by

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