ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

Oğuzhan TİMUR

ENERGY EFFICIENCY IMPROVEMENT AND ENERGY SAVING OPPORTUNITIES AT ÇUKUROVA UNIVERSITY BALCALI HOSPITAL

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ADANA, 2013

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We certify that the thesis titled above was reviewed and approved for the award of degree of the Master of Science by the board of jury on 21/08/2013.

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ABSTRACT

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ÇUKUROVA UNIVERSITY
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The increasing demand for energy and the depletion of existing fossil fuel based resources have made it mandatory for the efficient use of energy, energy saving 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.

In this thesis, the required applications for energy efficiency improvement and energy saving are given with their payback period calculations by examining the present situation of Balcalı Hospital where consumed energy is approximately 40-45% of the energy used in Çukurova University. Energy saving practices especially emphasizing on electricity and fuel consumptions are presented with examples. The additional works should be performed are summarized by considering the legal regulations on energy efficiency in Turkey. Furthermore, investigations on use of cogeneration/trigeneration system and renewable energy sources considering the geological location of the hospital are performed. A software program that tracks and analyzes the electricity bills, suggests the best electricity tariff and controls the active and reactive power rates to protect paying any punishment is developed.

The properties of heat center, cooling and air conditioning system, air handling unit, lighting system, transformer, uninterruptible power supply, generator, water system, compressor and all electric motors in the hospital are reported after investigations. The estimated new energy consumption rates after suggested energy efficiency saving, improvement and energy management opportunities are compared with the present energy consumption rates. As a result of the detailed analysis on the existing system, 36% energy saving potential is estimated at the Balcalı Hospital.

Key Words: University Hospital, Energy Efficiency, Energy Saving, Energy Management.

ÖZ

YÜKSEK LİSANS TEZİ

ÇUKUROVA ÜNİVERSİTESİ BALCALI HASTANESİNDE ENERJİ VERİMLİLİĞİNİN İYİLEŞTİRİLMESİ VE ENERJİ TASARRUFU FIRSATLARI

Oğuzhan TİMUR

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
ELEKTRİK ELEKTRONİK MÜHENDİSLİĞİ ANABİLİM DALI

Danışman : Yrd. Doç. Dr. Ahmet TEKE
Yıl : 2013, Sayfa 245
Jüri : Yrd. Doç. Dr. Ahmet TEKE
: Prof. Dr. Mehmet TÜMAY
: Doç.Dr. Zekeriya TÜFEKÇİ

Artan enerji talebi ve mevcut fosil yakıt tabanlı kaynaklarının hızla tükenmesi, enerjinin verimli kullanılmasını, enerji tasarrufu yapmayı ve alternatif enerji kaynakları aramayı zorunlu hale getirmiştir. Enerji ihtiyaçlarını karşılamada başka ülkelere bağımlı olan bizim gibi gelişmekte olan ülkelerde, mevcut enerjiyi verimli kullanmak ve tasarruf çalışmaları yapmak daha büyük önem taşımaktadır.

Bu tezde, Çukurova Üniversitesinde kullanılan enerjinin yaklaşık olarak %40-45'sini tüketen Balcalı Hastanesi'ndeki mevcut durum incelenerek yapılması gereken enerji tasarrufu ve verimlilik arttırıcı çalışmalar, geri dönüşüm süreleri hesaplanarak verilmiştir. Özellikle elektrik ve akaryakıt harcamaları üzerinde durularak yapılabilecek tasarruf çalışmaları örneklenerek sunulmuştur. Türkiye'deki enerji verimliliği ile ilgili yasal düzenlemeler incelenerek yapılması gerekli ek çalışmalar özetlenmiştir. Ayrıca hastanenin bulunduğu jeolojik konum itibariyle kojenerasyon/trijenerasyon sistemi ve yenilenebilir enerji kaynaklarının kullanımı ile ilgili incelemeler yapılmıştır. Elektrik faturalarının analizi, takibi, tarife değişikliği kontrolü ve aktif-reaktif güç oranlarından dolayı ceza ödememek için oran kontrolü yapan bir yazılım programı geliştirilmiştir.

Hastanedeki ısı merkezi, soğutma ve havalandırma sistemleri, klima santralleri, aydınlatma sistemi, trafolar, kesintisiz güç kaynakları, jeneratörler, hidrofor sistemleri, kompresörler ve tüm elektrik motorları incelenerek özellikleri raporlanmıştır. Enerji verimliliği iyileştirilmesi, enerji tasarrufu ve enerji yönetimi fırsatları önerildikten sonra öngörülen yeni enerji tüketim oranları mevcut durumla karşılaştırılarak sunulmuştur. Mevcut sistem ve tüketim miktarları üzerinde yapılan incelemeler sonucunda %36 oranında tasarruf edilebileceği öngörülmüştür.

Anahtar Kelimeler: Üniversite Hastanesi, Enerji Verimliliği, Enerji Tasarrufu, Enerji Yönetimi

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LIST OF SYMBOLS

ABS_{VSD}	: Annual bill saving using VSD
AES	: Annual energy saving
C	: Price of fuel oil
CO_2	: Carbon dioxide
cosØ	: Power factor
E_{ee}	: Energy-efficient motor efficiency rating (%)
EF	: Emission factor
ER	: Emission reduction
E_{std}	: Standard motor efficiency rating (%)
ESVSD	: Energy saving with variable speed drive
H_{avg_usage}	: Annual average usage hours
hp	: Horse power
hr	: Usage hours
Hz	: Frequency
I	: Current
kg/kWh	: Kilogram/Kilowatt hour
kW	: Kilowatt
LF	: Load factor
n	: Number of the motor
P	: Motor power
SSR	: Percentage energy savings with speed reduction
V	: Voltage
η	: Motor efficiency

LIST OF ABBREVATIONS

^0C	: Centigrade Degrees
3-L	: Three Level
ABB	: ABB Power and Automation Technologies Company
ABS	: Annual Bill Saving
AC	: Alternative Current
ACH	: Air Change per Hour
AES	: Annual Energy Saving
AHU	: Air Handling Unit
ASHE	: American Society for Healthcare Engineering
ATES	: Aquifer Thermal Energy Storage
BEE	: Bureau of Energy Efficiency
BTU	: British Thermal Unit
CADDET	: Centre for the Analysis and Dissemination of Demonstrated Energy Technologies
CCHP	: Combined Cooling Heat and Power (Trigeneration)
CEMEP	: European Committee of Manufacturers of Electrical Machines and Power Electronics
CFL	: Compact Fluorescent Lamps
CFU/m^3	: Colony Forming Unit/Cubic meters
CHP	: Combined Heat and Power (Cogeneration)
CHP	: Combined Heat and Power (Cogeneration)
CHWP	: Chilled Water Pump
COP	: Coefficient of Performance
CRI	: Color Rendering Index
CT	: Color Temperature
DC	: Direct Current
DLL	: Domestic Lighting Lamp
DX	: Direct Expansion Systems
E1-E4	: Emergency Units

ECsg	: Energy Conservation
EFF	: Efficiency Level
EII	: Energy Innovators Initiative
EPA	: US Environmental Protection Agency
ERV	: Energy Recovery Ventilator
ET AL	: And Others
EUR	: European Union Currency
FCU	: Fan Coil Unit
FL	: Fluorescent Lamps
GGHH	: Global Green and Healthy Hospitals
GHG	: Greenhouse Gas
HEM	: High Efficiency Motor
HID	: High Intensity Discharge
HIMS	: Hospital Information Management System
HPS	: High Pressure Sodium Fixture
HVAC	: Heating, Ventilation and Air Conditioning
HWP	: Heating Water Pump
IE	: International Efficiency
IEA	: International Energy Agency
IEC	: International Electrotechnical Commission
IET	: Institute for Energy and Transport
INC	: Incandescent Lamps
INT	: Internal
K1-K3	: K Blocks
LED	: Light Emitting Diode
LID	: Low Intensity Discharge
LPNa	: Low Pressure Sodium
MH	: Metal Halide Fixture
NOx	: Nitrogen Oxides
OLED	: Organic Light Emitting Diode
P1-P13	: Polyclinics

PCM	: Phase Change Materials
PCS	: Pieces
PLC	: Programmable Logic Controller
PV	: Photovoltaic
SOx	: Sulfur Oxides
SSL	: Solid State Lighting
TCF	: Trillion Cubic Feet
TL	: Turkish Liras
UPS	: Uninterrupted Power Supply
VAV	: Variable Air Volume
VRF	: Variable Refrigerant Flow
VRV	: Variable Refrigerant Volume
VSD	: Variable Speed Drives
Y1-Y3	: Old Building Transformers No. 1-3
Y4	: New Building Transformer No. 4
Y5	: New Building Transformer No. 5
Y6	: New Building Transformer No. 6

1. INTRODUCTION

In this chapter, an introduction to the thesis with its general aims, background, research motivation, objectives, disposition and contributions are presented.

1.1. Background and Research Motivation

Energy is a vital input for social and economic development of any nation (Saidur et al., 2011). According to International Energy Agency (IEA) data, the final energy consumption of the building sector in the world has risen to 2,794 millions of tonnes of oil equivalent (Mteo) in 2007 as shown in Figure 1.1. The building sector represents around 34% of the world final energy consumption and hence is the first consumer sector (Missaoui and Mourtada, 2010).

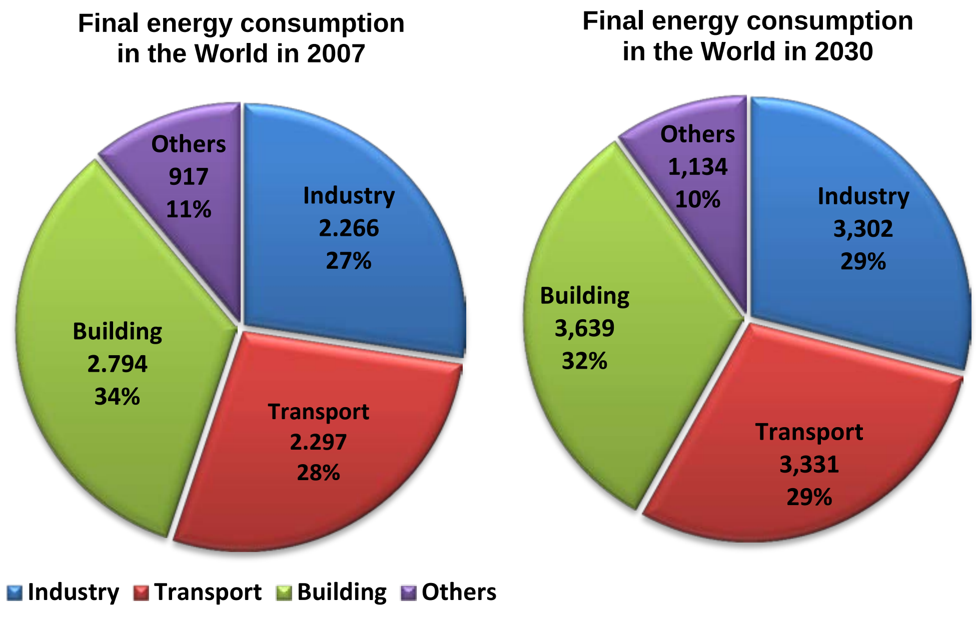


Figure 1.1. Final energy consumption prospective in the world in 2007 and 2030

According to the reference scenario of IEA, the building sector will remain the first consumer with in 2030 with consumption share of 32% (3,639 Mteo). Its energy demand will grow with an average of around 1.2% per year against 1.4% for the whole final energy consumption (Missaoui and Mourtada, 2010). The industrial sector is also consuming large amount of the world's total delivered energy use for diverse activities in manufacturing, agriculture, mining and construction. It was reported that global industrial energy consumption is estimated to grow from 5.129E+07GWh in 2006 to 7.198E+07GWh in 2030 for the next 25 years.

Presently, fossil fuel based energy such as oil, coal and natural gas are the major sources of energy for industrial activities. Over 80% of total industrial energy needs are met by fossil fuels. Burning fossil fuels produces CO_2 which is responsible for negative impacts to the environment (Saidur et al., 2011). According to BP Statistical Review of World Energy-2004, world oil and gas reserves are estimated at just 45 years and 65 years respectively. Coal is likely to last a little over 200 years. According to (Maggio and Cacciola, 2012), all fossil fuels should peak within about the next half century. The obtained results can be also summarized as follows.

- World crude oil and Natural Gas Liquids: assuming a global ultimate in the range 2250-3000 Gb, the peak was estimated to be in range 29.2-31.6 Gb/year and occurs between 2009 and 2021.
- World natural gas: assuming a global ultimate in range 9500-15400 Tcf, the peak was estimated to be in the range 121-135 Tcf/year and occurs between 2024 and 2046. A plateau is likely to occur, especially for high values of ultimate.
- World coal: assuming a global ultimate in range 550-750 Gtoe, the peak was estimated to be in range 4.1-4.9 Gtoe/year and occurs between 2042 and 2062.

Energy is also drawing the largest amount of private domestic and foreign investment in Turkey. Forecasts indicate that yearly increase in the demand for electricity in Turkey is 7% depending on the increasing population and social welfare. In total, number of power plants are 743 and installed capacity is 57,000 MW in 2012 (McBDC, 2012). Installed renewable energy capacity of Turkey in 2012 is shown in Figure1.2.

- Thermal power plants 35,000 MW
- Hydroelectric dams 19,600 MW
- Wind 2,260 MW
- Geothermal 162 MW

Turkey is energy importing country, which 70% of total energy consumption supplied by imported energy. Turkey is also generously endowed with renewable energy sources. There is an estimated yearly renewable energy potential of around 560 TWh from commercially exploitable sources such as hydropower, wind, biomass, geothermal and solar energy. In Turkey, it is expected that (Kotcioglu, 2011);

- Investments for energy will amount 90 Billion Dollars by 2023
- Installed capacity will reach 87.000 MW by 2023
- Renewables will take place by 30% in production of electricity

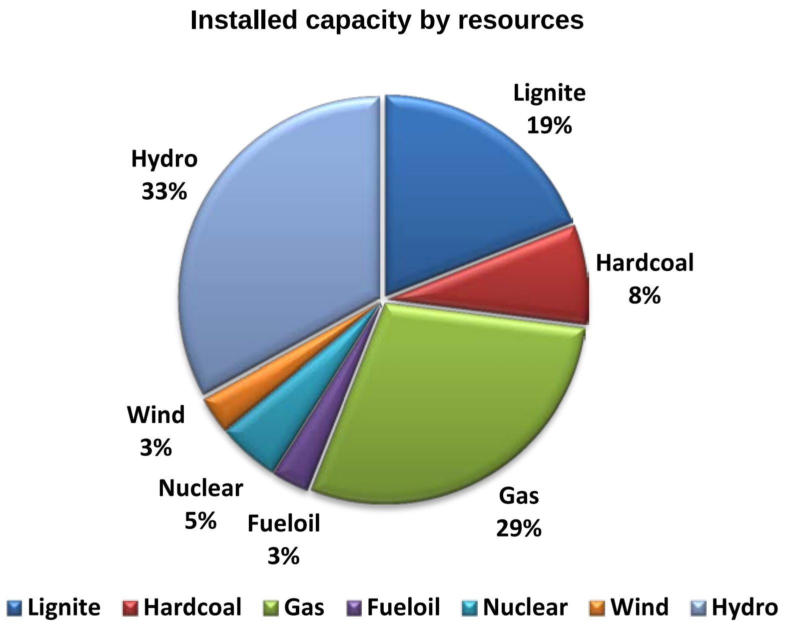


Figure 1.2. Installed renewable energy capacity of Turkey in 2012

Energy efficiency is the best way to satisfy the economic growth and environmental protection for all countries in the world. International demand of fuels grows exponentially that affects high international prices and contributes to global warming. Therefore, it becomes time to move towards fuel savings strategies and substitute alternatives sources of energy development along with new adapted technologies. There are currently several developments worldwide that focus on the implementation of policies and strategies to sustain the promotion of energy use efficiency (Lao Institute, 2006).

The benefits of energy efficiency are (Heur, 2008), (Teke and Timur, 2013) and (EPA):

- Reduces maintenance costs, operating costs and customer energy bills
- Gives customers greater control over energy costs
- Performs at lower cost than new energy supply from new power plants in many cases
- Reduces air pollution and greenhouse gases
- Can create jobs and improve state economies
- Reduce the impacts of future rate increases and dependency on energy imports
- Improve business competitiveness

An economic savings potential in existing commercial buildings is between 10 and 20% of current energy use with best practices. Around 10% primary energy savings are often achievable within a one year period (CADDET). Energy savings potential end-use sectors in 2020 are shown in Figure 1.3 (Rademaekers et al., 2012).

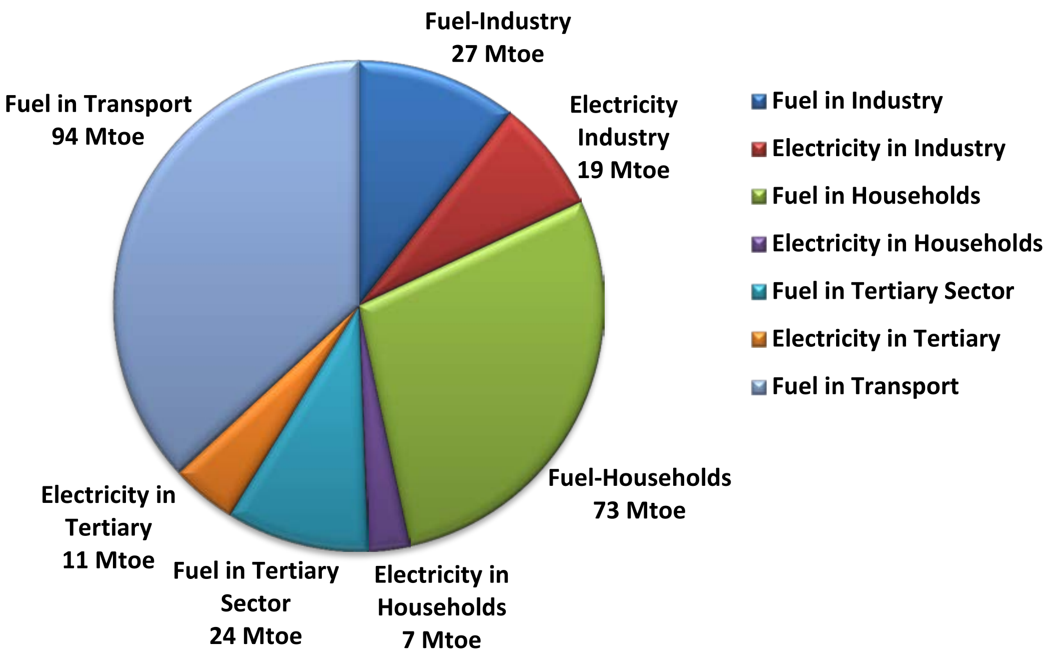


Figure 1.3. Energy savings potential end-use sectors in 2020

Buildings sector energy savings by sector and end-use is shown in Figure 1.4 (IEA, 2011).

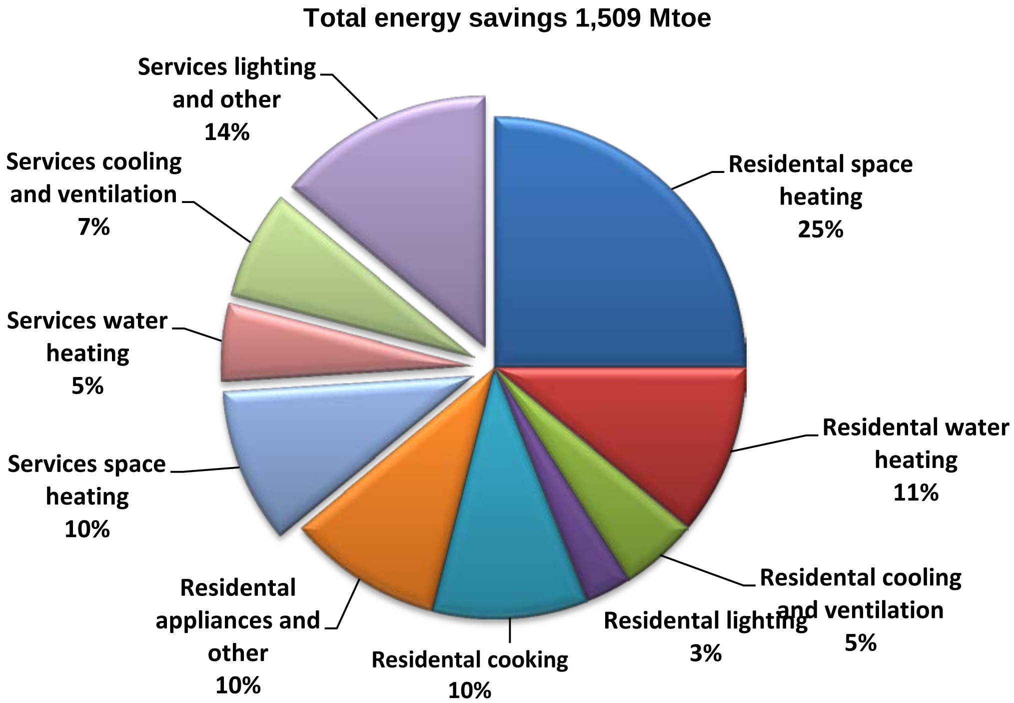


Figure 1.4. Buildings sector energy savings by sector and end-use

Researches focused on energy efficiency, saving potentials and energy management show that the hospitals represent 6% of total energy consumption at the utility buildings sector. Utility buildings are offices, shops, hotels, restaurants, educational establishments and care institutions.

Energy efficiency opportunities for healthcare organizations can find energy savings through multiple efforts (ENERGYSTAR). These opportunities can be investigated two types as low-cost measures and cost effective investments.

Low-cost measures are as following substances,

- Measure and track energy performance
- Check the gas and electrical energy tariffs
- Ensure all equipment is functioning as specified and designed
- Retrofit inefficient lighting
- Check the transformer loading factor and satisfy unity power factor
- Adjust thermostats for seasonal changes and occupancy

- Install VSDs and energy efficient motors
- Install air curtain system
- Check the thermal insulation of the building and HVAC system
- Balance air and water systems
- Educate staff and patients about how their behaviors affect energy use
- Install building energy management unit and perform regular maintenance

Cost-Effective Investments are following substances,

- Work with an energy service provider to manage and improve energy performance
- Install Combined Heat and Power System
- Investigate capital investments such as highly efficient HVAC systems
- Purchase energy efficient products like qualified office, electronic and commercial cooking equipment
- Maximize the usage of natural light during the day through corridors

Numerous building systems are typical candidates for cost-effective retrocommissioning. Among the most commonly retrocommissioned systems and the possible benefits can be presented in Table 1.1 (Crow, 2008):

Table 1.1. The commonly retrocommissioned systems and the possible benefits

Lighting system	▪ Reduce excessive lamp wattages through lamp replacement ▪ Program lights to go off during unoccupied periods ▪ Use high efficiency lamps offering high lumens/watt ▪ Use high efficiency ballast system
Controls	▪ Recalibrate sensors and correct improperly functioning control sequences ▪ Eliminate excessive, simultaneous heating and cooling ▪ Reset out-of-range or inappropriate set-points during unoccupied periods ▪ Repair disabled free-cooling economizers ▪ Eliminate equipment running excessively or inefficiently ▪ Reprogram equipment operating schedules to match building use ▪ Control building pressurization to prevent unwanted infiltration and exfiltration

HVAC equipment	▪ Balance air and water systems that are out of balance ▪ Repair variable-air-volume boxes that are not working properly and reduce excessive air-change rates ▪ Tighten loose fan belts and repair leaking control valves ▪ Replace leaking damper seals ▪ Repair or replace malfunctioning variable-speed drives ▪ Seal ductwork to minimize leaks
Building envelope	▪ Repair door and window seals to prevent excessive infiltration of unconditioned outdoor air and excessive exfiltration of conditioned air ▪ Replace inefficient glazing or install solar-control film ▪ Provide internal or external shading devices to control solar heat gain ▪ Install additional thermal insulation where needed to reduce heat gain and loss

The energy consumption distribution of a hospital can be classified by energy consumption types. HVAC (especially heating) and lighting are the major part of energy consumption. The hospital heating systems use approximately 43% of the total energy consumption at the hospitals. Lighting system consumes 21% of total energy consumed at the hospitals. The consumption of cooling and hot tap water systems represents around 10% of the total energy consumption. Electricity consumption by medical office equipment and other devices are named as “Other” category and its value is approximately 26% of the total energy consumption (ASHE, 2004) and (Heur, 2008).

In a typical hospital, water heating, space heating and lighting account for 61-79% of total energy use, depending on the climate relative to the number of cooling and heating degree days. For hospitals each $1 saved in energy costs equivalent to generating new revenues of $20 (Fournier, 2009). Hospital energy managers can use energy efficiency strategies to offset high costs caused by growing plug loads and rising energy prices. A typical 200,000-square-foot (ft2), 50-bed hospital in the U.S. annually spends $680,000 or roughly $13,611 per bed on electricity and natural gas. By increasing energy efficiency, hospitals can improve the bottom line and free up funds to invest in new technologies and improve patient care. An average U.S. hospital uses 27.5 kWh of electricity and 109.8 cubic feet of natural gas per ft^2 annually (Data are calculated using a 2003 U.S. Energy Information Administration survey of commercial buildings). Using average commercial energy prices of $0.10 per kWh and $8.59 per hundred cubic feet (ccf), the average cost of power per ft² for hospitals in North America is approximately $2.84 for electricity and $0.94 for natural gas. Figure 1.5 details healthcare energy consumption by end use in the U.S (E-4, 2010).

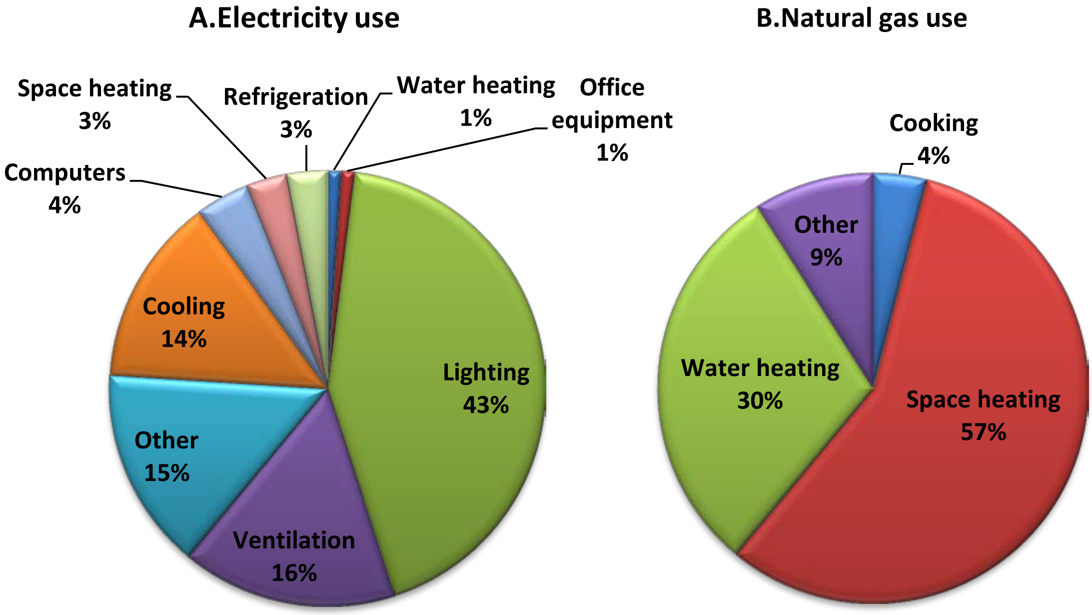


Figure 1.5. Healthcare energy consumption by end use in the U.S

Hospitals and hospital buildings are large consumers of energy. They have a high potential for energy savings, estimated to range from 20% up to 40%. Strategies for energy cost controls have led to a trend of dealing with energy supply costs, reliability and quality as managed risks. Approaches to handling ever-increasing energy requirements can include (ASHE, 2004):

Demand-side management (DSM): A management approach that involves ways to reduce the need for energy and greenhouse gas emissions. DSM typically includes modification of light fixtures, alteration of heating and cooling systems from constant volume to VSDs applications, addition or upgrade of process instrumentation, changeover of equipment and controls improvements.

Supply-side management (SSM): A management approach that seeks the most cost-effective ways to procure and distribute the needed energy supply for a hospital SSM typically includes load profiling or understanding existing loads, on-site generation alternatives such as cogeneration, new procurement strategies such as purchasing energy from suppliers other than the local utility company, electrical system upgrades to remove inefficient equipment, peak shaving opportunities.

Other considerations for energy use in the healthcare industry include power sources, deregulation and outsourcing energy management. Energy managements of hospitals can be described as a way of improving the energy efficiency in an existing building by continuously striving towards decreased energy consumption. This includes operating and maintaining building in a way that sustains the energy efficiency gains achieved. There are a number of steps that must be taken to introduce and implement energy management programs: Hospitals and hospital buildings are large consumers of energy. They have a high potential for energy savings, estimated to range from 20% up to 40%. Energy managements of hospitals can be described as a way of improving the energy efficiency in an existing building by continuously striving towards decreased energy consumption. This includes operating and maintaining building in a way that sustains the energy efficiency gains achieved. There are a number of steps that must be taken to introduce and implement energy management programs:

- Organization
- Implementation of an energy management program
- Energy audit
- Prioritizing possible measures implementation of measures
- Maintenance and follow-up

Energy management programs are useful because (Fournier, 2009):

- Energy costs are increasing and becoming a larger percentage of operating costs
- A systematic approach insures that all opportunities are considered
- Continual improvement insures new methods and technologies are incorporated into an existing program
- Energy can be managed and many operations are not capitalizing effectively on this opportunity

Table 1.2 summarizes a number of areas for potential energy savings. For each area a number of different measures are identified, which should be seen as a first overview of general measures that can be carried out. Each measure can be further divided into more detailed areas.

Table 1.2. An overview of energy saving areas in hospitals

Heating System	▪ Room thermostats ▪ Thermostatic radiator valves ▪ Insulation of hot water tanks and boilers ▪ Installation of local water heaters ▪ Use of high efficient boiler
Combined Heat & Power	▪ Determine the heating and electricity needs (MVA) carefully ▪ Usually most cost-effective when all heat and electricity can be used with in the hospital area ▪ Regular performance monitoring, maintenance and inspection of steam turbine ▪ Direct heat recovery ▪ Minimization of the steam vent valve usage
Building Fabric & Air-Conditioning	▪ Insulate roof ▪ Draught proofing ▪ Window shading ▪ Use of air curtain
Lighting System	▪ Replace incandescent tungsten lamps with compact fluorescent lamps ▪ Replace old fluorescent tubes with new low-energy ones ▪ Replace old electromagnetic ballast with electronic ▪ Check applicability for time controls, presence detectors and daylight compensators ▪ Use LED lamps for exterior lighting
Mechanical Ventilation	▪ Install variable speed drives on fans and large pumps ▪ Check the present system, especially the control settings ▪ Use outside air for ‘’free cooling’’ ▪ Explore opportunities for heat recovery from exhaust air
Building Energy Management System (BEMS)	▪ Explore all possibilities to make better use of systems installed ▪ If no BEMS is installed, consider installation ▪ Make use of system within the energy management program
Maintenance	▪ Regular inventories of systems equipment and components ▪ Time schedule for inspection and maintenance ▪ Inventory of stock kept for critical repairs ▪ Data and supply equipment parts
Services	▪ Laundry; typically potential for heat and water savings ▪ Kitchen; typically large potential for reduction of heat usage ▪ Elevator; typically large potential for energy saving with VSDs

Before embarking on an energy management program, especially if consultants are to be contracted, it is important to have sufficient knowledge of the building, so that quotations received can be compared properly as shown in Figure 1.6 (Caddet). If, for instance, consultants are to be contracted to carry out the energy audit, then the cost of the consultant should not be allowed to exceed the savings which can reasonably be expected. At this stage the first of three decisions has to be taken; whether the energy management program is viable according to the potential energy/economic savings that can (reasonably) be achieved.

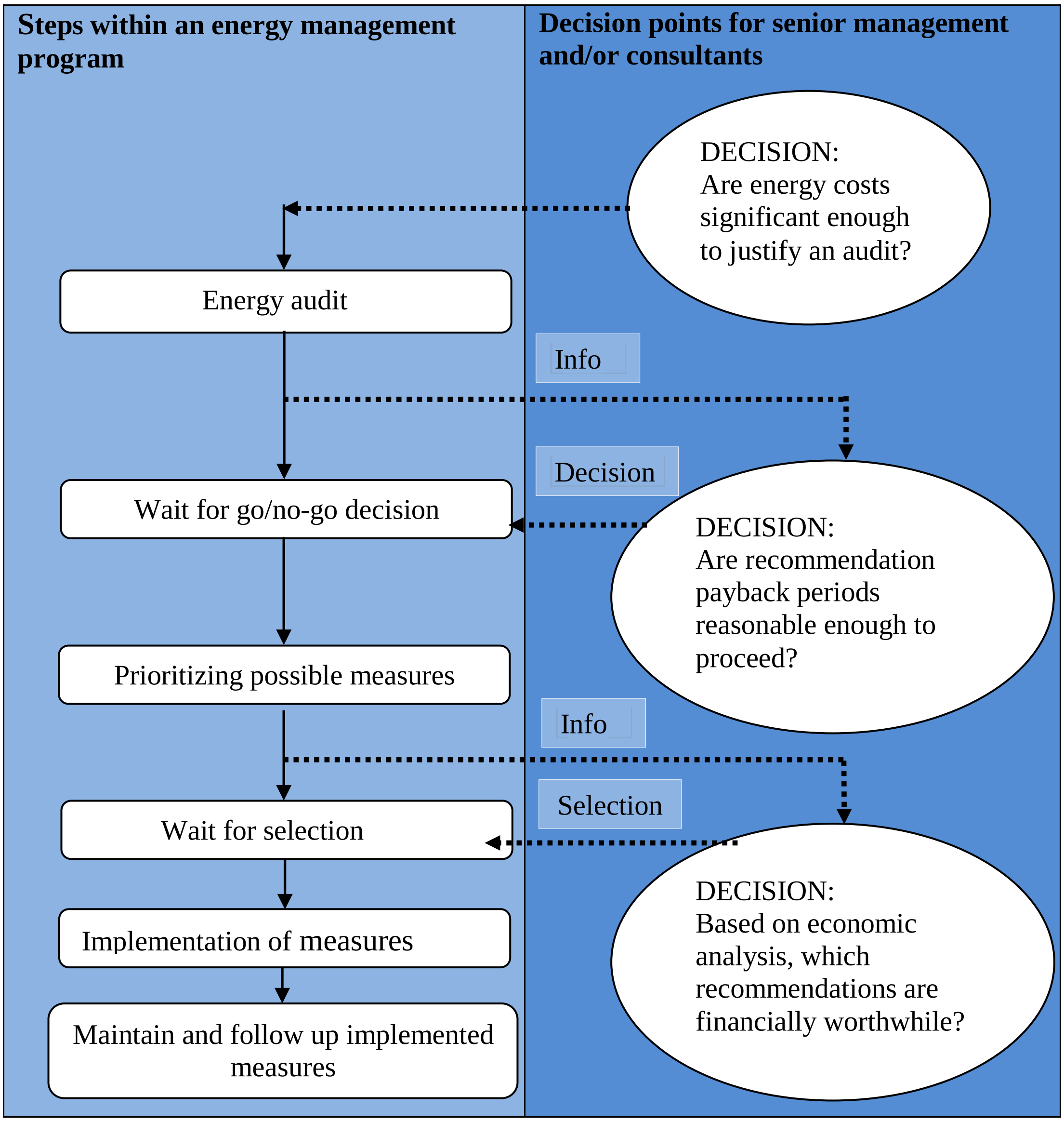


Figure 1.6. Implementation of an energy management program

Areas of high potential savings ranging from 20% up to 40% in the hospitals can be obtained with following solutions (Sullivan, 2010):

- Advanced and integrated control techniques that regulate all building systems can help a hospital save 5 to 20% annually on HVAC and lighting costs.
- By installing VSD for air-conditioning pumps and fans, a hospital can reduce motor speeds and optimize fan and pump runtime. A 20% motor speed reduction could deliver a 50% energy savings.
- Integrated lighting control systems with low-consumption lighting can offer up to a 30% savings on energy.
- Energy efficiency measures for operating theatre can reduce the air change rate based on operating theatre occupancy, with potential for as much as 25% savings.
- In a hospital datacenter, in-row cooling devices for servers could save 30% on energy.

There are some interesting new studies on hospital energy efficiency. Health Facilities Management and the American Society for Healthcare Engineering of the American Hospital Association performed completed surveys for 691 hospitals to learn about trends in hospital energy management. Conducting energy audits remains the most common energy monitoring measure, cited by 40%, even if many perform them infrequently. Other strategies used by at least a fourth of respondents include setting energy budget and performance targets and monitoring them annually 38%. When it comes to reducing energy costs, strategies varied. Preventive maintenance, light emitting diode exit signs and electronic ballast and energy efficient lamps are used by at least three-quarters of the respondents. Beyond those, roughly half the organizations also are buying energy star certified products (55%), upgrading building control systems (53%) or implementing energy conservation programs (49%) (Carpenter et al., 2011).

Taiwan National Cheng Kung University Hospital performed some progress such as lightning system renovation, adapted heat pump/hot water system and conducted air conditioning system renovation. In lightning system progress, the result was luminosity increased 30%, energy saving rate was 46.53% with a cost-recovery period of 2.6 years. The annual power saving was nearly $129,600; lowered air-conditioning loads by 82.9 RT/year; reduced 1,362 tonnes of CO_2 emission per year; the total energy saving rate is 52.1% In adapted heat pump/hot water system progress, the annual power saving was nearly $157,705; annual CO_2 emission reduction was 1,228.9 tonnes/year; energy saving rate was 64.6%. In conducted air conditioning system renovation, the results were achieved energy saving rate of 33.56%; estimated annual cost saving from 2012 and on is nearly $342,491; estimated annual CO_2 emission reduction is 2,668 tonnes (GGHH) and (Da'as,2008) presented the potential for energy savings in the Palestinian hospitals' sector by implementing energy conservation measures. They have achieved average total savings of 17% for hospitals and 14%, 43% and 17% for cooling and heating, oxygen generation units, power factor correction and 5% for lighting systems, respectively. Apollo Hospitals in Chennai reduced 61.31 units of power consumption per day to 57.62 by replacing reciprocating compressors with centrifugal and screw type compressors, CFL with electronic chokes for lighting, old elevator machinery with variable frequency drive, maintaining power factor of 0.97, using APFC fitted with harmonic suppression filters, waste steam used to pre-heat water and minimizing diesel generation by using steam generation. Ruby Hall Clinic in Pune reduced the consumptions by over 27% by installing of solar heating panels, water treatment plant, utilizing waste heat recovery from air-conditioning systems, optimizing indoor and street lighting, checking the air-conditioning systems and implementation of effective automation and control (Deepalakshmi, 2008).

1.2. Objectives and Disposition of Thesis

The main objectives of this thesis are as follows.

- To describe the importance of energy efficiency and energy saving potentials at the hospitals.
- To identify the wide range of energy savings options applicable to hospitals.

- To present literature survey studies on lighting, electric motors, VSDs and HVAC systems giving practical applications with their payback periods.
- To present the energy consumption profile of a university hospital (Balcalı Hospital)
- To specify and develop suggestions for the best energy saving approaches and energy efficiency improvement methods for Balcalı Hospital giving the payback periods of the suggestions.
- To develop and test an electricity bill analysis and recommendation program.

After an introductory section where the background and research motivation of the study are introduced, the structure of this thesis is as follows:

In Chapter 2, literature survey studies on lighting, electric motors, VSDs and HVAC systems giving practical applications with their payback periods are presented. Under the sub-sections, the latest literatures including research articles, conferences, e-books, handbooks and company reports interested in energy efficiency, energy saving and energy management systems are summarized.

In Chapter 3, after wide literature survey, the general information on Balcalı Hospital (a university hospital) and the energy and load profile of the hospital are clearly presented and analyzed.

In Chapter 4, the best energy saving approaches and energy efficiency improvement methods for Balcalı Hospital with their payback periods are presented. A proposed electricity bill analysis and recommendation program is presented.

In Chapter 5, the conclusions, contributions of the thesis and author’s recommendations for future work are explained.

Finally, all the references used in the thesis, biographical information of the author and sections of the Appendices are presented.

1.3. Contributions of Thesis

The main differences and important contributions of this thesis can be summarized as follows:

1) The wide literature surveys for lighting, electric motors, VSDs and HVAC systems at the hospitals giving practical applications and their payback periods have been accomplished.

2) Practical recommendations and suggestions for a number of significant energy efficiency studies at the hospitals are presented.

3) The energy consumption profile of a large capacity university hospital including electrical single line diagram, numbers and distribution of lamps, motors, HVAC systems are presented.

4) An electricity bill analysis and recommendation program is developed and tested.

5) The information in this thesis helps the engineers and managers in the hospitals for reducing energy consumption while maintaining the quality of service.

2. REVIEW OF RELATED LITERATURE

The research papers and practical studies on energy efficiency and energy saving potentials on HVAC systems, electric motors, variable speed drives and lighting at the hospitals are presented in this section. Under the following sections, the latest literatures including research articles, conferences, e-books, company reports, web pages, MSc and PhD theses interested in energy efficiency, energy saving and energy management are summarized.

(Maheswaran et al., 2012) have investigated about energy efficiency methods in electrical systems and reduction of the greenhouse gases at their study. The some of the latest energy efficiency technologies such as the using of the energy efficient motors, the using of the soft starters, the using of the VSDs, the using of the energy efficient transformers with low loss, the selection of the electronic ballast, the using of the lighting control systems and the using of the energy efficient lamps have been explained.

Energy efficient lighting is one of the best and most cost effective ways to reduce total energy consumption in the world. It is very important to evaluate and change current lighting system to satisfy energy efficient lighting. Researches focused on energy efficiency, saving potentials and energy management show that the hospitals represent 6% of total energy consumption at the utility buildings sector. Utility buildings are offices, shops, hotels, restaurants, educational establishments and care institutions. The energy consumption distribution of a hospital can be classified by energy consumption types. HVAC (especially heating) and lighting are the major part of the energy consumption. The energy consumption distribution of a hospital can be classified by energy consumption types. HVAC (especially heating) and lighting are the major part of the energy consumption. The hospital heating systems use approximately 43% of the total energy consumption at the hospitals. Lighting system consumes 21% of total energy consumed at the hospitals. The consumption of cooling and hot tap water systems represents around 10% of the total energy consumption. Electricity consumption by medical office equipment and other devices are named as "Other" category and its value is approximately 26% of the total energy consumption (Heur, 2008).

2.1. Literature Review on Lighting Systems

Lighting represents approximately 20% of total world electricity consumption (Gorgulu and Ekren, 2013). 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. At the following subsections, lamp types, general characteristics of lamps, various saving methods and lighting system projects are investigated. The related survey studies on lighting systems are presented at the following subsections.

2.1.1. The Components of Lighting Systems

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. There are some features to be considered for selecting the lamps. These are annual operating cost (TL/$ or €), luminous efficacy (lumens/watt), color temperature (kelvins), lamp lifetime (operating hours), color rendering index (CRI) and installation time. The luminous efficacy of a lamp is light output (lumens) divided by the electrical power input (watts). Lumen is the unit of luminous flux output from a lamp and watt is the unit of the electrical power value. It is the ratio of luminous flux to power. Luminous efficacy (also called as lamp efficiency) is the amount of light as a result of one watt power consumption. The luminous efficacy criterion is the most preferred method when selecting the lamp. The color properties of a lamp are described by its color temperature and its color rendering index. Color temperature is a measure of the color appearance of the light of a lamp and it is expressed by using kelvin unit. The color of light is determined by color temperature. Figure 2.1 shows the general color temperature of a lamp (XY chromaticity diagram). Saturated colors are arrayed along the outside of the arc. Blackbody emission (Wein's law) falls along the curved line. The lines crossing the Wein's law curved line correspond to different "color correlated temperatures". Ovals are examples of McAdam's ellipses, enlarged by a factor of ten. Within these ovals the eye does not distinguish color variations (Azevedo et al., 2009).

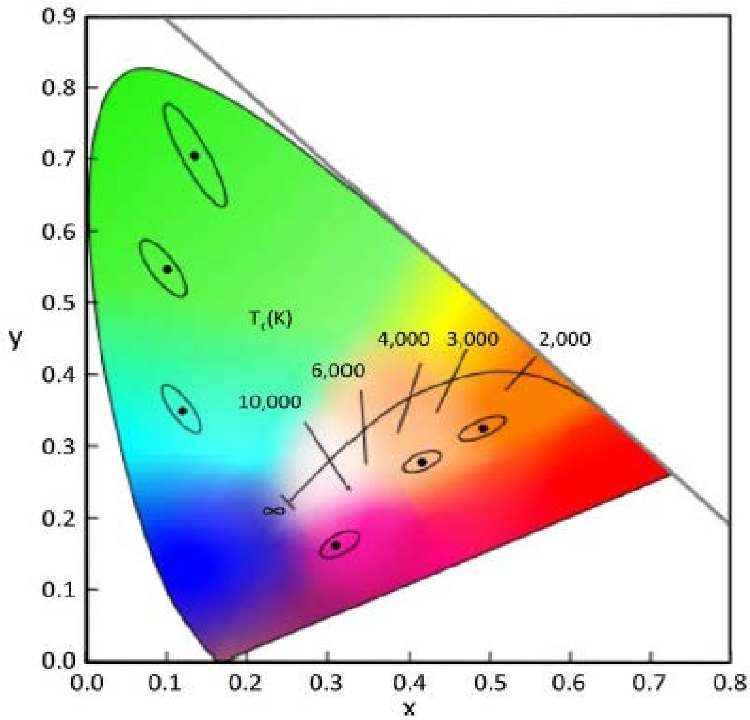


Figure 2.1. General color temperature of a lamp

(Azevedo et al., 2009) was about transition to solid state lighting and lighting systems was investigated with white light emitting diodes. Firstly, historical development of lamps was given. And then, the lamp characteristic properties as CRI, lifetime and efficacy were analyzed as shown in Table 2.1. All lamps with each other from the first invention of the incandescent lamp to today's most efficiently lamps named as solid state or light emitting diode lamps were compared. The positive and negative features of solid state and other lamps have been displayed.

Finally, they had proven to efficient use of electrical energy and lower lighting costs as well as reduced atmospheric pollution by using solid state lighting systems.

Similarly, (Capehart et al., 2008) have studied about energy management. At lighting chapter in their book, they have mentioned lamp characteristics and their importance. They showed that the color temperature affects the color appearance. According to color temperature, lamp colors usually consist of three main groups. If the color temperature is lower than 3300 K (Kelvin) then warm white color appearance is occurred. If the color temperature is between 3300 K and 5300 K, then natural white color appearance is occurred. If CT is higher than 5300 K then daylight is occurred. Some resources use 3000 K instead of 3300 K and 5000 K instead of 5300 K.

Table 2.1. General lamp characteristics

Lamp	Type	Power (W)	Efficacy (lumen/W)	Life time (x1000 h)	CT (K)	CRI
INC	-	3-150	4-18	1	2400-3100	98-100
Halogen	-		15-33	2-6	3000-3100	98-100
HID	-	40-400	14-140	6-28	2900-5700	15-62
LID	LPNa	26-180	70-200	7.5-30	1700-7500	75-95
	T12	14-90	60-105	7-20	3000-6500	62-75
	T8				3000-6500	75-98
	T5				3000-6500	75
CFL	Ballast integrated	4-120	35-80	5-15	3000-6500	75-90
CFL	External ballasts	40-95	60-80	10-20	2700-6500	80-85
White SSL	LED	1-20	20-55 160 (lab.)	20-40	5000-6000	70-80
	OLED	1-20	<18	<4	3000-6000	80

Figure 2.2 shows the color temperature of generally used fluorescent lamp. For example, a daylight fluorescent lamp rated at 6300 K appears bluish, while a warm-white fluorescent lamp rated at 3000 K appears yellowish or reddish (Capehart et al., 2008). Some materials look better at special color temperatures. For example,

tomatoes at greengrocer shelves look redder under warm lamp lighting. Normally, the color of tomatoes is light red or yellow but under the warm color temperature, their colors look red. Therefore, large shopping centers particularly use incandescent, compact fluorescent or fluorescent lamp with yellow light or warm color temperatures (3000 K and below) to show better foods as red meat, citrus fruits and vegetables with orange or red color. Similarly, they use lamps with white or cool white color (between 3300 K and 5300 K) at white goods section.

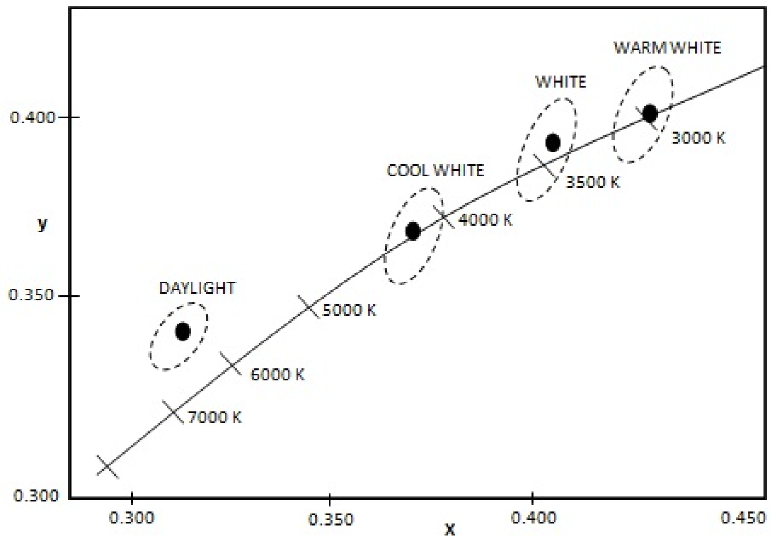


Figure 2.2. Color temperature of general fluorescent lamp

Another important criterion of the lamp characteristics is color rendering index. CRI of a lamp gives back capacity to colors of the objects of a lamp-lit. The maximum value of CRI is 100. If CRI of a lamp is 70 or above, this lamp is generally considered as good. While CRI value of 20 and below are considered poor value. CRI of the most incandescent lamps is about 100. CRI for high pressure sodium lamps is about 40 and CRI for the low pressure sodium lamp is 85. CRI of a typical warm-white fluorescent lamp is 42 and CRI of a typical cool white fluorescent lamp is 67. At the high quality fluorescent lamps, this CRI value can be achieved 90. This value is considered excellent. A similar value has been found for LED lamps.

When choosing a lamp, color temperature, color rendering index and especially luminous efficacy should be checked. When considering the energy saving, the requirements should be defined correctly. Normally, lamps which have high luminous efficacy should be selected and the values of CT and CRI should be high but requirements can change this situation. For example, the candle for a dinner delivers only 0.1 lm/W. This light level is enough to eat meals and to see each other.

According to (Dalke et al., 2006), little information or guidance has been available to assist the development of a hospital’s visual environment. Firstly, 20 hospitals were audited to establish a picture of current practice and to identify key issues where color design could broadly enhance the environment for patients, staff and visitors. Critical areas were outlined in this report, where color design can be utilized and applied, for the benefit of all users, from ambience to essential legal requirements such as color contrast for the visually impaired. Provision of staff relaxation rooms that are different in terms of color and lux levels from immediate work spaces or thoughtfully designed areas for patients awaiting intensive treatment have been shown to have some beneficial effects on a sense of well-being. They investigated the impact of color and lighting on people. According to them, the visual environment, including quality of daylight and electric light, is a vital element influencing hospital staff morale and productivity. Research was carried out in 20 hospitals and standards were occurred for design of attractive visual environments. After these standards were realized in a hospital, it was aimed to improve some of the benefits such as stress reduction, energy efficiency, ease of navigation and way finding, safety and staff productivity. As a result of studies, simple economical solutions such as regular re-painting can have an unbelievable effect on appearance, boost morale and raise interest. Selection of the appropriate color and lighting has positive sides to patients, visitors and staff.

Similarly, (Kamali and Abbas, 2012) investigated how the quality services provided by the nurses could be achieved through proper lighting design in a recently built healthcare center in Malaysia. 120 nurses participated in that study as questionnaire respondents. Data collection involved personal site observations, photographic documentations, interviews and questionnaire surveys. At that study, an age criterion affects the lighting quality sensation. It is suggested that the task be assigned to the nurses according to their ages, considering the main areas where the respondents have difficulty performing their tasks. For example, bed-making and serving medication can be done by younger nurses while other tasks are performed by the older nurses. It can be suggested that the lighting design of those tasks which are done by difficulty needs improvement, also appropriate lighting equipment needs to be used for those areas. As a result of that study, it was understood clearly that the amount of the light in relation to age affects both positive and negatives sides and it affects the nurse performance indirectly. Similarly, it is possible to generalize for all people who come to hospital.

2.1.2. Energy Efficiency and Saving at Lighting Systems

In the last 50 years, incandescent, fluorescent, halogen, discharge and LED lamps have been used at lighting technologies for general illumination in industrial, commercial, hospital and residential buildings. At the lighting systems, various methods are used for energy saving such as:

- Efficient lighting: Replacing conventional magnetic ballasts, dimming and new technology lamps (LEDs).
- Lighting management systems: Daylight (photo) sensors, vacancy (occupancy) sensors and timers

2.1.2.1. Efficient Lighting

Efficient lighting can be examined by focusing on topics of replacing conventional magnetic ballasts, dimming and new technology lamps (LEDs). Both electromagnetic ballasts and electronic ballasts have positive and negative features. Electronic ballasts have several advantages over magnetic ballasts such as higher efficacy, better illumination quality, longer lamp life and smaller size. Electromagnetic ballasts have the advantages of extremely high reliability, long lifetime, robustness against transient voltage surge and hostile working environment. Also, the inductor core materials and winding materials are recyclable. Electronic ballasts for fluorescent lamps have been widely used and have been shown that their use has overall economic benefits. They have good technical performance characteristics, such as high input power factor, low input current total harmonic distortion, low electromagnetic interference, good lamp current crest factor and low flickering (Chen and Chung, 2011).

In (Heur, 2008), it is stated that magnetic ballasts have the disadvantage that a large amount of energy is lost in the ballast itself, as much as 15-20% of the energy consumption of the light source. Electronic ballasts on the other hand have losses of only 1 or 2%. Magnetic ballasts still tend to be used widely in hospitals that are more than 5 or 10 years old. An estimated 70% or so of the lighting is currently equipped with obsolete and conventional magnetic ballasts. (Zotos et al., 2012) introduces the experimental development of an energy efficient, intelligent outdoor lighting management and monitoring system with remote control. After one month of installation, it has been confirmed that 37% of energy can be saved without causing problems or disturbing daily routing and safety. Similarly, European Commission Institute Energy and Transport upgrades the old lamps and lamp fixtures with news. Practical studies of efficient lighting in various countries in Europe are summarized at this Table 2.2 (IET, 2013) and (Toronto, 2011).

Table 2.2. Practical studies of efficient lighting

Place	**Application details**	**Annual lighting energy savings (kWh)**	**Annual energy cost saving (Euro)**	**Payback period (Year)**
Palma Airport Passenger Terminal in Spain	Change of old lamps with new induction projectors and reduce luminance level from 350 to 240 lux **(Replacement lamps and reduce luminance)**	131,276	7,361	9.8
Trezzano Rosa Street Lighting in Italy	Install new luminaries, reducing the lamp power and substituting the high pressure mercury lamps with high pressure sodium lamp **(Replacement lamps and reduce luminance)**	96,531	-	3
Bologna Airport in Italy (Parking Space)	Install new projectors with 1x1000 W instead of projectors with 2x400 W and reduce the numbers of the projectors**. (Replacement lamps and reduce numbers of lamps)**	400,000	-	5

Dolce & Gabbana Showroom Building in France	Replacement of 3.100 halogen lamps with 700 fluorescent lamps and 900 T5 fluorescent lamps instead of metal halide and halogen lamps **(Replacement lamps and reduce numbers of lamps)**	280,000	-	-
Madrid Airport in Spain	Change of the general switch with 25 units voltage stabilizer and flux luminous dimmer and reduce luminance level from 400 to 200 lux**. (Using dimmer)**	1,135,296	47,492	3
Salidas Terminal in Spain	Replace the magnetic ballast with high frequency electronically one, using a different lighting control system, with flux luminous dimmer and zone control. The luminance level was reduced from 400 to 300 lux **(Replacement ballast and using of the new control system with dimmer)**	279,685	30,761	1.7
Alanod Aluminum in Germany	Change of the 26mm diameter fluorescent lamps with magnetic ballast with different types of 16 mm diameter lamps with the electronic ballast and dimming **(Replacement lamps, ballast and dimming)**	11,973	1,198	5
Street Lightings of five different place in Spain	Remove the old inefficient mercury vapor lamps and replace them with new high pressure sodium ones and install new control system. **(Replacement lamps and use of control system)**	673,529	78,283	-
Lea Foods Co-operative	Change of 377 metal halide and T-12 fluorescent fixtures with 434 lower wattage T-5 and T-8 compact fluorescent fixtures with occupancy sensors **(Replacement lamps and use of control system)**	-	26,419	2.2
Bologna Airport in Italy	Install three flux regulators at Hangar/car park for vehicles and materials **(Adjustment flux level)**	46,253	4,163	1
Athens International Airport in Greece	Change of high-loss magnetic ballasts with electronic ballasts **(Replacement ballasts)**	3,298,000	131,956	< 1
Porto Football Club in Portugal	Installed electronic non dimmable ballast instead of the old magnetic conventional one**. (Replacement ballast)**	1,044,667	59,095	5

GreenLight Natural Gas Partner in Spain	Replaced the incandescent fixtures with modern compact fluorescent lamps. **(Replacement lamps)**	533,028	27,230	3.5 - 8
Auchan Hypermarkets in France	According to location; install new lamp types such as white sodium lamps for illuminating fresh foods and compact fluorescent lamps were used for services and cashiers. **(Replacement lamps)**	393,802	21,659	-
Ripalimosani Street Lighting in Italy	Change of the old high pressure mercury lamps (D13) with high pressure sodium lamps (D15). **(Replacement lamps)**	164,250	13,550	4
Holland Casino Breda in Netherlands	Replaced all the old mercury lamps (400W) with new 16 mm diameter fluorescent lamps. **(Replacement lamps)**	9,450,000	414,000	6
Ducati Motor Holding in Italy	Replacement of 250 linear fluorescent lamps (2x58), magnetic ballasts, with 250, new more efficient linear fluorescent lamps (2x58) **(Replacement lamps)**	75,600	7,258	1.7
Feira Nova Hypermarket In Portugal	The old lamps (HPL-N400W) were changed with more efficient ones (TLD 58-36W). **(Replacement lamps)**	1,058,186	64,550	0.6
Arquivo Municipal Building in Portugal	Change of the incandescent lamps with the fluorescent lamps and electronic dimmable ballasts. **(Replacement lamps and ballasts)**	49,275	-	1.2-5
Virgen University Hospital in Spain	Change of the old incandescent lamps with geared with electronic ballasts and aluminized reflectors **(Replacement lamps and ballasts)**	782,025	49,585	5

In contrast to traditional views, according to (Yan et al., 2009), dimmable magnetic ballast systems are more efficient than the dimmable electronic ballast systems. Recent trend of using electronic ballasts to replace magnetic ballasts has prompted an increasingly serious problem of accumulation of large amount no biodegradable and/or toxic electronic wastes. Compared with magnetic ballast which can last for over 30 years and recyclable at the end of their long lifetime, electronic ballasts and electronic compact fluorescent lamps have very short lifetimes due to the use of the electrolytic for providing the high dc voltage link in the electronic ballast designs. Dimmable magnetic systems have many favorable features in terms of energy saving and environmental protection (Yan et al., 2009).

2.1.2.2. Lighting Management System

Lighting management systems can be examined by focusing on topics of daylight (photo) sensors, vacancy (occupancy) sensors, timers and automatic control systems. Lighting management is important to save energy, reduce building operating costs, comply with energy codes, meet sustainable design goals (i.e., LEED) and enhance occupant comfort and productivity. Lighting management strategies are mainly scheduling, occupancy/vacancy sensing, multi-level lighting/dimming, daylight harvesting, high end trim/tuning, personal light control, controllable window shades, demand response, plug-load control (Nema, 2012).

Photo sensor controls monitor daylight conditions and allow fixtures to operate only when needed. Photo sensors detect the quantity of light and send a signal to a main controller to adjust the lighting. Photo sensors are commonly used with outdoor lighting to automatically turn lights on at dusk and off at dawn, a very cost-effective control device. This helps to lower energy costs by ensuring that unnecessary lighting is not left on during daytime hours (Michegan, 2013). Photo sensors can also be used indoors. Building areas with lots of windows may not require lights to be on all of the time. Photocells can be used to ensure fixtures operating only when the natural light is inadequate by either controlling one light fixture or a group of lights. Table 2.3 demonstrates the cost savings from day light controls (Michegan, 2013).

Table 2.3. Potential energy saving with day lighting controls

Day lighting strategy	Control type	Potential annual energy savings
Window side lighting	On/off	32%
	Stepped	44%
	Continuous dimming	56%
Sky lighting	On/off	52%
	Stepped	57%
	Continuous dimming	62%

Time control saves energy by reducing lighting time using preprogrammed scheduling. Time clock equipment ranges from simple devices designed to control a single electrical load to sophisticated systems that control several lighting zones. They are one of the simplest, least expensive and most efficient energy management devices available (Michegan, 2013).

Time controls should include the followings:

- Simple time switches automatically turn lights, fans or other electronic devices off after a pre-set time.
- Multi-channel time controls have the ability to control many duties.
- Special-purpose time controls include cycle timers for repetitive short duration cycling of equipment or outdoor lighting time controls that combine time clock and photo sensor technologies (Michegan, 2013).
- Vacancy or occupancy sensors sense the movements. When someone enters into a room included in one of these type sensors, switch is on and light will illuminate. When someone leaves the room, switch is off again and light will be dark. These sensors should be included with time delay relay to avoid dark before people have left the room. Table 2.4 shows energy saving potential with occupancy sensors.

Table 2.4. Energy savings potentials with occupancy sensors

Application	**Potential energy cost savings**
Offices (private)	25-50%
Offices (open areas)	20-25%
Restrooms	30-75%
Corridors	30-40%
Storage areas	45-65%
Meeting rooms	45-65%
Conference rooms	45-65%
Warehouses	50-75%

Another example on occupancy sensor is shown in Table 2.5 (EII, 2013). Annual operating time is decreased with the occupancy sensor and 2.761 kWh energy/year is saved. Payback time of this project is about 3 years.

Table 2.5. Savings estimate for occupancy sensors: An example

System: 24 Fixtures, 2-lamp 32W T-8	**Existing manual control**	**Retrofit with DTOS**
Total Power (kW)	1.4	1.4
Annual Hours	6500	4550
Total kWh	9204	6443
kWh/m^2	65.7	46
Savings Analysis		
Energy Savings (kWh)		2761
Installation Costs		$550
Energy + Maintenance savings @ $0.05 per kWh (payback period)		$140 (4 years)
Energy + Maintenance savings @ $0.07 per kWh (payback period)		$200 (2.85 years)

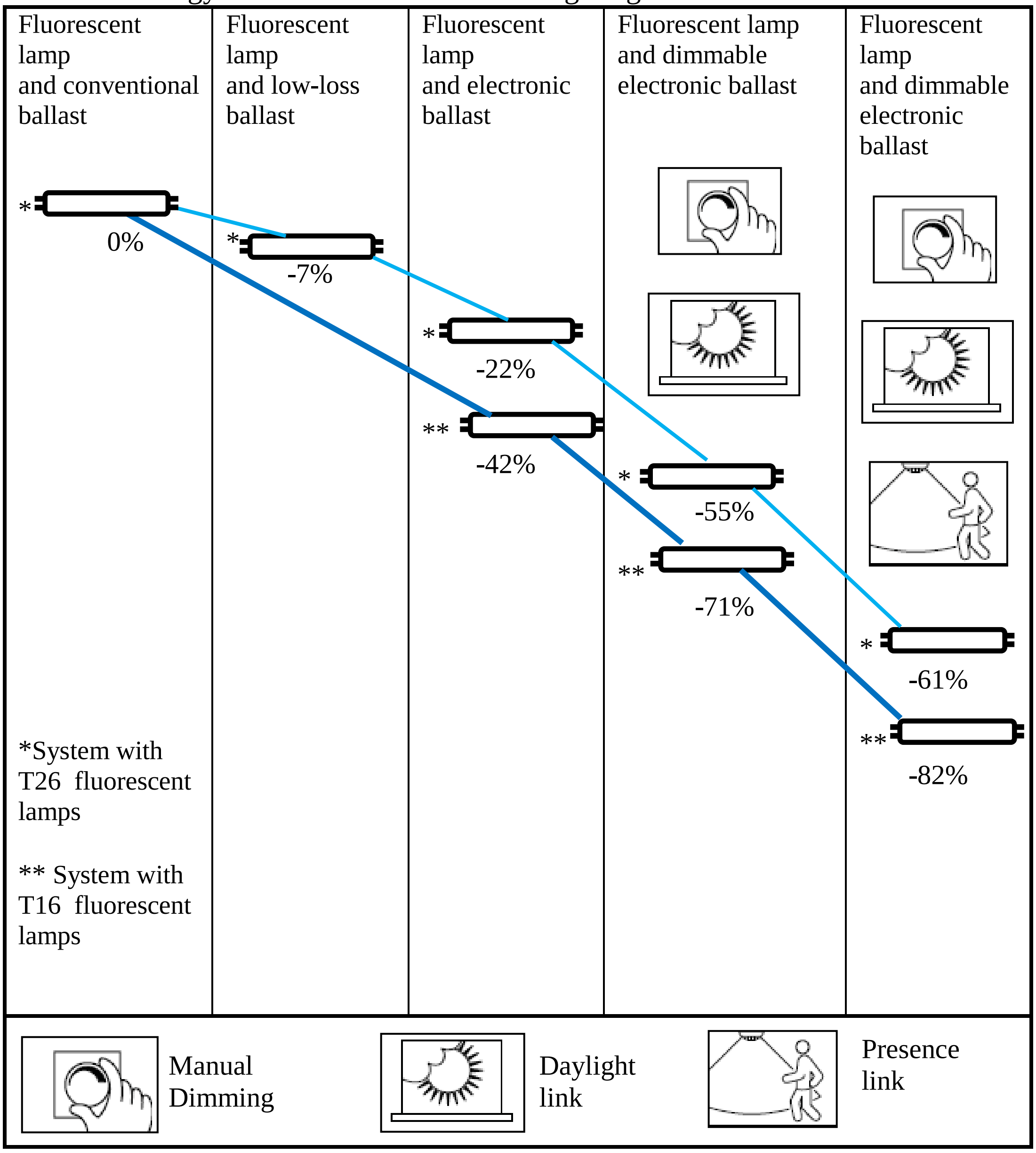
Another study shows saving potentials which can be satisfied with the different energy strategies as shown in Table 2.6 (Dubois and Blomsterberg, 2011).

Table 2.6. Energy saving strategies and potentials

No	**Energy saving strategy**	**Relative savings potential**
1	Improvement in lamp technology	10% (T12 to T8) 40%[a] (T12 to T5)
2	Improvement in ballast technology	4-8%
3	Improvement in luminaire technology	40%[b]
4	Use of task/ambient lighting	22-25%
5	Improvement in maintenance factor	5%[c]
6	Improvement in utilization factor	Depends on application and context
7	Reduction of maintained illuminance level	20% (500 to 400 lux)
8	Reduction of total switch –on time	6%[d]
9	Use of manual dimming	7-25%
10	Use of switch-off occupancy sensors	20-35%
11	Use of daylight dimming	25-60%[e]
a) However , this number also includes improvements due to HF ballast and improvement in luminaire		
b) However, this number also includes dimming and improved ballast.		
c) About 5% of light output would be each year without a proper maintenance program		
d) By reducing average existing total switch-on time only 2600h/year.		
e) This number highly dependent on climate, the shading strategy and the baseline for comparison.		

In Table 2.7 (Thorn, 2013), conventional and modern saving systems are shown as schematically. The percentage of the energy saving can be increased using the modern control systems with dimming, daylight and occupancy (vacancy) sensors.

Table 2.7. Energy conservation with modern lighting



2.1.3. Latest LED Lighting Technology

LEDs are the best energy saving lamps for many applications so far known. They can be preferred instead of other classical lamp types due to their advantages such as long life, robust structure, energy saving potential, decreased initial and installation costs. The performance of domestic lighting lamps was investigated in (Aman et al., 2013). Their study presents a detailed comparative analysis between domestic lighting lamps (DLLs) use for producing artificial light. DLLs include incandescent lamp (INC), fluorescent lamp (FL) and compact fluorescent lamp (CFL). LED based lamp technology is relatively new in comparison with conventional incandescent and discharge lamps. The light is produced by heating the tungsten filament in INC lamps. Efficacy of INC lies in the range of 10–20 lm/W depending on their construction and the filament operating temperature. Discharge lamps are those lamps in which the light is created by an electric discharge within a gas or a vapor. A small amount of mercury "Hg" is introduced in the fluorescent tube for illumination purpose. Special phosphor material is used to convert the ultra-violet light into the visible light output. Discharge lamps have a significantly higher efficacy and longer life than an INC. Fluorescent and CFL come under the category of discharge lamp. They are also investigated electromagnetic and electronic ballast with both positive and negative properties. In addition, they have examined LEDs which are semiconductor devices, filled with gases and coated with different phosphor materials. After the comparison between INC, discharge lamps and LEDs, the following key-point can be concluded.

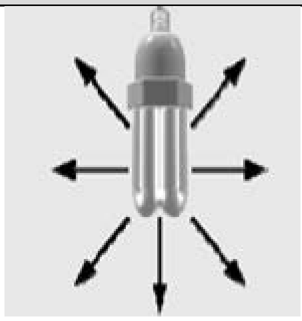
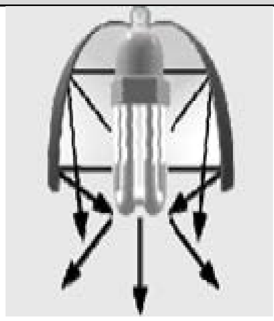
1. The replacement of INC with energy saving devices is useful for consumer as well as for the utility. FL and CFL both could be a good choice against INC due to their higher efficacy and longer lifetime.

2. Replacement of FL with CFL is not favorable from consumer and utility perspective. This can lead to a significant increase of harmonic distortion and high power consumption for same level of illumination rather than the power saving.

3. The current development shows a tremendous improvement in LED lighting performance and at the same time reduction in their technology cost. Hence, it is expected that the major portion of lighting system will be provided by LED lamps in near future.

Similarly, in the other study, CFLs and LEDs are compared with each other. (Sinnadurai et al., 2012) investigated the development of white LED downlight for indoor lighting. The study presents the potential of LED for indoor applications and demonstrates a white LED lamp module to replace the CFL and to reduce the energy consumption. As shown in Table 2.8 (Sinnadurai et al., 2012), the loss of the LED with down light reflector is less than the losses of CFL with down light reflector. They have experimented that, two LED's are mounted in a PCB board with different distances of 1 cm, 1.5 cm and 2 cm. Then, PCB boards are placed in a down light reflector and installed at a height of 3 meters while readings are taken on the floor for different angle values from the center point of two LED's. It is observed that the development of LED down light module has no shadow and gave the same amount of the brightness as per CFL light. Comparison study shows the LED light has greater tendency to save energy.

Table 2.8. Comparison of CFL and LED

Light source	Light source efficacy	Coefficient of utilization	Future efficacy
CFL	 65 lm/W	 54%	**35 lm/W**
Xlamp XR-E Neutral White SSL	 58 lm/W	 77%	**44 lm/W**

According to (Fassbinder, 2013), when LED lamps are compared with fluorescent lamps, LEDs are expensive and weak, their light is cold and their energy efficiency is no better than that of fluorescent lights, so they are not very suitable replacements. When LED lamps are compared with the incandescent lamps, LEDs are much more efficient than incandescent light bulbs and this alone would be a sufficient argument.

(Hsiao and Chang, 2012) aims to study the economic benefit calculation, using LED street lamps and traditional high-intensity discharge lamps for roadway lighting in Taiwan to analyze the practical value and payback period of various types of street lamps. LED street lamps can be more energy efficient than traditional lighting sources. However, it is not the first choice at the present stage, in terms of the overall calculation of economic benefit in cases of long-term roadway lighting. Despite the long service life advantage of LED lamps, the initial investment costs and follow-up maintenance issues are prohibitive. It has been concluded that, if the 400 W mercury lamps are replaced with the 150 W LED lamps, payback time is calculated as 5 years. Finally, in recent years, the prices of LED products have been considerably reduced, while luminous efficiency has gradually improved. The LED street lamps have considerably excellent lighting quality and energy saving.

In the other study, the installation of new LED lamps in a parking structure replace with existing metal halide (MH) fixtures. It was also agreed to provide LED luminaries for an entrance roadway and a parking lot to replace existing high pressure sodium (HPS) fixtures. As a result of the study, payback time was given as shown in Table 2.9. This project demonstrated that properly designed LED luminaries can provide energy savings up to 52% without compromising light characteristics required for parking structure applications (Jerine et al., 2010). The payback time is also related with the operating time of the LED lamps.

Table 2.9. LED lighting sample at parking and its environment

Application	**Number of units**	**Total installed costs ($)**	**Annual energy cost savings ($)**	**Simple payback period (years)**
Parking structure	14	17,030	3,097	5.5
Parking lot	20	31,300	3,928	8.0
Entrance roadway	4	2,675	140	19.1

(Gan et al., 2013) examines the feasibility of adopting LED lamp in replacing the conventional fluorescent lamp. Analysis and comparison have been carried out on the two lighting systems in terms of electrical and photometrical performance. They have tried to replace or to strengthen the existing system and have found results as shown in Table 2.10. The study suggests that LED tubes have great potential to replace fluorescent lamps, mainly driven by the cost savings.

Table 2.10. Reduction in energy consumption by various saving strategies

Savings strategies	Power (kW)	Electricity bill ($/Year)	Reduction (%)
T8(Existing lighting)	243	89,352	0
T8+Sensor	243	57,225	36
T5 Retrofit	145	51,103	43
T5 Retrofit + Sensor	145	34,069	62
LED T8	91	32,099	64
LED T8 + Sensor	91	21,399	76

In (Orzaez and Diaz, 2013), interest in energy savings in urban lighting is gaining traction and has become a priority for municipal administrations. According to them, LED technology appears to be the clear future lighting choice. However, this technology is still developing very quickly and is not sufficiently tested. According to them, energy saving can be succeed with existing system which occurred high intensity discharge lamps. That study shows that high intensity discharge lamps can be intended to coexist with new LED technologies in the short and medium term. That study demonstrated that ceramic metal-halide lamps are dimmable with both energy-saving technologies without affecting the service life and the light quality. However, a 30% failure rate was observed for the dimmable electronic ballasts (without causing lamp failure). The savings that can be obtained with electronic ballasts are double (40%) that of the lighting flow dimmer-stabilizer equipment (20%).

In (Gorgulu and Ekren, 2013), the aim is to illuminate a windowless room via a light-pipe and dimmable electronic ballasts. Light-pipe is used for the illumination of the space during the daytime. In case of inadequate daylight, artificial lighting is made via dimmable electronic ballasts and fluorescence lamps. Artificial lighting is supervised by a fuzzy logic control system to keep the illumination level at 350 lux. When there is a motion in the room, the system works with the message of the motion sensor which enables energy saving. Additionally, dimming the lamps result in conversation of the electrical energy used for illumination. In (Gorgulu and Ekren, 2013), light pipe, electronic ballast and 2x36W fluorescent lamps, motion sensor, light sensor and data acquisition card were used. Motion sensor was placed 260 cm above the floor. Light sensor measurement ranges are between 0 and 20,000 lux. Depending on the input values, output values obtain range 4 and 20 mA. When the input value is 0 lux, output value obtains 4 mA and when the input value is 20.000 lux, output value will be 20 mA. As a result of the study, during the operation of the system the required 350 lux illumination level on the work plane was measured and retained by the controller throughout the day. The designed fuzzy logic control system continuously maintained the illumination level with a ±10 lux error level. As the measurement period being in autumn and winter months caused the required illumination level to be obtained mainly from the artificial lighting. Still, approximately 30% saving was achieved by the proposed controller implementation. In the summer time, the energy saving from the lighting system will be even higher.

In (Leavitt et al., 2010) the parking lot lighting consisted of seven 250 W metal halide (MH) fixtures. Based upon industry technical data, each MH fixture, consisting of the lamp and ballast, consumes 291 W. The new LED luminaries were rated at 135 W. This results in the LED luminaries using 52% less demand than the MH fixtures as shown in Table 2.11. Table 2.12 shows the payback time without any maintenance cost. If the annual maintenance cost value is added to these values, payback time decrease about 1 year as shown in Table 2.13.

Table 2.11. Demand and energy savings

Parking lot	**# of units**	**Power (W)**	**Demand (kW)**	**Reduction (%)**	**Energy (kWh)**	**Reduction (%)**
250 W MH	7	291	2.0	--	8,484	--
135 W LED	7	139	1.0	52	4,053	52

Table 2.12. Simple payback new construction

Parking lot	**#of units**	**Product costs ($)**	**Incremental costs ($)**	**Energy cost Annual ($)**	**Payback (years)**
250 W MH	7	8,196	-	-	-
135 W LED	7	13,423	5.227	886	5.9

Table 2.13. New construction of simple payback

Parking lot (4165 operating hours), qty. of 7	**250 W MH**	**135 W LED**
Incremental costs ($)	-	5.227
Annual maintenance costs ($)	8.484	4.053
Annual maintenance costs savings ($)	1.697	4.431
Annual energy cost savings ($)	-	886
Total annual savings ($)	-	5.137
Payback (years)	-	1,0

2.1.4. Other Lighting Saving Options

Architectural structure of building and the position of all windows affect light intensity and illumination quality. The greater the amount of daylight entering into the building will reduce the need for lighting. In (Alzoubi et al., 2010), the purpose is to examine the effect of space occupancy on indoor daylight quality in hospitals. It assesses the effect of various design variables on the indoor daylight quality in King Abdullah University Hospital in Jordan. They have investigated firstly, occupancy using the lighting analysis software to conduct graphical and numerical simulation and secondly post-occupancy, focusing on field measurements to develop a framework for hospital lighting design. The study found significant effects of hospital occupation and interior design parameters on the indoor daylight performance in terms of illuminance level and daylight factor. The interior design parameter, finishing and furniture in patient rooms are essential factors affecting the indoor daylight performance. Light designers should utilize the effect of interior design in integrating lighting and thermal models in buildings since efficient lighting designs normally reduce solar heat gain, which eventually contributes positively to minimizing energy bills.

Regular maintenance and cleaning is vital important for the lighting systems. If the maintenance is made regularly and replace or repair all broken or failure parts as soon as possible, performance of lighting system can be increased. At the same time, the amount of the energy saving will also be increased too and the payback time will be smaller. While determining the maintenance days, maintenance factor value is considered. Although the maintenance factor of lamps in the clean room is about 0.8, the maintenance factor of the lamps in very dirty room is about 0.5. As shown, lamps in the clean room are 30% more efficient than the lamps in very dirty room. Pollution in lighting systems will result the losses and decrease the system efficiency. As a result of the pollution, lighting capacity generally will be reduced about 18-33%.

Development of technology has a positive impact on lighting system. Especially in the environmental and other exterior lighting as road, street and outside of the building, renewable energy sources and lighting systems have been used together. In recent years, light emitting diodes (LED) have gradually been applied to illumination for street, indoor room, tunnel and airport field. The combination of LED lighting system and photovoltaic (PV) array are widely applied in the outdoor illumination. The generated energy of PV array is stored by rechargeable batteries in the day and LED is lighted by the batteries at night. The power output of PV array depends strictly on weather condition and PV array may not give enough power for LED lighting in rainy weather for several days. To avoid this problem, this LED lighting system connects to the power grid. Figure 2.3 gives the structure of the PV grid-connected LED lighting system. It includes the PV array, battery, inverter, PLC, LED lamp and power grid. During the day, PV array converts the solar energy into power energy, which is stored into the battery. The excess power is transported into power grid by inverter. At night, the battery discharges power to light the LED. When the power in the battery is used up, the power grid is connected to light LED. PLC controls the switching status of Kl and K2 switches (Zhou et al., 2010).

For economic evaluation of a lighting solution system, the cost analysis was carried out for the PV system assuming useful life for 15 years for solar panel and two years life for battery bank. This cost analysis includes initial and variable costs. Such a PV system could be environmentally friendly and reliable and has the potential to contribute to the development of sustainable electricity generation. In long-term operation, a PV system can perform and maintain the quality of electricity generated at a lower cost. The system could be a cost-effective solution in areas where there is no electrical grid such as rural areas and worksites (Amogpai, 2011).

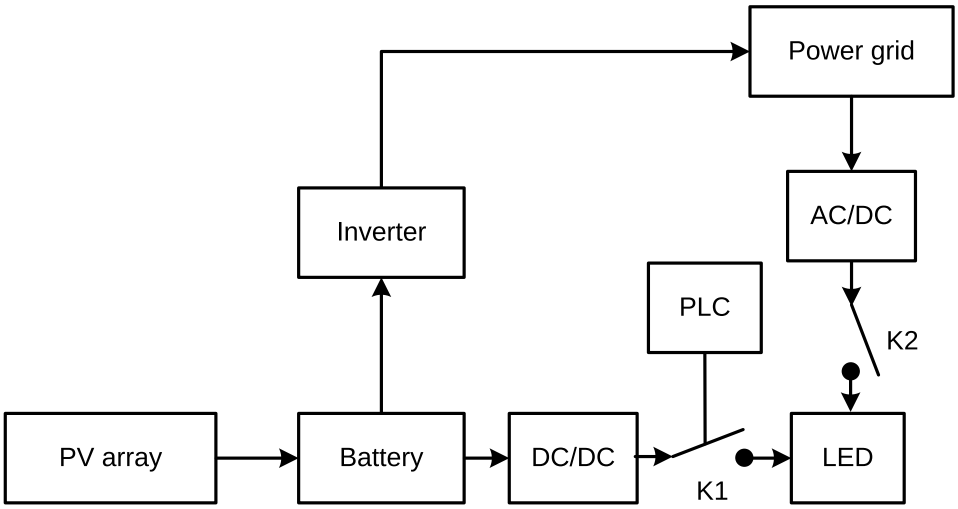


Figure 2.3. Structure of LED street lighting system with PV

In some countries, especially during the summer months, ambient temperature is between 40 and 50˚C. High temperature decreases the life of the battery. The battery based systems can be preferred in areas without any grid systems. When there is no electrical grid, the generator can also be used. At this situation, the costs of the liquid fuel and maintenance will increase the electric costs directly. Instead of this system, different combinations of LED and PV can be used. After every system should be investigated with details according to initial cost and payback time, the most appropriate and efficient system should be selected.

2.1.5. Summary

This section summarizes papers and practical studies on lighting which are investigated at the hospitals.

- Lamp characteristics which are important to choose the lamp and lighting quality, such as efficacy, CT, CRI, cost, lifetime and lamp types are described.
- Approximately 20% of total world electricity consumption is consumed by lighting. Researches show that, hospitals represent approximately 6% of total energy consumption in the utility buildings sector. Lighting systems in a hospital uses approximately 21% of the total energy consumption.
- Energy savings methods can be summarized as following paragraphs.

✓ Low efficient lamps should be replaced with high efficient lamps. For example, lamps with low efficient magnetic ballast can be changed with the lamps with more efficient magnetic ballast. Thus, approximately 7-8% of total consumption energy can be saved.

✓ Electronic ballasts should be used instead of conventional magnetic ballasts or low loss magnetic ballasts. In this instance, the amounts of the energy saving are between 20% and 45%. Depending on the number of lamps used and annual operating hours, payback time can be changed among the minimum less than 1 year and maximum 5 years. Payback time is inversely proportional to the number of lamps replaced.

✓ When lamps which has old magnetic ballast are changed with the lamps which has new dimmable electronic ballasts. The light of new lamps will be adjustable. Light intensity are decreased or increased by a dimmer. The systems with a dimmer can be saved energy about 50%. Dimmer can be controlled manually or automatically. Depending on the dimming ratio and the number of the lamps used, payback time can be changed between 1.7 and 5 years.

✓ Automatic control systems should be used in lighting system. These systems use sensors to control the lighting systems. Daylight or occupancy sensors can be shown as samples. The combination of these sensors or the using single of sensors in the control systems is possible. Approximately from 35% to 55% of energy can be saved by using of the control systems in lighting (especially for interior lighting). Payback time is between 1.5 and 5 years depending on the control systems and lamp numbers.

✓ All exterior lighting should have a control system operated by either a photocell or programmable astronomical time clock. Scheduling can reduce lighting costs by 10 to 35%.

✓ At lamp fixtures, reflectors which can reflect high light should be used. In this instance, lamp efficacy will increase automatically. Same efficacy can be obtained with the less number of the lamp. So, energy can saved directly. Payback time can change depending on the lighting requirements. At the investigated examples, payback time will be less than 1 year.

✓ The architecture structure of the buildings is important for daylight in lighting. Architects should consider the amount of daylight entering the room while designing a new building. Electrical engineer should calculate lamp requirements for region with and without windows.

✓ LEDs are the latest technology in lighting systems. The positives properties such as long lifetime and high efficacy are the most important factors for their selection. Initial installation costs of LEDs are more expensive than the other lamps. They are not generally preferred primarily because of their expense. LEDs can be investigated into two parts as interior and exterior lighting. When they are compared with CFLs, it is shown that LEDs are more efficient than CFLs but payback time is so long about 10 years. At external or environmental lighting, when LEDs compare with the old lamps such as MH and HPS, payback time will be 5 years or smaller. Especially at external lighting, the reduction of the LED cost day by day and the increase of efficiency will be increased the level of the LEDs selection.

✓ At the same time, LEDs can be used with the renewable energy sources such as PV due to their low power consumption. If there is no electrical grid, LED supported with PV and battery can be used efficiently. Because initial cost of this system is expensive it can be evaluated without battery.

This paper summarizes the most important energy efficiency options for lighting in the hospitals. Energy efficiency should be a major consideration when a lighting system is designed or revised. It is also shown that the LED lighting technology is improving rapidly, prices are coming down and will be the most efficient and preferable system in the future.

2.2. Literature Review on Electric Motors and Variable Speed Drives

Electric motors have broad applications in such areas such as industry, business, public service, hospitals and household electric appliances, powering a variety of equipment including wind blowers, water pumps, compressors and machine tools. In industrially developed nations and large developing nations, electric motors account for a considerable proportion of total national power consumption. Statistics indicate that electric motors are generally responsible for about 2/3 of industrial power consumption in each nation or about 40% of overall power consumption. Electric motors in a hospital represent approximately 19% of total energy consumption. According to estimates, the approximately 11-18% of this energy can be saved by using energy saving methods. Among the various sectors contributing to greenhouse gas (GHG) emissions, the contribution of the industrial sector was significant. Implementing a few options with little or no cost in the industrial sector could reduce 10-30% of GHG emissions (Saidur, 2010) and (Hu et al., 2004).

GHG emissions and air pollution have been affected the future of the world negatively. The reduction of them is extremely important for the clean and green environment. After the Kyoto protocol, developed countries accepted the responsible for the current high levels of GHG emissions in the atmosphere and they promised for the reduction of GHG in their country atmosphere. So, they took a heavier burden on themselves. GHG amounts of some developed countries are shown in Figure 2.4 (Maheswaran et al., 2012).

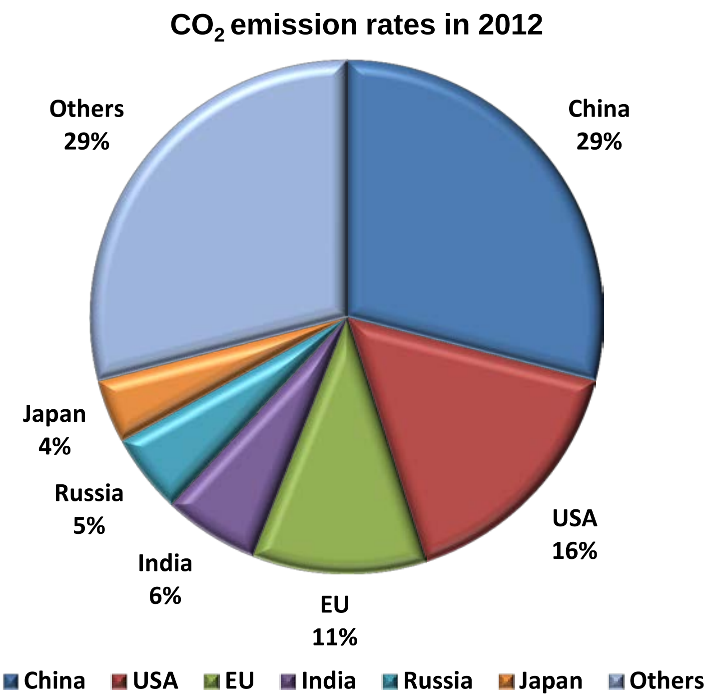
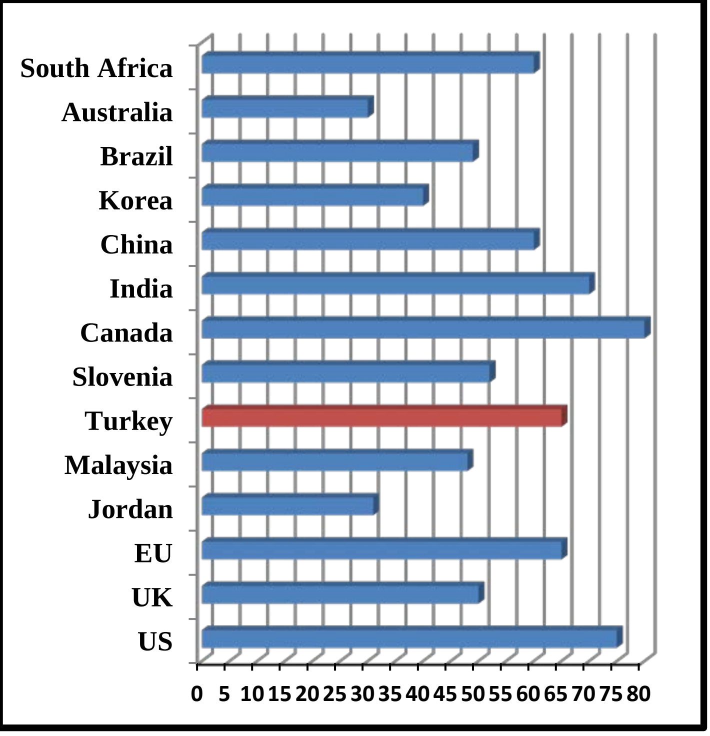


Figure 2.4. CO_2 emission rates of some major countries in 2012

In the hospitals, if the absorption chiller is not in use, then the air-conditioning system would consume about 70% of the total electricity. Among them, the chillers, the chilled water pumps and the fan of the cooling towers would need 43.94% of the total electricity. The lighting system consumes 19.22% of electricity (Heur, 2008) and (Hu et al., 2004). Approximately 65% of total electricity consumption is consumed by electric motors in Turkey as shown in Table 2.14 (Saidur, 2010). In addition, about 35% of total energy is used in the industrial sector in Turkey (Saidur et al., 2010a). 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 (Abdelaziz, 2011).

Table 2.14. Electrical motor energy consumption for some selected countries

Country	**Motor Energy Use (%)**
India	10-40
Australia	30
Jordan	31
Korea	40
Malaysia	48
Brazil	49
UK	50
Slovenia	52
China	60
South Africa	60
EU	65
Turkey	**65**
US	75
Canada	80



Electric motors are generally divided into AC motors and DC motors. AC motors can be synchronous or asynchronous (induction) type. Asynchronous motors are most commonly run on 1-phase or 3-phase power. 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 the industrial sector is shown in Figure 2.5 (Yumurtaci et al., 2011).

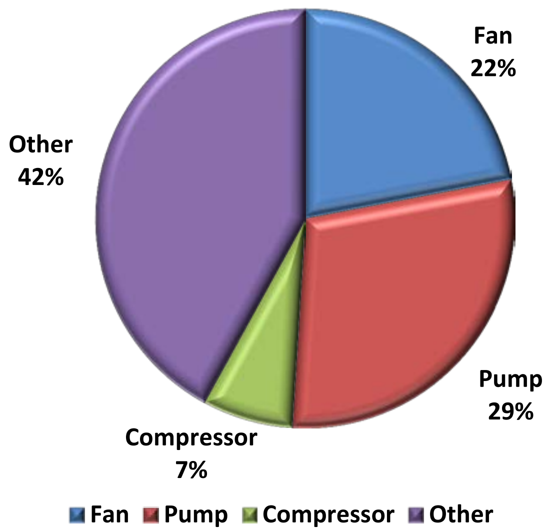


Figure 2.5. Motor electricity consumption by end-use in the industrial sector

The study of (Saidur, 2010) is one of the most comprehensive studies focused on analysis of energy use and energy saving of electric motors. At that study, (Saidur, 2010) compiles latest literatures about electric motor energy analysis and analyses on electric motor energy use, losses, efficiency and energy saving strategies. Different types of losses that occur in a motor were identified and ways to overcome these losses were explained in detail. An energy audit to identify motor energy wastages were discussed extensively. As motors are the major energy users, different energy savings strategies such as use of high-efficient motor, variable speed (frequency) drive (VSD) and capacitor bank to improve the power factor have been reviewed. In (Saidur, 2010), computer tools to analyze electric motors energy usage were discussed. Cost parameters to perform economic analysis have been shown as well. Moreover, payback periods for different energy savings strategies have been identified.

2.2.1. Efficiency Standards in Electric Motors

In many industrialized countries, more than 70% of the total produced energy is used by electric motors. Therefore, it is important to choose high-efficiency motors in plants (Saidur, 2010). The nameplate of an electricity motor has given important information about the motors such as efficiency class, manufacturer name and etc. The written data are named as nominal or rated value by technical people. Motor nameplate detail is shown in Figure 2.6 (CarbonTrust, 2011).

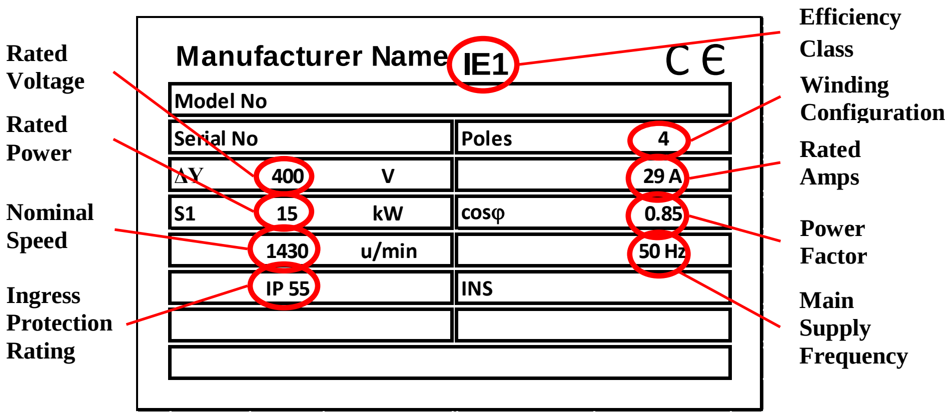


Figure 2.6. Motor nameplate details

The "efficiency" describes how efficiently an electric motor transforms electric energy into mechanical energy. Previously in Europe, low voltage 3-phase motors have been graded and marketed in three efficiency classes such as EFF3, EFF2 and EFF1. This defines are named by the European sector committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) and European Commission. This classification system is well proven and has now been adapted in many countries around the world. After that, other countries have also developed their own national systems, which are very different from the European system. As a result to avoid confusion, the objective was to have a common international standard that replaces all the different national systems. These standards and the methods to determine the efficiency of these motors are improved by International Electrotechnical Commission (IEC) (Blab and Sattler, 2011).

In the past, three efficiency classes were described for the power range of 1.1 kW to 90 kW as EFF3, EFF2 and EFF1. These classes can be defined at below.

- EFF3= Motors with a low efficiency level
- EFF2= Motors with an improved efficiency level
- EFF1= Motors with a high efficiency level

The new international standards describe efficiency classes IE1, IE2 and IE3 for 3-phase motors with a power range from 0.75 kW to 375 kW. As shown that, there is no EFF3 at new efficiency standards.

- IE1=Standard efficiency (instead of EFF2)
- IE2=High efficiency (instead of EFF1)
- IE3=Premium efficiency
- IE4=Super premium efficiency

It's important to notice that the so-called IE4 super premium efficiency motors are not commercially common yet and it is awaited that in average, their losses reduction should be 15-20% compared to IE3. ABB is launching the world's first range of low voltage IE4 (International Efficiency Class 4) motors. The IE4 motors cover 75 – 375 kW in frame sizes 280-355. They are available for 400 V 50 Hz and 440/460 V 60 Hz, in 2- 4- and 6-pole versions. Premium efficiency IE3 is the most efficient available motor, while lower efficiency motors in use now EFF3 are banned in the new classification (Benhaddadi et al., 2010). At that study, experimental comparison of the performance characteristics of 3-Hp premium efficiency induction motors has been presented. It is shown that in the rated frequency and voltage case, the experimental results are in good agreement with nameplate manufacturer's information. Particularly, a comparison of the rated operating point shows that, the discrepancy is approximately 0.2%.

According to UK law, from the 16th June 2011, all motor efficiency levels had to be minimum IE2 class. From the 1st January 2015, all motor rated 7.5 kW to 375 kW shall either meet efficiency level IE3 or be supplied as IE2 with VSD. From 1st January 2017, all motors rated 0.75 kW to 375 kW shall either meet efficiency level IE3 or meet IE2 and be equipped with VSD (Wilkonson, 2009). The efficiencies of motors with a power range from 0.75 kW to 375 kW for 50 Hz are shown in Table 2.15 (Blab and Sattler, 2011).

Table 2.15. Motor efficiency classes for 2-, 4- and 6-pole motors

P_N in kW	IE1, 50 Hz			IE2, 50 Hz			IE3, 50 Hz		
	Number of poles								
	2	4	6	2	4	6	2	4	6
0.75	2.1	2.1	0.0	7.4	9.6	5.9	0.7	2.5	8.9
1.1	5.0	5.0	2.9	9.6	1.4	8.1	2.7	4.1	1.0
1.5	7.2	7.2	5.2	1.3	2.8	9.8	4.2	5.3	2.5
2.2	9.7	9.7	7.7	3.2	4.3	1.8	5.9	6.7	4.3
3	1.5	1.5	9.7	4.6	5.5	3.3	7.1	7.7	5.6
4	3.1	3.1	1.4	5.8	6.6	4.6	8.1	8.6	6.8
5.5	4.7	4.7	3.1	7.0	7.7	6.0	9.2	9.6	8.0
7.5	6.0	6.0	4.7	8.1	8.7	7.2	0.1	0.4	9.1
11	7.6	7.6	6.4	9.4	9.8	8.7	1.2	1.4	0.3
15	8.7	8.7	7.7	0.3	0.6	9.7	1.9	2.1	1.2
18.5	9.3	9.3	8.6	0.9	1.2	0.4	2.4	2.6	1.7
22	9.9	9.9	9.2	1.3	1.6	0.9	2.7	3.0	2.2
30	0.7	0.7	0.2	2.0	2.3	1.7	3.3	3.6	2.9
37	1.2	1.2	0.8	2.5	2.7	2.2	3.7	3.9	3.3
45	1.7	1.7	1.4	2.9	3.1	2.7	4.0	3.2	3.7
55	2.1	2.1	1.9	3.2	3.5	3.1	4.3	4.6	4.1
75	2.7	2.7	2.6	3.8	4.0	3.7	4.7	5.0	4.6
90	3.0	3.0	2.9	4.1	4.2	4.0	5.0	5.2	4.9
110	3.3	3.3	3.3	4.3	4.5	4.3	5.2	5.4	5.1
132	3.5	3.5	3.5	4.6	4.7	4.6	5.4	5.6	5.4
160	3.8	3.8	3.8	4.8	4.9	4.8	5.6	5.8	5.6
200-375	4.0	4.0	4.0	5.0	5.1	5.0	5.8	6.0	5.8

Cost premiums for high-efficiency motors range from 10% to 30%, but since a motor may use 75% its initial cost in electric energy over its life time, the savings potential is great. Return on investment can be obtained within short period of time (i.e. 2-3 years). Because high efficiency motors decrease the motor losses, efficiency will increase automatically. Energy savings associated with high efficient motors and summary of savings are presented in Table 2.16 (Saidur, 2010).

Table 2.16. Energy saving using high-efficient motors

Motor HP	Standard efficiency	High efficiency	Energy savings (kWh/Year)
1	76.8%	82.5%	111
5	83.9%	87.5%	301
20	88.3%	91%	1,020
50	91.5%	93%	1,604
100	91.9%	94.5%	7,141
200	94%	95%	5,213
500	94.1%	95.8%	25,880

2.2.2. Several Types of Motor Losses

The efficiency of a motor is determined by intrinsic losses that can be reduced only by changes in motor design. Intrinsic losses are of two types: fixed losses and variable losses. Even though standard motors operate efficiently, with typical efficiencies ranging between 83% and 92%, energy-efficient motors perform significantly better. Efficiency saving from 92% to 95.8% results in a 47% reduction in the losses. Since motor losses result in heat rejected into the atmosphere, reducing losses can significantly reduce cooling loads on hospital and industrial facility's air conditioning system. Motor loss types and amount of the losses that take place in motors are shown in Figure 2.7.

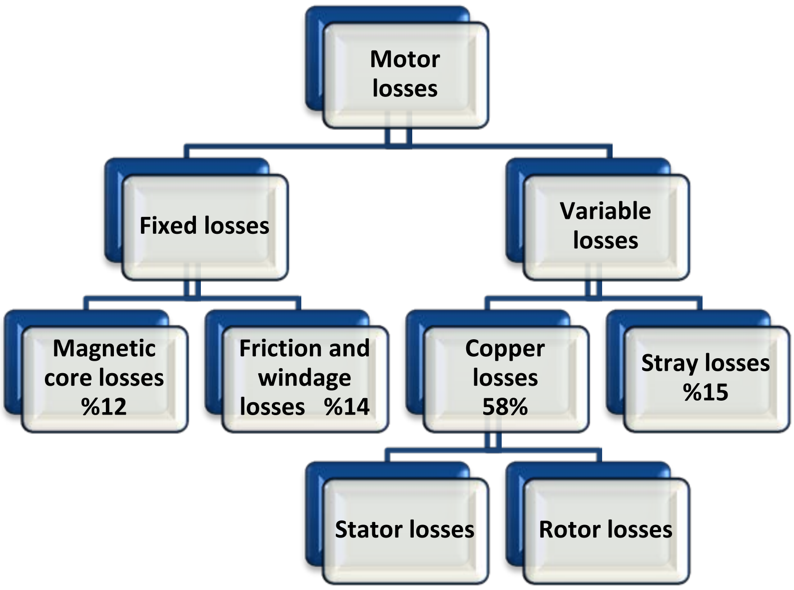


Figure 2.7. Motor loss types in a typical motor

The only way to improve motor efficiency is to reduce motor losses. Since motor losses produce heat, reducing losses not only saves energy directly but also can reduce cooling load on a facility's air conditioning system. Table 2.17 (Saidur, 2010) summarizes the ways of reducing motor losses.

Table 2.17. Ways to minimize motor losses

Power loss area	Ways to reduce
Stator	Use of more copper and larger conductors increases cross sectional area of stator windings. This lowers the resistance of the windings and reduces losses due to current I^2 R losses can be decreased by modifying the stator slot design or by decreasing insulation thickness to increase the volume of wire in the stator. Motor operation closer to synchronous speed will also reduce I^2 R losses.
Rotor	Use of larger motor conductor bars increases the cross section, thereby lowering conductor resistance and losses due to current flow.
Core/iron losses	Use of thinner gauge because lower loss core steel reduces eddy current losses. Longer core adds more steel to the design, which reduces losses due to lower operating flux densities. Core losses can be reduced through the use of improved permeability electromagnetic (silicon) steel and by lengthening the core to reduce magnetic flux densities. Eddy current losses are decreased by using thinner steel laminations.
Windage and friction	Use of low loss fan design reduces losses due to air movement. Use of bearing with lower frictions.
Stray load	Use of optimized design and strict quality control procedures minimizes stray load losses.

2.2.3. Selection of an Electric Motor in Suitable Power/Motor Load Factors

It is very important to select an electric motor of suitable power to work efficiently. Motor oversize is one of the most frequently misapplication encountered and difficult to be fixed. Oversizing accounts for a considerable share of the efficiency problems often found in motor applications. In general, motors are chosen in large capacities to meet extra load demands. Big capacities cause motors to work inefficiently at low load. Normally, motors are operated more efficiently at 75% of rated load and above. The preferred optimum operating region is between 60% and

90% of the rated load for motors; the ideal value is when the motor is operated in its full load. Oversized, under-loaded motors should be replaced with smaller premium energy-efficient motors immediately or when purchasing new motors, energy saving motors should be preferred (Saidur, 2010), (Kaya et al., 2008).

In (Kaya et al., 2008), energy efficiency studies performed in a large industrial facility’s pumps are reported. For this purpose; the electrical power drawn by the electric motor, flow rate, pressure and temperature have been measured for each pump in different operating conditions and at maximum load. The efficiencies of the existing pumps and electric motor have been calculated by using the measured data. The required investments have been determined and simple payback periods have been calculated. The main energy saving opportunities result from: replacements of the existing low efficiency pumps, maintenance of the pumps whose efficiencies start to decline at certain range, replacements of high power electric motors with electric motors that have suitable power, usage of high efficiency electric motors and elimination of cavitation problems.

2.2.4. Energy Savings with VSDs

AC induction motor develops more torque than required torque at full speed when starting. This stress is transferred to the mechanical transmission system resulting in excessive wear and premature failure of chains, belts, gears, mechanical seals, etc. Additionally, rapid acceleration also has a massive impact on electricity supply charges with high inrush currents drawing 600-800% of the normal run current. Soft starter provides a reliable and economical solution to these problems by delivering a controlled release of power to the motor, thereby providing smooth, step less acceleration and deceleration. Motor life will be extended as damage to windings and bearings is reduced. Energy savings are of appreciable quantity only if the time period is more than 5 years (Maheswaran et al., 2012). VSD can replace a soft starter since most drives can also satisfy current limiting ramp to start and stop the electric motor. VSD is an electronic power converter that generates a multi-phase, variable frequency output that can be used to drive a standard AC induction motor and to modulate and control the motor's speed, torque and mechanical power output. Application with VSD offers a significant energy saving if applied in many hospital and industrial applications. One of the many possible circuits to control the speed of an induction motor is schematically represented in Figure 2.8 (Abdelaziz et al., 2011).

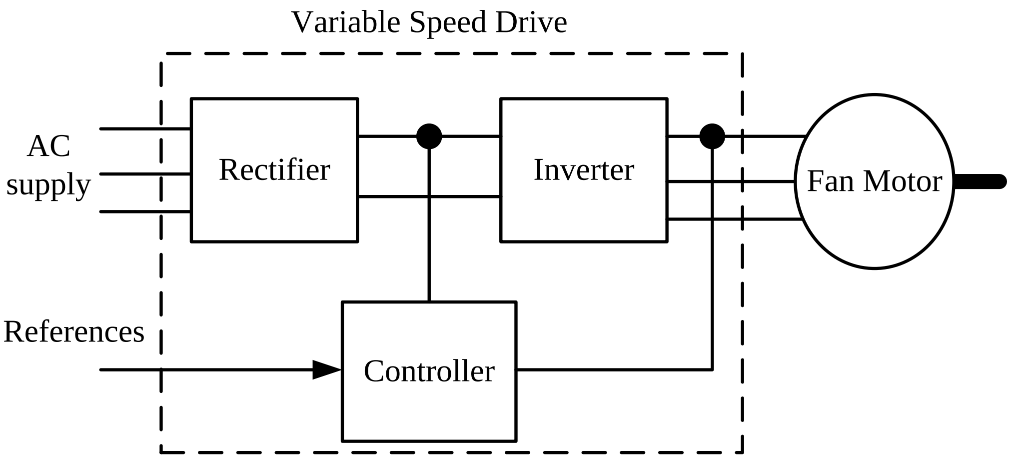


Figure 2.8. The variable speed drive system

The basic components of a VSD are a rectifier, an inverter and a controller. The rectifier takes the alternating current input power and converts it to direct current. The inverter changes the DC power back to AC power. According to coming reference signal, the overall pulses are controlled to keep the correct voltage to frequency (V/Hz) ratio in order to generate the rated torque (Miller et al., 2012). (Miller et al., 2012) have been investigated that a techno-economic model was created in order to develop curves that show the typical annual energy savings, rate of return and payback for retrofitting aerial coolers with VSDs for up to 50 motors, motor sizes from 4 to 186 kW and varying climate conditions. The cost savings due to installing a VSD depends on the reduction in energy used, as well as the reduction in power demand, the capital cost of the VSD, installation cost of the VSD, change in operating cost and cost of electricity. At result of that study, the simple payback becomes less than 2 years for motor sizes greater than 40 kW and less than 1 year for motor sizes greater than 90 kW. At the same time, the usage of VSD affects the reduction of emission gases positively. They are also shown that ambient temperature and geographic location affect the profitability of VSD investment.

Most induction motors used in buildings are fitted to fans or pumps. The traditional approach to pipe work and ductwork systems has been to oversize pumps and fans at the design stage and then to use commissioning valves and dampers to control the flow rate by increasing the system resistance. While mechanical constrictions are able to control the flow rate delivered by fans and pumps, the constriction itself increases the system resistance and results in increased energy loss.

An alternative approach to the use of valves and dampers is to control the flow rate by reducing the speed of the fan or pump motor via VSD (Saidur, 2010). When the VSD is used, the using requirements of the valves, dampers, gears and the other mechanical parts will be decreased or disappeared.

Flow-generating equipment like fans, pumps and compressors are often used without speed control. Instead, flow is traditionally controlled by throttling with a valve or damper. When flow is controlled without regulating the motor speed, it runs continuously at full speed. Using VSD to control the motor speed can save up to 15-40% of the energy. Figure 2.9 shows the basic principle of energy saving with VSD (Ristimaki, 2008). Valves and their similar equipment can be used to control flow rate but during the controlling, this devices can be caused to high temperature of motors and pumps, because of the pipeline resistance and motor running at full load.

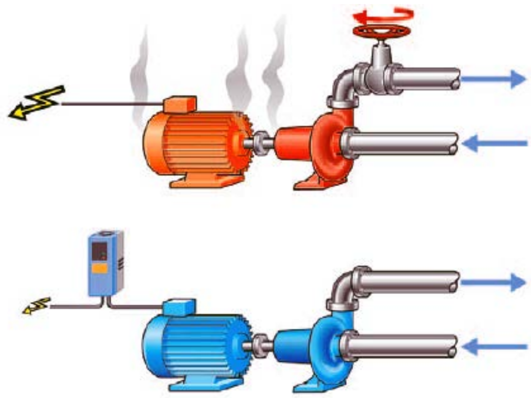


Figure 2.9. The principle of energy saving with VSD

Most motors are designed to operate at a constant speed and provide a constant output. The benefits of applying VSDs are in both productivity improvements and energy savings in pumps and fans. Generating compressed air is another process in the hospitals and industry. A survey conducted by the U.S. Department of Energy indicated that for a typical industrial facility, approximately 10% of all of the electricity used was attributable to generating compressed air. The use of compressed air for performing mechanical or process-related work is inherently inefficient; the overall efficiency of a typical compressed air system can be as low as 10% to 15%. Optimizing a compressed air system has the potential to generate energy efficiency improvements in the range of 20% to 50% (Nexant, 2013).

VSD installation increases energy efficiency, saves energy consumption, improve power factor and process precision, soft start up and over speed capability. They also eliminate throttling mechanisms and frictional losses affiliated with mechanical or electromechanical adjustable speed technologies and expensive energy-wasting. VSDs increase the life of the equipment by adjusting motor speed to meet load requirements. Generally, energy savings translate into cost savings and reduction in GHG emissions (Saidur et al., 2012).

Variable-frequency drives provide continuous control, matching motor speed to the specific demands of the work being performed. Variable-frequency drives are an excellent choice for ASD users because they allow operators to fine-tune processes while reducing costs for energy and equipment maintenance. Motors without adjustable speed may often operate at a single level that is well above the necessary speed for a particular application and therefore, be quite wasteful of energy. Adjustable speed motors can be used for a variety of applications including fans, pumps, compressors, conveyors and robots. Adjustable speed motors can provide significant savings in energy usage and costs. Energy used by electric motors generally represents up to about 75% of an industrial plant's entire energy use and about two-thirds of the motors in industrial use are for fans and pumps which do not need constant motor speeds. So any increase in the energy efficiency of such machines will result in significant savings. The department of energy estimates that replacing conventional motors with adjustable speed motors in appropriate applications would result in saving 41% of the energy used in industrial motors. Power consumption actually drops far more than the drop in motor speed, so the savings can accumulate quickly. For example a 10% reduction in shaft speed results in a 27% decrease in power consumption. Table 2.X4 shows the energy savings associated with the speed reductions as a result of using VSDs (Saidur, 2010).

Table 2.18. Potential savings using VSD

Average speed reduction (%)	Potential energy savings (%)
10	22
20	44
30	61
40	73
50	83
60	89

The affinity laws (also called the cubic laws) states that pump output or flow are directly proportional to the speed of the pump. Therefore, to produce 50% flow, the pump would be run at 50% speed. At this operating point, the pump would require only 12.5% of rated horsepower (0.5*0.5*0.5 = 0.125 or 12.5%). VSD also offers a significant annual bill saving and emissions reduction; for example, the food manufacturer Northern Foods in the UK achieved an annual energy saving of 769 MWh/year, over £30,000 saving a year in electricity costs, payback period of just 10 months and annual CO_2 reduction of 338 tonnes. Another example shows that a fan motor speed is decreased from 1450 to 255 rpm using (VSD) to reduce the amount of excess air that is not needed in low loads. After implementation of the VSD, the results obtained were increasing of the boiler efficiency by 2.5%, 8000 kWh electrical energy saving in a month and a payback period of 1.8 months (Abdelaziz, 2011).

Similarly, from the affinity laws, flow is directly proportional to speed, while pressure is proportional to the square of speed (Ristimaki, 2008). Most importantly from the energy savings perspective is that the power consumed is proportional to the cube of speed. This means even minimal reductions in speed can provide savings in consumed power. So, for example, it can be seen from Figure 2.10 that at 75% speed this provides 75% of the flow, but uses only 42% of the power needed to generate full flow; when the flow is lowered to 50%, the power consumption is reduced to 12.5%.

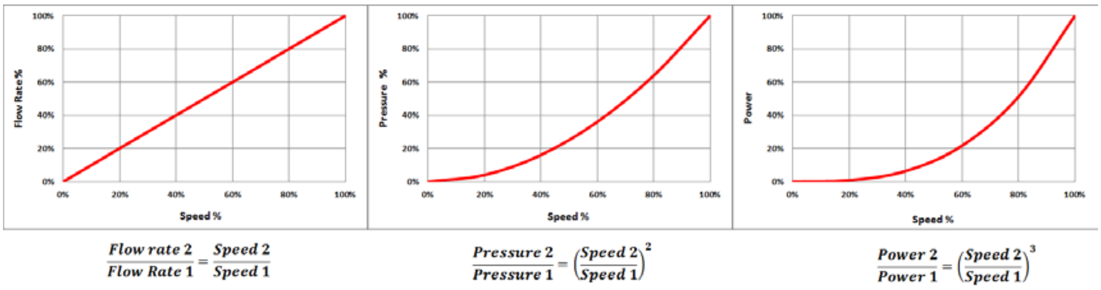


Figure 2.10. Affinity Laws to calculate the savings

2.2.5. Equations for Energy Efficiency

Equation 2.1 is used to calculate the energy efficiency (η) of 3-phase induction motors.

$$P = \sqrt{3} \times V \times I \times \cos\phi \times \eta \tag{2.1}$$

Then, the last statement of efficiency can be written as;

$$\eta = \frac{P}{\sqrt{3} \times V \times I \times \cos\phi} \tag{2.2}$$

In Equation 2.2, P is motor rated power *(W)*, V is motor rated voltage (V), I is motor rated current (A), cosØ is power factor and η is efficiency of motor.

For example, the estimated energy efficiency of 15 kW 3-phase induction motor with a power factor of 0.83 can be calculated by using Equation 2.2. Motor rated current is 30 A and motor rated voltage is 380 V.

$$\eta = \frac{15{,}000}{\sqrt{3} \times 380 \times 30 \times 0.83} = \frac{15{,}000}{16{,}369.26} = 0.92$$

Annual energy savings (*AES*) by replacing a standard efficient motor with a high energy-efficient motor (*HEM*) can be estimated using methodology described by Equation 2.3.

$$AES = Hp \times n \times LF \times 0.746 \times hr \times \left[\frac{1}{E_{std}} - \frac{1}{E_{ee}} \right] \tag{2.3}$$

In Equation 2.3, *Hp* is the motor rated horsepower, *n* is the number of motors, *LF* is the load factor, *hr* is annual operating hours, E_{std} is percentage of the standard motor efficiency rating and E_{ee} is percentage of the energy-efficient motor efficiency rating (Saidur et al., 2010a). Load factor is equal to ratio of average motor load to rated motor load.

If 3 motors rated at 5 Hp are used, total consumption power will be 5 x 0.746 x 3 = 11.19 kW. Estimated AES with replacement of 15 kW fan motor of air conditioner, 1460 rpm motor low efficiency motor (efficiency value is 92%) with premium efficiency (efficiency value is 95.8%) of the same size and type. This calculation assumes both motors have the same load factor, 74% and annual operation hours are taken 3,600 hours. By using the Equation 2.3,

$$AES = 15 \times 1 \times 0.74 \times 1 \times 3600 \times \left[\frac{1}{92} - \frac{1}{95.8} \right] \times 100$$

$$= 39960 \times (1.087 - 1.044) = 1{,}718.28\ kWh/year$$

AES equation should be multiplied by the unit price of electricity to find annual energy savings cost. In Turkey, the unit price of electricity is average 0.16$. All taxes are included to this price.

$$Total\ Saving\ Cost = AES \times Unit\ price\ of\ Electricity \tag{2.4}$$

$$= 1{,}718.28 \frac{kWh}{year} \times 0.16 \frac{\$}{kWh} = 274.92 \frac{\$}{year}$$

The average price of the 15 kW high efficiency asynchronous motor is 760$L. If old used motor is changed with the high efficiency motor, payback time can be calculated using Equation 2.5.

$$Payback\ Time = \frac{Purchase\ Price\ of\ the\ new\ motor}{Total\ savings\ cost\ in\ a\ year} \tag{2.5}$$

$$= 760\$ / 274.92\$ = 2.76 \text{ year are payback time}$$

There are many ways to estimate the energy savings associated with the use of VSD for electric motors for various applications. Energy use of fans and pumps varies according to the speed raised to the third power, so small changes in speed can result in huge changes in energy use. Using VSD systems provide the opportunity to save about 15-40% of the energy and extend equipment lifetime by allowing gentle start-up and shutdown. Energy savings of motors when installing VSDs can be calculated from either Equation 2.6 or 2.7.

$$AES_{VSD} = n \times P \times 0.746 \times H_{avg\_usage} \times S_{SR} \tag{2.6}$$

$$AES_{VSD} = (1 - S_{SR}^3) \times 100\% \tag{2.7}$$

In Equation 2.7, P is motor power (Hp), H_{avg_usage} is annual average usage hours, S_{SR} is the percentage energy savings associated certain percentage of speed reduction. For example, if the speed reduces 5% then, energy saving is occurred about 14%.

The annual cost savings is related to annual energy savings and price of the fuel. The annual bill savings of motor when using VSDs can be calculated using below at Equation 2.8.

$$Annual\ Bill\ Savings\,(ABS_{VSD}) = AES_{VSD} \times C \tag{2.8}$$

The payback period is the function of the incremental cost of VSDs divided by the annual bill savings of VSDs in a particular year. Payback period can be expressed mathematically by Equation 2.9.

$$Payback\ Time = \frac{Incremental\ cost\ of\ VSD}{Annual\ bill\ savings} \tag{2.9}$$

It is estimated that replacing conventional motors with adjustable speed motors in appropriate applications would result in saving 41% of the energy used in electric motors. Power consumption actually drops far more than the drop in motor speed, so the savings can accumulate quickly (Saidur et al., 2010a), (Saidur et al., 2010b) and (Saidur et al., 2012).

The energy saving is likely to reduce the electricity generation from power plants. As a consequence, the reduction of CO_2 and other emissions from the fuels used by the power sector can be estimated. The amount of emission that can be reduced associated with the energy savings can be estimated using the following equation (Saidur et al., 2010a).

$$ER = AES \times EF \tag{2.10}$$

In Equation 2.10, *ER* is emission reduction in kg and *EF* is emission factor. The unit of the emission factor is kg/kWh.

(Corino et al., 2010) were investigated energy savings of energy efficient electric motors compared with standard motors and rewound motors. They had made some analysis interested in changing HEMs with standard motors and rewound motors. At the end of that analysis, there are different practical cases in where energy efficient motors compared with standard motors and rewound motor. In all these cases energy savings can be achieved and the simple payback is less of five years.

The practical implementations of energy efficiency realized by different companies are presented in Table 2.19.

Table 2.19. The examples interested in energy saving

Application details	Energy saving (kWh/year)	Energy savings $/€ per year)	Simple payback (years)
A new energy efficient motor (EFF1 with 94.6% efficiency) is going to be bought and it is compared with a motor EFF2 with 93.2% efficiency. Their size and speed are 55 kW and 1500 rpm, respectively. It assumes a 75% load**. (New purchase of energy efficient motor and comparing of EFF1 motor with EFF2 motor)**[1]	3,393	€240	4.47
An old standard motor (EFF3 with 92.1% efficiency) of size of 90 kW and speed of 3000 rpm is going to be replaced by an energy efficient motor (EFF1 with 94.8% efficiency) of size of 75 kW and the same speed. They are operating 75% load. **(Replacing existing motor with smaller energy efficient motor)**[1]	83,687	€5,021	0.81
An old standard motor (EFF3 with 90% efficiency) of size of 75 kW and speed of 3000 rpm is going to be replaced by an energy efficient motor (EFF1 with 94.8 efficiency) of the same size and the same speed. They are operating 75% load. **(Replacing existing motor with same-sized energy efficient motor)**[1]	15,221	€913	4.46
A rewound standard motor (EFF3 with 90.4% efficiency) of size of 75 kW and speed of 3000 rpm is going to be compared by an energy efficient motor (EFF1 with 94.8% efficiency) of the same size and the same speed. They are operating 75% load. **(Rewinding)**[1]	17,275	€1,036	2.02
In a stainless steel factory, two 800 kW fans blow air into the convertor. The air flow is controlled by a valve. Replacing the valve with a VSD implies an energy saving. **(Replacement of valve with VSD)**[2]	4,188,277	€90,000	1.16
600 Hp blower motor with VSD was installed. **(Energy saving with VSD)**[3]	1,209,677	$75,000	3
Cooling towers, heating pumps and boiler fans motors were driven with VSD. **(Energy saving with VSD)**[3]	583,922	€51,803	0.7
Two 336 kW fixed speed booster pumps, which supply water to descaling pumps, with medium voltage drives. **(Energy saving with VSD)**[3]	2,930,000	$145,000	2.33

50 Hp fan motor needs to supply air 10 hrs/day for 250 days. 25% of time at 100%; 50% of time at 80%; 25% of time at 60%.**(Energy saving with VSD)**[4]	41,030	$3,282	1-2
10 numbers of 110 kW fan motors were fed by VSD. Total kW values of motors are 1100 kW. **(Energy saving with VSD)**[5]	2,423,750	€172,020	0.83
18.7 kW fan motor was driven with VSD in a hospital. **(Energy saving with VSD)**[6]	118,545	$11,855	<1
Designed and installed VSDs and controls on the supply and return fans of 8 rooftop units at MIT. **(Energy saving with VSD)**[7]	1,000,000	$180,000	1.3
Replacement of 100 Hp fixed speed air compressor with 100 Hp variable speed drive air compressor **(Energy saving with VSD)**[8]	260,000	$26,000	2.2
Up gradation of refrigeration system with computer controls and ASD compressors. **(Energy saving with VSD)**[9]	741,000	$37,000	>2
Replacement of one 100 Hp and two 150 Hp rotary screw compressors with 100 Hp fixed-speed unit and a new 100 Hp ASD compressor. **(Energy saving with VSD)**[9]	471,000	$50,000	0.55
The modernization of lifts involved the replacement of the existing motor with a new motor in each of the 13 lifts equipped with electronic speed variator and the installation of a control system **(Replacing existing motor and Energy saving with VSD)**[10]	687,660	€76,321	4.9
[1](Corino et al., 2010), [2](Pauwels,2001), [3](ABB), [4](Telemecanique,2006), [5](Wilkinson,2009), [6](Saidur et al., 2012), [7](BSE, 2013), [8](Toronto, 2011), [9](Brush et al., 2011), [10] (Gordo, 2011)			

Table 2.19 shows that the use energy efficient motors and/or VSDs are an opportunity to improve the efficiency of motor systems, leading to large cost-effective energy savings, improving of the hospital and industrial economic efficiency and reducing the environmental impacts (Corino et al., 2010).

Next section will be interested in HVAC (Heating Ventilating and Air Conditioner) systems. Especially, most of the consumption energy has been used by electricity motors at ventilating and air conditioner in the HVAC systems.

2.2.6. Summary

The most important conclusions of this section are as follows:

- In many industrialized countries, more than 70% of the total consumed energy is used by electric motors (Saidur, 2010). 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 (Abdelaziz, 2011). Three phase asynchronous motors are 95% of used motors in industry.
- In Turkey, approximately 65% of total electricity consumption is consumed by electric motors and about 35% of total energy is used in the industrial sector (Saidur et al., 2010a). Motor-driven equipment such as pump and fan accounts for 51% of manufacturing electricity use (Yumurtaci et al., 2011).
- Kyoto protocol has forced the countries to reduce GHG emissions in their atmosphere. GHG emissions are increasing the global warming. When the countries are buying new motors, these motors should be high efficiency and low carbon emissions.
- In the past, motors were classified by efficiency standards as EFF1, EFF2 and EFF3. A new international standard for efficiency classes of motors have been developed by IEC (The International Electrotechnical Commission) namely IE1 (standard efficiency), IE2 (high efficiency), IE3 (premium efficiency) and IE4 (super premium efficiency). When the old standards compare with the new standards, IE1 is used instead of EFF2 and IE2 is used instead of EFF1. There is no comparable standard of EFF3 at new efficiency standards. European Union has been prohibited the sale of motors that do not meet EFF2 criteria. This means that low efficient motors with EFF3 standard have taken place in history pages.
- In general, motors are chosen in large capacities to meet extra load demands. Big capacities cause motors to work inefficiently at low load. Normally, motors are operated more efficiently at 75% of rated load and above. The preferred optimum operating region is between 60% and 90% of the rated load for motors. Oversized and under-loaded motors should be replaced with smaller premium

energy-efficient motors immediately or when purchasing new motors, energy saving motors should be preferred (Saidur, 2010), (Kaya et al., 2008).

- The initial purchase price of AC induction motor is only about 2% of its lifetime costs. If the low efficiency motor is replaced by the high efficiency motor at the same power rating, the payback time will be about 4-5 years. For example, when 90 kW EFF3 electric motor with 92.1% efficiency is replaced by EFF1 electric motor with 94.8% efficiency, payback time is calculated as 0.81 year.
- The efficiency of a rewound motor decreases. Rewound motors practically have an efficiency loss of 1-3%. If the repair cost is more than 60% of a new premium energy-efficient motor cost then a new motor with high efficiency should be bought. The payback time of rewinding is approximately 2-3 years.
- It has been found that highest amount of loss taking place at the rotor and stator parts of a motor. These losses are named as copper losses and the amount of the losses is approximately 58%. Losses at a motor affect energy efficiency directly. High losses motors should be replaced with high efficient motors immediately.
- While a motor starts to run at the acceleration time, 600-800% of the normal run current is drawn. This high current can be dangerous for stator windings. If motor runs the full load at a constant speed, it is enough to use a soft-starter. Soft-starter prevents to motor against the inrush current. If the motor runs at the variable speeds or different loads, VSD can be preferred instead of soft-starter.
- VSD saves the energy by reducing the speed of motor. Payback time is changed between 0.5 and 3 years depending on the motor power. When the power rating of electric motor increases, the amount of savings will increase. If the control devices such as thermocouple, encoder, resolver etc. are used with the VSD together, the amount of savings will reaches to maximum values.
- The relationship between variables, such as pressure, flow rate, shaft speed and power can be expressed with affinity laws. They mean that flow is directly proportional to speed, while pressure is proportional to the square of speed and power consumed is proportional to the cube of speed. At the practical calculations, the use of affinity laws will save time in especially pump and fan applications.

- The overall efficiency of a typical compressed air system can be as low as 10% to 15%. Use of highly efficient motors (payback period ranges from 0.53 to 5.05 years), VSD (payback period ranges from 0.4 to 1.5 years), leak prevention payback period ranges from 0.33 to 0.75 years, use of outside intake air, reducing pressure drop, recovering waste heat, use of efficient nozzle and use of variable displacement compressor to save compressed-air energy are the various energy-saving measures (Saidur, 2010c).

2.3. Literature Review on HVAC Systems

HVAC systems provide conditioned air (cooling, ventilation, thermal comfort and humidity control) to the people and locations in the hospitals, airports, industrial and office buildings. HVAC systems control temperature, humidity and air quality inside the buildings and locations. They are generally used in large office buildings or climate controlled places such as hospitals, offices, hotels and government buildings. In this thesis, the central HVAC system with water cooled chiller is focused instead of the individual systems. Central system is an air conditioning system which uses a series of equipment to distribute cooling media to exchange heat and supply conditioned air from one point (e.g. plant room) to more than one rooms (ECSG). Central HVAC system consist of heating unit comprise of boiler, ventilation unit comprise of fans and cooling unit comprise of chiller as shown in Figure 2.11 (Sugarman, 2005).

HVAC system is the single largest energy consumer in buildings. It accounts for almost 60% of total energy cost in a building (ECSG). 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 (Heur, 2008), (Hu et al., 2004). Heating function is commonly used in cold climates and cooling function is commonly used in warm and hot climates. Air conditioning means removal of the indoor air humidity. In the medium or large buildings, central HVAC systems are generally used but in the small buildings such as houses, direct expansion system such as split system is preferred.

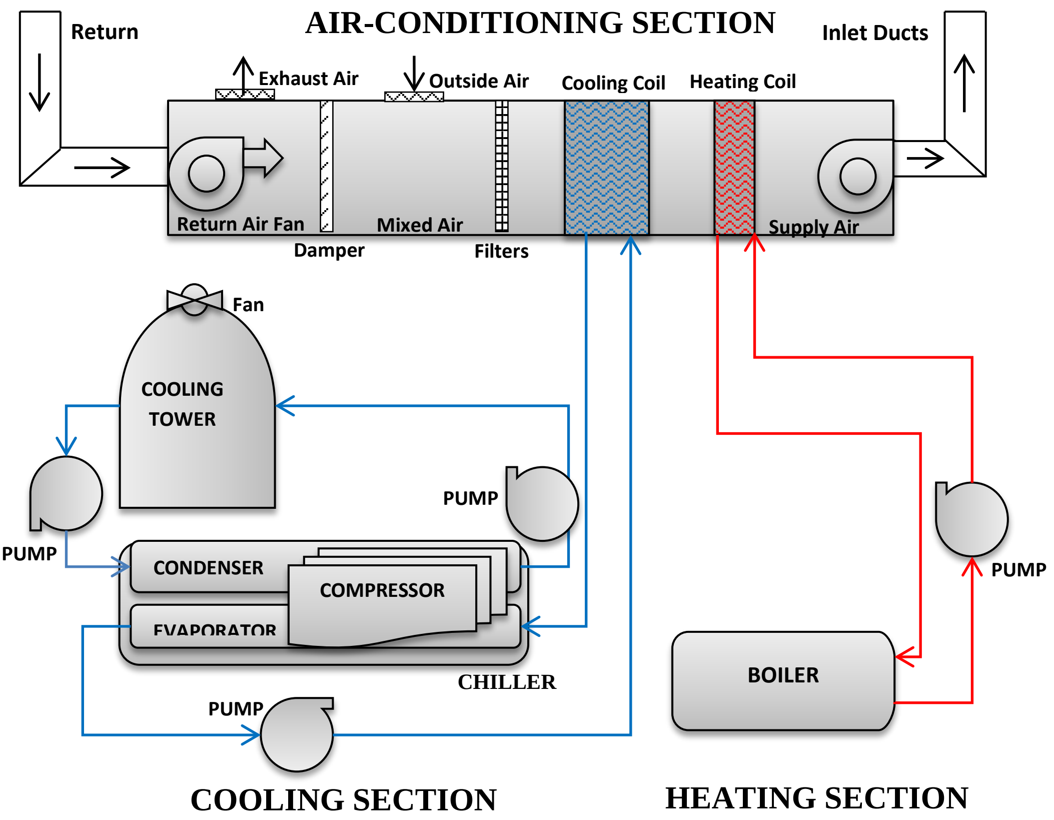


Figure 2.11. Schematic diagram for the conventional HVAC system

HVAC systems are divided into two parts namely direct expansion (DX) and central systems as shown in Figure 2.12 (ECSG). DX systems use the refrigerant directly as the cooling media. The refrigerant inside the evaporator absorbs heat directly from the air used for space conditioning. Central system is an air conditioning system that uses series of equipment to distribute cooling media to exchange heat and supply conditioned air from one point to more than one rooms. According to the type of condenser used, DX system is either air-cooled or water-cooled systems and similarly, the central air-conditioning system is either air-cooled or water-cooled system. Air-cooled and water-cooled systems are categorized by their capacity and efficiency.

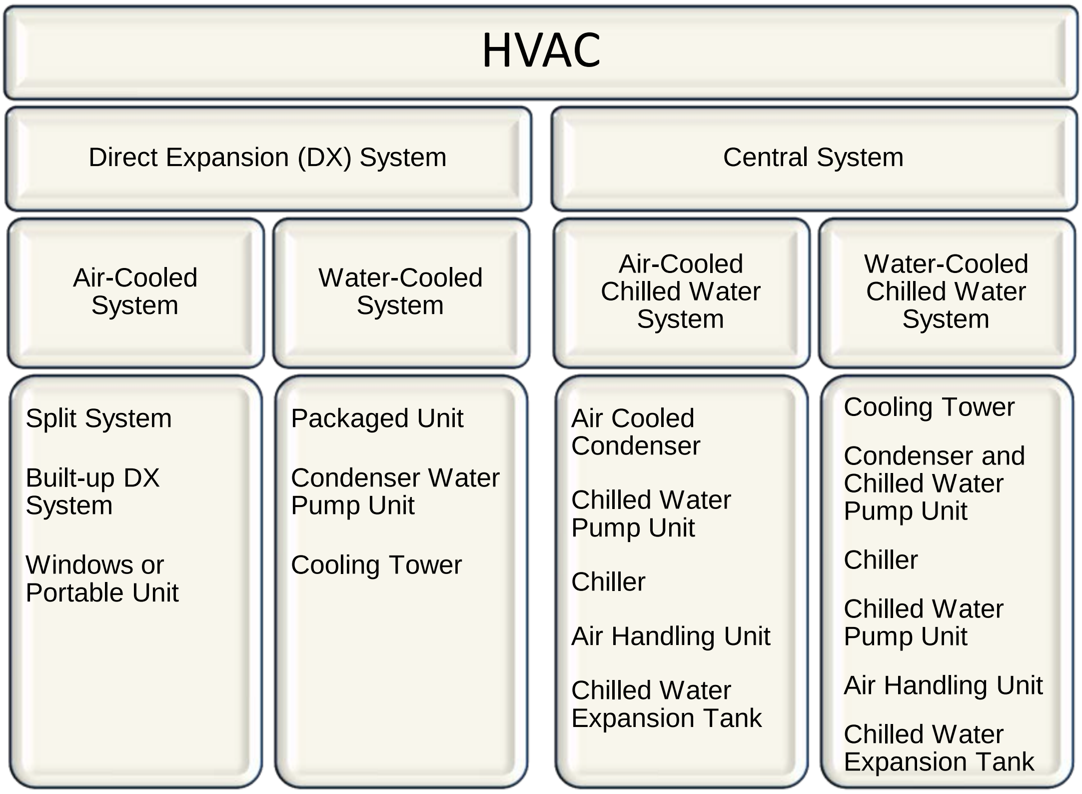


Figure 2.12. HVAC system description

In the literature, there are many papers on HVAC systems. (Balaras et al., 2007) reviewed published standards and guidelines on design, installation, commissioning, operation and maintenance of HVAC installations in hospital operating rooms, indoor thermal conditions and summarized measured data from short monitoring of indoor thermal conditions along with audit results and main characteristics of 20 operating rooms in 10 major hospitals. The commonly faced problems are insufficient indoor air exchange, poor control on indoor thermal conditions, bad space ergonomics that influence the ventilation system operation, poor technical installations maintenance and understaffed technical departments. According to international regulations and standards, the desirable indoor air temperature is usually 20-24°C and the recommended levels of indoor relative humidity are 30-60%. Most of the standards recommend 20 ACH (Air Change per

Hour) to obtain 50-150 colony forming units (CFU)/m^3 of air. After the measurements, they have identified the problems of HVAC systems and given some advices to mitigate these problems. They have advised regular maintenance and the sealing of operable windows in the older buildings. In addition, pipe penetrations and joints should be tightly sealed. The layout of objects in room is important for HVAC systems. Objects near the radiators or blowers of fan should be moved to the free space. According to different conditioning spaces, hospitals should be divided to zones and different AHUs should be used for every zone. Finally, they advise that the hospitals should be controlled by officials.

Research was conducted by (Ahmadzadehtalatapeh and Yau, 2011) to study the effect of heat pipe heat exchangers (HPHXs) on the existing air conditioning system of a hospital ward located in Malaysia, a tropical region. Fieldwork study showed that the existing air conditioning system operating in the Orthopedic Ward, University of Malaya, Malaysia is not capable of providing the desired supply duct air and indoor air to the space. Therefore, the possibility of improving the air conditioning system by adding HPHXs was investigated. The impact on energy consumption, power savings, supply duct air and indoor air with HPHXs incorporated in the air conditioning system were simulated and the results were compared with the existing system. Based on the present research work, the system with the added eight-row HPHXs is recommended to provide convenient and healthy air into the ward space according to the ASHRAE recommendations. The simulation results for the entire year show that the new system makes it possible to save a total amount of 455 MWh by using the eight-row HPHXs in the system. The research also showed that by considering the cooling equipment efficiency and tariff rate for power in Malaysia, a total amount of $42,227 could be saved annually with the application of the eight-row HPHXs in the ward air conditioning system. Moreover, it was found that by recovering the energy in the AC system, the eight-row HPHXs retrofit would pay for itself in 1.6 years.

(Khodakarami and Nasrollahi, 2012) investigated literature reviews of thermal comfort in hospitals has published until 2012. In addition, they investigated the direct effect of thermal comfort on health. They accepted that thermal comfort as a parameter of indoor air quality in hospital affects the working conditions, wellbeing, safety and health of the medical personnel who work in these environments. Although different researches are undertaken on thermal comfort for patients in hospitals, it is also necessary to study the effects of thermal comfort conditions on the quality and the quantity of healing for patients in hospitals. Thermal comfort variables can change, based on different conditions of patients, the different activities of staff, the different types and numbers of equipment. To solve this problem the best recommended option is to prepare different thermal zones based on different temperature and air velocity for different thermal comfort requirements. Their study finally concluded that it is important to find some solutions to reconcile the different thermal comfort conditions required by different occupants in hospitals. According to their opinions, their solutions could be used whenever patients and the attending caregivers have to stay in one room for a long time compulsorily.

Air volume in the building is important for the livings. (Kim et al., 2013) evaluates the adaptive variable air volume (VAV) operation over the current practice of the VAV that is set to constant air volume. The adaptive VAV temporarily increases the volume offset before the door is opened and thus induces a higher negative pressure differential. (Congradac et al., 2012) perform a study to increase energy efficiency in hospitals, using a variety of currently available technologies. (Congradac et al., 2012) concentrates on the creation of a mathematical tool for the exact calculation of room/building energy demands. A prerequisite for the determination of savings is the accurate calculation of energy consumption and then the application of different methods of intelligent control for the energy savings, which should be combined with a system of expert advices in order to gain the highest efficiency.

In (Dascalaki et al., 2008), indoor conditions in Hellenic operating rooms (ORs) were monitored and data were used to assess the exposure of medical personnel to anesthetic gases and other indoor chemical compounds. Measurements were performed in 17 ORs at nine hospitals. Even though mechanical ventilation and active scavenging systems were employed in the audited ORs, medical personnel are still exposed to poor indoor air quality as a result of various gaseous compounds encountered. (Yau et al., 2011) focuses on the ventilation of multiple-bed hospital wards in the tropical climate, taking into account the design, indoor conditions and engineering controls. The required indoor conditions such as temperature, humidity, air movements and indoor air quality in the ward spaces are summarized based on the current guidelines and practices. Recent studies and engineering practices in the hospital indoor environment are elaborated. Usage of computational fluid dynamics tools for the ventilation studies is discussed as well.

Measurement and monitoring of energy consumption is very important. (Chen et al., 2005) proposes practical predictions of hospital air-conditioner electricity using the artificial neural network, owing to its excellent predict ability. The influence variables of hospital air-conditioner electricity are included temperature, relative humidity, the previous one hour electricity, the time in day and some uncontrolled variables, e.g. the number of surgical operations, the number of persons; and some fix variables. (Chen et al., 2005) obtained the results that the weekday load model is better than whole day although the air-conditioner load belongs to. The irregular load of medical treatment is the main reason. According to (Chen et al., 2005), the results not only be referred to control the operation for air-conditioner system, but also to forecast the hot water production with the reheat system in hospital. The focus of the study performed by (Esmaeili et al., 2011) is to estimate the overhead energy consumption of healthcare facilities where buildings are open and operating 24 hours a day/365 days a year. In (Esmaeili et al., 2011), 3 different methods for estimating overhead energy consumption of the CT and X-ray rooms in the radiology department of a hospital: a heuristic using annual energy consumption, thermal analysis and simulation were investigated and compared. The comparison of methods will provide information and guidance on the selection of a method with a given level of accuracy and ease of application.

Air curtains are also useful when it is wished to separate two contiguous areas while permitting traffic of people, vehicles, materials or objects between the two separated zones. Diffusion and transport of heat (hot or cold temperatures), moisture, insects, dust, smoke, pollution, particulate matter and odors between the two areas separated aeraulically in this manner can thus be kept to a minimum. The efficiency of such devices ranges from 60% to 85%. Air curtains are commonly used at the entrance of volumes presenting only one opening to the outside (a room and its door) to preserve prescribed climatic conditions in this volume. The use of multiple gaseous barrier systems to sustain given climatic conditions (in the broadest sense of the term) within a given domain is rather new (Cortes et al., 2009).

2.3.1. Cooling Systems of HVAC

Different cooling systems are used in hospital, industry and other sectors. One of the cooling systems in HVACs is shown in Figure 2.13. The operation principle of the cooling system is very simple. The cooled water in the cooling tower is sent to condenser by condenser water pump. Condenser converts steam with water which is named as vapor to liquid. Compressor is used to pump this liquid in the cooling system. It is also used to compress gases refrigerant in the system. Compressor can be though the heart of the cooling system. The vapor is pumped from evaporator by compressor. The main functions of a compressor are to pump refrigerant through the cooling system and to compress gaseous refrigerant in the system. Air handling unit is used for air conditioning. Fan coiled unit is used instead of air handling unit for smaller systems.

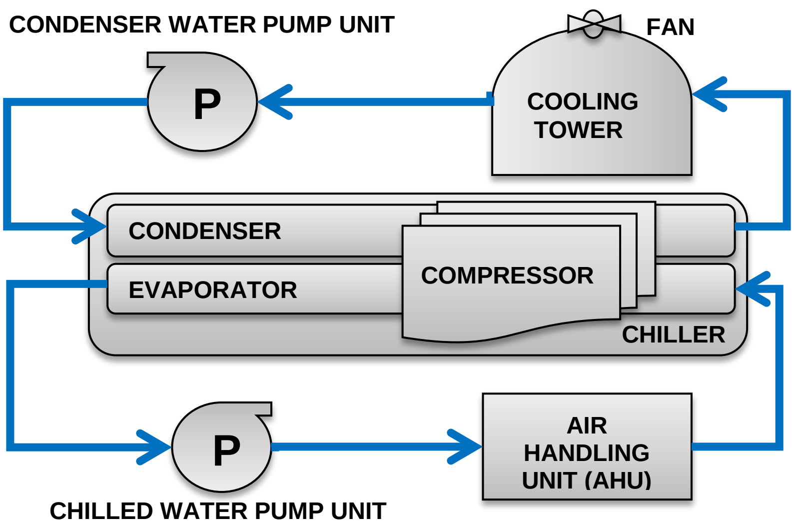


Figure 2.13. Schematic diagram of a cooling system

The main component of cooling system is chiller that mainly consists of evaporator, condenser, compressor and expansion valves as shown in Figure 2.14 (Brandemuehl). Chillers are the largest consumer of energy in cooling systems. The main duty of a chiller is to process vapor compression and vapor absorption via condenser and evaporator. Evaporator is used to evaporate refrigerant liquid and then gas form is occurred. Compressor with the refrigerant gases cools the water in evaporator. Heat is generated while the water is cooling. The generated hot air is sent to condenser. Condenser is used to condense vapor to liquid. The generated new hot liquid is sent to cooling tower with the pumps. Condenser can be classified into two major types, air cooled and water cooled. There are advantages and disadvantages sides of two systems against each other. For example, at the place that has no water, the chiller with air cooled condenser should be preferred. Similarly, at the very cold climate as continental climate, air cooled systems are preferred because water freezes at 0°C. If all climatic conditions are satisfied, water cooled condenser is preferred in large buildings and air cooled condenser is preferred in the smaller buildings such as single house or small office.

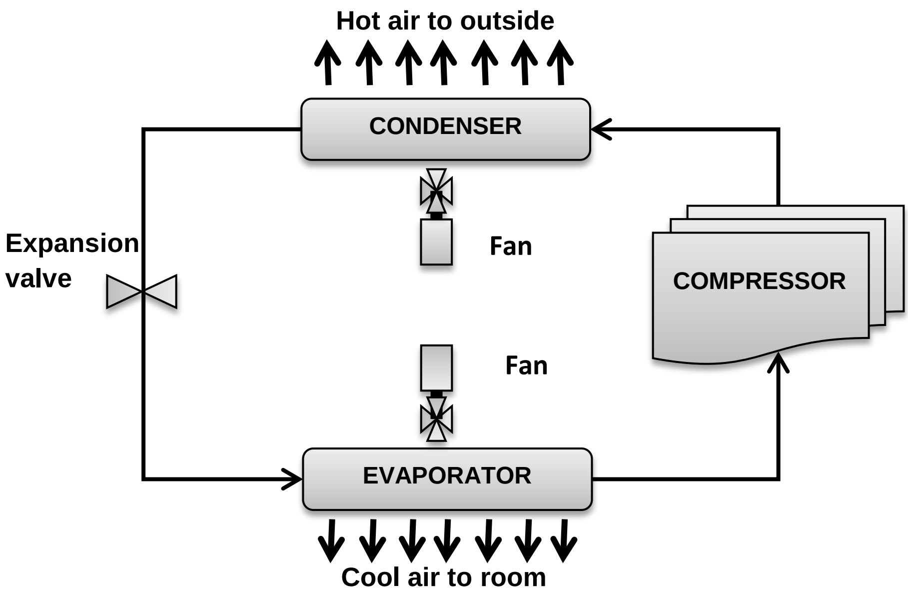


Figure 2.14. The operation principle of the chiller

In cooling systems, it is no matter whether the system is air cooled or water cooled. According to requirements, the structure of building and climatic conditions, the selection is performed. According to electricity consumption, when the cooling section in HVAC systems are investigated by considering energy efficiency, chiller group, pumps and fans should be especially focused. According to REHVA Federation of European Heating, Ventilation and Air-conditioning Associations, Chillers' sales by construction type are 69% air cooled non-ducted, 25% water cooled, 4% water cooled ducted and 2% condenserless. By applying an efficient design concept, selecting efficient components and controls and commissioning the system, it is possible to produce a chiller plant that uses 30 to 50% less energy than a system designed (Chillers 39% savings, pumps 65% savings, cooling towers 40% savings) (Design, 2010). The energy usage percentages of chilled water system at full load are shown in Figure 2.15 (Trane, 2000). A neglected or poorly maintained cooling tower can reduce chiller efficiency by 10% to 35% and a dirty coil condenser of an air cooled chiller as much as 5% to 15%. Chemical cleaning of the inside of the condenser and evaporator heat transfer surfaces can result in a 5% to 10% energy savings kW/ton (Chillers, 2010).

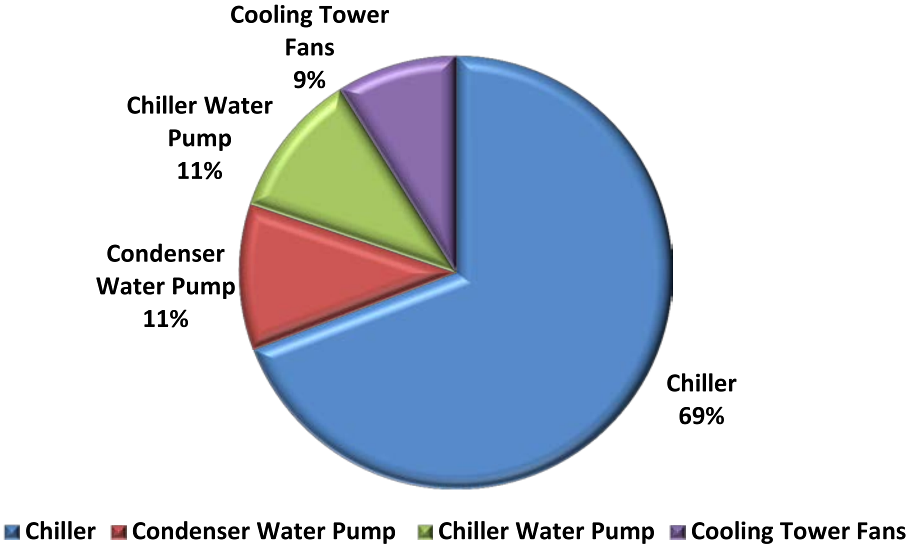


Figure 2.15. Equipment energy use by percentage of chiller system at full load

The selection of cooling materials used in cooling system is very important. (Zhai et al., 2013) reviews the previous works on phase change cold storage for air-conditioning systems focusing on two aspects including phase change materials (PCMs) and applications. According to studies on PCMs, the first step is to composite PCMs to achieve an appropriate phase change temperature. The second step is to change the structure of PCMs by adding nanoparticles or by packaging the materials with capsules or porous medium in order to achieve desired thermo physical properties. Based on the existing researches, the technology of PCM storage seems to be practical in solar air-conditioning systems, latent cooling storage and transport systems, mixed cold storage air-conditioning systems and some other novel air-conditioning systems. The work performed by (Hatamipour et al., 2007) was designed to estimate the cooling load power consumption during the summer in the hot and humid areas of Iran. The actual electrical energy consumption for cooling systems of some typical buildings including a city hospital in a hot and humid region in South of Iran was recorded during the peak load period of the year (July–August). The records were used for estimating the total power consumption of the cooling systems in this region. The cooling systems power consumption in this region accounted for more than 60% of the total power consumption during the peak load period of the year. A computer program was developed for simulating the effect of various parameters on cooling load of the buildings in hot and humid regions. According to the simulation results, use of double glazed windows, light colored walls and roofs and insulated walls and roofs can reduce the cooling load of the buildings more than 40%. To enhance clean room energy efficiency, a new methodology is proposed in (Su and Yu, 2013) for determining the proper chilled piping pressure set point for the pumps. Test results showed that, with their method, the proper differential pressure set point for chilled water pumps with VSDs could be effectively determined. The results also indicated that, by using the new set point obtained from the proposed approach, the percent energy savings would be in the range of 42%-53%, depending on the existing set point and pipeline data. The investment benefit of new or planned pumps would be about 43%-81% due to taking a proper set point into account.

2.3.2. Heating Systems of HVAC

The main component of heating system is a boiler. Boiler is a member of the pressure vessel class and can be classified into different types, according to temperature, pressure, capacity, burner types and etc. Boilers are designed to produce steam and obtain hot water. Produced hot water in a boiler is sent inside the buildings via steam pipelines. Collectors are used to prevent the pressure losses at the pipelines. Collector points are placed in the buildings and deliver the steam to other locations. In a boiler, combustion affects the energy efficient directly. Burner is a device which is used to perform combustion. There are some important factors such as supplied air, mixing of air and fuel, temperature and combustion time for combustion.

A typical heating system is shown in Figure 2.12. Approximately 40% of all commercial buildings use boilers for space heating. 65% of the boilers are gas fired, 28% of the boilers are oil fired and 7% of the boilers are electric. The combustion efficiency of older boilers is generally between 65% and 75%, although inefficient boilers can have efficiencies between 40% and 60%. Energy-efficient gas-fired or oil-fired boiler systems can have efficiencies between 85 and 95% (Energystar).

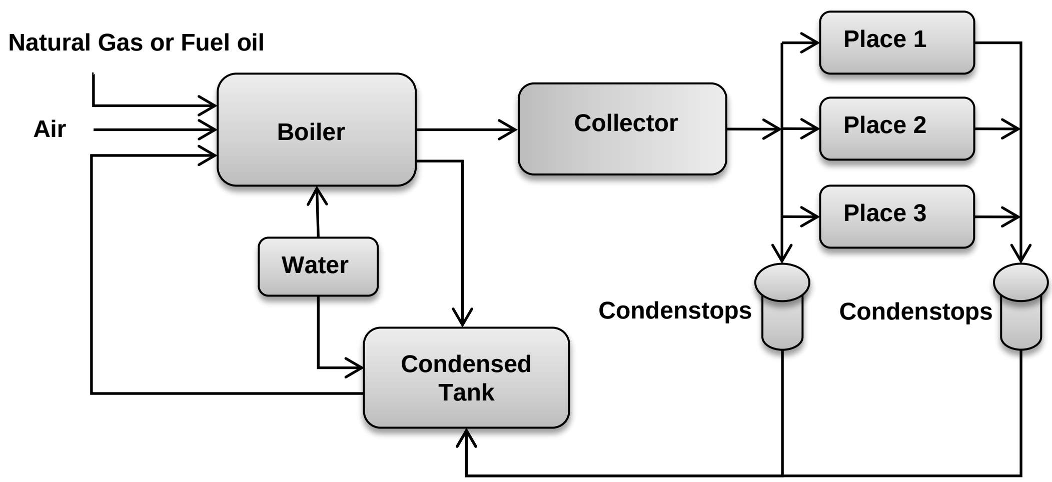


Figure 2.16. A typical heating system

Heating exchangers, economizers and combustion on burners should be investigated deeply when the heating section of HVAC systems are focused on. Economizers are used to heat boiler feed water by the using waste heat of the flue gases. The economizer can be considered as a type of heat exchangers.

(Bujak, 2010) analyzed heat consumption for heating domestic water in large hospital facilities with over 600 hospital beds. The tests were carried out in 2 hospitals: the 715-bed University Hospital and 690-bed Provincial Hospital. The tests were performed over a period of 4 years among the 2005 and 2008 for the first hospital and 2003-2006 for the second hospital. The aim of that study was to analyze the variations and seasonal changes in the heat consumed to produce domestic hot water during the specified time periods. The results of that study have shown the yearly, monthly, daily and hourly consumption of heat for domestic hot water. Daily observations show that the average daily heat consumption on weekdays (Monday–Friday) was always higher than on saturdays and sundays. The results of that study can be used in the design of new hospital facilities to predict heat consumption.

Heat pump installations increase energy efficiency day by day in HVAC applications. Energy efficient cooling at Aarhus University Hospital was realized by Danfoss (Shen et al., 2009). Aarhus University Hospital replaced a huge amount of old decentralized cooling units with one, new centralized plant with a cooling capacity of 2.5 MVA. New centralized cooling plant will annually save 800,000 kWh. The new cooling plant consists of two large air/liquid heat pumps (two 180 kW heat pumps), 9 air-cooled chillers and a number of compressors. According to (Shen et al., 2009) a heat pump system has been set up to replace a natural gas boiler for the supply of hot water in a medium size hospital in central Taiwan. The total capacity of the pump is 280 kW. This system was built in 2007 and has been run since then. This system could supply steady demand of hot water in temperature and flow rate. Compare to natural gas boiler, heat pump system saving 90,000 US$ in 7 months and the payback period was 1.8 years.

2.3.3. Heat Exchanger System

Heat exchangers are used in cooling and heating systems for energy saving. They are generally preferred for heat recovery for heating systems. The working principle of the heat exchanger is to transfer thermal energy between two different ambiences having different temperatures. Generally, external heating source is not used as the heat exchangers. Exhaust, flue gases or hot liquid material which is processed in the production are preferred instead of external heating source. A typical heat exchanger is shown in Figure 2.17. If the cold water or other refrigerant material such as Freon gas is used instead of steam or hot water, cooling is performed instead of heating.

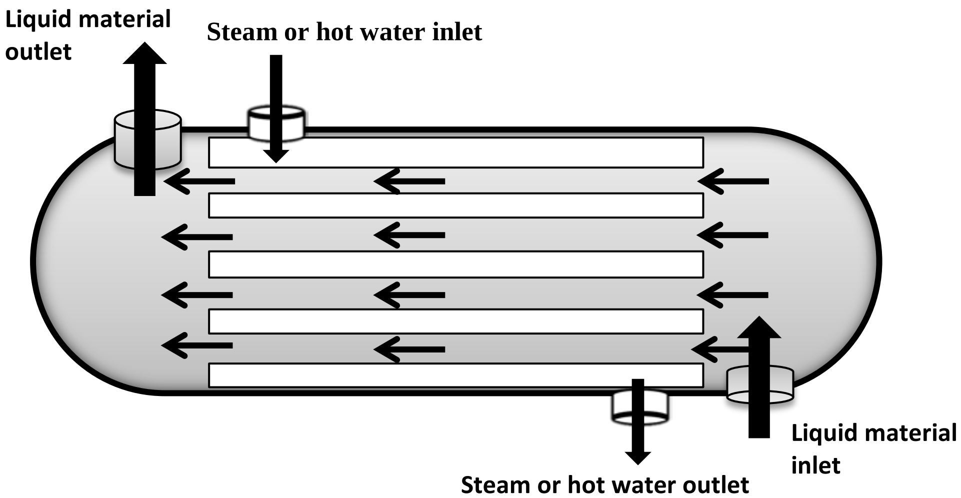


Figure 2.17. A typical heat exchanger system

Similarly, energy recovery ventilators (ERVs) are exhausted air energy recovery devices for outdoor ventilation air preconditioning in building HVAC systems. In (Resole et al., 2013), a sensitivity analysis is used to evaluate the impact of uncertainty of building and HVAC system parameters on the energy savings potential and economics of ERVs. The results in (Resole et al., 2013) show that the ventilation rate has the most significant impact on total HVAC system energy performance. The results also illustrate that an ERV with 75% sensible and 60% latent effectiveness can reduce the peak heating load by 30%, the peak cooling load by 18%, the annual heating energy usage by 40% and the annual cooling energy usage by 8% with a payback period of 2 years.

Insulating steam systems with valve insulation jackets is one of the most cost-effective energy-saving measures. Insulation jackets for steam traps can save significant amounts of energy by reducing heat loss and keep the workplace safer.

2.3.4. VRF/VRV Systems

A multi-split air conditioning system, featuring variable refrigerant flow (VRF) or variable refrigerant volume (VRV) technology, so-called the multi-split VRF/VRV system can satisfy the same needs for the installation of several individual units with less space, because this system consists of one outdoor and multiple indoor units (VRV is a trademark of a leading VRF manufacturer and VRF is a generic term used by all of the VRF manufacturers). Basically, a multi-split VRF system is a refrigerant system that varies the refrigerant flow rate with the help of the variable speed compressor and the electronic expansion valves located in each indoor unit to match the space cooling or heating load in order to maintain the zone air temperature at the indoor set temperature (Tolga, 2010). The schematic view of VRF system is shown in Figure 2.18 (Bhatia).

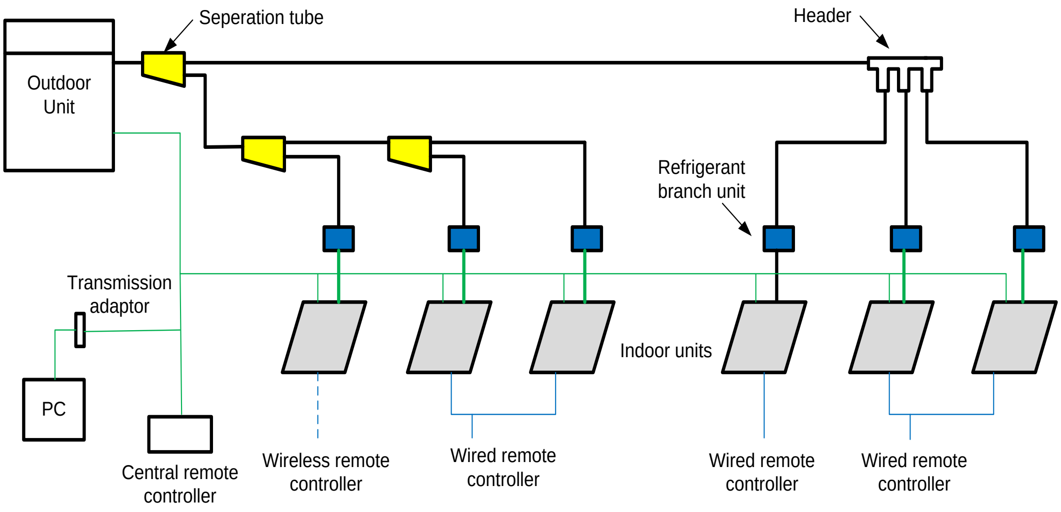


Figure 2.18. The schematic view of VRF

Ductless products are fundamentally different from ducted systems in that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. In contrast, conventional systems transfer heat from the space to the refrigerant by circulating air (in ducted systems) or water (in chillers) throughout the building. VRF systems are larger capacity, more complex versions of the ductless multi-split systems with the additional capability of connecting ducted style fan coil units. They are inherently more sophisticated than multi-splits, with multiple compressors, many evaporators and complex oil and refrigerant management and control systems. They do not provide ventilation, so a separate ventilation system is necessary. VRF systems have several key benefits, including: installation advantages, design flexibility, maintenance and commissioning, comfort, energy efficiency (Goetzler, 2007). Field testing has indicated that this technology can reduce the energy consumption by as much as 30 to 40% in a year compared to traditional rotary or reciprocating type compressors. VRF technology yields exceptional part-load efficiency. Since most HVAC systems spend most of their operating hours between 30-70% of their maximum capacity, where the coefficient of performance (COP) of the VRF is very high, the seasonal energy efficiency of these systems is excellent. A VRF system minimizes or eliminates ductwork completely. This reduces the duct losses often estimated to be 10% to 20% of the total airflow in a ducted system.

As with chilled water systems, installed costs for VRF systems are highly variable, project dependent and difficult to pin down. Total installed costs for VRF systems are estimated by some sources to be 5% to 20% higher than for chilled water systems providing equivalent capacity, but actual costs are highly project dependent (Goetzler, 2007).

2.3.5. Fundamentals of Cogeneration Systems

Cogeneration or CHP (stands for Combined Heat and Power) is the simultaneous generation of electrical and heat energy together with respect to a single fuel type. CHP system is shown schematically as shown in Figure 2.19.

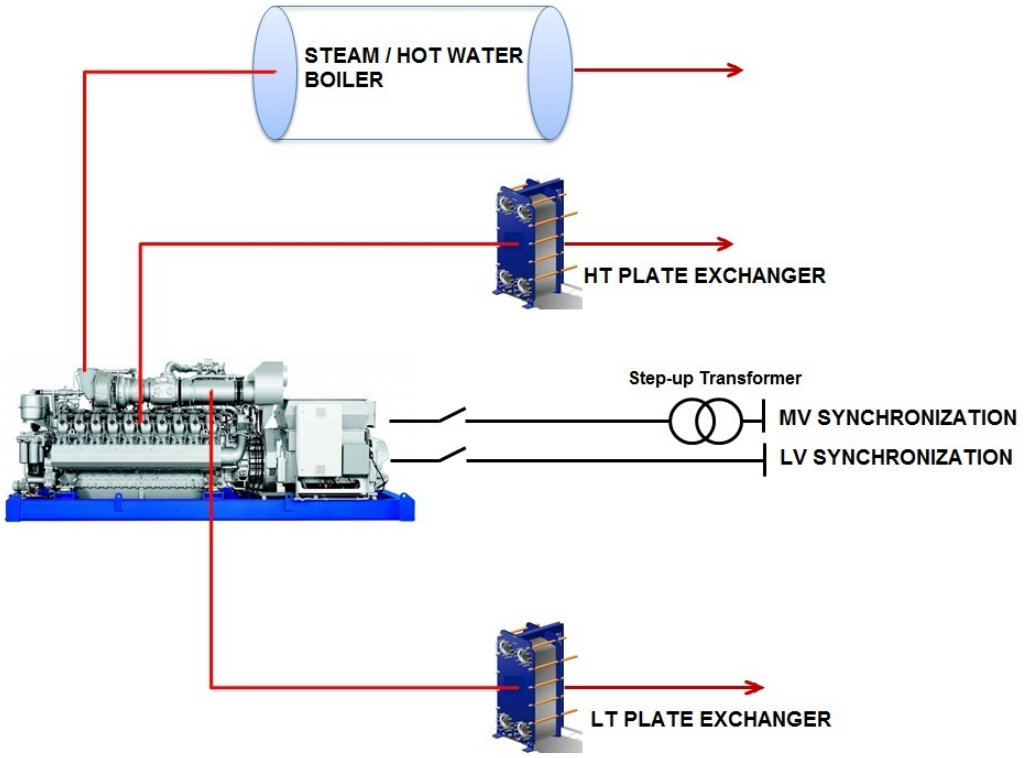


Figure 2.19. Combined heat and power system

Cogeneration systems present higher efficiency than the conventional generation methods that generates the electricity and heat separately. The total efficiency of conventional system is close to 60%. The total efficiency of cogeneration system is close to 85%. Natural gas, liquid natural gas and biogas are the most common fuel types used in CHP systems. In an ordinary cogeneration system, outputs can be classified as exhaust gases, high temperature liquid circuit so called jacket water and low temperature liquid circuit so called after cooler or intercooler output. Exhaust gas is generally more than 500°C can be evaluated through a steam boiler, hot oil boiler or hot water boiler. The main criteria are the need of the facility where cogeneration system will be installed to select the boiler type. High temperature liquid circuit is connected with a high temperature plate exchanger that transfers its heat to the facility for utilization. For the low temperature liquid circuit, operation principle is the same as jacket water. Meanwhile, vital output is electricity generated in the synchronous generator which is directly coupled to the gas engine. In general, electricity is produced in the cogeneration system is cheaper than the grid and the heat outputs are extra gains of the cogeneration principle. CHP systems are preferred especially in hotels, hospitals, textile industry, paper factories, food industry, electrolytic copper industry, mining and waste water treatment plants where need both electricity and heat.

(Alexis et al., 2013) present a work to investigate whether a Hospital named as “Tzaneio”, located in Piraeus, Greece, is a potential candidate for the implementation of a cogeneration system and also to determine the most suitable cogeneration system (electricity and heat). Alternative energy scenarios have been examined that propose the installation of cogeneration units of different power capacity for various profiles of operational hours. A comparative evaluation has been carried out for the selection of the most suitable CHP unit. (Alexis et al., 2013) showed that when the main gas engine (Diesel with natural gas) operates 8000 h/year and the backup unit 5000 h/year, the cogeneration system is most economically profitable. The total annual energy cost has been reduced by 32.4%. The benefit-cost ratio is greater than one, the net present value is positive and the internal rate return for 20 year lifetime of system is 19%. Also there is reduction of annual primary energy consumption by 28%, as well as a significant annual reduction of pollutant emissions.

(Silveria et al., 2012) aimed an approach for cogeneration plants evaluation based on thermo-economic functional diagram analysis. The thermo economic optimization method developed has been applied to allow a better configuration of the cogeneration plant associated to a university hospital. Also ecological efficiency has been evaluated. The method was efficient and was contributed for thermo economics modeling and analysis and can be applied to any sort of thermal system, especially those with CHP in thermal parity. Their case study has shown cogeneration alternatives to supply the energy demand of University Hospital of Campinas by using an alternative internal combustion engine. This hospital has 400 rooms, was built on a 60,000 m^2 area with 3000 people working there. Around 30% of all electric energy consumed have destined to air-conditioning system which is based on steam compression cycle. In the hospital, two different cogeneration technologies were used. The first technology appoints to use the residual heat from exhaust gases to produce steam and the other one uses the same residual heat from exhaust gases to produce cold water in an absorption machine. Four different cases were defined in their study, The most important case is that, alternative internal combustion engine with natural gas associated to an absorption refrigeration system with direct use of exhaust gases to produce cold water at 7°C replacing electric chillers, corresponding to a capacity of 700TR (2506 kWc). A double effect (two stages) absorption refrigeration system is jointed (COP = 1.2) to this system. At this case it is possible to achieve a global efficiency around 58% and the payback is five years, is viable with interest rates up to 8.5% with viability guaranteed for a minimum surplus electricity sale price of 0.035 US$/kWh. In (Gimelli and Muccillo, 2013), with regard to the S. Paolo Hospital in Naples, solutions that use three gas engines are particularly interesting and are characterized by energy savings of approximately 18%, simple payback of approximately 4 years and electric power output in the range 225-240 kW for each engine.

Similarly, Micro-CHP has been constructed at Mississippi State University (MSU) to show the advantages of these micro scale systems. (Giffin et al., 2013) evaluate the performance of a Micro-CHP system as opposed to a conventional high-efficiency HVAC system that utilizes electrical power from the existing power grid. It was concluded that the combined cycle efficiency from the demonstration site was averaged at 29%. The cooling technology used, an absorption chiller exhibited an average COP of 0.27. The conventional high-efficiency system, during cooling season, had a COP of 4.7. During heating mode, the conventional system had an efficiency of 47% with a fuel.

2.3.6. Fundamentals of Trigeneration Systems

Trigeneration or CCHP (stands for Combined Cooling, Heat and Power) is the simultaneous production of electricity, heat and cooling with respect to a single fuel type. CCHP system is shown schematically as given in Figure 2.20.

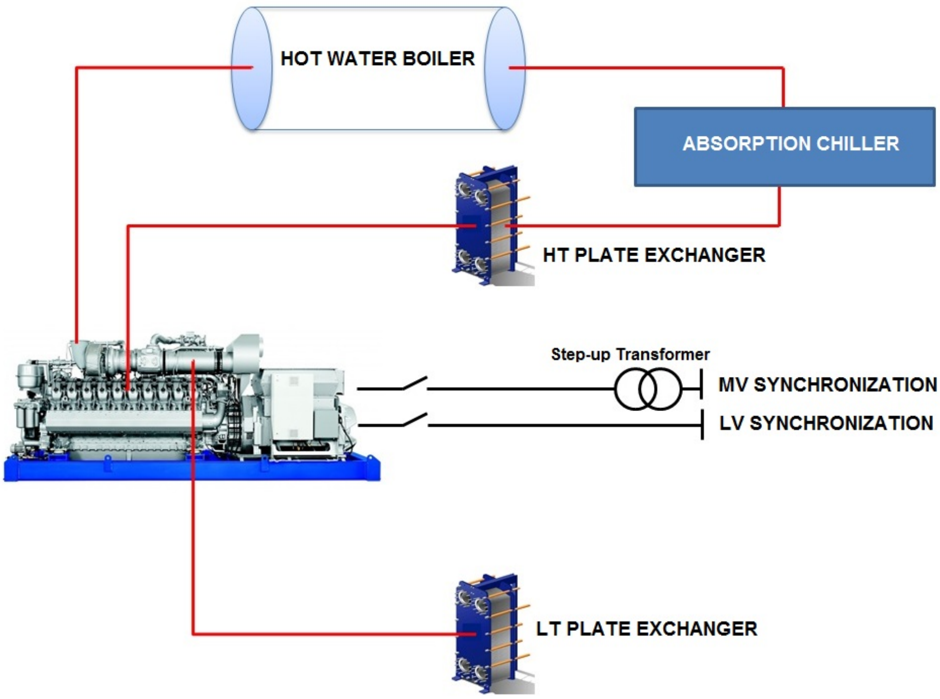


Figure 2.20. Combined cooling, heating and power system

Comparing with the conventional generation methods provide the generation of electricity, heat and cooling separately, trigeneration systems present higher efficiency. The total efficiency of trigeneration system exceeds 90%. Natural gas, liquid natural gas and biogas are the most common fuel types used in CCHP systems. In an ordinary cogeneration system, outputs can be classified as exhaust gases, high temperature liquid circuit so called jacket water and low temperature liquid circuit so called after cooler or intercooler output. The main difference between cogeneration and trigeneration in the structural design is the utilization of absorption chillers and cooling towers. Exhaust gas is generally more than 500°C may be evaluated through a hot water boiler that is linked with an absorption chiller and cooling tower in order to obtain cooling from heat. High temperature liquid circuit is also connected with a high temperature plate exchanger that also transfers its heat to the absorption chiller for cooling. For the low temperature liquid circuit, operation principle is the same as jacket water, but heat can be used for the facility like in cogeneration. Meanwhile, vital output is electricity generated in the synchronous generator which is directly coupled to the gas engine. In general, electricity is produced in the trigeneration system is cheaper than the grid and the cooling and heat outputs are extra gains of the trigeneration principle. CCHP systems are utilized especially in chemistry industry, hospitals, shopping malls and airports where need electricity, cooling and heat together. The most important part of the CCHP is the absorption chiller. Absorption chiller is different from typical chillers as shown in Figure 2.21 (Brandemuehl). The features and differences of absorption chiller can be summarized as replacing of the compressor with pump, absorbing of refrigerant in other liquid, pumping of the liquid to higher pressure, the using of heat to drive refrigerant from solution and no fluorocarbons of the system (Brandemuehl).

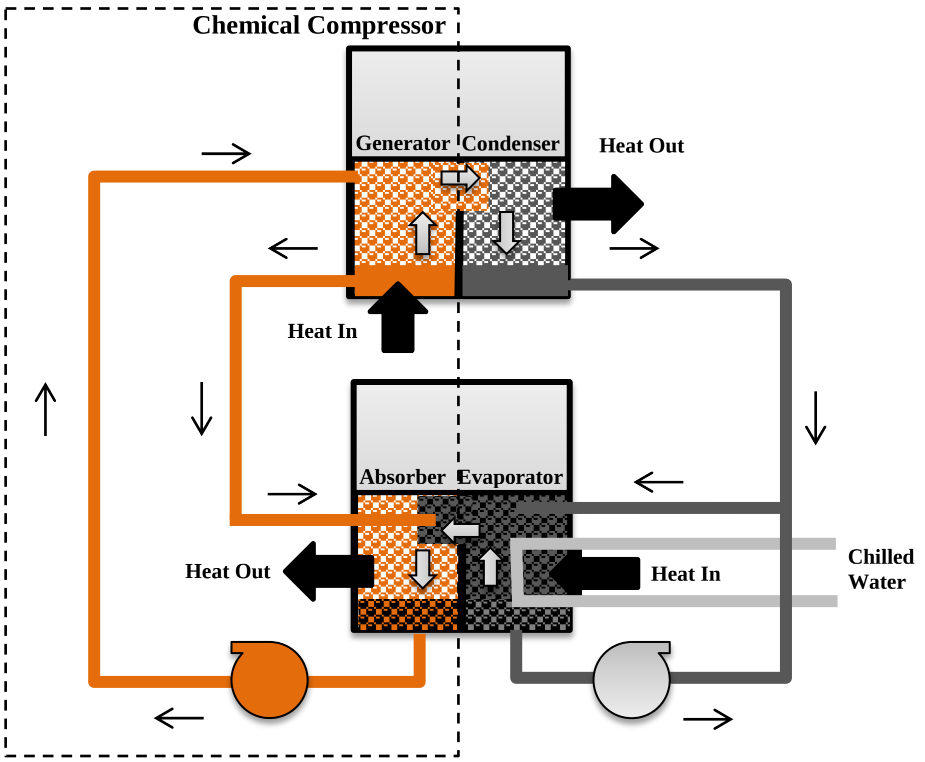


Figure 2.21. The schematic view of absorption chiller

In (Pagliarini et al., 2013), the feasibility study of a trigeneration plant intended to integrate the existing natural gas fired-boiler central plant serving a 714 bed hospital located in Parma, North of Italy, is presented. The electric load and the heat load for both sanitary hot water and process steam are estimated on an hourly basis from the monitored actual consumption. The space heating and the cooling loads, instead, are computed; on an hourly basis by the building energy software tool TRNSYS, by accounting for the actual climate of the considered location. The energy analysis points out that the primary energy saving index is inadequate for sizing the CHP. The approach based on the second principle of thermodynamics, instead, allows to identify its optimal configuration and size, i.e. CCHP with prime mover overall nominal capacity equal or higher than about 7 MW. The economic analysis shows that the maximum annual money saving occurs with tri-generation at a prime mover overall nominal capacity of about 7 MW with a system simple payback period is of about 1.25 years.

(Medrano et al., 2008) focuses analysis on the main economic, energy-efficiency and environmental impacts of the integration of three types of advanced DG technologies (high-temperature fuel cells, micro-turbines and photovoltaic solar panels) into four types of representative generic commercial building templates (small office building, medium office building, hospital and college/school) in southern California (e.g., mild climate), using eQUEST as energy simulation tool.

2.3.7. Different Studies on Cooling and Heating Systems

Energy saving in HVAC systems can be provided using natural thermal sources as thermal, solar and wind etc. (Paksoy et al., 2000) designed a new system which uses solar energy in combination with Aquifer Thermal Energy Storage (ATES) that will conserve a major part of the oil and electricity used for heating or cooling the Balcalı Hospital. The purpose of their system is to provide heating and cooling to the hospital by storing solar heat under ground in summer and cold in winter. As the main source of cold energy, ventilation air at the hospital and surface water from the nearby Seyhan Lake will be used. The system stores solar energy in the form of summer heat and winter cold in an aquifer. Two different well groups are used in the system. In the one of the well groups, cold can be stored and in the other well groups, heat can be stored. In the basic concept groundwater is pumped from one of the well groups and then heated or cooled within the building before being re-injected back into the aquifer in the other well group. At the result of their study, they have predicted that the environmental benefits from this project will be reduction in energy consumption as electricity and fuel oil and replacement of chillers using ozone depleting Freon-12 gas. The savings of fuel oil will be approximately 1000 m^3/year and this saving amount will approximately decrease the CO_2 emission by 2100 tonnes/year, SO_x by 7 tonnes/year and NO_x by 8 tonnes/year. The replacement of 2 MW of current chillers using Freon-12 will result in a saving of approximately 0.7 tonne/year of Freon-12.

Another study is also interested in ATES. (Vanhoudt et al., 2011) reports on a monitoring study of a low temperature ATES coupled to reversible heat pumps for heating and cooling a new hospital in near Antwerp over a three years period. The installation is used for conditioning of the ventilation air. The energy balance shows that the cooling was mainly provided by the direct use for groundwater (81% of the total cooling energy) while also 22% of the heating of the ventilation was provided by direct use of groundwater. The primary energy saving for the acclimatization of the ventilation air reaches 71% as compared to a reference installation composed of gas-fired boilers and compression cooling machines. Furthermore, it was reported that 1,280 tonnes CO_2 was saved after three years of operation.

The performance and economic evaluation of a solar heating and cooling system of a hospital in Crete is studied using the transient simulation program in (Tsoutsos et al., 2010). The investment cost of the proposed system is quite high. However, the application of the solar air conditioning system has several advantages compared to the conventional air conditioning system. The major benefit is that this technology is environmentally friendly and contributes to a significant decrease of the CO_2 emissions which cause the greenhouse effect.

(Ascione et al., 2013) has investigated building coating with isolation materials and its effects on cooling and heating systems. Energy, environmental and economic effects of rehabilitation of building envelopes have been investigated for health care facilities in the Day Hospital of “G. Pascale” Institute in (Ascione et al., 2013). Two building envelopes have been analyzed: the present building configuration and the designed renovated envelope. Adoption and improvements of effective air-conditioning systems are the main way for improving the use of energy.

The retrofit of the building envelope has been evaluated surely convenient also for health care facilities, in terms of energy savings and microclimatic control. However, being the energy requests of health care facilities mainly connected to the thermal-hygrometric transformations of the outdoor air, beyond the energy efficiency of the building envelope, adoption and improvements of effective air-conditioning systems are the main way for improving the use of energy. Usefulness of cogeneration and trigeneration systems combined, depending on specific peculiarities, to adsorption dehumidifiers and/or to absorption chillers is concluded in (Ascione et al., 2013).

Practical applications of improving energy efficiency and saving in HVAC systems are summarized in Table 2.20 (BSE, 2013), (Brush et al., 2011), (Lorenzo, 2010), (Gordo et al., 2011), (Gowrishankar et al., 2013), (Midwest, 2004).

Table 2.20. Energy saving applications in HVAC systems

Application details	**Energy saving (kWh/year)**	**Energy savings ($/€ per year)**	**Simple payback (years)**
Arcelor Mittal Indiana Harbor complex completed the installation of a 38-MW CHP system to utilize previously wasted blast furnace gas **(Installation of CHP)**		$20,000,000	1.6
Sikorsky's 10-MW CHP plant (Gas turbine, natural gas), which provides 84% of the facility's electricity needs and 85% of its steam-heating needs **(Installation of CHP)**		$6,500,000	<4
Baptist Medical Center installed a 4.3-MW natural gas turbine. Since the center's recent expansion, the CHP system is capable of meeting 60% of the facility's electrical needs, 80% of its steam needs and 30% of its cooling needs **(Installation of CHP)**		$800,000	6.3
Illinois hospital installed 3.2 MW CHP system **(Installation of CHP)**		$640,000	3.8
Beloit Memorial Hospital installed a 3-MW CHP system which provides the hospital with 1.5 MW of power and the additional 1.5 MW is sold to the local utility, Alliant. In addition, the CHP provides heating, cooling and hot water to the entire facility **(Installation of CHP)**		$223,000	5.4

3.45 megawatt Cooling, Heating and Power system was placed into operation by Ballard Engineering for Northwest Community Hospital **(Installation of CCHP)**		$722,000	2.9
2.0 MW CHP Application supplying all of their needed electricity, heating and cooling in Advocate South Suburban Hospital **(Installation of CCHP)**		$200,000	8
1,000 kW CHP system operating in a hypothetical hospital within the NIPSCO service area **(Installation of CHP)**		$187,459	3.6
In the dairy industry, one facility reported that by installing a system to track its real-time energy usage and emissions, significant opportunities were identified for no-cost behavior modification (staggered boiler start-ups) **(Compressed air, boiler system and refrigeration system improvements)**.	2,800,000		1.2
At the J.R. Simplot Company potato processing facility in Caldwell, Idaho, the installation of new burners equipped with process controls and a flue gas trim system led to significant annual savings in natural gas consumption. Natural gas consumption was reduced by 7.5% **(Installation of new burners)**		$279,000	1.16
At the Odwalla Juice Company's facility in Dinuva, California, an economizer was installed. **(Installation of new economizer)**		$21,000	0.83
A Unilever Canada margarine plant installed a condensing economizer **(Installation of economizer)**		$378,000	1.32
Green Giant of Canada, a manufacturer of frozen and canned vegetables, installed a shell and tube heat exchanger to recover heat from boiler blow down **(Installation of heat exchanger)**		$1,500	2
At a Land O'Lakes dairy facility in Tulare, California, a U.S. DOE sponsored energy assessment estimated that implementing a steam trap maintenance program **(Steam trap maintenance)**		$278,000	<0.33
Steam Traps Preventive Maintenance in Hoboken University Medical Center **(Steam trap maintenance)**		$6,840	1.8

U.S. based food processing facility predicted that the installation of a flash steam recovery system (**Installation of a flash steam recovery system)**		$29,000	<1.8
Stahlbush Island Farms, a grower, canner and freezer of fruits and vegetables in Corvalis Oregon, installed timers to cycle the evaporator fans of its cold storage unit **(Installation of a timer)**	133,000	$4,500	0.25
Solar air heating systems, such as Solar wall, use conventional steel siding painted black to absorb solar radiation for insulation. Ford Motor Company turned the south wall of its plant into a huge solar collector **(Installation of a solar air heating systems)**		$300,000	<3
The A. Lassonde Company replaced its old electric water heating system used for pasteurization with a pair of 880 kW natural gas-fired compact immersion tube water heating units. **(Installation of a natural gas-fired water heating unit)**		$18,100	<2
Existing HVAC system consisted of individual AHU on each floor equipped with DX cooling AHU rejecting heat to condenser water loop/cooling tower system. The system upgrade consisted of converting the DX cooling to central plant chilled water cooling by changing out the AHU coils and adding efficient variable speed drive centrifugal chillers **(Converting the DX cooling to central plant chilled water cooling)**	2,900,000		2.7
Chillers replacement in a public Portuguese hospital. Existing chiller: 375 kW, COP 2.53.New chiller: 317 kW, COP 3 **(Chiller replacement project)**	876,960	€98,414	3.8
Palm Beach Hotel increases cooling system efficiency by replacing old chillers of 300 kW with a higher COP new Chiller of 340 kW. **(Chiller replacement project)**		$23,760	3.3
Chillers replacement in a New York Hospital Queens. Super-efficient electric chiller bonus by exceeding standard energy efficiency criteria by at least 2% at full load and by at least 12% at part load. **(Chiller replacement project)**	175,200	$33,304	2.8

Four seasons hotel in Sydney replaced one of the site's three older chillers and a high efficiency water-cooled model and old 3-cell wooden cooling tower with two new fiberglass towers. **(Chiller and cooling tower replacement)**	721,559	$79,313	5.4
Design and installation of new efficient chiller plant including the use of a "free cooling" plate and frame heat exchanger in Cabot's facility. In addition, several other efficiency improvements were implemented including VSDs on the primary and secondary chilled water pumps, condenser water pumps and root top units. **(Installation of new efficient chiller plant)**	1,200,000	$300,000	>4
Harvard University in Cambridge, Massachusetts Installed new high efficiency central chiller, converted air systems to VAV, installed DDC EMS and installed VFDs on pumps and fans. **(Installation of new efficient chiller)**	2,100,000		3.3
Carney Hospital in Dorchester, Massachusetts installed new high efficiency chillers under VFD control, modified AHU VFD, installed additional EMS controls, converted fixtures to super T-8 technology, modified VAV system in office building. **(Installation of new efficient chiller plant)**	2,711,000	$470,400	3
Colonnade Hotel in Boston, Massachusetts installed 250-tonnes frictionless centrifugal chiller, replaced standard-efficiency motors with ECM motors, installed new BAS, modified AHUs, installed efficient lighting with occupancy controls in various areas. **(Installation of new efficient chiller)**	1,259,490	$255,693	2.3
The standard ASHRAE chillers at Emory University Winship Cancer Institute was replaced with high efficiency one **(Installation of new efficient chiller)**	920,364	$46,018	2.17
Retrofit/Replace 100% Outside Air AHUs with Re-circulating AHUs at Hoboken University Medical Center **(Capability of re-circulating air)**		$41,740	3.2

Air curtain application by TMI LLC company, a minimum of 70% of the heat from being lost is saved using air curtain **(Air curtain application)**		$3,066	1.2
Wrap-around valve insulation jackets will be fitted to all uninsulated valves in the London School of Hygiene & Tropical Medicine **(Valve insulation jacket application)**	35,080	$2,555	1.5
2,000 removable, reusable insulation covers are being added throughout the UC's Uptown Campus in the University of Cincinnati. **(Valve insulation jacket application)**		$500,000	0.6

2.3.8. Summary

The main points of HVAC systems can be outlined as follows.

- According to international standards, the desirable indoor temperature is usually 20-24°C and the recommended levels of indoor relative humidity are 30-60%. Most standards recommend 20 ACH in a room (Balaras et al., 2007).
- The heart of the cooling unit in HVAC systems is chiller and the heart of the heating unit in HVAC system is boiler. According to condenser type, chillers can be classified as water cooled and air cooled. 69% of chillers are air cooled non-ducted, 25% of chillers are water cooled, 4% of them are water cooled with ducted and 2% of them are conderserless (Design, 2010). Similarly, 65% of boilers are gas fired, 28% of the boilers are oil fired and 7% of the boilers are electric (Energystar).
- Energy usage of the cooling systems with water cooled are 69% of energy in chiller, 11% of energy in condenser water pump, 11% of energy of chiller water pump and 9% of energy in cooling tower fans.
- Although the most of chillers used are air cooled, because of the old HVAC systems which bought at the hospital first installation, the most of the chillers at our hospital are water cooled. Similarly, although the most of boilers are gas fired, all boilers in heat center of our hospital operate with the fuel oil.
- With the selection of the efficient components and controls at the water cooled systems, energy used by chiller plants can be decreased 30 to 50% less energy

than the system designed (Design, 2010). Similarly, the most efficient boilers are gas fired. Energy efficient gas-fired boiler systems can have efficiencies between 85% and 95% (Energystar). Payback period of chiller replacement depending on the chiller size and efficiency will last between 3 to 3.5 years.

- VRV/VRF type of HVAC has very high COP. The seasonal energy efficiency of this system is excellent. According to studies performed, total installed cost of VRF is estimated 5%-20% higher than for chilled water systems. But VRF systems more efficient then the chilled water systems at the same time (Goetzler, 2007)
- Heat exchangers should be used for the heat recovery in the heating systems. When the new heat exchanger is added into the system, payback time will be between 1 to 2 years.
- Especially, at systems with the natural gas, cogeneration or trigeneration systems should be used for energy efficiency. The total efficiency of conventional system is close to 60% and the total efficiency of cogeneration system is close to 85%. Trigeneration systems are more efficient than the cogeneration systems. Trigeneration plants can reach system efficiencies that exceed 90%. Depending on the project type and the size of projects, the efficiency percentages of CHP or CCHP can be different. When the new CHP or CCHP is installed, the average payback time will be between 2.5 to 5 years.
- Aquifer systems can be used as different heating and ventilating system to save energy alternatively. Other alternative methods should be analyzed in detail and then if payback time is between 2-3 years then, they should be absolutely applied.
- All leakages should be prevented by using isolation materials and all joints points should be tightly sealed.
- Regular maintenance should be performed and especially all filters in HVAC systems should be cleaned periodically. Maintenance personals should join the vocational training programs and take the required certifications. Regular maintenance payback time will be about 0.5 to 2 years.
- The layout of objects in room is important for HVAC systems. Objects near the radiators or blowers of fan should be moved to the free space.

- Hospitals should be divided to zones according to conditioning and different AHUs should be used for every zone.
- Especially drug rooms and critical places should be controlled by devices which measure ambient humidity, temperature and ACH values for 24/7.
- Internal auditors should check the all consumption bills such as electricity and fuel oil. In addition, they should also check hospital units according to quality standards.
- The hospital's services operate 365 days a year, 24 hours a day. It is normal that average daily heat consumption on weekdays is always higher than on weekends because fewer employees work on weekends. This point should not be ignored and the sources of heating system should be arranged again.
- VSDs should be used in HVAC components such as pump motors, VAV fans and cooling tower motors. As presented in Section 2.2 (motor section), in a pump system with VSD, when the speed of pump decreases to 10%, the power reduction will be 27% that satisfy the energy saving.

3. PRESENT PROFILE OF ENERGY CONSUMPTION AT BALCALI HOSPITAL

3.1. General Information for Balcalı Hospital

The Faculty of Agriculture, founded in 1967 by Ankara University and the Faculty of Medicine, founded in 1972 by Atatürk University, was combined to form Çukurova University in 1973. As of the year 2013, Çukurova University has sixteen faculties, five colleges, thirteen vocational schools, one state conservatory, three institutes and twenty seven research centers. Çukurova University built on 20,000 acres includes a third step university hospital. Balcalı Hospital is at the right sides of the campus entrance as shown in Figure 3.1 (Google Earth view).

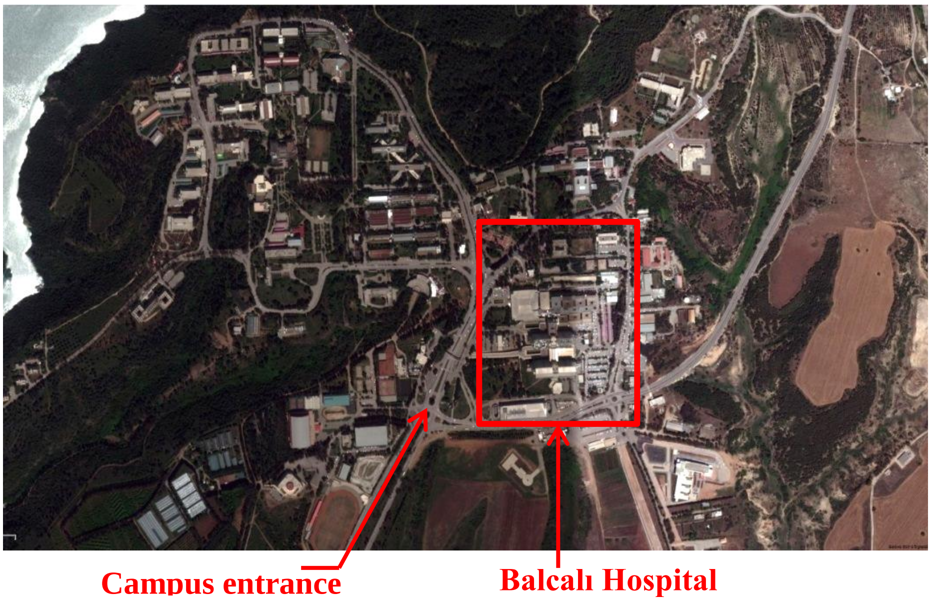


Figure 3.1. An aerial view of Çukurova University in Adana

The location plan of Balcalı Hospital is shown in Figure A.1 (Appendix A). The doctors working in the hospital are the personnel of Medicine Faculty. Divisions and departments of Ç.U. Medicine Faculty are shown in Table B.1 (Appendix B).

Balcalı Hospital continues its services with one emergency service, forty two polyclinics, twelve intensive care unit, twenty three operating room, forty three clinical services, five laboratories, one radiology unit, nuclear medicine, one blood center, one burn unit, one sterilization unit and one drugstore. The location plan of polyclinics is shown in Figures C.1, C.2 and C.3 (Appendix C). Balcalı Hospital (a pioneer hospital in Çukurova Region) includes one block with three floors polyclinics, two blocks with seven floors where forty three clinical services consist of a 128,536 m² closed area as shown in Figures D.1, D.2 and D.3 (Appendix D). Forty departments in the hospital (including Basic Medical Sciences) perform the scientific research and treatment services. Balcalı Hospital is accredited by Joint Commission International (JCI).

Internal Oncology, Pediatric Oncology, Pediatric Hematology Department, Department of Family Medicine and Departments of Child Psychiatry serve a separate building near the hospital with 3,960 m² closed area. In addition, outside of the hospital, 1,200 m² closed area of Nuclear Medicine and 570 m² indoor areas serving the Department of Radiation Oncology are located. Balcalı Hospital and its department are shown in Figure 3.2.

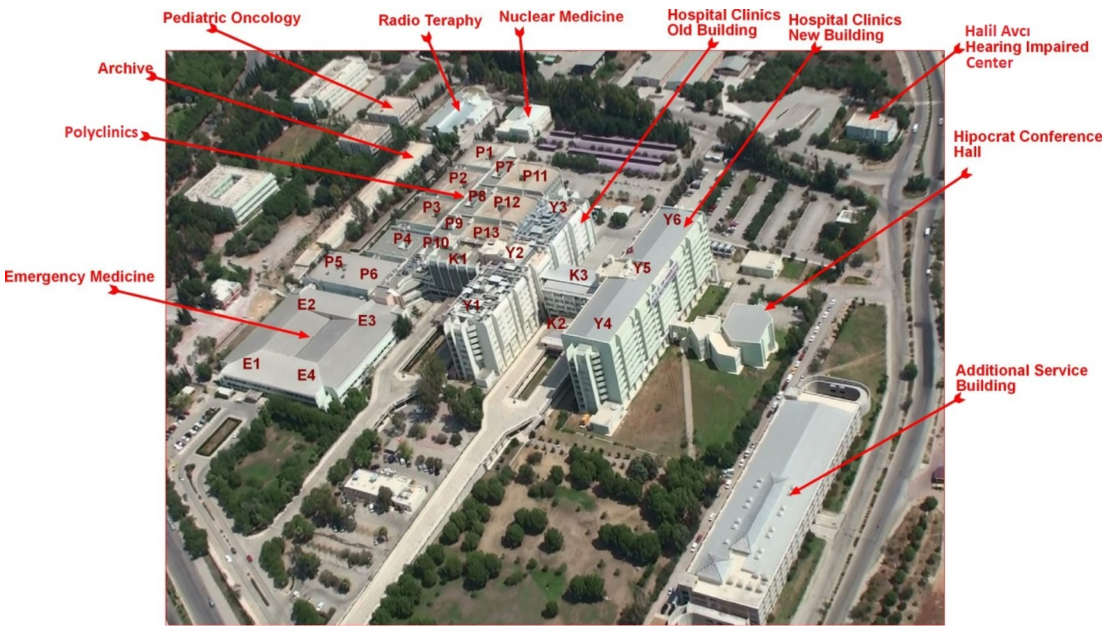


Figure 3.2. Departments of Balcalı Hospital

The total number of regular and 4B staff at Balcalı Hospital is 1584. The distribution of these staff is shown in Table E.1 (Appendix E). The total number of regular and 4B staff in the Faculty of Medicine Deanery is 182. The distribution of these staff is shown in Table E.2 (Appendix E). The titles of the staff in the hospital and faculty are given in Table E.3 in detail (Appendix E). The distribution of casual laborers is shown in Table E.4 (Appendix E). More than 2500-3000 patients in a day are treated at Balcalı Hospital. Hospital polyclinics serve approximately 52,034 hospital polyclinics patients and 4,005 clinical patients were treated at the beginning of June of 2013. This means that polyclinics patients in a year are approximately 625,000 patients and clinical patients in a year are approximately 50,000-60,000 patients. Intensive care unit including 179 registered hospital beds is one of the largest capacity unit of Çukurova region. Balcalı Hospital has 1000-1200 beds and approximately 65,000-85,000 surgical operations are performed in a year as shown in Table 3.1. Number of beds, medical examinations and inpatients in Ç.U. Balcalı Hospital is given in Table F.1 (Appendix F). Bed numbers in intensive cares are shown in Table F.1 (Appendix F).

Table 3.1. Surgical operations performed in 2010, 2011 and 2012

Surgical operation groups	**2010**	**2011**	**2012**
A	2,498	3,213	3,525
B	8,385	8,344	8,924
C	10,716	11,212	12,524
D	10,274	13,049	17,966
E	16,684	25,390	38,531
TOTAL	**48,557**	**61,208**	**81,470**

3.2. Transformers and Electricity Distribution Panels at Balcalı Hospital

Çukurova University has 56 distribution transformers and the installed capacity of the transformers is 43,930 kVA. 18,330 kVA of the 43,930 kVA belongs to Balcalı Hospital. The single line diagrams of transformers used in Çukurova University and Balcalı Hospital are shown in Figures G.1 and G.2 (Appendix G). List of transformers in Ç.U. is summarized in Table G.1 (Appendix G). The location of transformers at Balcalı Hospital is shown in Figure G.3 (Appendix G).

Single line diagrams of transformers and electricity distribution panels (EDP) at Balcalı Hospital are shown in Figures H.1 and H.2 (Appendix H), respectively. Single line diagrams of surgical operating room, electrical warehouse, laundry electricity distribution panel, Y4 electricity distribution panel, Y5 electricity distribution panel, Y6 electricity distribution panel, new central cooling system, Y1, Y2 and Y3 split air conditioners, kitchen electricity distribution panel, radiotherapy center, new intensive care, burn unit and emergency medicine, heat center electricity distribution panel and additional service building are shown in Figures H.3-H.16 (Appendix H), respectively. Total installed capacity of departments at Balcalı Hospitals is shown in Table I.1 (Appendix I)

Balcalı Hospital has 13 distribution transformers. The most of the compensation panels are equipped with harmonic filter reactors. The values of compansation capacitor groups and reactors are given in Table 3.2.

Table 3.2. The compansation capacitor groups and harmonic filter reactors

KVAR	2.4	7.5	10	12.5	15	20	25	30	40	50	60	80	100
L(mH)	15.3	5.11	3.83	3.07	2.56	1.92	1.53	1.28	0.96	0.77	0.64	0.48	0.38

The results of power quality measurements on these transformers are given in Table 3.3.

Table 3.3. Power quality measurements in transformers at the hospital

Unit		V1_rms (V)	V2_rms (V)	V3_rms (V)	U1_rms (V)	U2_rms (V)	U3_rms (V)	I1_rms (A)	I2_rms (A)	I3_rms (A)	THD_V1 (%)	THD_V2 (%)	THD_V3 (%)	THD_I1 (%)	THD_I2 (%)	THD_I3 (%)	PF_mean	DPF_mean	P (kW)	Q (kVAR)	S (kVA)
Surgical Operating Room	With Compensation	223.003	222.400	220.096	386.093	382.559	384.115	1259	1149	1217	0.667	0.702	0.876	2.409	2.087	1.820	0.992	0.992	791.112	95.875	797.664
	Without Compensation	218.563	217.329	216.269	377.184	375.453	377.027	1395	1422	1373	1.027	1.029	1.192	1.166	0.859	1.012	0.841	0.842	761.534	488.384	904.707

Y6		Y5		Y4		Laundry	
Without Compensation	With Compensation	Without Compensation	With Compensation	Without Compensation	With Compensation	Without Compensation	With Compensation
222.806	224.888	226.407	226.176	227.467	228.995	224.694	223.275
224.052	226.190	226.823	226.930	228.539	230.175	225.599	224.105
222.994	224.982	227.023	226.734	228.221	229.897	225.052	223.687
387.330	390.784	392.158	392.199	394.840	397.699	390.041	387.516
387.167	390.883	393.933	393.801	396.342	399.070	390.977	388.536
385.723	389.302	392.231	391.510	394.014	396.827	388.794	386.357
580.038	489.554	310.148	222.545	375.565	280.298	330.756	344.924
561.329	459.349	334.658	271.550	382.316	280.789	347.370	369.345
537.873	447.426	359.658	330.628	315.717	241.263	326.337	326.398
1.136	0.997	1.055	1.381	0.960	0.797	0.945	1.038
1.163	0.976	0.973	1.379	0.857	0.700	0.914	0.970
1.282	1.095	1.191	1.539	0.753	0.577	0.833	0.909
1.418	3.519	3.548	9.005	3.530	7.197	2.520	2.450
1.596	3.857	3.035	8.622	2.930	7.050	2.845	2.569
1.487	4.110	3.047	8.370	3.770	8.493	3.563	3.478
0.823	0.998	0.799	0.990	0.720	0.991	0.887	0.891
0.824	0.999	0.800	0.994	0.721	0.995	0.888	0.891
308.198	313.577	181.062	184.534	170.696	176.403	199.011	205.824
212.136	12.238	135.629	13.545	163.758	3.386	103.115	104.422
374.322	314.176	226.256	186.403	236.629	177.774	224.205	230.828

Radiation Oncology		Kitchen		Y1-Y3, Split Air Conditioner		Central Cooling Systems	
Without Compensation	With Compensation	Without Compensation	With Compensation	Without Compensation	With Compensation	Without Compensation	With Compensation
220.855	221.775	223.819	229.972	230.79	231.54	216.017	220.178
219.129	219.857	223.009	229.460	232.57	233.47	217.109	221.458
220.532	221.493	221.887	228.414	231.47	232.16	215.680	219.827
381.593	383.102	387.296	398.290	401.28	402.71	374.957	382.430
380.013	381.463	384.974	395.981	401.93	403.24	375.445	382.528
382.527	384.068	386.057	397.204	400.32	401.57	373.446	380.814
191.827	196.236	791.492	673.800	412.10	379.90	1419	1586
234.775	241.007	760.361	651.068	383.30	356.00	1472	1634
186.202	201.268	726.845	610.220	378.20	374.10	1461	1638
1.545	2.074	0.998	0.807	0.94	1.08	1.543	0.993
1.534	1.933	1.086	0.883	0.89	1.04	1.490	0.956
1.488	1.981	1.078	0.900	0.94	1.07	1.479	0.989
12.795	17.790	7.181	7.470	5.64	5.14	4.462	2.564
9.785	13.055	7.213	7.393	5.63	5.06	4.364	2.255
12.525	15.458	7.843	8.483	6.10	6.15	4.313	2.477
0.915	0.983	0.890	0.996	0.9443	0.9975	0.824	0.999
0.923	0.996	0.893	0.999	0.9966	0.9974	0.825	1.000
122.365	137.429	448.936	428.138	256.6	257.3	766.711	1061
53.390	-8.839	227.864	-3.364	89.5	-18.2	525.975	30.787
133.552	139.714	503.717	429.800	271.8	258	930	1062

Additional Service Building		Heat Center		Intensive Care II		Intensive Care I	
Without Compensation	With Compensation	Without Compensation	With Compensation	Without Compensation	With Compensation	Without Compensation	With Compensation
226.301	227.025	222.629	222.793	220.009	220.697	220.935	221.928
225.673	226.375	219.625	220.033	218.114	219.086	221.672	222.414
226.998	227.645	222.711	222.596	219.341	220.098	220.550	221.723
390.938	392.166	384.989	385.402	379.725	381.218	383.712	385.175
392.345	393.503	384.217	384.322	378.526	380.071	383.423	384.947
392.815	394.037	382.537	382.845	380.591	381.745	381.570	383.634
138.193	141.197	45.280	35.352	922.193	884.474	297.248	285.961
126.401	126.794	57.185	57.633	940.333	908.569	306.502	280.414
113.436	117.123	37.349	35.999	927.665	914.189	308.242	259.487
1.318	1.128	0.966	1.010	0.948	0.900	1.219	0.885
1.390	1.243	1.053	1.124	0.993	1.080	1.221	0.902
1.208	1.104	1.053	1.066	0.893	0.937	1.328	0.902
14.068	12.224	4.625	1.573	1.035	1.507	4.508	7.727
15.027	12.892	3.002	1.497	0.928	1.168	5.062	7.743
15.587	13.328	2.280	1.648	0.977	1.093	4.125	9.185
0.985	0.937	0.922	0.945	0.902	0.927	0.849	0.988
0.997	0.945	0.931	0.958	0.902	0.927	0.850	0.992
83.397	81.173	28.039	26.265	547.225	547.863	169.751	179.680
-9.847	-29.446	10.445	5.574	261.538	220.435	105.517	25.385
84.581	86.456	30.092	27.321	606.549	590.601	199.960	181.824

3.3. Electricity Consumption as kW and TL

Electricity consumptions as TL and kWh in 2011 and 2012 are shown in Figure 3.3 and Figure 3.4, respectively.

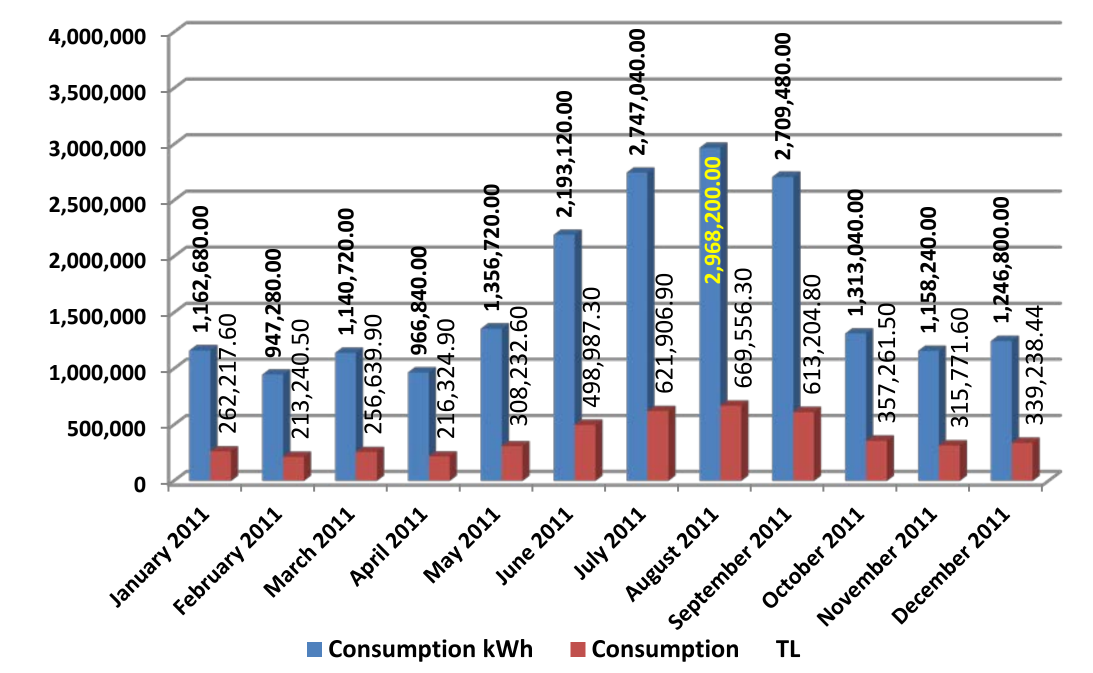


Figure 3.3. Electricity consumptions as TL and kWh in 2011

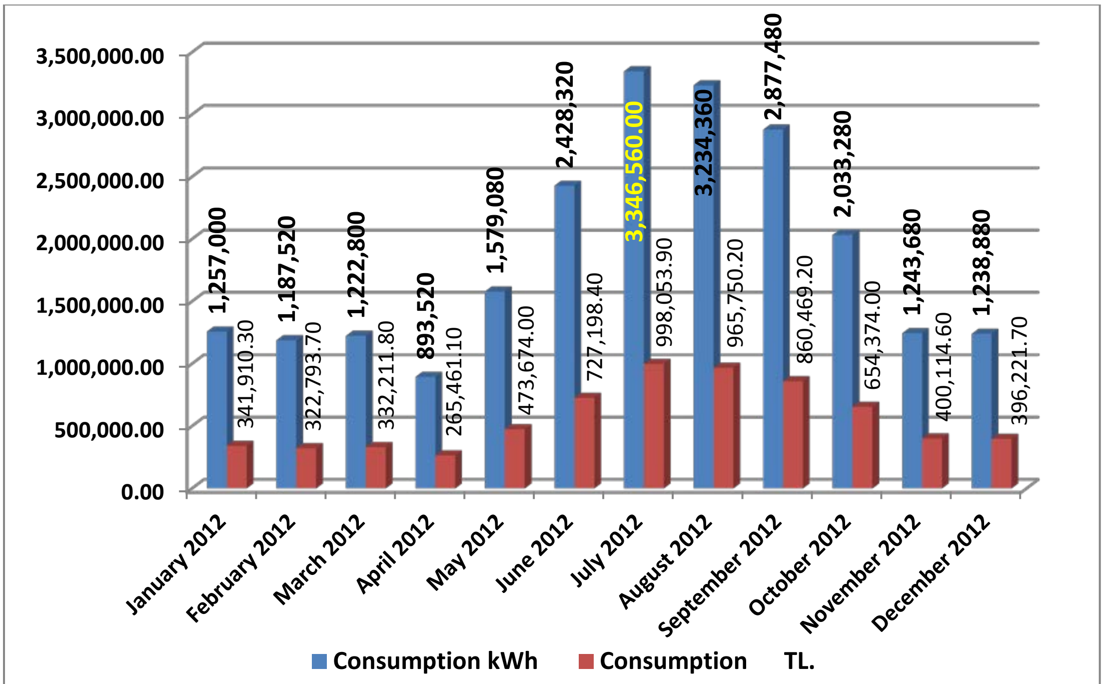


Figure 3.4. Electricity consumptions as TL and kWh in 2012

Electricity consumptions as TL and kWh for last five years are shown in Figure 3.5 and Figure 3.6, respectively.

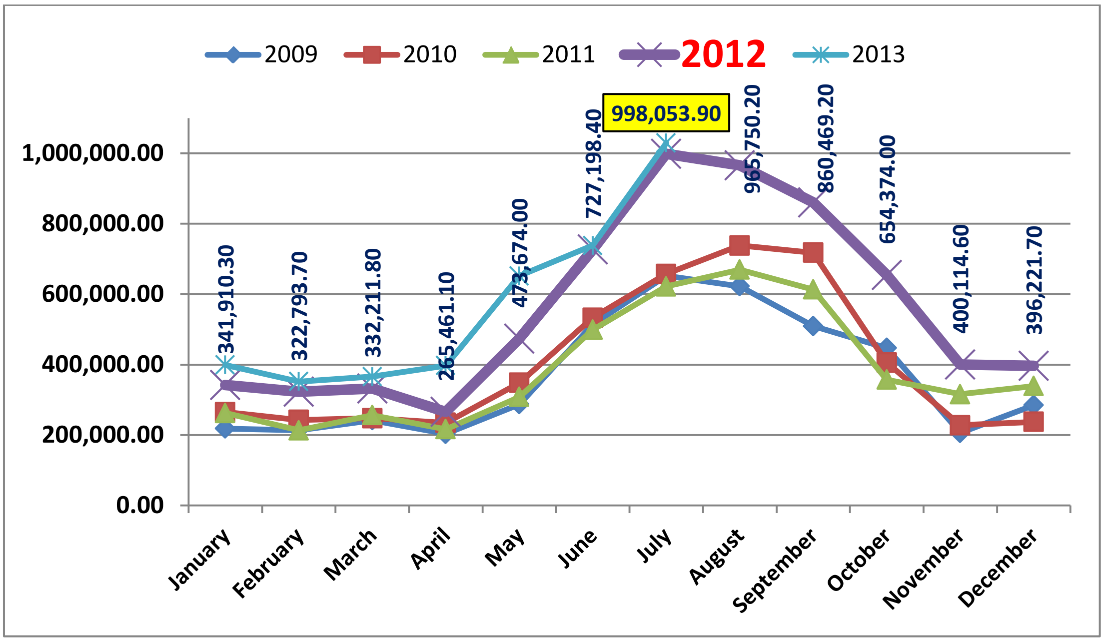


Figure 3.5. Electricity consumptions as TL for last five years

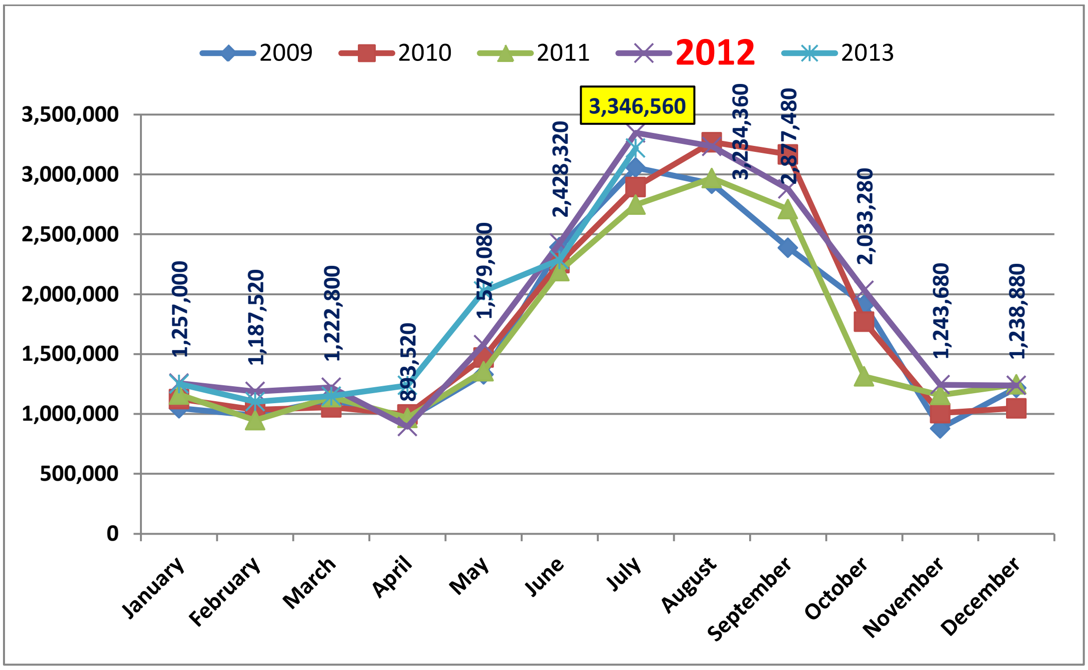


Figure 3.6. Electricity consumptions as kWh of last five years

Total electricity consumptions as TL and kWh for last five years in hospital are given in Table 3.4 and Table 3.5, respectively.

Table 3.4. Total electricity consumptions as TL for last five years in the hospital

Billing Period	2009	2010	2011	2012	2013
January	218,113.31	264,896.43	262,217.60	341,910.30	399,116.70
February	213,769.92	242,934.50	213,240.50	322,793.70	351,580.60
March	241,970.02	247,921.40	256,639.90	332,211.80	365,956.70
April	203,364.39	234,773.20	216,324.90	265,461.10	397,255.70
May	287,404.13	348,348.70	308,232.60	473,674.00	651,722.60
June	514,032.10	532,868.90	498,987.30	727,198.40	737.919,30
July	651,794.10	657,127.40	621,906.90	998,053.90	1.029.310,40
August	622,550.17	738,022.00	669,556.30	965,750.20	
September	509,526.50	717,846.70	613,204.80	860,469.20	
October	447,180.30	405,892.70	357,261.50	654,374.00	
November	206,016.88	228,070.30	315,771.60	400,114.60	
December	284,524.46	237,478.10	339,238.44	396,221.70	
Total	**4,400,246.28**	**4,856,180.33**	**4,672,492.34**	**6,738,232.90**	**3,932,862.00**
First 7 Months	**2,330,447.97**	**2,528,870.53**	**2,377,459.70**	**3,461,303.20**	**3,932,862.00**

Table 3.5. Electricity consumptions as kWh for last five years in the hospital

Billing Period	2009	2010	2011	2012	2013
January	1,048,080	1,124,520	1,162,680	1,257,000	1,250,640
February	987,960	1,034,400	947,280	1,187,520	1,102,680
March	1,120,320	1,055,280	1,140,720	1,222,800	1,148,760
April	956,520	995,880	966,840	893,520	1,238,880
May	1,330,320	1,471,320	1,356,720	1,579,080	2,025,840
June	2,391,600	2,259,960	2,193,120	2,428,320	2,285,760
July	3,056,880	2,894,520	2,747,040	3,346,560	3,220,080
August	2,922,120	3,268,920	2,968,200	3,234,360	
September	2,387,760	3,167,160	2,709,480	2,877,480	
October	1,909,320	1,769,400	1,313,040	2,033,280	
November	879,120	1,008,000	1,158,240	1,243,680	
December	1,217,520	1,046,880	1,246,800	1,238,880	
Total	**20,207,520**	**21,096,240**	**19,910,160**	**22,542,480**	**12,272,640**
First 7 months	**10,891,680**	**10,835,880**	**10,514,400**	**11,914,800**	**12,272,640**

Total electricity consumptions at Balcalı Hospital with detailed bill analyses in 2009, 2010, 2011, 2012 and 2013 are shown in Tables J.1-5 (Appendix J), respectively. Electricity consumptions at day, peak and night time periods in 2009, 2010, 2011, 2012 and 2013 are shown in Tables J.6-J.10 (Appendix J), respectively.

3.4. Lighting System of Balcalı Hospital

Types of lighting systems in the hospital consist of incandescent lamps, tungsten halogen lamps, fluorescent lamps, high pressure sodium lamps, low pressure sodium lamps, mercury vapour, metal halide and LED lamps blended. 18 W armature lamps in corridors are shown in Table K.1 (Appendix K). 36W and 4x18W armature lamps in corridors are given in Tables K.2 and K.3, respectively. 4x18 W, 2x18 W and 2x36 W armature lamps in the rooms at ground floor are shown in Tables K.4-6, respectively. 18 W and 2x36 W armature lamps in the rooms are given in Tables K.7-8, respectively. Armature lamps in surgical operating room are shown in Table K.9. Building at outside of Balcalı Hospital is shown in Table K.10. Environment lighting of Balcalı Hospital is shown in Table K.11. In Addition, all fluoresent lamps with electronic ballast are shown in Table K.12.

3.5. Heat Center of Balcalı Hospital

Heat Center: There are four steam boilers in heat center. 1-2-3 numbered steam boilers are HDR 550 type boilers. The steam production capacity of boiler is 5500 kg/hr. No.4 boiler is HDR 250 type. This boiler has 2500 kg/hour of steam production capacity. The operation pressure of all boilers is 4.2 bars. Safety ventils on boilers are set to 5.5 bars. When the pressure is reached at 5.5 bars, the more steam will be discharged. There are 80 pieces of fire-smoke pipe in No. 1-2-3 in boilers. There are 52 pieces of fire-smoke pipe in No. 4 boilers. There are degrading the flame inside of pipe turbulator. There are bottom and surface blowdown valves of the boilers. Bottom blowdown valves remain open for a period of 15 seconds for each hour. Blowdown valves are open during this process. Here the mixture of water vapor, condensation exchanger is connected to the blow-off came to the surface where No.4 boiler condensate tank for raw water pre-heating is going. No.1-2-3 boilers outlet stream valves have valve in 150. No. 4 boiler steam outlet valve have valve in 100. Boiler behind the chimney through the flue gas economizers are given out. As stated by the contractor during installation economizers, boiler feed water by heating to provide savings of 10%. No. 1-2-3 boilers have 55 cm in diameter, 19 m high chimneys. Boiler maintenance is performed general maintenance at the end of each season, intermediate care units are needed. The pressure testing is annually performed to the boilers by the Chamber of Mechanical Engineers. The details of boilers and burners at Balcalı Hospital are shown in Table L.1 (Appendix L). The view of distribution lines for the heat center is shown in Figure 3.7.

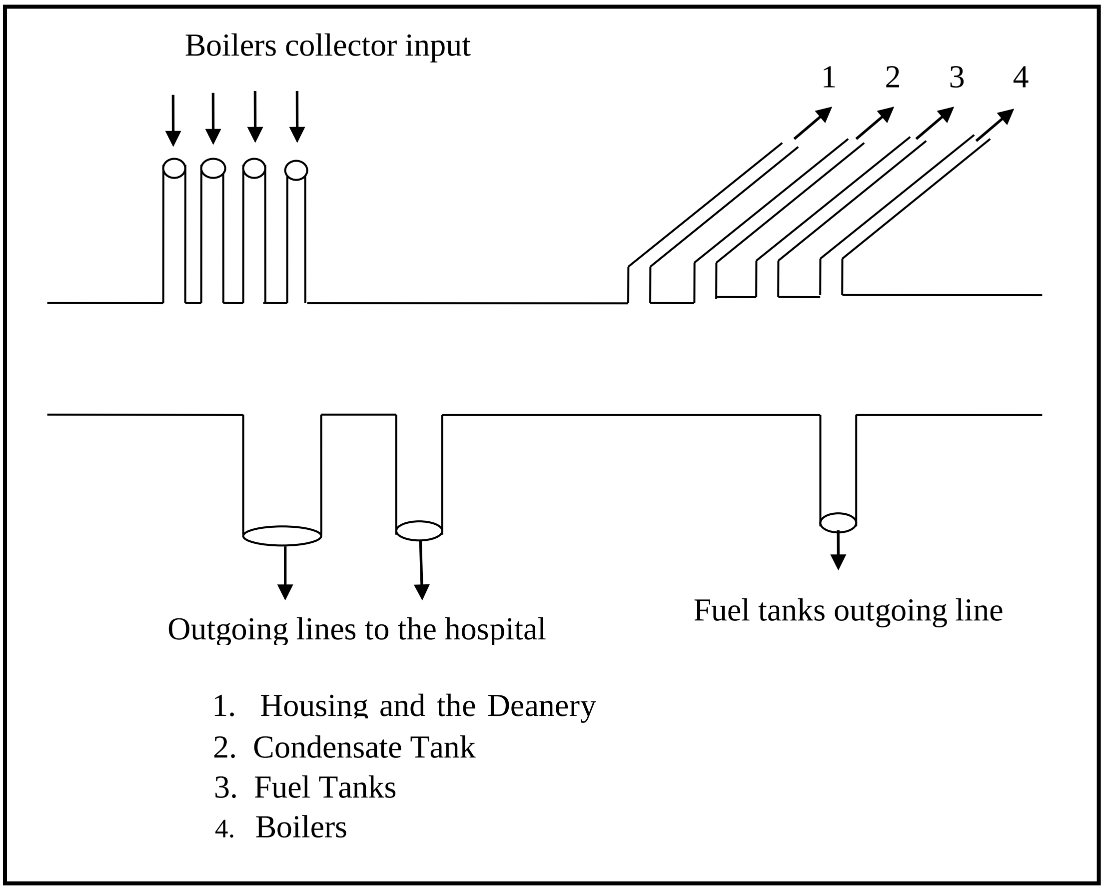


Figure 3.7. Distribution lines of the heat center

Burners: The burner is fully mixed with the appropriate ratio of fuel to be burnt with air in a device. No. 1-2-3 boiler burners are Eco 8 type. The burner works as proportionally. This burner is called as burner mamillate, their capacities are 165-

500 kg/h. Angled at 45 degree hill. Over 450 kg / hour capable of burning breast attached. For combustion of the fuel burners efficiently through the pot warmers after being heated to 110˚C, the burning of the fuel pump should be sprayed with a minimum pressure of 22 bars. Fuel, the pot before the ring heaters with a maximum of 2 bar pressure and circulation pumps (ring) is rotated and when necessary, pre-heaters are heated line.

Fuel Tanks: Fuel type used in the heat center is fuel-oil number 5. In former, fuel-oil number 6 had been used. The difference between the number 5 and 6 types is the ratio of sulfur to harbor. The maximum sulfur contents of fuel-oil number 5 and 6 are 2.8% and 3.5%, respectively. There was not any difference in their price of the number 5 and number 6 until 02/20/2009. Today, number 5 is 0.3 penny expensive than number 6. The main fuel tank capacity is 1600 tonnes of fuel oil. Transfer tank is 100 tonnes capacity. Daily fuel tank and fuel tank capacity of 5 tonnes. Fuel is stored in the main fuel tank. Fuel tank according to the level transfer of fuel is taken, there may be increased by means of transfer pumps. While daily fuel tank is filled by fuel, dispensing chemicals are added into the fuel pump. Daily fuel tank, fuel burners is transferred through the circulation pumps. There are pre-heating pots next to each burner, by the burner where the fuel is heated prior to cremation. In addition, given the main fuel tank and transfer the vapor to the fuel tank is heated.

Steam, condensate tank and water preparation: Condensate tank has a capacity of 60 tonnes. Condensation of water into steam turns into steam lines. Traps in the hospital, using the condensate line, condensate line coming from the condensate tank of water come together. The remaining water as soft water in the condensate tank is being reinforced. Raw water is filtered before the water softener in the sand, which has hardness of 0.5. The condensation exchanger is condensated by pre-heating. Condensate tank with soft water given to vicious anti-boiler chemical dosing pump providing flow at the mouth, water conditioning is done. Condensate tank, dosing pump in the boiler water through the suction line when the anti-corrosion chemical conditioning of water is dosed. The water in condensate tank is heated up by 70 ˚C using steam. Lines of 250 and 125 of the steam produced in boilers are sent to the hospital, a nurse with the line of 150 buildings, housing and medical school dean printed.

3.6. Fuel Oil Consumption as Tonnes and TL

Fuel oil consumptions tonnes of last five years are shown in Figure 3.8. The detailed views of consumption rates (the amount of steam as kg and kg/h) for years between 2009 and 2013 are shown in Tables L.2-L.6 (Appendix L), respectively.

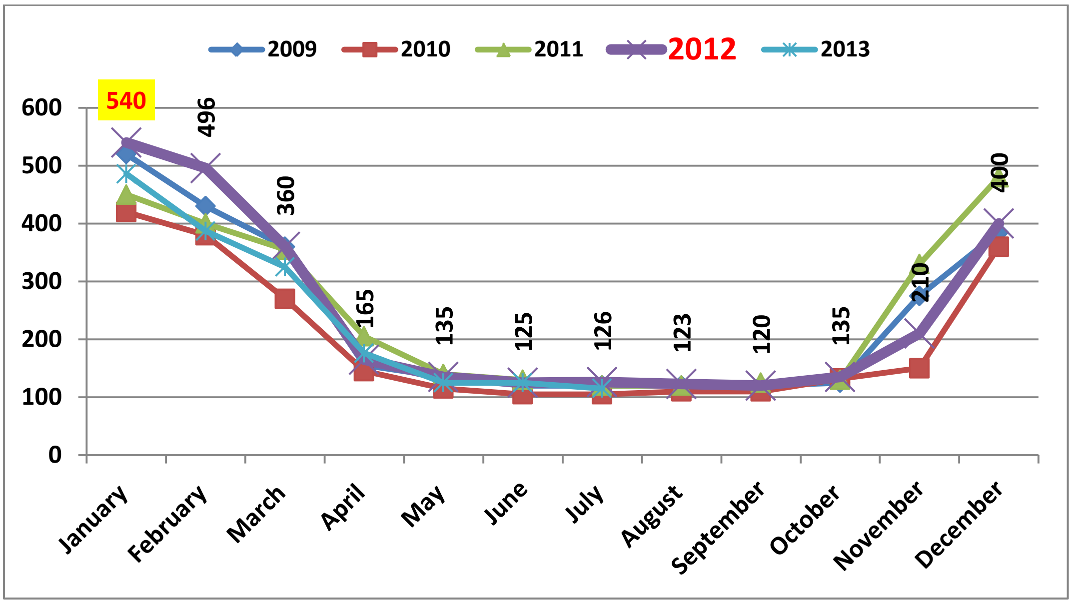


Figure 3.8. Fuel oil consumptions tonnes of last five years

Table 3.6. Fuel oil consumptions tonnes of last five years

Consumption period	Fuel oil consumption									
	2009		2010		2011		2012		2013	
January	520	tonnes	420	tonnes	450	tonnes	540	tonnes	486	tonnes
February	430	tonnes	380	tonnes	400	tonnes	496	tonnes	387	tonnes
March	360	tonnes	270	tonnes	355	tonnes	360	tonnes	325	tonnes
April	155	tonnes	145	tonnes	205	tonnes	165	tonnes	176	tonnes
May	135	tonnes	115	tonnes	140	tonnes	135	tonnes	125	tonnes
June	120	tonnes	105	tonnes	130	tonnes	125	tonnes	125	tonnes
July	120	tonnes	105	tonnes	120	tonnes	126	tonnes	115	tonnes
August	120	tonnes	110	tonnes	120	tonnes	123	tonnes		tonnes
September	120	tonnes	110	tonnes	125	tonnes	120	tonnes		tonnes
October	125	tonnes	132	tonnes	130	tonnes	135	tonnes		tonnes
November	275	tonnes	150	tonnes	330	tonnes	210	tonnes		tonnes
December	385	tonnes	360	tonnes	480	tonnes	400	tonnes		tonnes
TOTAL	**2865**	**tonnes**	**2402**	**tonnes**	**2985**	**tonnes**	**2935**	**tonnes**	**1739**	**tonnes**

As shown in Table 3.6, average consumption of fuel oil is approximately 3000 tonnes. Total of bill values is approximately 5,000,000-6,000,000 TL per a year.

3.7. Cooling and Air Conditioning System at Balcalı Hospital

Schematic view of the chiller cooling groups and the planned trigeneration plant at Balcalı Hospital is given in Chapter 4. The existing cooling system capacity and compressor values in the hospital are shown in Table M.1. The required cooling capacity, compressor motors, condenser and chiller motors, cooling tower fan motors, vantilator and aspirator motors and air conditioners, conditioning areas are shown in Tables M.2-8, respectively.In Addition, the matching of cooling groups and air conditioners is given in Table M.9. At Figure M.1, conditioning areas of cooling groups are shown.

There are 777 split air conditioner in the hospital. The numbers of split air conditioners at Balcalı Hospital is summarized in Table M.10.

Air conditioners in Additional Service Building: At the additional service building, there are new technology 26 VRF air conditioners. 8 numbers of these air conditioners are at the basement floor and the other 18 numbers of air conditioners are at the roof floor. 6 numbers of the air conditioner at the roof floor are at the east of building and the other 12 numbers of air conditioners are the west of the building. These air conditioners have 138 numbers internal unit and 4 numbers aspirator.

3.8. Boosters, Elevators, Compressors and Other Energy Consumption Devices

The features of boosters, elevators and compressors in the hospital are given in Tables N.1-N.3 (Appendix N), respectively. Table N.4. The properties of UPSs and generators used at Balcalı Hospital are shown in Table N.5 and Table N.6, respectively. The location of lightning rods at Balcalı Hospital is shown in Figure N.1.

4. ENERGY EFFICIENCY AND ENERGY SAVING OPPORTUNITIES AT BALCALI HOSPITAL

Energy-efficiency improvement projects can reduce in utility bill costs and in operations and maintenance costs. There are numbers of energy efficiency improvement applications for lighting, motors, VSDs and HVAC systems as stated in Chapter 2. 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 (Comed).

4.1. Implemented and Suggested Projects for Lighting Systems

Reducing lighting load pays back twofold. Not only is there less energy required for lighting, but it also reduces demand on the chiller due to reduced load (Wyczalkowski, 2009). Most of the lamps used for interior lighting of hospital are CFLs with magnetic ballast.

4.1.1. Exterior Lighting at Balcalı Hospital

The lamps used for the exterior lighting at Balcalı Hospital are 79 pcs 125 W mercury vapor lamps, 20 pcs 250 W mercury vapor lamps, 18 pcs 750 W metal halide lamps, 50 pcs 23 W CFL and 72 pcs 18 W fluorescent lamp with the conventional magnetic ballast as shown in Table K.11 (Appendix K).

- **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. 2 pcs 23 W fluorescent lamps and armature cost are 110 TL including all taxes.

Table 4.1. 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	49.7W	40	11	360	7,872	110	4,400	13,908	4,451	0.99

As shown in Table 4.1, 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:** At Balcali Hospital, the total installed capacity of mercury lamps for exterior lighting is approximately 5 kW at the back side of the parking. Table 4.2 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% ballast losses too. 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.

Table 4.2. 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	1000	17,931	5,738	0,17

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 years = 2.04 months.

Calculations:

Total Consumption of 250 W Mercury Lamp = 20 x250/1000x11x360x1.1
= 21,780 kW

Total Consumption of 45 W CFL = 20x45/1000x11x360x1.08
= 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) = 0.17x 12 = 2.04 month

Similarly to Table 4.2, if the 20 pcs of mercury lamps replace with 65 W LED armature. The cost of a LED armature is 472 TL. LED lamps have approximately 6% losses. As shown in Table 4.3, payback time will be found 1.81 years as a result of this replacement.

Table 4.3. The planned project_1b 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	-	-	-	-	-
65 W LED	68.9	20	11	360	5,457	472	9,440	16,323	5,223	1.81

As the below studying, 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.

Table 4.4. The planned project_2 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)
23 W CFL	24.84	50	11	360	4,918	-	-	-	-	-
7.5 W LED	7.95	50	11	360	1,574	35.4	1770	3,344	1,070	1,65

As shown in Table 4.4, when 23 W CFLs are replaced with 7.5 W LED lamps, saving TL in a year can be found 1,070 TL and payback time will be found 1.65 years.

- **Replacement Fluorescent Lamp with LED lamps:** At the exterior lighting, there are 72 pcs 18 W fluorescent lamps with magnetic ballast at the cafeteria under the viaduct. 18 W fluorescent lamps with the magnetic ballast have 50% ballast losses and LED lamps have 6% losses.

Table 4.5. The planned project_3a 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)
18 W Fluorescent	27 W	72	11	360	7,698	-	-	-	-	-
7.5 W LED FL	7.95	72	11	360	2.267	35.4	2549	5,431	1,738	1.47

As shown in Table 4.5, when 72 pcs 18 W fluorescent lamps with the conventional magnetic ballast are replaced with the 72 pcs 7.5 W LED fluorescent lamps, 1,738 TL will be saved in a year and payback time will be found 1.47 years.

- **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 under the viaduct. 18 W fluorescent lamps with magnetic ballast have 50% ballast losses and 18 W fluorescent lamps with electronic ballast have 14% ballast losses.

Table 4.6. The planned project_3b 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)
18 W Fluorescent	27 W	72	11	360	7,698	-	-	-	-	-
18 W Fluorescent with electronic bal.	20.5 W	72	11	360	5,845	14	1008	1,853	593	1.7

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 14 TL (All taxes are included to this price). After the calculations, payback time will be found 1.7 years and saving TL in a year will be 593 TL as shown in Table 4.6.

- **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.

Table 4.7. The planned project_4 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)
750 W Metal Halide	855W	18	11	360	60,994	-	-	-	-	-
120 W LED lamps	127W	24	11	360	12,070	680	16,320	48924	15656	1.04

As shown in Table 4.7, 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 period of these projects is changed between 0.17 and 1.65 as shown in Figure 4.8.

Table 4.8. 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	**5,431**	**1,738**	**2,549**	**1.47**
3b	1,853	593	1,008	1.7
4	**48,924**	**15,656**	**16,320**	**1.04**
Feasible projects	**75,630**	**24,202**	**21,639**	

4.1.2. Interior Lighting at Balcalı Hospital

Most of the interior lightings armatures at Balcalı Hospital are conventional fluorescent lamps with the magnetic ballast as shown in Table K1-K10. 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 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. In the following paragraphs, replacement analysis is performed.

- **Replacement mercury lamps with the CFL and LED:** During this thesis 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.

Table 4.9. The implemented project for interior 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	16	24	360	38016	-	-	-	-	-
45 W CFL	48.6	16	24	360	6718	50	800	31298	9389	0.09

As shown in Table 4.9, 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 0.3 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 = 16 x250/1000x24x360x1.1
= 38,016 kW

Total Consumption of 45 W CFL = 16x45/1000x24x360x1.08
= 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
= 31,298 * 0.3 TL = 9,389 TL.

Payback time (year) = Total Installed Cost / Total Saving TL.
= (Lamp Cost x # of Lamp) / Total Saving TL.
= (50x16) / 9,389 = 0.09 year

Payback time (month) = 0.09 x 12 = 1.08 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.

Archieve, radiation oncology and nuclear medicine building are taken as example areas. Armature, lamp pcs and total capacity are shown in Table K.10. 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 0.31 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 14 TL (All taxes are included to this price). 18W and 36 W electronic ballast prices are almost same.

As shown in Table 4.10 and Table 4.11, 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.

Table 4.10. 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)
18 W conventional FL with magnetic ballast	27W	766	9	360	67,010	-	-	-	-	-
18 W FL with electronic ballast	20.5W	766	9	360	50,878	14	10724	16132	5001	2.14

Table 4.11. The planned project_2 for interior 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)
36 W conventional FL with magnetic ballast	54 W	402	9	360	70,334	-	-	-	-	-
36 W FL with electronic ballast	41 W	402	9	360	53,402	14	5,628	16932	5248	1.07

- **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 4.12.

Table 4.12. The planned project_3 for interior 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)
18W conventional FL with magnetic ballast	27 W	766	9	360	67010	-	-	-	-	-
7.5 W FL LED	7.95W	766	9	360	19731	35.4	27116	47279	14656	1.85

As shown in Table 4.12, 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 4.13. By using the value of kWh/m^2, energy saving values and saved money as TL are calculated for all hospital.

Table 4.13. 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**

Total area of Balcalı 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 fluorescent lamps are calculated easily. If 4-lamp fixture with 18 W FL is used, 17,370 pcs 4-lamp fixture can be calculated.

Table 4.14. Energy saving potentials for replacement of all 18 W FL lamps

Lamp type	**18 W conventional FL ballast**	**7.5 W LED fluorescent lamps**	**18 W fluorescent lamps with electronic ballast (only ballasts will be changed)**
Energy consumption (W)	27 W	7.95 W	20.5
# of lamps	69,481	69,481	69,481
Hours/day	9	9	9
Days/year	360	360	360
kWh/	6,078,198	1,789,692	4,614,928
Unit cost (TL)	-	35.4	14
Total cost (TL)	-	2,459,627	972,734
Savings/year (kWh)	-	4,288,506	1,463,270
Savings/year (TL)	-	1,329,437	453,613
Payback period (year)	-	1.85 year	2.14 year

As shown in Table 4.14, 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.

- **Use of occupancy sensor for lighting control**: Use of occupancy sensors is most suitable for some corridors in the hospitals. As shown in Table 4.15, the occupancy sensors can be used in corridors of 7500 m^2 areas and can save approximately 30% energy as stated in Table 2.4. The total capacity of corridors will be equipped with occupancy is 67,248 W. The annual consumption including ballasts losses is 326,825 kWh.

Table 4.15. 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)
7500 m^2	326,825	98,047	29.414	16.5	12,375	0.42

Table 4.16. Feasible projects for interior lighting

Project Number	Energy saving kWh / year	Energy Saving TL	Investment, TL	Payback Period ,year
1	16,132	5,001	10,724	2.14
2	16,932	5,248	5,628	1.07
3	47,279	14,656	27,116	1.85
4	**98,047**	**29,414**	**12,375**	**0.42**
Feasible projects	**98,047**	**29,414**	**12,375**	**0.42**

The total investment and energy saving potential for exterior and interior lighting are summarized in Table 4.17.

Table 4.17. 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	75,630	24,202	21,639
TOTAL	**173,677**	**53,616**	**34,014**

4.2. 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 4.18. Reducing the speed of the motor 15% of its nominal speed, 36% of energy saving can be provided by VSD.

Table 4.18. 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

4.2.1. Energy Saving with VSD

The total capacity of motors in the hospital greater than 5.5 kW is given in Table 4.19. 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.

Table 4.19. 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**

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.

4.2.2. 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 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.

Table 4.20. 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

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 4.21. Bold color project is feasible for the hospital.

Table 4.21. Energy saving potentials for overall motor and VSD systems

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

4.3. Implemented and Suggested Projects on the HVAC Systems

4.3.1. Heating System:

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 blowdown 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 our 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 (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.

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.Annual saving from these control devices is approximately 10,177,920 kcal. There are 1250 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 measuments is shown in Figure 4.1 and Figure 4.2,

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=712,739,000kg 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 1250 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.

Cost-effective, high-return investment is needed to be done urgently.

Figure 4.1. Steam Valves with/without valve jacket.

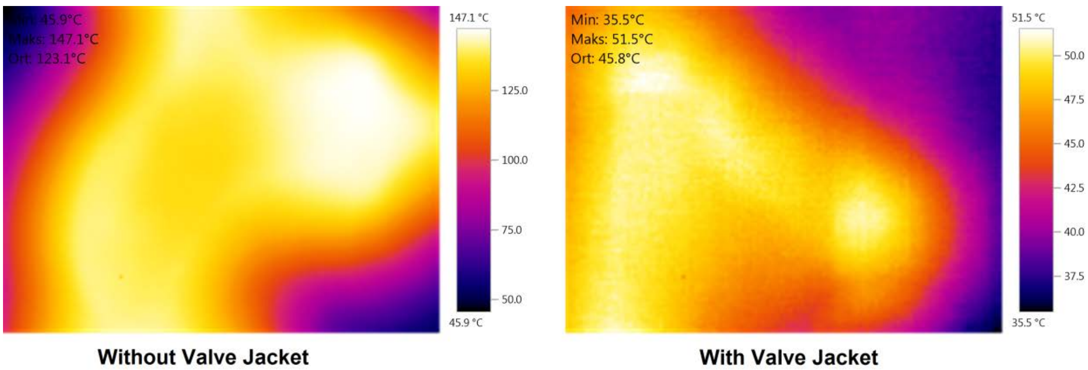


Figure 4.2. The measurement of the steam valves with thermal camera

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 7,000TL. 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 Balcalı Hospital for last 12 months is 4,749.40 TOE (23,960,320 kWh electrical energy (2060.58 TOE) and 2727 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**.**

4.3.2. 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.**

After installing to inverter system (central air-conditioning system or VRV system can be) average saving will be **40%.** 2,444,428.8 kW*0.40=977,771.52 kWh*0.3TL=293,331.45 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 4.9 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.

4.3.3. Implemented and Suggested Projects on the Cogeneration System

Cogeneration systems are getting more popular day by day because they create more energy efficient systems and reduce energy bills especially in industrial and social facilities whose electrical and heat energy demands exist simultaneously during whole year.

This feasibility study analyzes the electrical energy and heat energy consumption of Balcalı Hospital to establish an accurate and proper cogeneration power plant which will supply the hospital needs to generate electricity, steam and hot water. While analyzing energy demands, the first thing to do is examining the electrical energy consumptions. Hospital bill tariff is divided into three periods:

- Day time period (06:00-17:00)
- Peak time period (17:00-22:00)
- Night time period (22:00-06:00)

According to the local electrical distribution authority, without taxes and additional fees, unit price of the daytime period is 0.2187458 TL/kWh, the peak time period is 0.3645493TL/kWh and the night time period is 0.1091187TL/kWh respectively. Cumulative tariff price average with respect to 24 hours per day depending upon the below prices is approximately 0.23 TL/kWh and to 16 hours per day (without night time) is calculated as 0.286 TL/kWh.

Consider that the system fuel input is going to be natural gas and a general approach while calculating the per unit price of cogeneration is;

$$Per\,Unit\,Price = \frac{(Nat.\,gas\,consumption\;per\;hour \times Unit\;price\,of\;natural\;gas)}{Total\,electrical\,output\;power\;per\;hour} \quad (4.1)$$

This calculation is vital in order to prove that electricity production by cogeneration fuelled by natural gas is cheaper than tariff price of distribution company:

$$Per\,Unit\;Price = \frac{(513.9m^3 \times 0.75\,TL/m^3\;)}{2145\;kWh}$$

Per unit price can be approximately calculated as 0.18 TL/kWh. By this result, it is shown that, the electricity production by cogeneration system propelled by natural gas is cheaper and economic comparing with the distribution company's tariff price despite neglecting heat energy production. If amount of heat energy production is taken into account, then per unit price roughly decreases to 0.14 TL/kWh at least.

This per unit price for cogeneration also mentions that buying electricity from the grid is more advantageous than producing electricity by cogeneration at nights, hence night time tariff is approximately 0.109 TL/kWh and indicates that it is not feasible to run the cogeneration systems at nights. The electricity consumption of hospital in 2012 is demonstrated in Figure 4.3, Figure 4.4 and Figure 4.5 respectively.

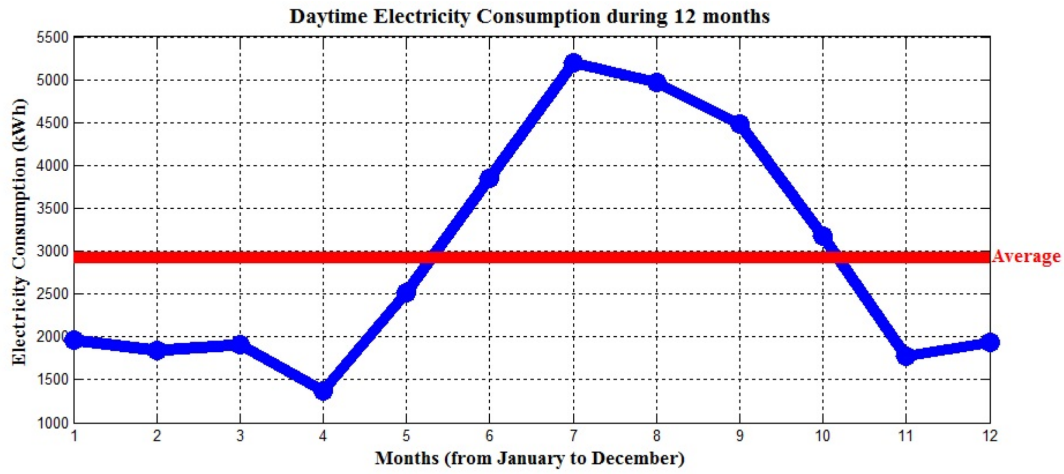


Figure 4.3. The daytime electricity consumption of hospital during 12 months

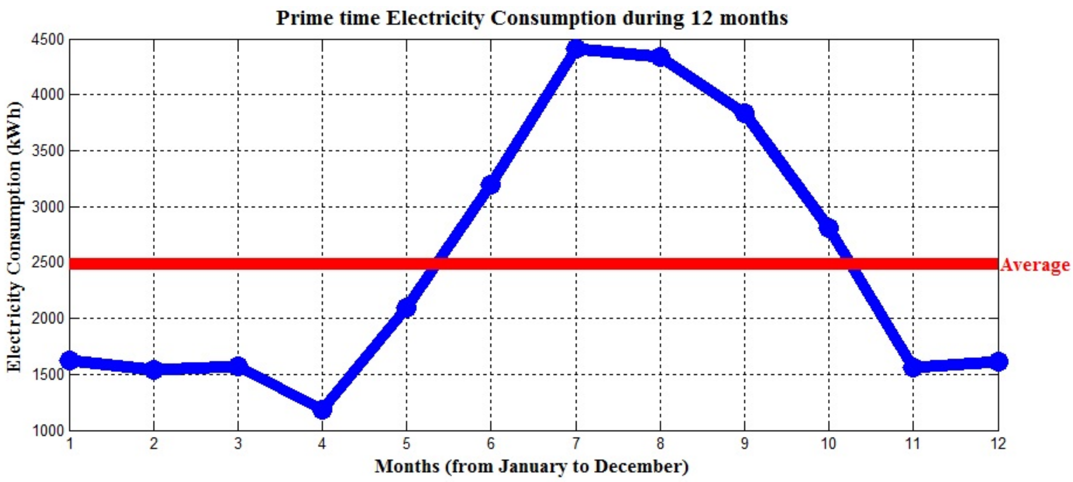


Figure 4.4. The prime time electricity consumption of hospital during 12 months

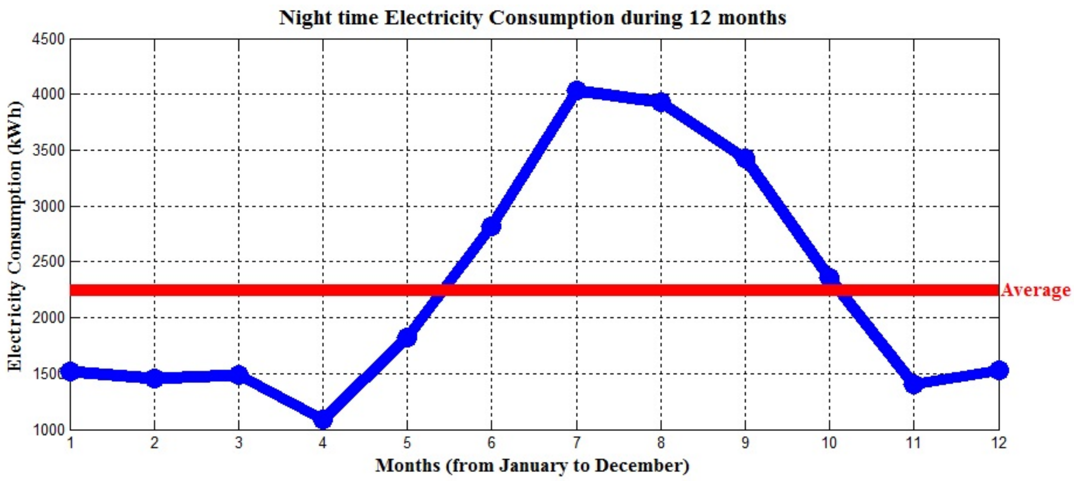


Figure 4.5. The night time electricity consumption of hospital during 12 months

While evaluating the electricity consumptions of a facility, a safe and optimum cogeneration capacity can be determined as selecting the capacity below the average consumption line for all periods. By combining this approach with the idea that the cogeneration system will not be run for the nights because of low electricity prices provided by the grid and according to the figures given above states that stable operation of cogeneration system in electrical meaning shall be facilitated around a capacity which should be less than 2.5 MW.

Meanwhile, a stable operation for cogeneration system should be provided by balancing the heat and electrical energy production simultaneously by selecting a capacity which can meet the desired demands for the facility at the highest level. It is also critical to place the cogeneration system should be close to the heat centers and medium voltage bus bars. Here in this hospital, there is an available site to establish cogeneration system very close to both heat collectors of the hospital and medium voltage level bus bars as shown in Figure.4.6

New cogeneration plant has been thought the inside of the existing heat center of Balcalı Hospital. At this situation, pipeline installation cost will be decreased automatically. All old pipelines can be used at the new cogeneration plant of hospital.

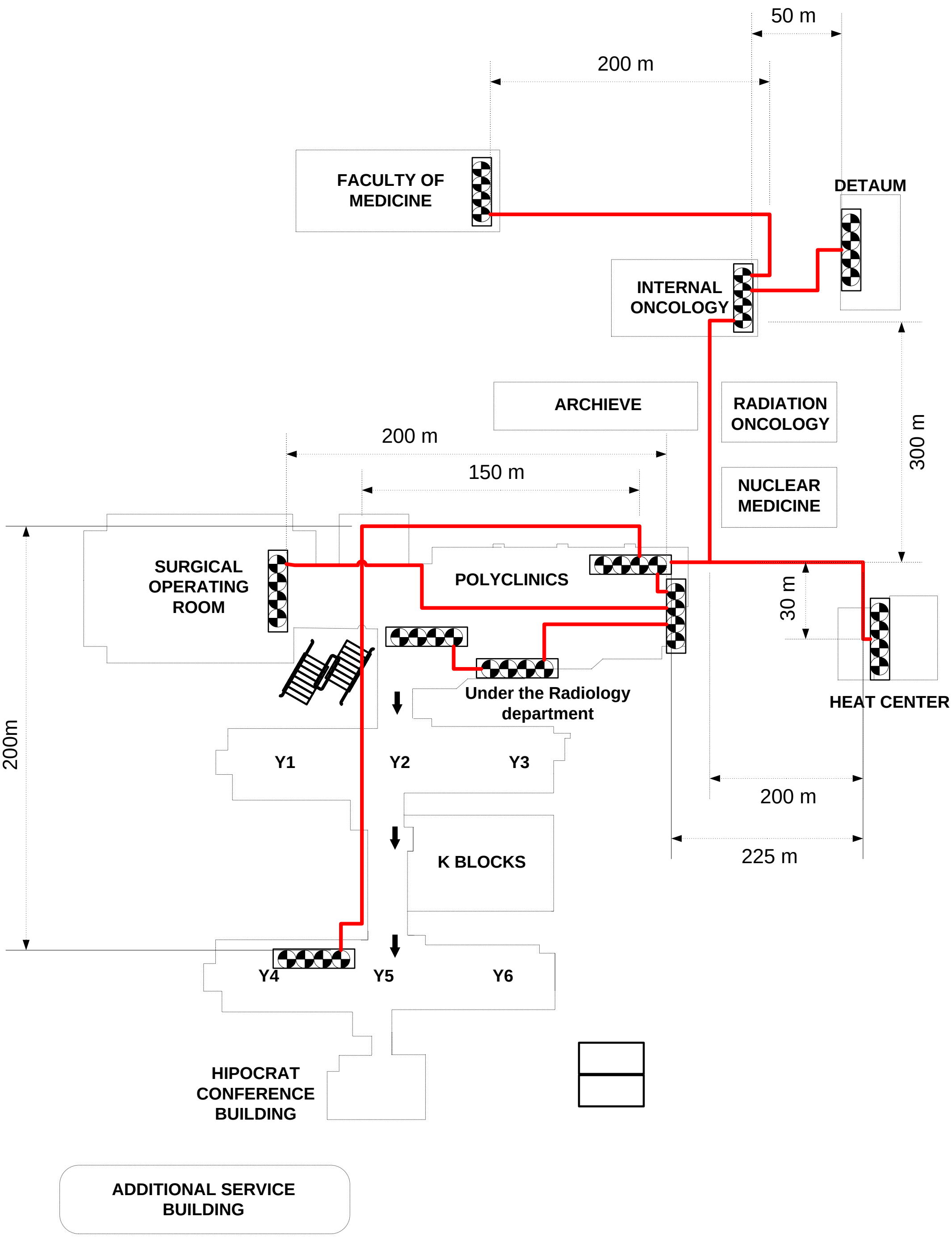


Figure 4.6. Schematical view of planned cogeneration plant

At Balcalı Hospital, there is a constant steam requirement about 2 tonnes/hour and a 2 MW cogeneration unit can supply at least 75% of this need, thus the capacity selected above is an optimum solution for the hospital. Moreover, hospital can utilize the HT circuit heat and LT circuit heat by absorbing from the plate exchangers.

To sum up, an efficient cogeneration system contains engine-alternator set, steam boiler, 0.4kV/31.5kV step-up transformer and a container can be settled at Balcalı Hospital (MTU, 2009). Feasibility of hospital will indicate below results: Total operating time is 5400 h/year.

Electricity Savings, (η=100%)

=5400h/year*2000kW*0.286TL/kWh

=3,088,800TL/year **(928.8 TOE/year)**

Heat Energy Savings, (Calculations were realized according to the utilization of natural gas for heat production)

- Steam, (η=70%)

=[[5400h/year*1000kW*80%$^{\text{Boiler Eff.}}$/(10$^{\text{LHV}}$kWh/m^3)]*(0.75TL/m^3)]*70%

=226,800TL/year **(249.48 TOE/year)**

- HT circuit, (η=20%)

=[5400h/year*1000kW*80%$^{\text{Exchanger Eff.}}$/(10$^{\text{LHV}}$kWh/m^3)]*(0.75TL/m^3)*20%

=64,800TL/year **(71.28 TOE/year)**

- LT circuit, (η=20%)

=[5400h/year*100kW*80%$^{\text{Exchanger Eff.}}$/(10$^{\text{LHV}}$kWh/m^3)]*(0.75TL/m^3)*20%

=4,880TL/year **(7.13 TOE/year)**

Total Savings,

=3.088.800+226,800+64,800+4,880

=3,385,280TL/year,

Fuel consumption,

=5400h/year*510m^3/h*0.75TL/ m^3

=2,065,500TL/ year

Internal electricity consumption,

=5400h/year*50kW*0.286TL/kWh

=77,220TL/year **(23.22 TOE/year)**

Internal electricity consumption will be subtracted from total electricity saving. As a result, total electricity saving can be calculated as (928.80-23.22=905.58 TOE/year)

Service and spare parts expenses,

=5400h/year*50TL/h

=270,000TL/year

Total Expenses,

=2,065,500+77,220+270,000

=2,412,720TL/year

Total Profit,

=Total savings-total expenses,

=3,385,280-2,412,720

=972,560TL/year

Cogeneration system expense:

Engine-generator set in a sound-isolated container,

Heat recovery steam boiler and its mechanical piping,

Switchgear units for medium voltage synchronization by using step-up transformer,

Neutral resistor and electrical cabling

Total Price: 2,250,000 TL

Depreciation period,

=Total price/Total profit

=2,250,000/972,560

=**2.3 years** (Estimated payback period)

A cogeneration system with steam boiler and electrically synchronized from medium voltage level would be a very sensible investment for Balcalı Hospital according to the calculations due to the above electrical and heat energy consumptions.

4.3.4. Implemented and Suggested Projects on the Trigeneration System

Trigeneration systems are creating more energy efficient systems and reducing energy bills especially in industrial and social facilities whose electrical, cooling and heat energy demands exist simultaneously during whole year.

This feasibility study analyzes the electrical energy, cooling energy and heat energy consumption of Çukurova University Balcalı Hospital to establish an accurate and proper trigeneration power plant which will supply the hospital needs in order to produce electricity, cooling, steam and hot water.

While analyzing energy demands, the first thing we have to do is examining the electrical energy consumptions. Hospital bill tariff is divided into three periods:

- Daytime (06:00-17:00)
- Prime time (17:00-22:00)
- Night time (22:00-06:00)

According to the local electrical distribution authority, without taxes and additional fees, unit price of the daytime period is 0.2187458 TL/kWh, the prime time period is 0.3645493TL/kWh and the night time period is 0.1091187TL/kWh respectively.

Cumulative tariff price average with respect to 24 hours per day depending upon the below prices is approximately 0.23 TL/kWh and to 16 hours per day (without night time) is calculated as 0.286 TL/kWh.

Consider that the system fuel input is going to be natural gas and a general approach while calculating the per unit price of trigeneration is;

$$Per\ Unit\ Price = \frac{(Nat.\ gas\ consumption\ per\ hour \times Unit\ price\ of\ natural\ gas)}{Total\ electrical\ output\ power\ per\ hour} \quad (4.2)$$

This calculation is vital in order to prove that electricity production by trigeneration fuelled by natural gas is cheaper than distribution company's tariff price:

$$Per\ Unit\ Price = \frac{(513.9m^3 \times 0.75\ TL/m^3)}{2145\ kWh}$$

Per unit price can be approximately obtained as 0.18 TL/kWh. By this result, we can obviously state that electricity production by trigeneration system propelled by natural gas is cheaper and economic comparing with the distribution company's tariff price despite neglecting heat energy production. If we take the amount of cooling and heat energy production into the account, then per unit price roughly decreases to 0.14 TL/kWh at least.

This per unit price for trigeneration also mentions that buying electricity from the grid is more advantageous than producing electricity by trigeneration at nights, hence night time tariff is approximately 0.109 TL/kWh and indicates that it is not feasible to run the trigeneration systems at nights.

The electricity consumption of hospital is demonstrated as shown in Figure 4.7, Figure 4.8 and Figure 4.9 respectively.

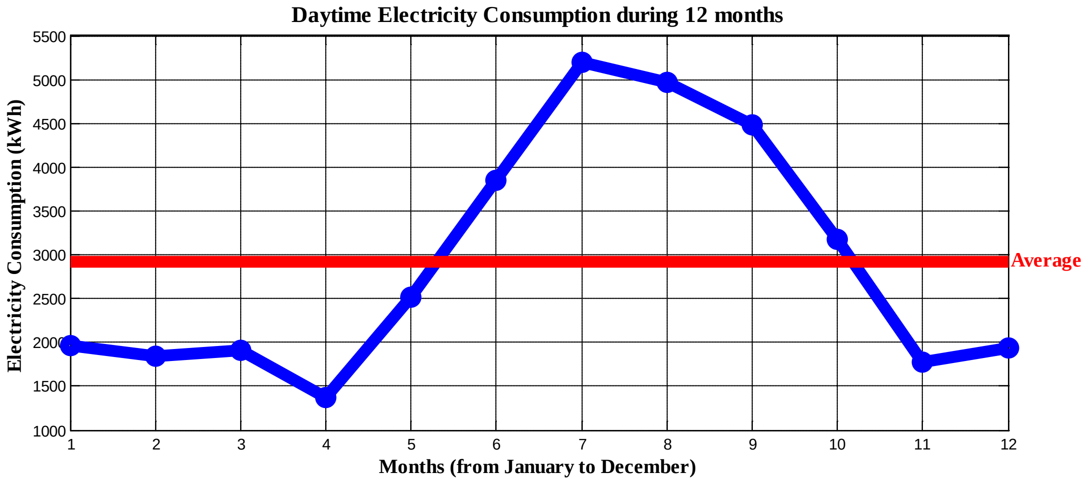


Figure 4.7. The daytime electricity consumption of hospital during 12 months

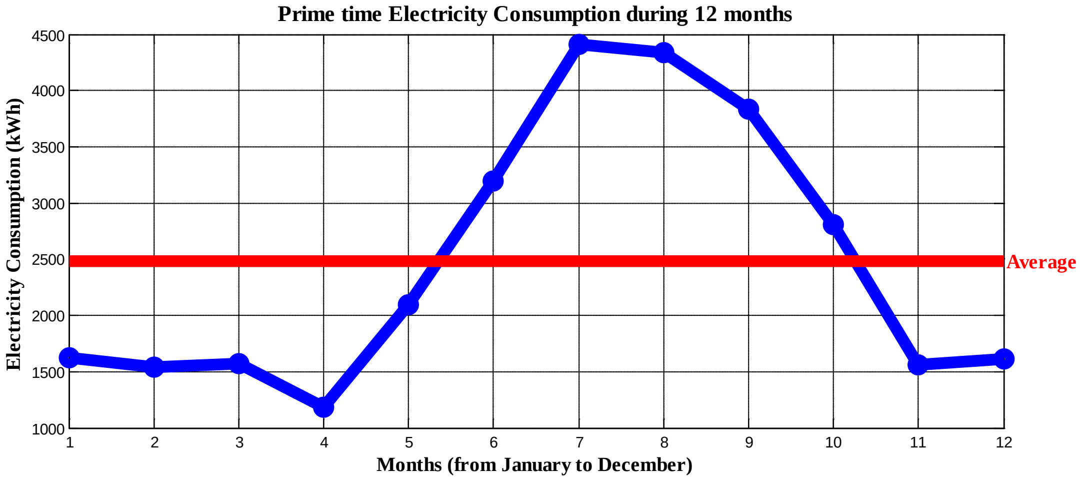


Figure 4.8. The prime time electricity consumption of hospital during 12 months

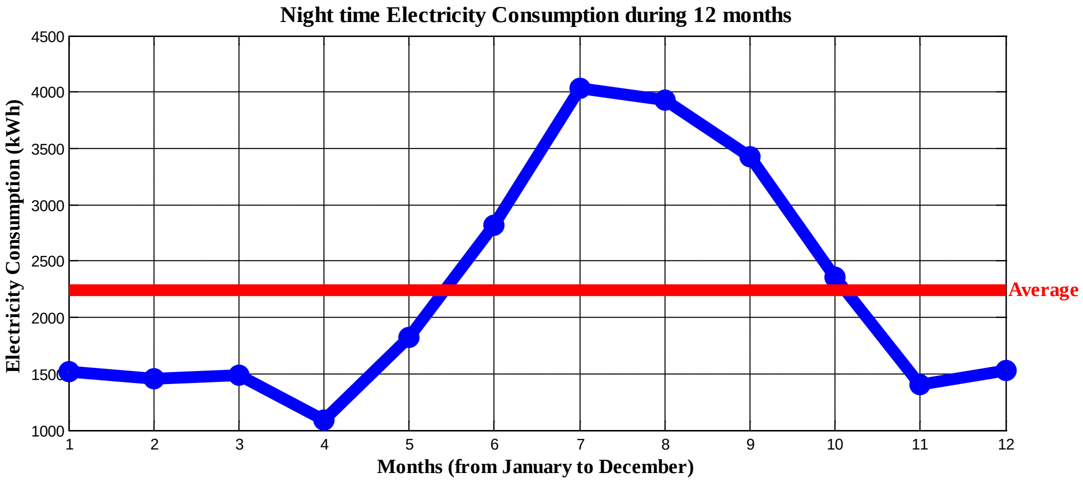


Figure 4.9. The night time electricity consumption of hospital during 12 months

While evaluating the electricity consumptions of a facility, a safe and optimum trigeneration capacity can be determined as selecting the capacity below the average consumption line for all periods. By combining this approach with the idea that the trigeneration system will not be run for the nights because of low electricity prices provided by the grid and according to the figures given above states that stable operation of trigeneration system in electrical meaning shall be facilitated around a capacity which should be less than 2,5MWh.

Meanwhile, a stable operation for trigeneration system must be provided by balancing the cooling, heat and electrical energy production simultaneously by selecting a capacity which can meet the desired demands for the facility at the highest level.

It is also critical to place the trigeneration system should be close to the cooling and heat centers and medium voltage busbars. Here in this hospital, there is an available and common site to establish trigeneration system very close to both heat collectors of the hospital and medium voltage level busbars, but in the hospital there is not a common cooling entrance point for the trigeneration system such as a collector component like in hot water systems. Chiller units are grouped in this facility, each group feeds different sectors indeed and any of them does not have an interaction in common. Thus, we are going to design a trigeneration center illustrated in the figure below by taking the idea that all chiller units have mechanical piping and interaction with each other into account. However this facility can be considered unfeasible for trigeneration because of high cost related with the extra piping in order to create a common line provides cooling interacted with absorption chiller unit belongs to trigeneration system.

The suggested location of trigeneration system is shown in Figure 4.10 and schematical view of planned trigeneration plant is shown in Figure 4.11.

Figure 4.10. The planned location of trigeneration plant

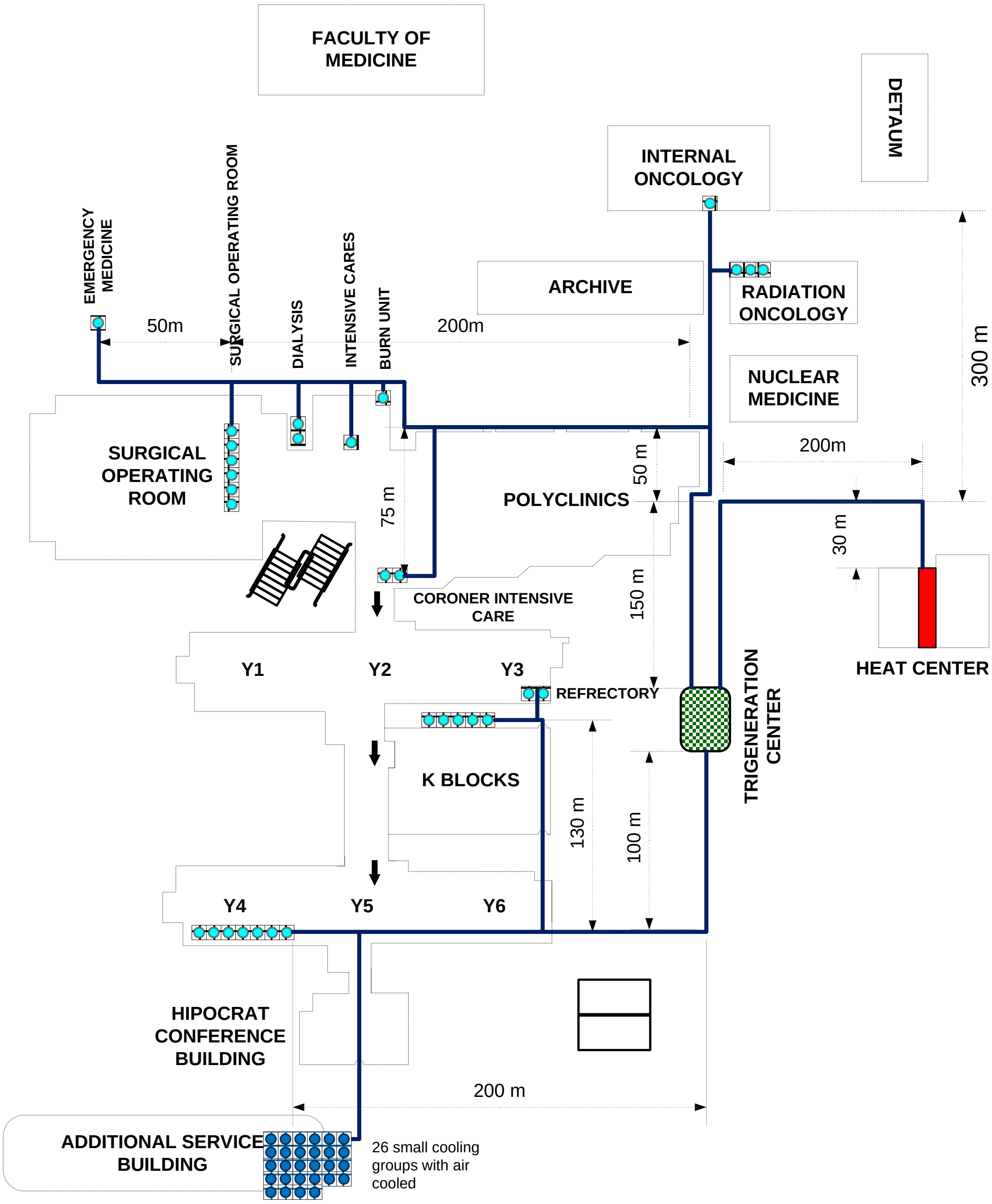


Figure 4.11. Schematical view of planned trigeneration plant

In Balcalı Hospital, there is a constant cooling necessity for 6 months of a year and a 2 MWh trigeneration unit can supply a part of this need and for the rest of the year, absorption chiller unit would be closed and hot water boiler should feed the hospital especially in winters, thus the capacity selected above may be an optimum solution for the hospital.

Moreover, hospital can utilize the HT circuit, heat in winters and as an input of absorption chiller in summers while LT circuit heat is being absorbed by the plate exchangers.

To sum up, a trigeneration system contains engine-alternator set, hot water boiler, absorption chiller and cooling tower, 0.4kV/31.5kV step-up transformer and a container can be settled in Çukurova University Hospital.Total operating time is 5400 h/year.

Feasibility of hospital will indicate below results:

Electricity Savings, (η=100%)

=5400h/year*2000kW*0.286TL/kWh

=3,088,800TL/year **(928.8 TOE/year)**

Cooling Energy Savings, (Absorption chillers will run for 4 months)

=5400h/year/3*2000kW*0.3 ^{COP} *0.286TL/kWh

=308,880 TL/year **(92.88 TOE/year)**

Heat Energy Savings, (Calculations were realized according to the utilization of natural gas for heat production)

- Hot Water Boiler, (η=800%) (for 8 months)

=5400/year*2/3*1000kW*80%$^{\text{Boiler Eff.}}$/(10^{LHV}kWh/m^3)*(0.75TL/m^3)*80%

=172,800TL/year **(190.08 TOE/year)**

- HT Circuit,(η=70%) (for 8 months)

=5400h/year/*2/3*1000kW*80%$^{\text{Exchanger Eff.}}$/(10^{LHV}kWh/m^3)*(0.75TL/m^3)*70%

=151,200TL/year **(166.32 TOE/year)**

- LT circuit, (η=20%)

=[5400h/year*100kW*80%$^{\text{Exchanger Eff.}}$/(10^{LHV}kWh/m^3)]*(0.75TL/m^3)*20%

=4,880TL/year **(7.13 TOE/year)**

Total Savings,

=3,088,800+308,880+172,800+151,200+4,880

=3,726,560TL/year

Fuel consumption,

=5400h/year*510m^3/h*0.75TL/ m^3

=2,065,500TL/ year

Internal electricity consumption,

=5400h/year*50kW*0.286TL/kWh

=77,220TL/year **(23.22 TOE/year)**

Service and spare parts expenses,

=5400h/year*50TL/h

=270,000TL/year

Total Expenses,

=2,065,500+77,220+270,000

=2,412,720TL/year

Total Profit,

=Total Savings-Total Expenses,

=3,726,560-2,412,720

=1,313,840TL/year

Trigeneration System Expense:

Engine-Generator Set in a Sound-Isolated Container,

Double-Effect Absorption Chiller and Cooling Tower and extra piping,

Heat Recovery Hot Water Boiler and Its Mechanical Piping,

Switchgear Units for Medium Voltage Synchronization by using Step-up Transformer,

Neutral Resistor and Electrical Cabling

Total Price: 3,750,000

Depreciation period,

=Total Price/Total Profit

=3,750,000/1,313,840

=**2,9** years (Payback time)

A trigeneration system with hot water boiler, absorption chiller, cooling tower and electrically synchronized from the level at medium voltage can seem a very sensible investment for Çukurova University Hospital according to the calculations due to the above electrical and heat energy consumptions, but the hospital infrastructure is not conformable to realize a trigeneration center, hence it is unfeasible.

A cogeneration system with steam boiler and electrically synchronized from medium voltage level would be a very sensible investment for Balcalı Hospital according to the calculations due to the above electrical and heat energy consumptions.

As a result, energy saving potentials for overall HVAC systems and feasible project are shown in Table 4.22. Bold color projects are feasible.

Table 4.22. 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	293,331.45	1,450,000
Installation of Cogeneration system	**10,530,000 (905.58)**	**327.89**	**1,233.47**	**972,560**	**2,250,000**
Installation of Trigeneration system	10,530,000 (905.58)	456.41	1,361.99	1,313,840	3,750,000
Feasible projects	**10,530,000 (905.58)**	**502.6**	**1,408.18**	**1,672,647**	**2,380,000**

4.4. 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 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*0.3=1,500,000*4/12=500,000.00 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*0.30= 1,680,000 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 1,680,000 + 500,000+250,000= 2,430,000 TL. The total investment is considered as 5,250,000.

Investment will take to pay for itself in 2.1 years (5,250,000/2,430,000). Because the total installation cost of this project is very high, this project is not feasible to implement.

PV system installation for hospital: Installed capacity of the hospital is nearly16 MVA. Average of current consumption is also 4 MVA during summer season and 2.5 MVA during winter season.

General average consumption/month = 3.5 MVA

The cost of 1 kW solar power installation is about 5000-7000 Sterling.

TL equivalent = 14,000 TL/kWh

3.5 MVA x 14,000 TL = **49,000,000 TL**

16 MVA PV panels will approximately generate 6,716,000 kWh in a year (16,000*5 hours * 365 days). Above 1000 acres land is needed for these panels to be

placed. If we think about the processing costs of the system (Battery, panel, etc. expenses) this investment is not suitable for our hospital. This system may be suitable for the places where small and it is difficult to supply energy in normal ways.

Thermal Camera: Buying thermal camera, heat losses and heat level can be measured easily. Faults which can be occurred on motors and the other electrical panels can be detectable before a failure occurs. The purchasing cost of a new thermal camera is approximately 12,000 TL.

Personals and end Users' Education: It is important to keep windows and doors closed for cooling and heating. In addition, the lamps which are not needed to operate should be turned off. Personal should turn off the electrical and electronic devices which are not needed except drug box, refrigerator etc. at the end of the working hours. Especially split air conditioners, computers and printers must be closed.

Reactive Power Compensation Panels: The process of changing the transformers compensation panels by harmonic filtered modern panels which was started before by us, continues.

Electricity Consumption of Canteens and Cafeterias: The electricity consumption price of leased places such as canteens, cafeterias and cash payments at hospital's garden are paid to rectorate of the university. But these places take their energy from the lines of Hospital. Total canteen consumption is around 20,000 TL per month. These amounts should be paid to the hospital's revolving fund.

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 Balcalı Hospital, all UPSs (kVA) 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)*0.1*0.3*24*360= 131,544 kWh.

Because Balcalı hospital operates continuously 24 hours a day 7 days, this project is not feasible.

Transformer Losses: According to technical specification for MV/LV distribution power transformers by Turkish Electricity Distribution Company, 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 $. The purchase price of Type-A 1000 kVA transformer is approximately 2,400$ more expensive than a standard one. The payback period of this investment is nearly 10 months.

Because Balcalı hospital operates continuously 24 hours a day 7 days, this project is not feasible.

5. CONCLUSION AND FUTURE WORK

5.1. Summary of Thesis Work

The energy use in the world is increasing significantly owing to increasing energy consumption per capita and to the growing population. Due to increased energy demand and the depletion of existing fossil fuel based sources, it is required to use the energy more efficient and implement an energy management program. The energy efficiency and saving applications reduces maintenance and operating costs, gives customers greater control over energy costs and reduces air pollution and greenhouse gases. Researches show that, the buildings sector consumes 34% of final energy consumption in the world. Hospitals represent approximately 6% of total energy consumption in the utility buildings sector. The hospital heating systems use approximately 43% of the total energy consumption at the hospitals. Lighting system consumes 21% of total energy consumed at the hospitals. The consumption of cooling and hot tap water systems represents around 10% of the total energy consumption. The percentage distributions of energy consumption can change according to geographical positions and climatic values.

The main objectives of this thesis are as follows.

1- To describe the importance of energy efficiency and energy saving potentials at the hospitals.

2- To identify the wide range of energy savings options applicable to hospitals.

3- To present literature survey studies on lighting, electric motors, VSDs and HVAC systems giving practical applications with their payback periods.

4- To present the energy consumption profile of Balcalı Hospital

5- To specify and develop suggestions for the best energy saving approaches and energy efficiency improvement methods for Balcalı Hospital giving the payback periods of the suggestions.

6- To develop and test an electricity bill analysis and recommendation program.

5.2. Summary of the Chapters in the Thesis

In the first chapter of this thesis, an overview of the present status and future prospects of world and Turkey's energy consumption and the fundamentals of energy savings, energy efficiency and energy management are presented. An overview of energy saving areas in hospitals is also summarized.

In the second chapter, wide literature survey studies on lighting, electric motors, VSDs and HVAC systems giving practical applications with their payback periods were presented.

HVAC systems are the major part of electrical energy consumption at the hospitals. The heart of the cooling unit in HVAC systems is chiller and the heart of the heating unit in HVAC system is boiler. The air-conditioning system is responsible for around 70% of total electricity consumption. Lighting systems in a hospital represents approximately 21% of the total energy consumption. Electric motors in a hospital represent approximately 19% of the total energy consumption. Table 7.1 summarizes the most important energy saving applications in lighting systems, HVAC systems and Electric motors&VSDs.

Table 5.1. Most important energy saving applications in the thesis

Most important energy saving applications in	
Lighting systems	Replacement lamps, reducing luminance and numbers of lamps, using dimmer, replacement ballast and using of the new control system with dimmer use of intelligent control system, adjustment flux level
HVAC systems	Installation of CHP/CCHP, steam recovery system, timer, solar air heating systems, new burners, new economizer, condensing economizer, heat exchanger and improvements in compressed air, boiler system, converting the DX cooling to central plant chilled water cooling, new efficient chiller and cooling tower replacement, air curtain application, valve insulation jacket application, steam trap maintenance and refrigeration system
Electric motors and VSDs	New purchase of energy efficient motor and comparing of EFF1 motor with EFF2 motor, replacing existing motor with smaller energy efficient motor, replacing existing motor with same-sized energy efficient motor, rewinding, replacement of valve with VSD, energy saving with VSD

In chapter three, the energy consumption profile of a large capacity university hospital including electrical single line diagram, numbers and distribution of lamps, motors, HVAC systems are presented with detailed field visits.

In chapter four, the best energy saving approaches and energy efficiency improvement methods for Balcalı Hospital giving the payback periods of the suggestions were developed. An electricity bill analysis and recommendation program is also developed and tested.

The main points, contributions and recommendations for future work of this thesis are concluded in Chapter 5.

Finally, all the references used in the thesis, biographical information of the author and sections of the Appendices are presented.

5.3. Statement of Contribution to Knowledge

To use the energy efficiently and perform energy saving studies have great importance for developing countries like ours that are dependent on other countries to meet their energy needs. While we are meeting our needs such as heating, lighting and transportation, using electrical household appliances, shortly in every phases of our daily lives we can contribute positively to the country's economy and the preservation of our environment by using energy efficiently without limiting our needs.

To the author's best knowledge, the followings are original contributions in the thesis:

1- The wide literature survey for lighting, electric motors, VSDs and HVAC systems at the hospitals giving practical applications and their payback periods have been accomplished.

2- Practical recommendations and suggestions for a number of significant energy efficiency studies at the hospitals are presented.

3- The energy consumption profile of a large capacity university hospital including electrical single line diagram, numbers and distribution of lamps, motors, HVAC systems are presented.

4- An electricity bill analysis and recommendation program is developed and tested.

5- The information in this thesis helps the engineers and managers in the hospitals for reducing energy consumption while maintaining the quality of service.

This thesis proves that applying the mentioned energy efficiency and saving practices will save considerable amounts in the electrical energy bills and fuel. In this thesis, 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 Balcalı Hospital.

5.4. Recommendations for Future Work

In the future, researches will concentrate on reliability of electric power, efficient energy use and maximum use of renewable energy sources. Further research can be carried out in the following areas:

1- Preparing a detailed energy management program for the university hospital by energy management unit,

2- Identifying operation and predictive maintenance practices,

3- Following the performance of installed LED lighting, VSDs and insulations of HVAC systems with measurements.

4- Maximum use of renewable energy sources especially from photovoltaic and heat pump system.

5- Following the performance of cogeneration system to be installed.

6- Education of staff and patients on how their behaviors affect energy use

7- The proposed software program for single user will be rendered for multi-user.

Table 5.2. Energy saving projects for Balcalı Hospital

Feasible projects	**Estimated energy savings**		**Total energy savings (TOE)**
	Electricity saving kWh (TOE)	**Other Saving TOE**	
Lighting system	173,677 (14.93)	-	14.93
Motors and VSD system	3,409,046 (293.12)	-	293.12
HVAC system	10,530,000 (905.58)	502.6	1,408.18
TOTAL			**1,716.23**

Total energy consumption of the Balcalı Hospital for last 12 months is 4749.40 TOE (23,960,320 kWh electrical energy (2060.58 TOE) and 2,727 tonnes fuel oil (2,688.82 TOE)). The estimated energy saving is 1,716.23 TOE. This means that as a result of the detailed analysis on the existing system, 36% energy saving potential is estimated at the Balcalı Hospital if all feasible projects are performed.

REFERENCES

ABB, ABB electric motor drives, Technical case notes. ABB Power and Automation Technologies Company, 32 p.

ABDELAZIZ E.A., SAIDUR R., MEKHILEF S., 2011. A review on energy saving strategies in industrial sector. Elsevier: Renewable and Sustainable Energy Reviews, Vol. 15, Page(s) 150-168.

AHMADZADEHTALATAPEH M., YAU Y.H., 2011. The application of heat pipe heat exchangers to improve the air quality and reduce the energy consumption of the air conditioning system in a hospital ward - A full year model simulation, Energy and Buildings, Vol. 43, Page(s) 2344-2355.

ALEXIS G.K., LIAKOS P., 2013. A case study of a cogeneration system for a hospital in Greece: Economic and environmental impacts. Applied Thermal Engineering, Vol. 54, Page(s) 488-496.

ALZOUBI H., AL-RQAIBAT S., BATAINEH R.F., 2010. Pre-versus post-occupancy evaluation of daylight quality in hospitals. Elsevier: Building and Environment, Vol. 45, Page(s) 2652-2665.

AMAN M.M., JASMON G.B., MOKHLIS A., BAKAR A.H.A., 2013. Analysis of the performance of domestic lighting lamps. Elsevier: Energy Policy, Vol. 52, Page(s) 482-500.

AMOGPAI A., 2011. LED lighting combined with solar panels in developing countries. Aalto University Publication Series, Doctoral Dissertations 110/2011, 49 p.

ASCIONE F., BIANCO N., MASI R.F., VANOLI, G.P., 2013. Rehabilitation of the building envelope of hospitals: Achievable energy savings and microclimatic control on varying the HVAC systems in Mediterranean climates. Energy and Buildings, Vol. 60, Page(s) 125-138.

ASHE, 2004. American society for healthcare engineering, healthcare energy guidebook, Results of the healthcare energy project November 2001 through December 2003. 26 p.

AZEVEDO I.L., MORGAN M.G., MORGAN F., 2009. The transition to solid state lighting. Proceeding of the IEEE, Vol. 97, No. 3, Page(s) 481-510.

BALARAS A.C., DASCALAKI E., GAGLIA A., 2007. HVAC and indoor thermal conditions in hospital operating rooms. Elsevier: Energy and Buildings Vol. 39, Page(s) 454-470.

BENHADDADI M., OLIVIER G., YELLE J., 2010. Premium efficiency motors effectiveness. IEEE SPEEDAM 2010, International Symposium on Power Electronics, Electrical Drives, Automation and Motion, Page(s) 1607-1612.

BHATIA A., HVAC variable refrigerant flow systems, continuing education and development, Inc., Page(s) 1-38.

BLAB H.W., SATTLER B., 2011. Standards and legal requirements for the energy efficiency of low-voltage three-phase motors. CEMEP Electric Motors and Variable Speed Drives, Page(s) 1-16.

BRANDEMUEHL M.J., HVAC systems overview presentation, University of Colorado, USA, 37 p.

BRUSH A., MASANET A., WORRELL E., 2011. Energy efficiency improvement and cost saving opportunities for the dairy processing industry, An Energy Star Guide for Energy and Plant Managers, Page(s) 1-137.

BSE, 2013, Bluestone Energy Services: Case Studies, www.bluestoneenergy.com.

BUJAK J., 2010. Heat consumption for preparing domestic hot water in hospitals. Elsevier: Energy and Buildings, Vol. 42, Page(s) 1047-1055.

CADDET, Saving energy with energy efficiency in hospitals. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies, Maxi Brochure 05, CADDET Energy Efficiency, 24 p.

CAPEHART B.L., TURNER W.C., KENNEDY W.J., 2008. Guide to Energy Management, Sixth Edition. The Fairmont Press, Lilburn, 630 p.

CARBONTRUST, 2011. Motor and drives. Technology overview presentation, 38 p.

CARPENTER D., HOPPSZALLERN S., 2011. Advancing efficiency: Hospital energy management survey. HFM Magazine, Page(s) 15-22.

CHEN C.R., SHIH S.C., HU S.C., 2005. Short-term electricity forecasting of air-conditioners of hospital using artificial neural networks. IEEE/PES

Transmission and Distribution Conference and Exhibition: Asia and Pacific, Page(s) 1-5.

CHEN N., CHUNG H.S., 2011. A driving technology for retrofit LED lamp for fluorescent lighting fixtures with electronic ballasts. IEEE Transactions on Power Electronics, Vol. 26, No. 2, Page(s) 588-601.

CHILLERS, 2010. Chillers, Energy saving fact sheet, N.C. Department of Administration, 2 p.

COMED, Calculating energy savings estimates for the Chicago Bungalow energy efficiency showcase home, www.comed.com, 9 p.

CONGRADAC V., PREBIRACEVIC B., JORGOVANOVIC N., STANISIC D., 2012. Assessing the energy consumption for heating and cooling in hospitals. Elsevier Energy and Buildings, Vol. 48, Page(s) 146-154.

CORINO S., ROMERO E., MANTILLA L.F., 2010. Energy savings by means of energy efficient electric motors. Department of Electrical Engineering and Energy at Universidad de Cantabria in Spain, Page(s) 1-5.

CORTÉS J.C.E, DEMARCO R., VALENCIA A., PAVAGEAU M., 2009. Heat confinement in tunnels between two double-stream twin-jet air curtains. International Communications in Heat and Mass Transfer, Vol. 36, Page(s) 438-444.

CROW C., 2008. Energy management: A strategy for HVAC savings, www.facilitiesnet.com.

DA'AS B.A.S., 2008. Energy management procedures and audit results of electrical, thermal and solar applications in hospitals sector in Palestine. AnNajah National University Faculty of Graduate Studies, MsC Thesis, 147 p.

DALKE H., LITTLE J., NIEMANN E., CAMGOZ N., STEADMAN G., HILL S., STOTT L., 2006. Colour and lighting in hospital design, Elsevier: Optics & Laser Technology, Vol. 38, Page(s) 343-365.

DASCALAKI E.G., LAGOUDI A., BALARAS C.A., GAGLIA A.G., 2008. Air quality in hospital operating rooms, Building and Environment, Vol. 43, Page(s) 1945-1952.

DEEPALAKSHMI D., 2008. Energy management in hospitals, Express Healthcare.

DESIGN, 2010. Design brief: Chiller plant efficiency, Energy design resources, 28 p.

DUBOIS M.C., BLOMSTERBERG A., 2011. Energy saving potential and strategies for electric lighting in future North European, low energy office buildings: A literature review. Elsevier: Energy and Buildings Vol. 43, Page(s) 2572-2582.

E-4, 2010. E-4 Source Companies LLC. Managing energy costs in hospitals.

ECSG, available at: http://www.energyconservation.sg/

EII (Energy Innovators Initiative) Technical Fact Sheet http://oee.nrcan.gc.ca/eii

ENERGYSTAR, Commercial real estate: An overview of energy use and energy efficiency opportunities, www.energystar.gov.

EPA, US Environmental Protection Agency. www.epa.gov, Energy efficiency: Reduce energy bills, protect the environment, National action plan for energy efficiency, 4 p.

ESMAEILI M.A., JAHROMI A.S., TWOMEY J., YILDIRIM B., OVERCASH M., DOMINQUEZ F., THOMAS N., MCADAM A., 2011. Hospital radiology department overhead energy estimation. IEEE International Symposium on Sustainable Systems and Technology (ISSST), Page(s) 1-6.

FASSBINDER R., 2013. European Copper Institute: Leonardo Energy – Application note the properties of LED lighting, Page(s) 1-40.

FOURNIER D., 2009. Reducing hospital costs through energy efficiency presentation. Smart Energy Design Assistance Center, 55 p.

GAN C.K., SAPAR A.F., MUN Y.C., CHONG K.E., 2013. Techno-economic analysis of LED lighting: A case study in UTeM’s (Universiti Teknikal Malaysia Melaka) Faculty Building. Procedia Engineering, Vol. 53, Page(s) 208-216.

GGHH, Global Green and Healthy Hospitals (GGHH) network. Energy saving and carbon reduction policies at the Taiwan National Cheng Kung University Hospital, Case Studies, 4 p.

GIFFIN P.K., 2013. Performance and cost results from a DOE Micro-CHP demonstration facility at Mississippi State University. Energy Conversion and Management, Elsevier, Vol. 65, Page(s) 364-371.

GIMELLI A., MUCCILLO M., 2013. Optimization criteria for cogeneration systems: Multi-objective approach and application in a hospital facility, Elsevier Applied Energy, Vol. 104, Page(s) 910-923.

GOETZLER W., 2007. Variable refrigerant flow systems, ASHRAE Journal, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Page(s) 24-31.

GORDO E., CAMPOS A., COELHO D., 2011. Energy efficiency in a hospital building case study, Hospitais da Universidade de Coimbra, 3rd International Youth Conference on Energetics (IYCE), Page(s) 1-6.

GORGULU S., EKREN N., 2013. Energy saving in lighting system with fuzzy logic controller which uses light-pipe and dimmable ballast. Elsevier: Energy and Building, Vol. 61, Page(s) 172-176.

GOWRISHANKAR V., ANGELIDES C., DRUCKENMILLER H., 2013. Combined heat and power systems: improving the energy efficiency of our manufacturing plants, buildings and other facilities, NRDC issue paper, Page(s) 1-33.

HATAMIPOUR M.S., MAHIYAR H., TAHERI M., 2007. Evaluation of existing cooling systems for reducing cooling power consumption. Elsevier Energy and Buildings, Vol. 39, Page(s) 105-112.

HEUR R.V., 2008. Power quality utilization guide: Hospitals energy efficiency. European Copper Institute, Leonardo Energy, Page(s) 1-24.

HSIAO H.C., CHANG C.H., 2012. Economic benefit calculation and optimum design method about roadway lighting. 2012 International Conference on Future Electrical Power and Energy Systems, Lecture Notes in Information Technology, Vol. 9, Page(s) 477-482.,

HU S.C., CHEN J.D., CHUAH Y.K., 2004. Energy cost and consumption in a large acute hospital, International Journal on Architectural Science, Vol. 5, Number 1, Page(s) 11-19.

IEA, 2011. Technology roadmap energy efficient buildings: Heating and cooling equipment. International Energy Agency. The IEA Sustainable Energy Policy and Technology, 56 p.

IET (Institute for Energy and Transport).

JERINE A., ROSE G., DEJEAN D., 2010. Outdoor area LED lighting assessment. Emerging Technologies Associates Inc. Page(s) 1-25.

KAMALI N.J., ABBAS M.J., 2012. Healing environment: Enhancing nurses' performance through proper lighting design. Elsevier: Procedia - Social and Behavioral Sciences, Vol. 35, Page(s) 205-212.

KAYA D., YAGMUR E.A., YIGIT K.S., KILIC F.C., EREN A.S., CELIK C., 2008. Energy efficiency in pumps. Elsevier: Energy Conversion and Management, Vol. 49, Page(s) 1662-1673.

KHODAKARAMI J., NASROLLAHI N., 2012. Thermal comfort in hospitals – A literature review. Elsevier: Renewable and Sustainable Energy Reviews, Vol. 16, Page(s) 4071-4077.

KIM S.H., AUGENBROE G., 2013. Decision support for choosing ventilation operation strategy in hospital isolation rooms: A multi-criterion assessment under uncertainty, Elsevier Building and Environment, Vol. 60, Page(s) 305-318.

KOTCIOGLU I., 2011. Clean and sustainable energy policies in Turkey. Renewable and Sustainable Energy Reviews, Vol. 15, Page(s) 5111-5119.

LAO INSTITUTE, 2006. Survey on fossil fuel consumption for energy efficiency conservation to promote the new technology of biofuel in Lao PDR, The Lao Institute for Renewable Energy, LIRE, 29 p.

LEAVITT M., JERINE A., DEJEAN D., 2010. Parking lot LED lighting assessment. Emerging Technologies Associates Inc., Page(s) 1-15.

LORENZO J., 2010. Hoboken University Medical Center Energy Audit Report, Page(s) 1-55.

MAGGIO G., CACCIOLA G., 2012. When will oil, natural gas and coal peak? Elsevier Fuel, Vol. 98, Page(s) 111-123.

MAHESWARAN D., KAILAS K.J., RANGARAJ V., KUMAR V.A., 2012. Energy efficiency in electrical systems. 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems, Page(s) 1-6.

McBDC, 2012. Business Development & Consultancy Services Co. Ltd. Renewable Energy in Turkey, 11 p.

MEDRANO M., BROUWER J., MCDONELL V., MAUZEY J., SAMUELSEN S., 2008. Integration of distributed generation systems into generic types of commercial buildings in California. Energy and Buildings, Vol. 40, Issue 4, Pages 537-548.

MICHIGAN Government Energy efficient lighting, 2013 http://www.michigan.gov/documents/CIS_EO_Lighting_167401_7.pdf

MIDWEST, 2004. CHP education/assistance program guide for the Indiana hospital market sector. Midwest CHP Application Center, University of Illinois at Chicago, Energy Resources Center, Page(s) 1-119.

MILLER P., OLATEJU B., KUMAR A., 2012. A techno-economic analysis of cost savings for retrofitting industrial aerial coolers with variable frequency drives. Energy Conversion and Management, Vol. 54, Page(s) 81-89.

MISSAOUI R., MOURTADA A., 2010. Instruments and Financial mechanisms of energy efficiency measures in building sector WEC-ADEME case study on energy efficiency measures and policies, 58 p.

MTU, 2009. MTU Onsiteenergy Genset without heat recovery system. AoE 20V4000L63, Technical Description, 7 p.

NEMA, 2012. Implementing lighting management technologies and practices to drive building efficiency. enLIGHTen America, Page(s) 1-44.

NEXANT, 2013. Design brief: Compressed air, Energy Design Resources, San Francisco, CA., www.energydesignresources.com, 35 p.

ORZAEZ M.J.H., DIAZ J.R.A., 2013. Comparative study of energy-efficiency and conservation systems for ceramic metal-halide discharge lamps. Elsevier: Energy, Vol. 52, Page(s) 258-264.

PAGLIARINI G., CORRADI C., RAINIERI S., 2012. Hospital CHCP system optimization assisted by TRNSYS building energy simulation tool. Elsevier Applied Thermal Engineering, Vol. 44, Page(s) 150-158.

PAKSOY H.O., ANDERSSON O., ABACI S., EVLIYA H., TURGUT B., 2000. Heating and cooling of a hospital using solar energy coupled with seasonal thermal energy storage in an aquifer. Renewable Energy Vol. 19, Page(s) 117-122.

PAUWELS K.M., 2001. Energy savings with variable speed drives. CIRED Conference Publication No. 482, IEE 2001, Page(s) 1-5.

RADEMAEKERS K., BOONEKAMP P., HARMSEN R., BOEVE S., SIJM J., 2012. The energy efficiency investment potential for the building environment. Two approaches, ECORYS, 24 p.

RESOLE M, GE G, SIMONSON C J., BESANT R W., 2013. Uncertainties in energy and economic performance of HVAC systems and energy recovery ventilators due to uncertainties in building and HVAC parameters, Applied Thermal Engineering, Vol. 50, Pages 732-742.

RISTIMAKI T., 2008. Energy efficiency through variable frequency drives. Honeywell, Page(s) 1-8.

SAIDUR R., 2010. A review on electrical motors energy use and energy savings. Elsevier: Renewable and Sustainable Energy Reviews, Vol. 14, Page(s) 877-898.

SAIDUR R., ATABANI A.E., MEKHILEF S., 2011. A review on electrical and thermal energy for industries. Renewable and Sustainable Energy Reviews Vol.15, Page(s) 2073-2086.

SAIDUR R., HASANUZZAMAN M., RAHIM N.A., 2010a. Energy consumption, energy savings and emission analysis for industrial motors. Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management, Page(s) 1-6.

SAIDUR R., HASANUZZAMAN M., YOGESWARAN S., MOHAMMED H.A., HOSSAIN M.S., 2010b. An end-use energy analysis in a Malaysian public hospital. Energy, Vol. 35, Page(s) 4780-4785.

SAIDUR R., MEKHILEF S., ALI M.B., SAFARI A., MOHAMMED H.A., 2012. Applications of variable speed drive (VSD) in electrical motors energy savings. Elsevier: Renewable and Sustainable Energy Reviews, Vol. 16, Page(s) 543-550.

SAIDUR R., RAHIM N.A., HASANUZZAMAN M., 2010c. A review on compressed-air energy use and energy savings. Elsevier: Renewable and Sustainable Energy Reviews, Vol. 14, Page(s) 1135-1153.

SHEN C.C., LU J.H., CHUO W.H., 2009. Water management of heat pump system for hot water supply in a medium size hospital. World Academy of Science, Engineering and Technology, Vol. 29, Page(s) 386-392.

SILVERIA J.L., LAMAS W.Q, TUNA C.E., VILLELA I.A.C., MIRO L.S., 2012. Ecological efficiency and thermo economic analysis of a cogeneration system at a hospital. Elsevier Renewable and Sustainable Energy Reviews, Vol. 16, Page(s) 2894-2906.

SINNADURAI R., KHAN M.K.A., AZRI M., VIKNESWARAN I., 2012. Development of white LED down light for indoor lighting. IEEE Conference on Sustainable Utilization and Development in Engineering and Technology. Page(s) 242-247.

SU C.L., YU K.T., 2013. Evaluation of differential pressure set-point of chilled water pumps in clean room HVAC systems for energy savings in high-tech industries, IEEE Transactions on Industry Applications, Vol. 49, Page(s): 1015-1022

SUGARMAN S.C., 2005. HVAC fundamentals, First Edition. The Fairmont Press, Lilburn, 309 p.

SULLIVAN M., 2010. Saving energy and lives, Innovations in healthcare infrastructure. Hosmac Pulse, Vol. 1, Page(s) 11-13.

TEKE A., TIMUR O., 2013. Lighting systems at the hospitals: An overview. Majlesi Journal of Energy Management, Vol. 2, No. 2, Page(s) 39-51.

TELEMECANIQUE, 2006. Boosting the energy efficiency of HVAC systems with variable speed drives. Page(s) 1-4.

THORN, Applications in focus lighting for healthcare, www.thornlighting.com/com/en/

TOLGA N. A., 2010. Variable refrigerant flow systems: A review, Elsevier Energy and Buildings, Vol. 42, Page(s) 1106-1112.

TORONTO, 2011. With energy efficient retrofits, Gay Lea Foods whips up sustainable energy savings, saveONenergy programs, Page(s) 1-2.

TRANE, 2000. Chilled water system design and operation: Cost-reducing optimization strategies, 8 p.

TSOUTSOS T., ALOUMPI E., GKOUSKOS Z., KARAGIORGAS M., 2010. Design of a solar absorption cooling system in a Greek hospital. Elsevier: Energy and Buildings, Vol. 42, No. 2, Page(s) 265-272.

VANHOUDT D., DESMEDT J., VAN BAEL J., ROBEYN N., HOES H., 2011. An aquifer thermal storage system in a Belgian hospital: Long-term experimental evaluation of energy and cost savings. Elsevier: Energy and Buildings, Vol.43, No. 12, Page(s) 3657-3665.

WILKINSON J., 2009. Driving smart: Energy and cost reduction using drive technologies. Siemens Presentations, Page(s) 1-23.

www.eu-greenlight.org/pdf/GL_Catalogue/GL_catalog_12.pdf,

http://iet.jrc.ec.europa.eu/energyefficiency/greenlight

WYCZALKOWSKI A., 2009, Payback with lighting, Final report, Page(s) 35-37.

YAN W., HUI S.Y., CHUNG H.S, 2009. Energy saving of large-scale high intensity discharge lamp lighting networks using a central reactive power control system. IEEE Transactions on Industrial Electronics, Vol. 56, No. 8, Page(s) 3069-3078.

YAU H., CHANDRASEGARAN D., BADARUDIN A., 2011. The ventilation of multiple-bed hospital wards in the tropics: A review, Y. Building and Environment, Vol. 46, Page(s) 1125-1132

YUMURTACI Z., SARIGUL A., 2011. Santrifüj pompalarda enerji verimliliği ve uygulamaları. Makina Mühendisleri Odası Tesisat Mühendisliği Dergisi, Yıl:16, Sayı:122, Sayfa 49-58.

ZHAI X.Q., WANG X.L., WANG T., WANG R.Z., 2013. A review on phase change cold storage in air-conditioning system: Materials and applications, Renewable and Sustainable Energy Reviews, Vol. 22, Page(s) 108-120.

ZHOU J., WANG Z., YANG N., 2010. Research on inverting control of PV grid-connected LED street lighting system. 2010 International Conference on Information, Networking and Automation, Page(s) 94-96.

ZOTOS N., PALLIS E., SKIANIS C., STERGIOPOULOS C., 2012. Case study of a dimmable outdoor lighting system with intelligent management and remote control. 2012 International Conference on Telecommunications and Multimedia, Page(s) 43-48.

BIOGRAPHY

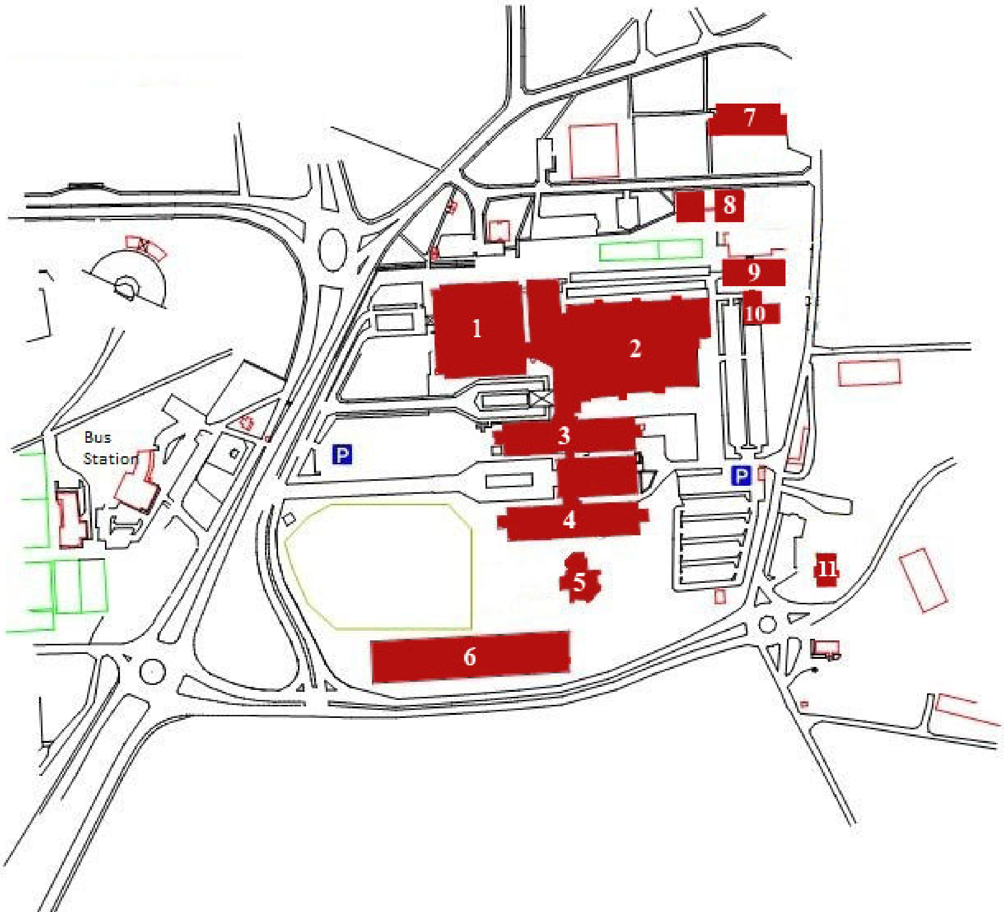
Oğuzhan Timur was born in Adana, Turkey in 1974. He received his B.S. degree in Electrical and Electronics Engineering Department from Çukurova University in 2000. After completion his B.S. education, he worked as Electrical and Electronics Engineer in textile factories (Özbucak and BosSA) until 2008.

He has been working as an Electrical and Electronics Engineer at Hospital Information and Management Systems Department of Çukurova University Balcalı Hospital since 2008. His research areas are power electronic, energy management, renewable energy resources, energy efficiency and energy saving. In addition, he is interested in computer network systems and servers.

He is a member of Turkish Chamber of Electrical Engineers.

APPENDIX

APPENDIX A: Location Plan of Ç.U. Balcalı Hospital



1	Emergency Medicine
2	Policlinics
3	Old Building (Clinics)
4	New Building (Clinics)
5	Conference Hall
6	Additional Service Building
7	Pediatric Oncology
8	Archive
9	Radiation Oncology
10	Nuclear Medicine
11	Halil Avcı Hearing Impaired Center

Figure A.1. Location plan of Ç.U. Balcalı Hospital

APPENDIX B: Divisions and Departments of Ç.U. Medicine Faculty

Table B.1. Divisions and departments of Ç.U. Medicine Faculty

No	Divisions	Departments
1	Basic Sciences Division	Department of Medical Biology
2		Department of Anatomy
3		Department of Histology and Embryology
4		Department of Physiology
5		Department of Biophysics
6		Department of Medical Microbiology
7		Department of Medical Parasitology
8		Department of Medical Biochemistry
9		Department of Medical History and Ethics
10		Department of Biostatistics and Medical Informatics
11	Medical Sciences Division	Department of Forensic Medicine
12		Department of Medical Pharmacology
13		Department of Internal Diseases
14		Department of Cardiology
15		Department of Thoracic Diseases
16		Department of Infectious Diseases
17		Department of Child Health and Diseases
18		Department of Mental Health
19		Department of Child and Adolescent Mental Health and Diseases
20		Department of Public Health
21		Department of Family Medicine
22		Department of Radiology
23		Department of Radiation Oncology
24		Department of Nuclear Medicine
25		Department of Neurology
26		Department of Skin and Venereal Diseases (Dermatology)
27		Department of Physical Medicine and Rehabilitation
28		Department of Emergency Medicine
29		Department of Medical Education
30		Department of Medical Genetics

31	**Surgery Sciences Division**	Department of General Surgery
32		Department of Pathology
33		Department of Cardiovascular Surgery
34		Department of Thoracic Surgery
35		Department of Pediatric Surgery
36		Department of Brain Surgery
37		Department of Plastic, Reconstructive and Aesthetics Surgery
38		Department of Obstetrics and Gynecology
39		Department of Ear, Nose and Throat (Otolaryngology)
40		Department of Ophthalmology (Eye Diseases)
41		Department of Urology
42		Department of Orthopedics and Traumatology
43		Department of Anesthesiology and Reanimation

APPENDIX C: The Location Plans of Policlinics

Figure C.1. Basement floor location plan

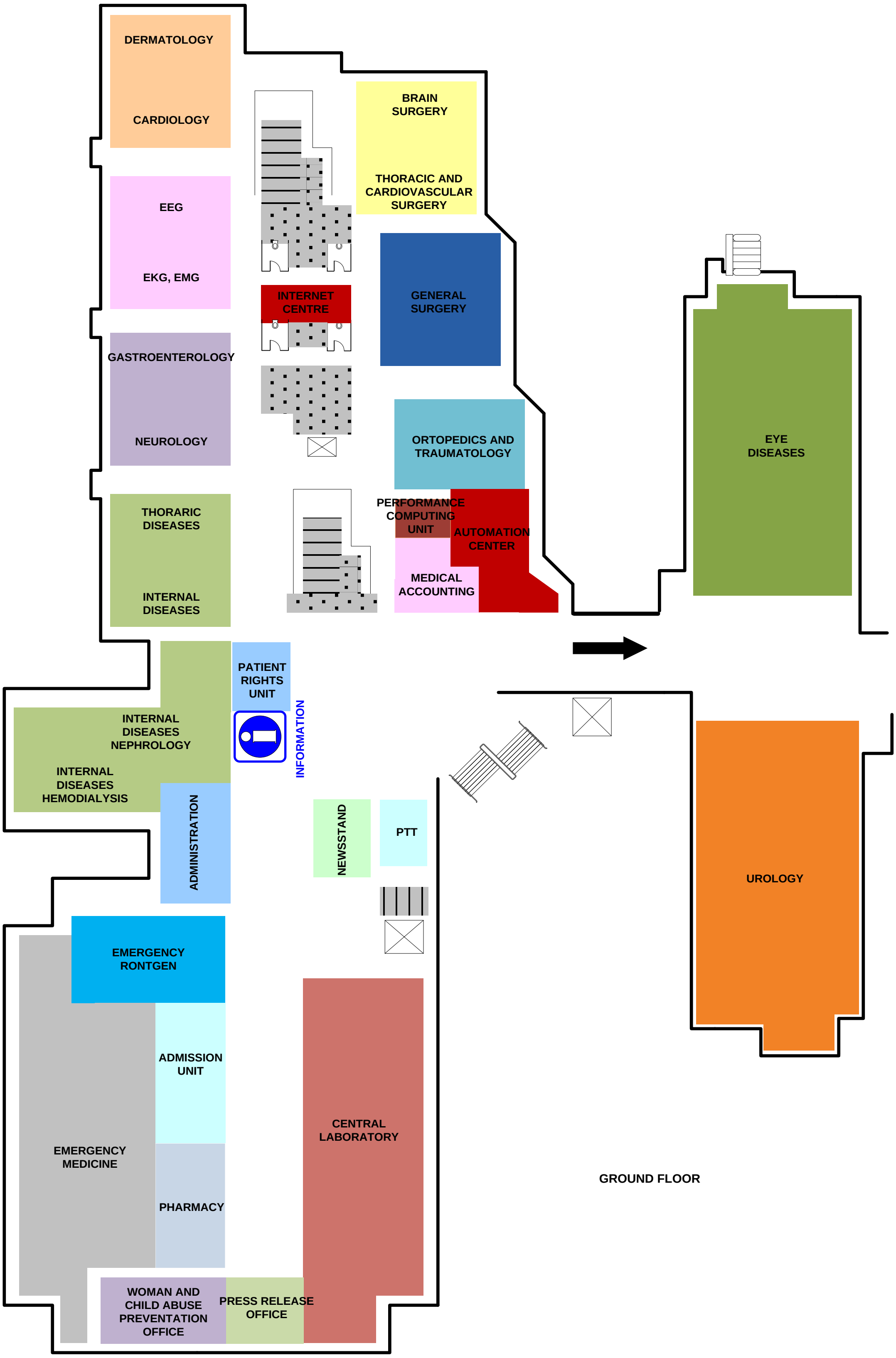


Figure C.2. Ground floor location plan

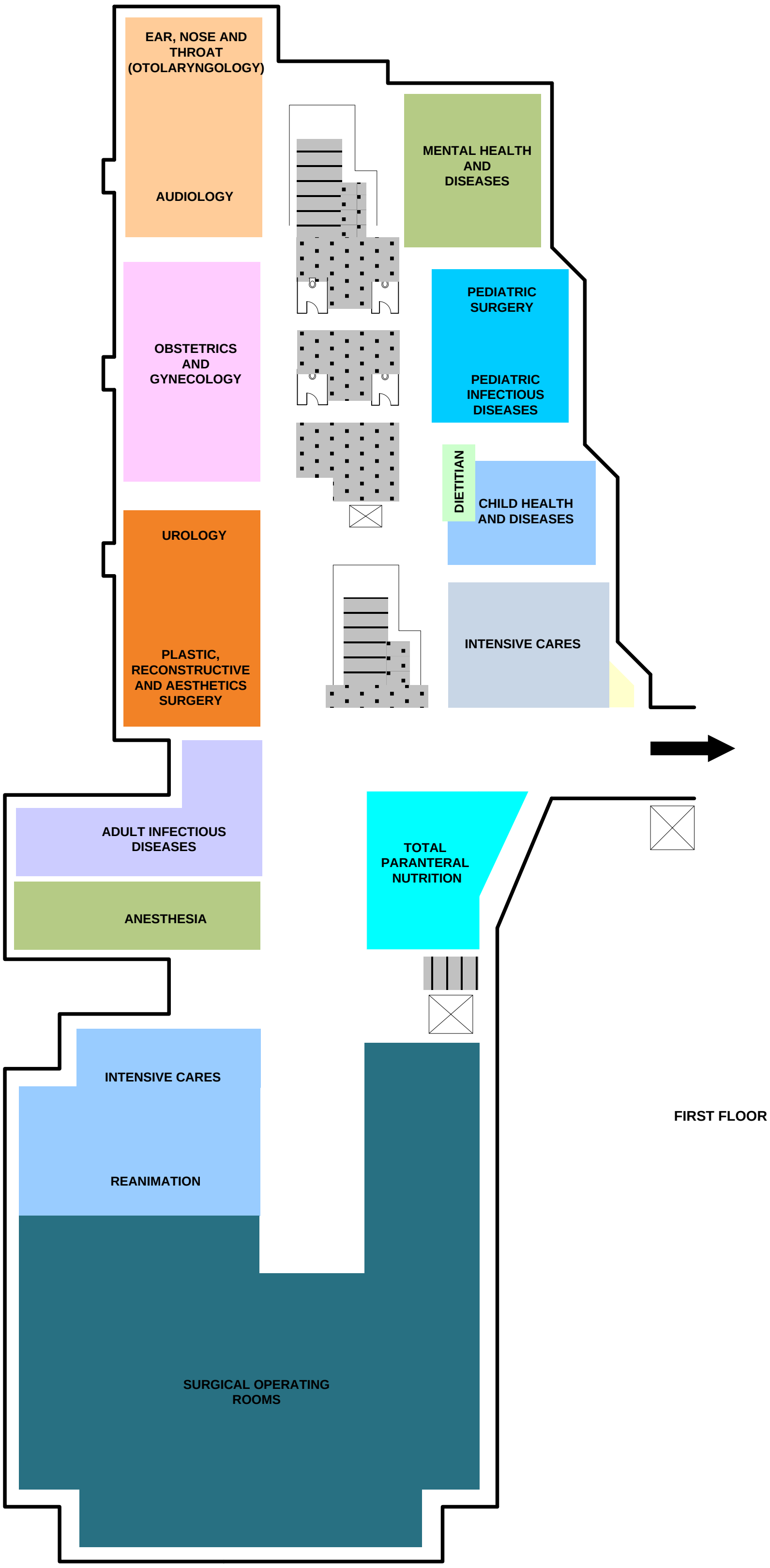


Figure C.3. First floor location plan

APPENDIX D: Areas of Departments at Balcalı Hospital

Table D.1. Total areas of departments at Balcalı Hospitals

Department	**Area (m^2)**
Department of Emergency Medicine	1333
Department of Forensic Medicine	700
Department of Family Medicine	660
Department of Anesthesiology and Reanimation	540
Department of Brain Surgery	1940
Department of Child Health and Diseases	7695
Department of Pediatric Surgery	1670
Department of Child and Adolescent Mental Health and Diseases	420
Department of Internal Diseases	8330
Department of Skin and Venereal Diseases (Dermatology)	1670
Department of Infectious Diseases	1670
Department of Physical Medicine and Rehabilitation	1240
Department of General Surgery	4040
Department of Thoracic Diseases	822
Department of Thoracic and Cardiovascular Surgery	1873
Department of Eye Diseases (Ophthalmology)	2800
Department of Obstetrics and Gynecology	5440
Department of Cardiology	1095
Department of Ear, Nose and Throat (Otolaryngology)	1940
Department of Neurology	2320
Department of Nuclear Medicine	1200
Department of Orthopedics and Traumatology	1940
Department of Pathology	1000
Department of Plastic, Reconstructive and Aesthetics Surgery	2210
Department of Mental Health and Diseases	1940
Department of Radiation Oncology	570
Department of Radiology	1870
Department of Urology	2370
Organ Transplant Center	276
Hemapheresis, Stem Cells and Cryopreservation Unit	276
TOTAL AREA OF DEPARTMENTS (m^2)	**61850**

Table D.2. Total closed areas at Balcalı Hospitals

Total of department areas	61850
Hospital general used area (Central laboratory, etc.)	66686
TOTAL CLOSED AREA OF BALCALI HOSPITAL (m²)	**128536**

Table D.3. Total closed areas at Balcalı Hospitals with deanery building

Hospital total closed area (m²)	128536
Faculty of Medicine and other places as Int. Oncology, DETAUM	31971
TOTAL CLOSED AREA (m²) WITH DIANERY BUILDING	**160507**

Total money spent on fuel-oil is approximately **6,500,000.00 TL** (Turkish Liras) in 2012. According to department areas, the cost price per square meter is **40.49668** TL (6,500,000.00 / 160,507.00 = 40.49668). By multiplying this unit price with department areas, the cost of fuel-oil per department can be calculated. For example, the cost of the fuel-oil consumed by department of internal diseases in 2012 is approximately calculated as **341,252.44** TL (40.49668 x 8,330 = 341,252.44 TL).

At another example, the cost of fuel oil consumed by department of medicine faculty can be calculated. The consumption as TL can be calculated as **40.49668 x 31,971 = 1,294,719.36 TL.**

APPENDIX E: The Total Number of Staff

Table E.1. Number of regular and 4B staff inside Balcalı Hospital

BALCALI HOSPITAL		
No	**Departments**	**Number of Regular and 4B Staff**
1	Department of Emergency Medicine	47
2	Department of Forensic Medicine	10
3	Department of Family Medicine	17
4	Department of Anesthesiology and Reanimation	89
5	Department of Brain Surgery	40
6	Department of Child Health and Diseases	222
7	Department of Pediatric Surgery	27
8	Department of Child and Adolescent Mental Health and Diseases	11
9	Department of Internal Diseases	162
10	Department of Skin and Venereal Diseases (Dermatology)	16
11	Department of Infectious Diseases	20
12	Department of Physical Medicine and Rehabilitation	32
13	Department of General Surgery	55
14	Department of Thoracic Diseases	16
15	Department of Thoracic and Cardiovascular Surgery	44
16	Department of Eye Diseases (Ophthalmology)	31
17	Department of Obstetrics and Gynecology	50
18	Department of Cardiology	34
19	Department of Ear, Nose and Throat (Otolaryngology)	30
20	Department of Neurology	31
21	Department of Nuclear Medicine	18
22	Department of Orthopedics and Traumatology	27
23	Department of Pathology	30
24	Department of Plastic, Reconstructive and Aesthetics Surgery	33
25	Department of Mental Health and Diseases	24
26	Department of Radiation Oncology	17
27	Department of Radiology	78
28	Department of Urology	25
29	Hospital General	348
TOTAL		**1584**

Table E.2. Number of regular and 4B staff in Faculty of Medicine Deanery

FACULTY OF MEDICINE DEANERY		
No	**Departments**	**Number of Regular and 4B Staff**
1	Department of Anatomy	12
2	Department of Medical Parasitology	5
3	Department of Biostatistics and Medical Informatics	6
4	Department of Histology and Embryology	13
5	Department of Medical Biology	19
6	Department of Medical Pharmacology	18
7	Department of Public Health	21
8	Department of Medical History and Ethics	1
9	Department of Medical Microbiology	16
10	Department of Biophysics	5
11	Department of Medical Genetics	2
12	Department of Physiology	12
13	Department of Medical Biochemistry	20
14	Deanery General	32
TOTAL		**182**

Total number of regular and 4B= Balcalı Hospital + Faculty of Medicine Deanery

= 1584 + 182

= 1766

Table E.3. Number of regular and 4B staff details at Balcalı Hospital

Regular and 4B Staff Details (Number of Academic and Administrative Staff)	
Professors	136
Associate Professors	37
Assistant Professors	49
Teaching Assistants	22
Expert Doctors	16
Research Assistants	335
Nurses	609
Other Staff (Engineer, Technicians and etc.)	562
TOTAL	**1766**

Table E.4. Number of casual laborers at Balcalı Hospital

Types of Staff	Number of Temporarily Staff
Cleaning Staff	253
Food Firm Staff	150
Technical Support and Maintenance Staff	570
Health Staff	750
TOTAL	**1723**

- **Total Staff Number** = Regular and 4B + Temporarily Staff

  = 1766 + 1723

  = 3489

APPENDIX F: Number of Beds, Medical Examinations and Inpatients

Table F.1. Number of beds, examinations and inpatients in Ç.U. Balcalı Hospital

Department name	Field of study	Number of beds	Number of beds	Medical examinations number	Medical examinations number	Daily patients number	Number of inpatient	Number of inpatients
Emergency Medicine	Emergency Medicine	11	11	3504	3504	258	164	164
Forensic Medicine	Forensic Medicine	0	0	591	591	0	0	0
Family Medicine	Family Medicine	0	0	45	45	0	0	0
Anesthesiology and Reanimation	Anesthesiology	0	9	318	318	53	4	20
	Reanimation	9		0		0	16	
Brain Surgery	Brain Surgery Intensive Care	16	48	0	808	0	16	91
	Neurosurgery	32		808		32	75	
Child Health and Diseases	Child Emergency	8	184	1650	9611	84	45	611
	Pediatric Allergy Immunology	0		1119		0	0	
	Pediatric Infectious	20		335		0	47	
	Pediatric Gastroenterology	0		498		1	0	
	Pediatric Hematology	23		494		174	62	
	Pediatric Cardiovascular	8		20		0	0	
	Pediatric Nephrology	0		615		16	0	
	Pediatric Neurology	0		856		20	0	
	Pediatric Oncology	18		369		107	55	
	Pediatric Health and Diseases	54		3655		16	291	
	Pediatric Neonatal 1	24		0		0	37	
	Pediatric Neonatal 2	18		0		0	44	
	Pediatric Intensive Care	11		0		0	30	

Pediatric Surgery	Pediatric Surgery	22	35	400	400	2	124	124
	Pediatric Surgery Neonatal Intensive Care	7		0		0	0	
	Pediatric Surgery Intensive Care	6		0		0	0	
Child and Adolescent Mental Health and Diseases	Child and Adolescent Mental Health and Diseases	0	0	1652	1652	9	0	0
Internal Diseases	Internal Diseases Intensive Care	11	134	0	9604	0	21	363
	Internal Diseases Endocrine	18		1676		0	56	
	Internal Diseases Gastroenterology	20		1319		121	61	
	General Internal Diseases	0		352		0	0	
	Internal Diseases Hematology	18		1278		159	50	
	Internal Diseases Hypertension	0		233		0	0	
	Internal Diseases Nephrology	19		1034		1	43	
	Internal Diseases Oncology	18		2210		891	78	
	Internal Diseases Hem. Onc. Common Use	12					0	
	Internal Diseases Rheumatology Immunology	18		1502		59	54	
Skin and Venereal Diseases (Dermatology)	Skin and Venereal Diseases (Dermatology)	19	19	1859	1859	0	42	42
Infectious Diseases	Infectious Diseases	28	28	921	921	0	48	48
Physical Medicine and Rehabilitation	Physical Medicine and Rehabilitation	20	20	1216	1216	0	39	39
General Surgery	General Surgery 1	37	94	1314	1314	68	140	301
	General Surgery 2	37					139	
	General Surgical Intensive Care	20		0		0	22	
Thoracic Diseases	Chest Diseases	25	25	690	690	7	79	79
Thoracic Surgery	Thoracic Surgery	18	18	149	149	3	38	38

Cardiovascular Surgery	Cardiovascular Surgery	12	20	346	671	1	100	143
	POS-OP Care Unit	8		325		0	43	
Ophthalmology (Eye Diseases)	Eye Diseases (Ophthalmology)	30	30	2896	2896	250	212	212
Obstetrics And Gynecology	Delivery Room	11	82				478	478
	Gynecology	36					0	
	Obstetrics	35		2434	2434	97	0	
Cardiology	Cardiology	28	46	1336	1336	1	220	300
	Coronary Int. Care	18		0		0	80	
Ear, Nose and Throat (Otolaryngology)	Ear, Nose and Throat (Otolaryngology)	37	37	2060	2060	18	245	245
Neurology	Neurology	37	49	2131	2131	46	176	191
	Neurology Intensive Care	12		0		0	15	
Nuclear Medicine	Nuclear Medicine	3	3	0	0	0	0	0
Orthopedics and Traumatology	Orthopedics and Traumatology	36	36	1409	1409	32	158	158
Plastic, Reconstructive and Aesthetics Surgery	Plastic Reconstructive and Aesthetics Surgery	36	45	725	725	85	94	101
	Burn Service	9		0		0	7	
Mental Health and Diseases	Mental Health and Diseases	30	30	1355	1355	0	30	30
Urology	Urology	26	26	1635	1635	89	227	227
Daily Patient Clinics	Daily Patient Clinics	28	28	0	0	0	0	0
Prisoner Room	Prisoner Room	7	7	0	0	0	0	0
Organ Transplant Center	Organ Transplant Center	10	10	0	0	0	0	0
VIP	VIP	14	14	0	0	0	0	0
TOTAL		**1088**	**1088**	**49334**	**49334**	**2700**	**4005**	**4005**

Table F.2. Bed numbers in intensive cares

Field Name	Number of Beds
Reanimation	9
Brain Surgery Intensive Care	16
Pediatric Neonatal 1	24
Pediatric Neonatal 2	18
Pediatric Intensive Care	11
Pediatric Surgery Neonatal Intensive Care	7
Pediatric Surgery Intensive Care	6
Internal Diseases Intensive Care	11
General Surgical Intensive Care	20
Cardiovascular POS-OP Care Unit	8
Coronary Intensive Care	18
Neurology Intensive Care	12
Burn Service	9
Organ Transplant Center	10
TOTAL	**179**

APPENDIX G: Transformers in Çukurova University and Balcalı Hospital

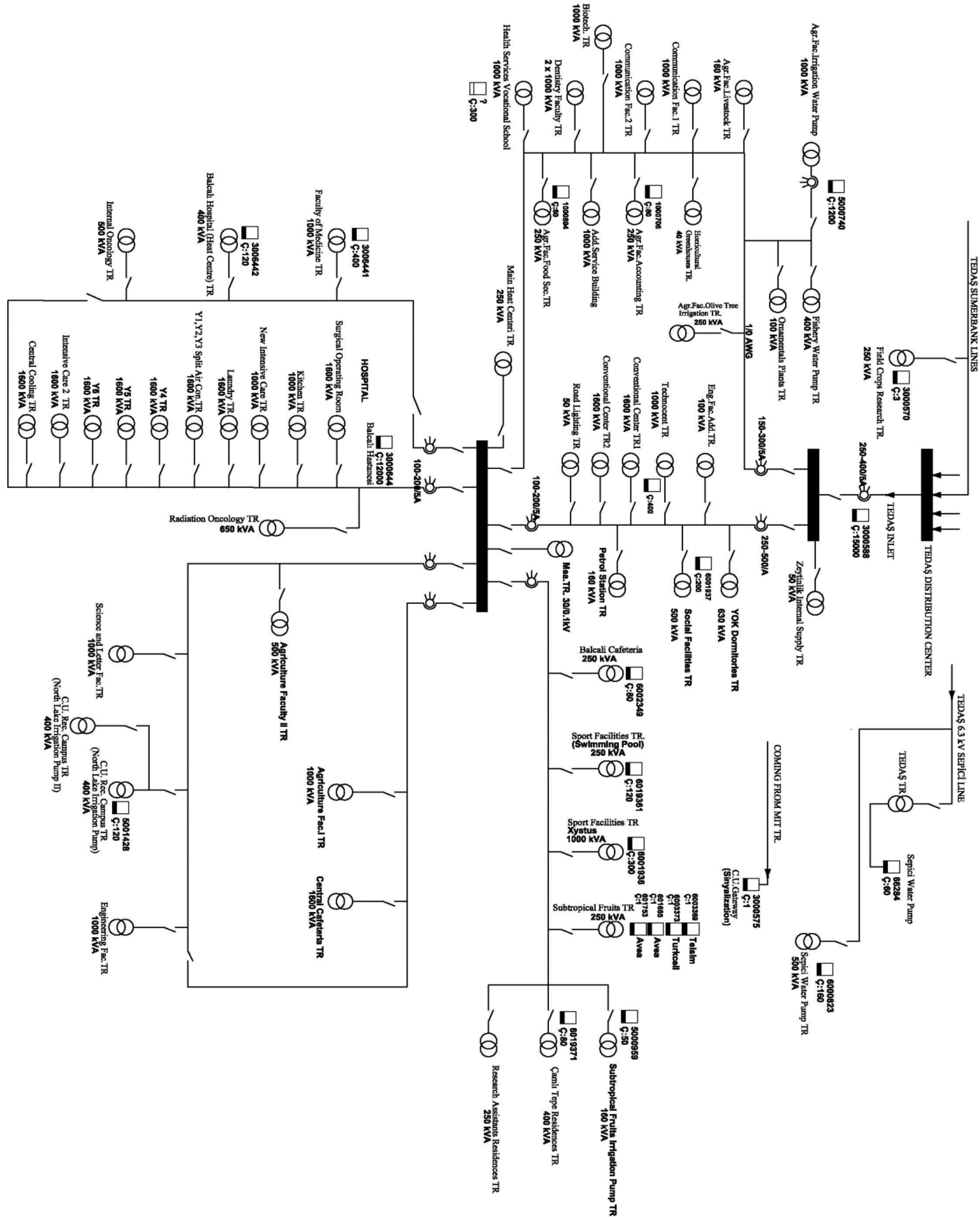


Figure G.1. The single line diagram of transformers in Ç.U.

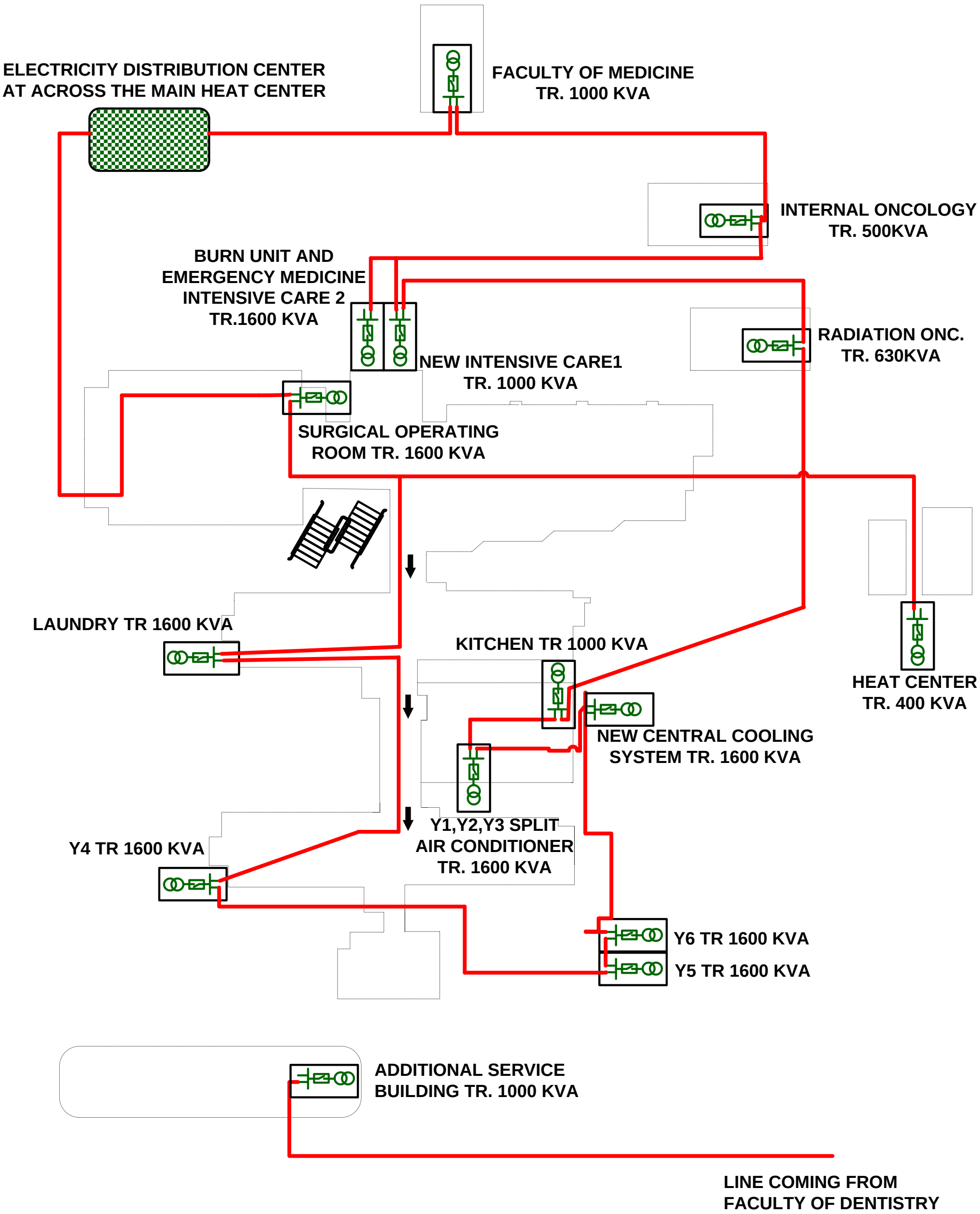


Figure G.2. The location of transformers at Balcalı Hospital

Table G.1. List of transformers in Ç.U.

No	Unit Name	Power rating	
1	Zeytinlik Distribution Center Internal Supply Center TR	50	kVA
2	Y.Ö.K. Dormitories TR	630	kVA
3	Residences (Social Facilities) TR	500	kVA
4	Sepici Water Pump TR	400	kVA
5	Field Crops Research TR	100	kVA
6	Agricultural Faculty Irrigation Pump TR	1000	kVA
7	Fishery Water Pump TR	400	kVA
8	Ornamentals Plants TR	100	kVA
9	Agricultural Faculty Livestock TR	160	kVA
10	Horticulture Greenhouse TR.	40	kVA
11	Agricultural Faculty Accounting Workshop TR	250	kVA
12	Communication Faculty TR 1	1000	kVA
13	Communication Faculty TR 2	1000	kVA
14	Biotechnology Building TR	1000	kVA
15	Dentistry Faculty TR 1	1000	kVA
16	Dentistry Faculty TR 2	1000	kVA
17	Agricultural Faculty Food Faculty TR	250	kVA
18	Health Care Vocational School TR	1000	kVA
19	Agricultural Faculty Olive-Tree Irrigation Pump TR	250	kVA
20	Engineering Faculty Additional Building TR	100	kVA
21	Techno City TR	1600	kVA
22	Convention Center TR 1	1600	kVA
23	Convention Center TR 2	1600	kVA
24	Road Lighting TR	100	kVA
25	Petrol Station TR	160	kVA
26	Balcalı Cafeteria TR	250	kVA
27	Sports Facilities (Swimming Pool) TR	250	kVA
28	Subtropical Fruits TR	250	kVA
29	Subtropical Fruits Irrigation Pump TR	160	kVA
30	Research Assistants Residences TR	400	kVA
31	Çamlı Tepe Residences TR	250	kVA
32	Sports Facilities (Xystus) TR	1000	kVA
33	Physical Education and Sports School TR	1600	kVA
34	Agricultural Faculty TR 1	1000	kVA
35	Agricultural Faculty TR 2	500	kVA
36	Central Cafeteria TR	1600	kVA
37	Engineering Faculty TR	1000	kVA
38	Science and Letter Faculty TR	1000	kVA
39	North Lake Irrigation Pump TR 1	400	kVA
40	North Lake Irrigation Pump TR 2	400	kVA

41	Main Heat Center TR	250	kVA
42	Additional Service Building TR	1000	kVA
43	Internal Oncology Building TR	500	kVA
44	Faculty of Medicine TR	1000	kVA
Total transformer capacity of campus		**28100**	**kVA**
Transformes at Balcalı Hospital		**Power rating**	
45	Balcalı Hospital (Heat Center) TR	400	kVA
46	Surgical Operating Room TR	1600	kVA
47	Laundry TR	1600	kVA
48	Y4 (New Building 4) TR	1600	kVA
49	Y5 TR	1600	kVA
50	Y6 TR	1600	kVA
51	Central Cooling Systems TR	1600	kVA
52	Y1,Y2,Y3 Split Air Conditioner TR	1600	kVA
53	Kitchen TR	1000	kVA
54	Intensive Care 1 TR	1000	kVA
55	Intensive Care 2 TR	1600	kVA
56	Radiation Oncology TR	630	kVA
Total transformer capacity at Balcalı Hospital		**15830**	**kVA**
GENERAL TOTAL		**43930**	**kVA**

APPENDIX H: Single Line Diagram of Transformers and (EDP)

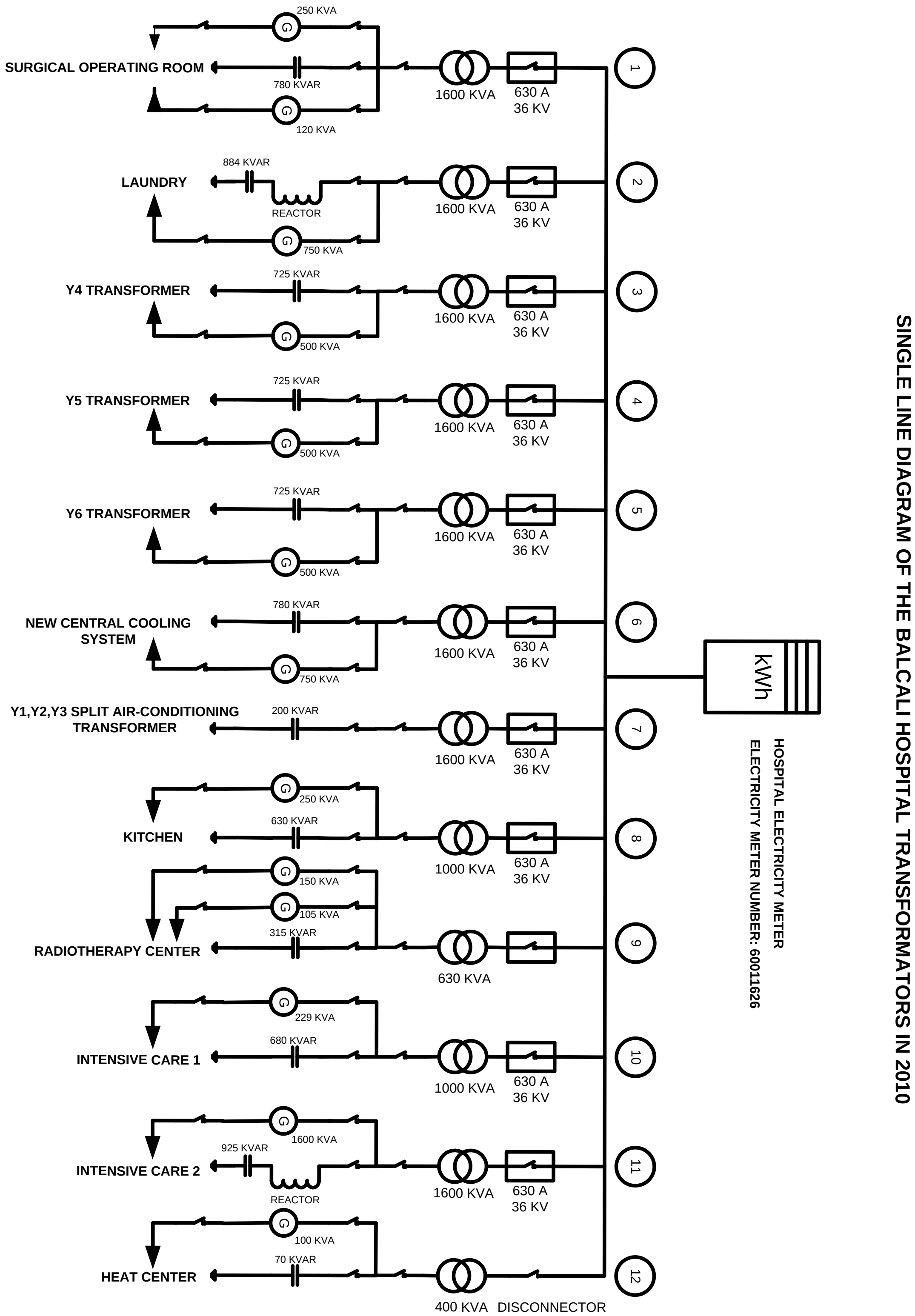


Figure H.1. Single line diagram of transformers at Balcalı Hospital in 2010

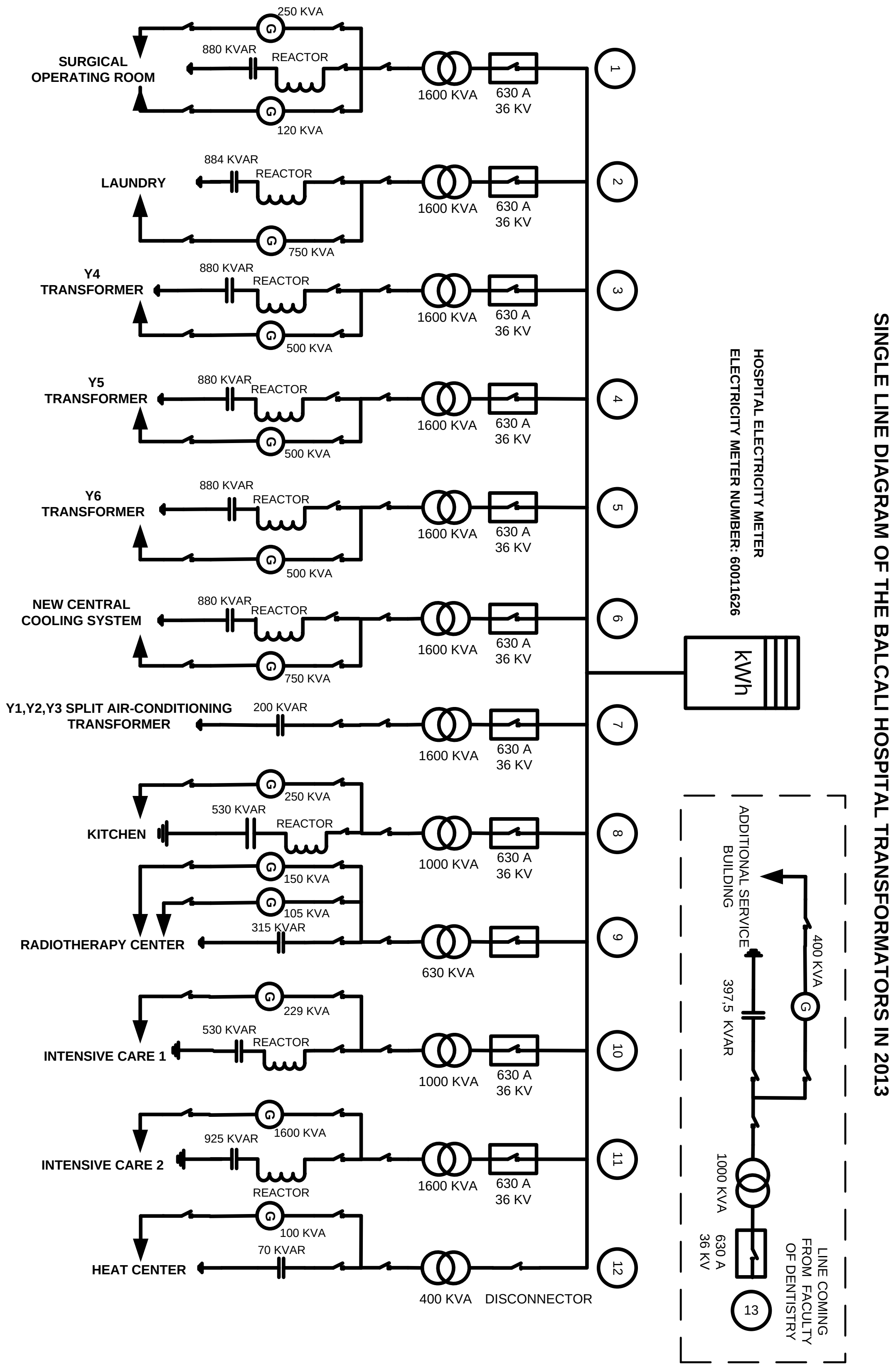


Figure H.2. Single line diagram of transformers at Balcalı Hospital in 2013

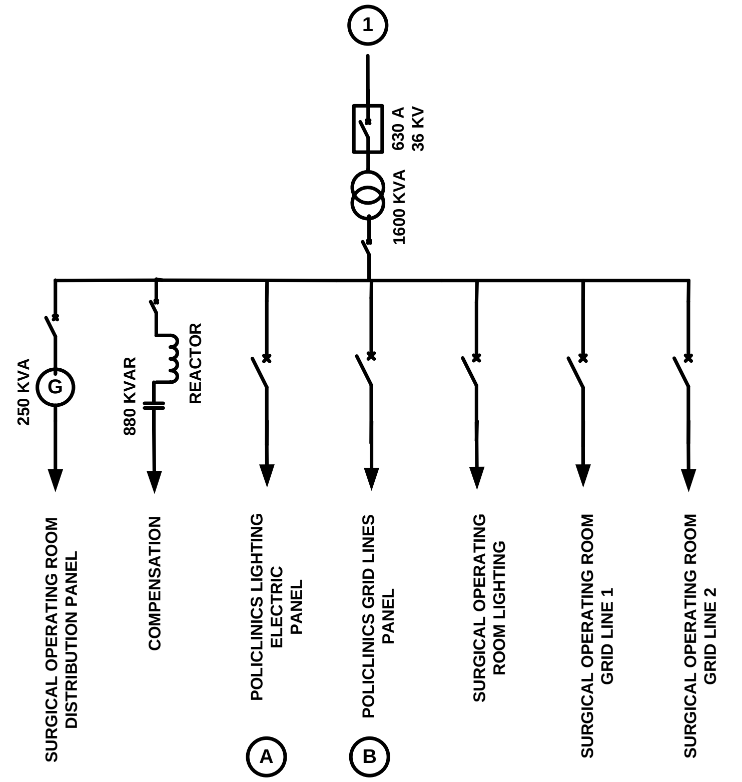


Figure H.3. Single line diagram of surgical operating room EDP

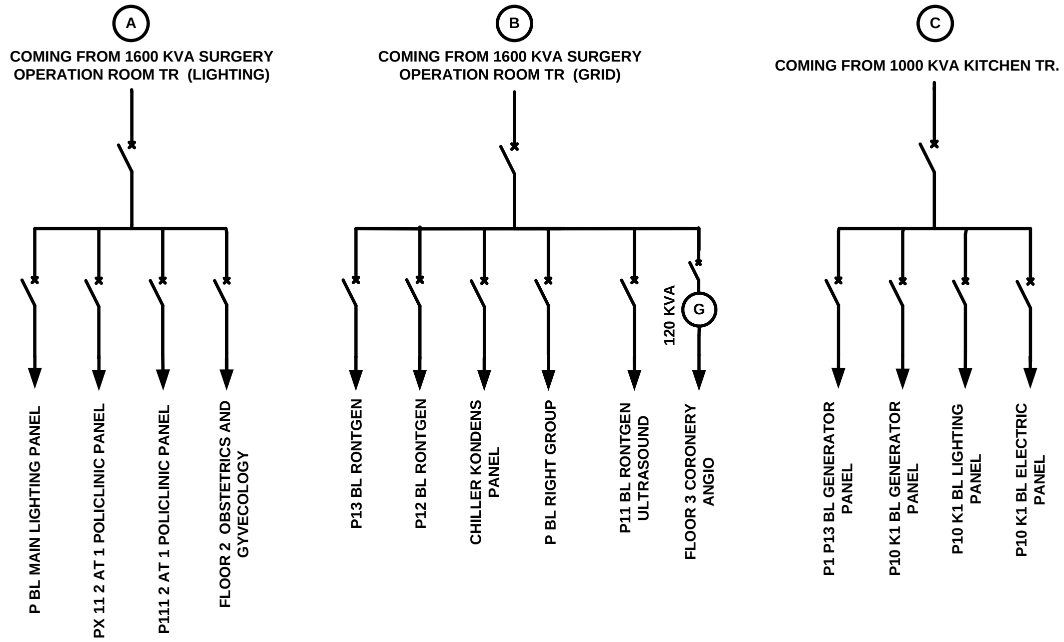


Figure H.4. Single line diagram of electrical warehouse EDP

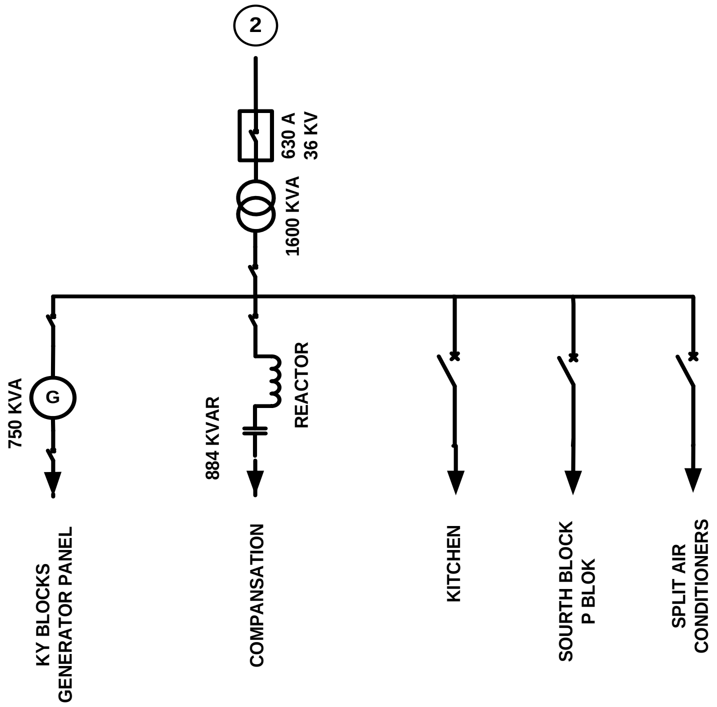


Figure H.5. Single line diagram of laundry EDP

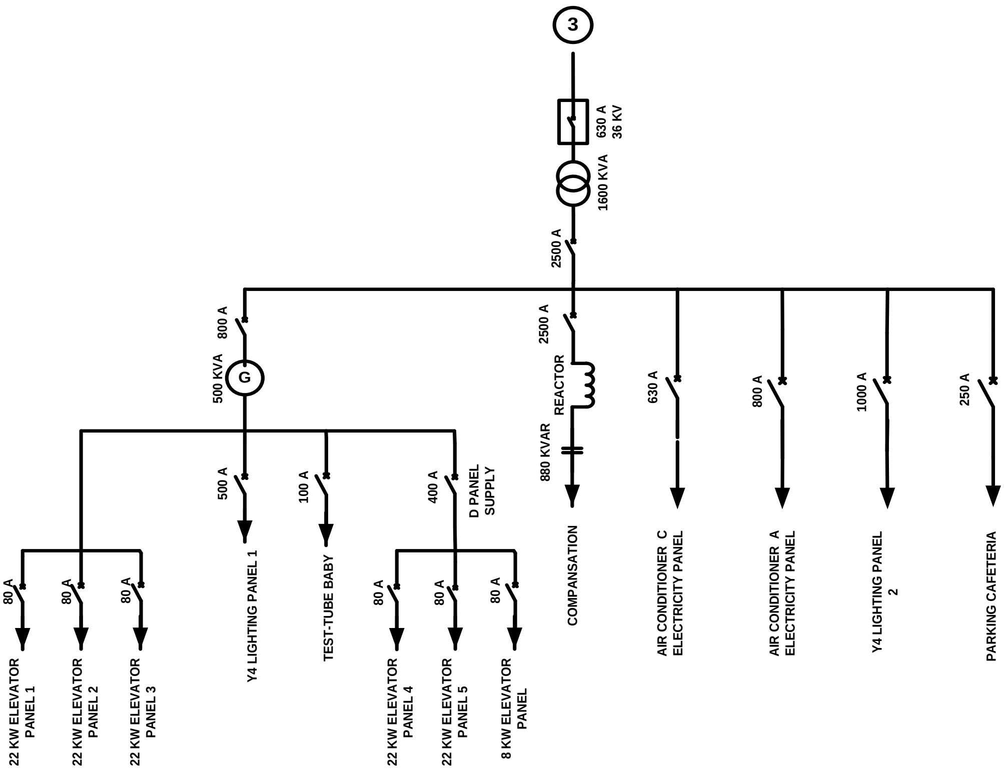


Figure H.6. Single line diagram of Y4 EDP

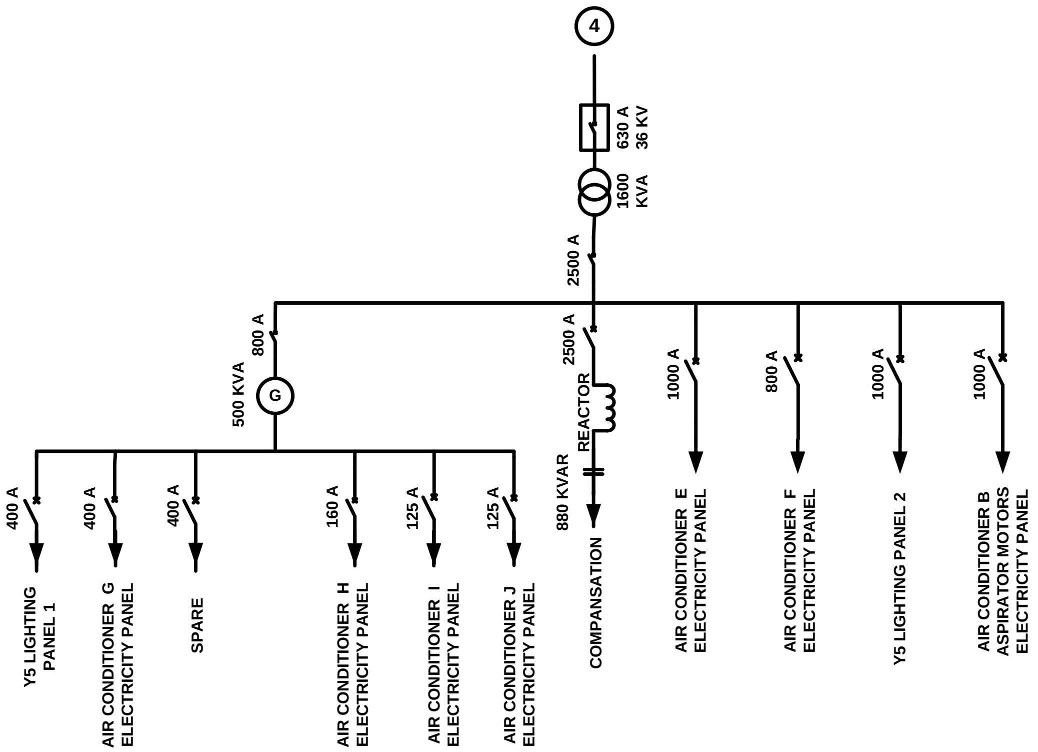


Figure H.7. Single line diagram of Y5 EDP

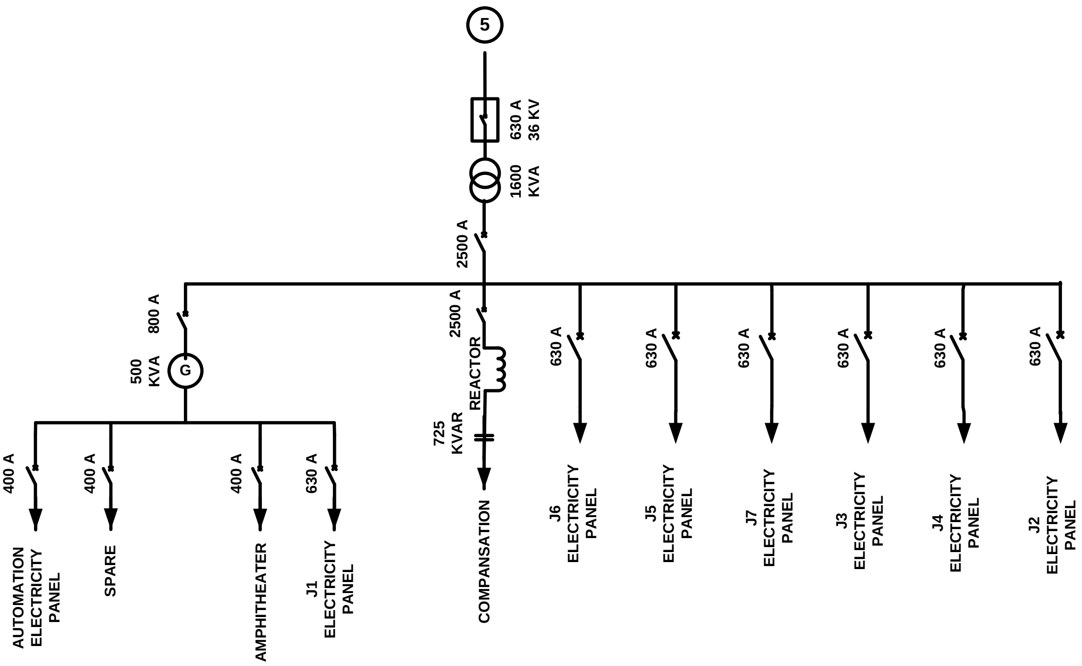


Figure H.8. Single line diagram of Y6 EDP

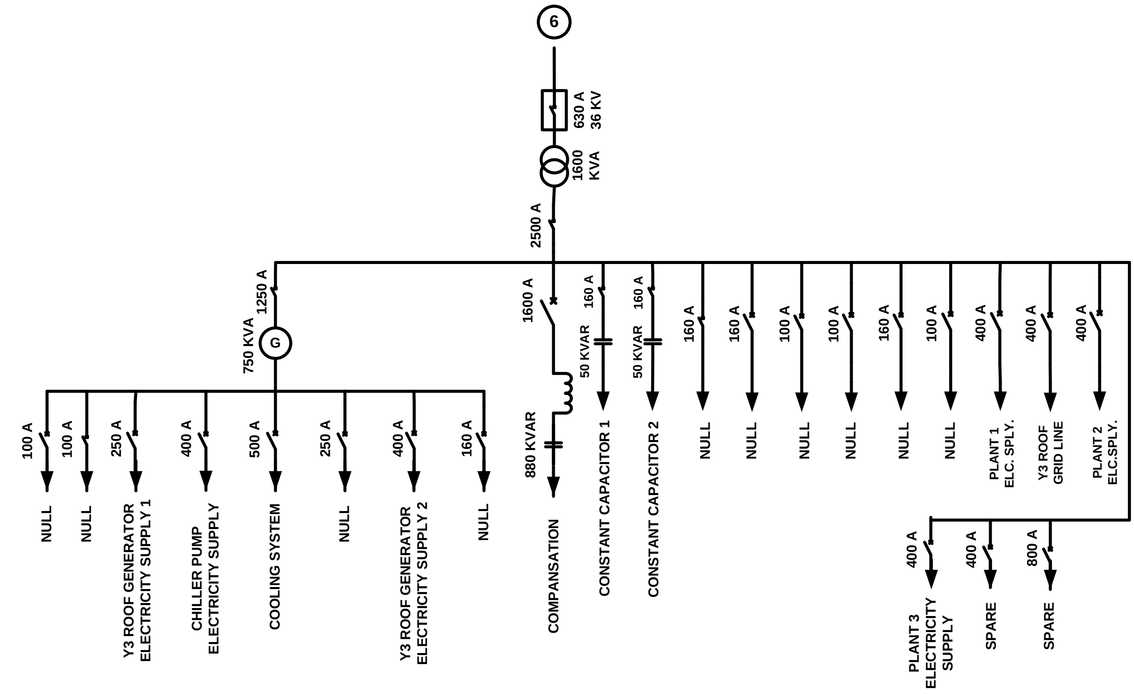


Figure H.9. Single line diagram of new central cooling system EDP

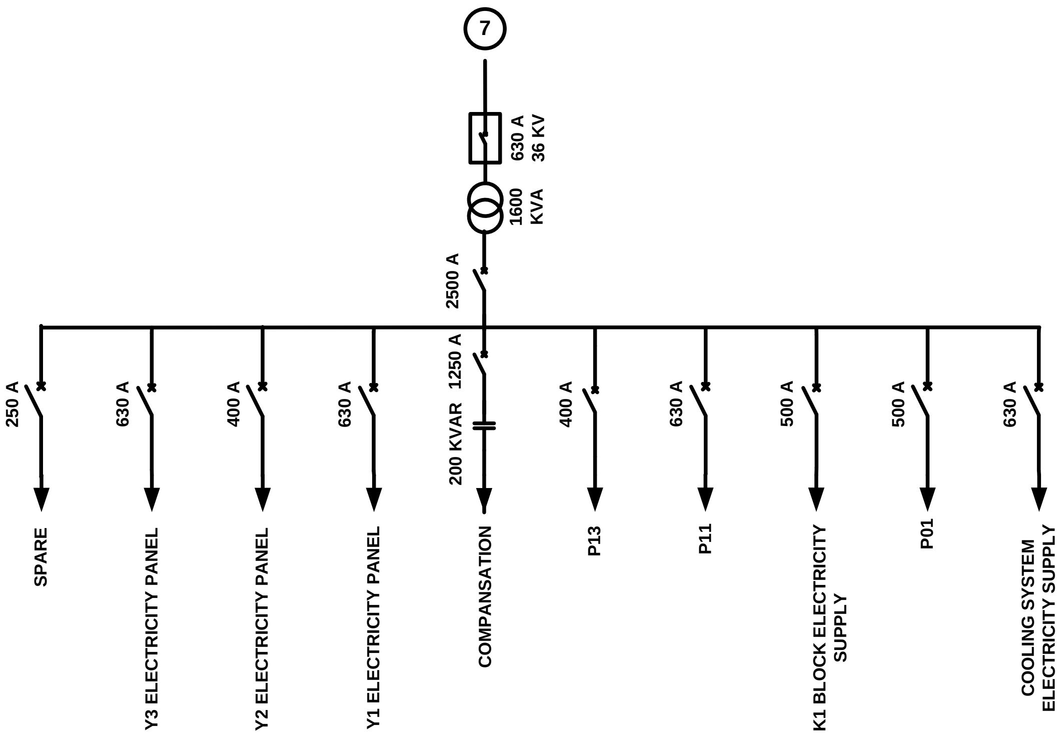


Figure H.10. Single line diagram of Y1, Y2 and Y3 split air conditioners EDP

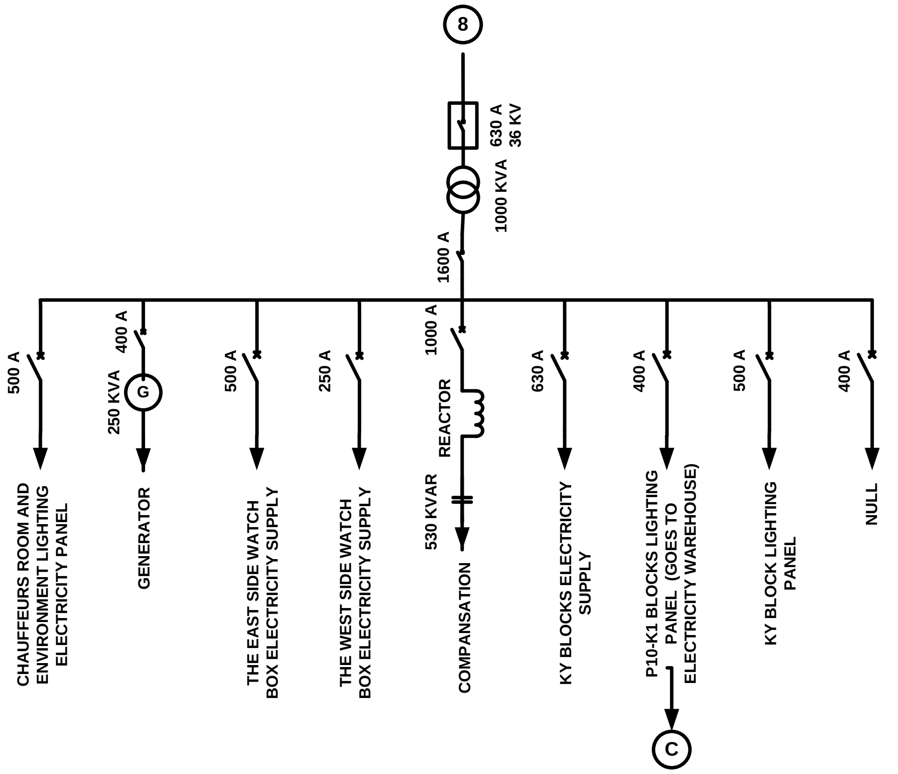


Figure H.11. Single line diagram of kitchen EDP

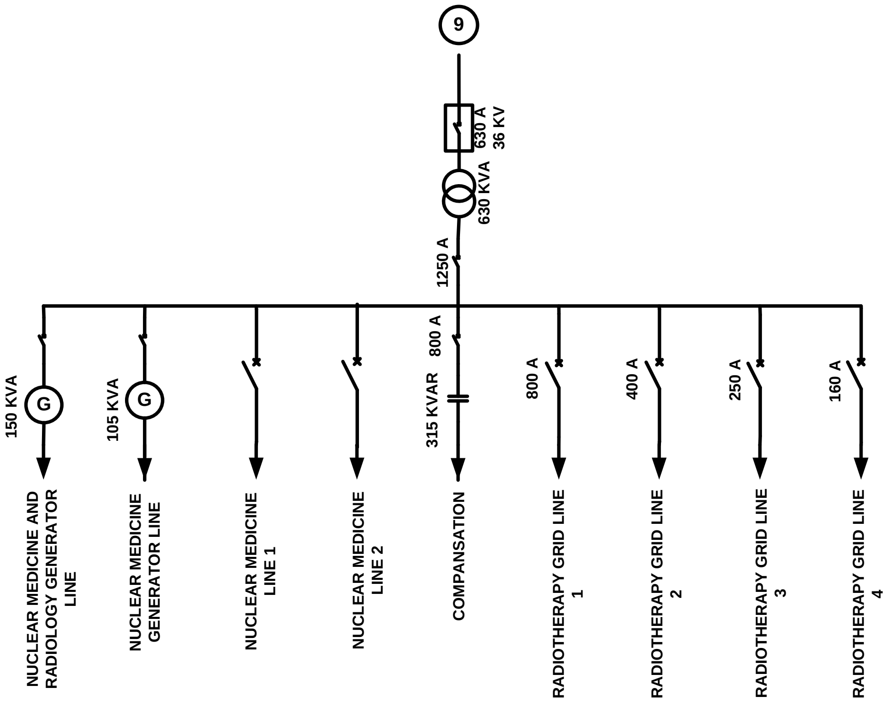


Figure H.12. Single line diagram of radiotherapy center EDP

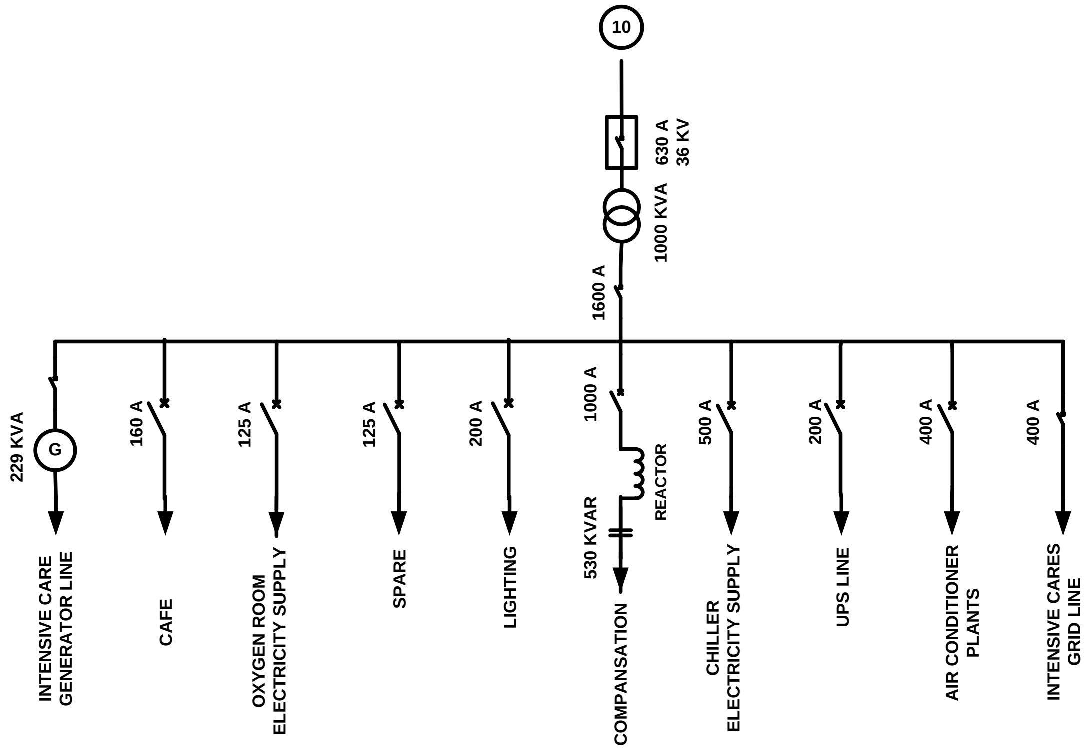


Figure H.13. Single line diagram of new intensive care EDP

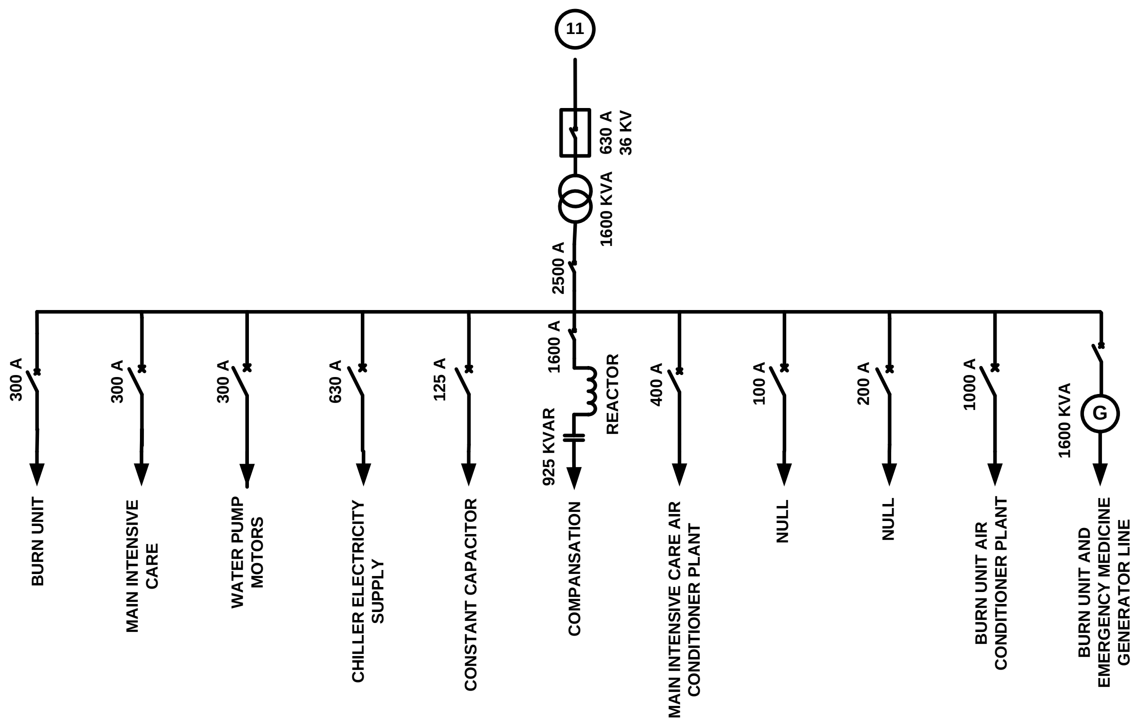


Figure H.14. Single line diagram of burn unit and emergency medicine EDP

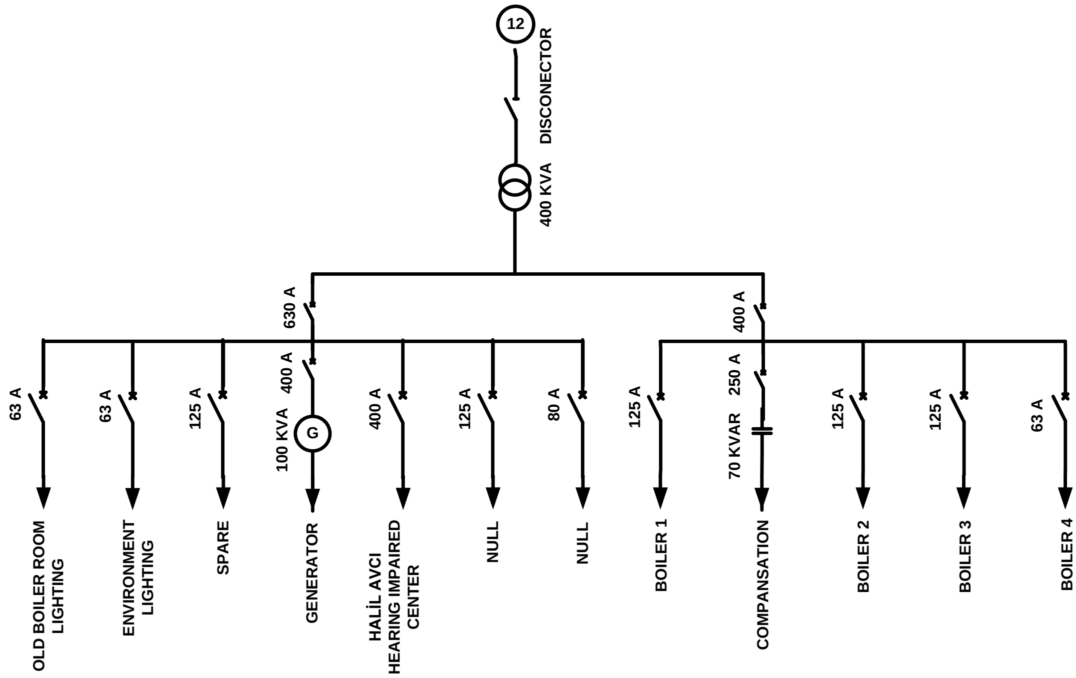


Figure H.15. Single line diagram of heat center EDP

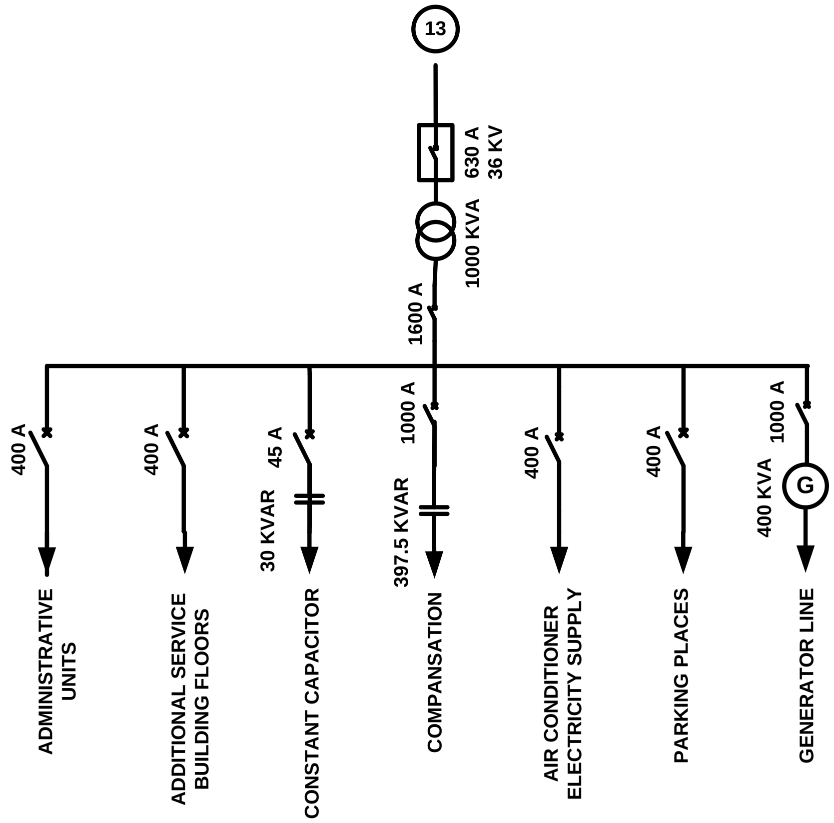


Figure H.16. Single line diagram of additional service building EDP

APPENDIX I: Total Installed Capacity of Departments

Table I.1. Total installed capacity of departments at Balcalı Hospitals

Department	Nominal Powers (kVA)
Department of Emergency Medicine	150.00
Department of Forensic Medicine	57.00
Department of Family Medicine	16.50
Department of Anesthesiology and Reanimation	248.00
Department of Brain Surgery	190.00
Department of Child Health and Diseases	756.00
Department of Pediatric Surgery	178.00
Department of Child and Adolescent Mental Health and Diseases	20.00
Department of Internal Diseases	704.00
Department of Skin and Venereal Diseases (Dermatology)	149.00
Department of Infectious Diseases	150.00
Department of Physical Medicine and Rehabilitation	113.00
Department of General Surgery	364.00
Department of Thoracic Diseases	75.00
Department of Thoracic and Cardiovascular Surgery	269.00
Department of Eye Diseases (Ophthalmology)	228.00
Department of Obstetrics and Gynecology	428.00
Department of Cardiology	284.00
Department of Ear, Nose and Throat (Otolaryngology)	156.00
Department of Neurology	201.00
Department of Nuclear Medicine	195.00
Department of Orthopedics and Traumatology	154.00
Department of Pathology	57.00
Department of Plastic, Reconstructive and Aesthetics Surgery	170.00
Department of Mental Health and Diseases	156.00
Department of Radiation Oncology	728.00
Department of Radiology	1007.00
Department of Urology	196.00
Hemapheresis, Stem Cells and Cryopreservation Unit	20.00
Hospital General	2200.50
Installed capacity of the Balcalı Hospital	**9620.00**
The Faculty of Medicine	**937.00**
Total of electricity nominal values	**10557.00**

APPENDIX J: Total Electricity Consumptions at Balcalı Hospital

Table J.1. Electricity consumptions in 2009

Billing Period	BALCALI HOSPITAL First Index	BALCALI HOSPITAL Last Index	BALCALI HOSPITAL Difference	BALCALI HOSPITAL Multiplier	BALCALI HOSPITAL Consumption kWh	BALCALI HOSPITAL Consumption TL	FACULTY OF MEDICINE First Index	FACULTY OF MEDICINE Last Index	FACULTY OF MEDICINE Difference	FACULTY OF MEDICINE Multiplier	FACULTY OF MEDICINE Consumption kWh	FACULTY OF MEDICINE Consumption TL	Total TL
Jan 09	3,611.28	3,698.62	87.34	12,000	1,048,080.00	218,113.31							218,113.31
Feb 09	3,698.62	3,780.95	82.33		987,960.00	213,769.92							213,769.92
Mar 09	3,780.95	3,874.31	93.36		1,120,320.00	241,970.02							241,970.02
Apr 09	3,874.31	3,954.02	79.71		956,520.00	203,364.39							203,364.39
May 09	3,954.02	4,064.88	110,86		1,330,320.00	287,404.13							287,404.13
June 09	4,064.88	4,264.18	199.30		2,391,600.00	514,032.10							514,032.10
July 09	4,264.18	4,518.92	254.74		3,056,880.00	651,794.10							651,794.10
Aug 09	4,518.92	4,762.43	243.51		2,922,120.00	622,550.17							622,550.17
Sep 09	4,762.43	4,961.41	198.98		2,387,760.00	509,526.50							509,526.50
Oct 09	4,961.41	5,120.52	159.11		1,909,320.00	447,180.30							447,180.30
Nov 09	5,120.52	5,193.78	73.26		879,120.00	206,016.88							206,016.88
Dec 09	5,193.78	5,295.24	101.46		1,217,520.00	284,524.46							284,524.46
TOTAL					20,207,520.00	4,400,246.28							4,400,246.28

Table J.2 Electricity consumptions in 2010

Billing Period	BALCALI HOSPITAL First Index	BALCALI HOSPITAL Last Index	BALCALI HOSPITAL Difference	BALCALI HOSPITAL Multiplier	BALCALI HOSPITAL Consumption kWh	BALCALI HOSPITAL Consumption TL	FACULTY OF MEDICINE First Index	FACULTY OF MEDICINE Last Index	FACULTY OF MEDICINE Difference	FACULTY OF MEDICINE Multiplier	FACULTY OF MEDICINE Consumption kWh	FACULTY OF MEDICINE Consumption TL	Total TL
Jan 10*	0.00	52.93	52.93	12,000	1,124,520.00	264,896.43							264,896.43
Feb 10	52.93	139.13	86.20		1,034,400.00	242,934.50							242,934.50
Mar 10	139.13	227.07	87.94		1,055,280.00	247,921.40							247,921.40
Apr 10	227.07	310.06	82.99		995,880.00	234,773.20							234,773.20
May 10	310.06	432.67	122.61		1,471,320.00	348,348.70							348,348.70
June 10	432.67	621.00	188.33		2,259,960.00	532,868.90							532,868.90
July 10	621.00	862.21	241.21		2,894,520.00	657,127.40							657,127.40
Aug 10	862.21	1,134.60	272.39		3,268,680.00	738,022.00							738,022.00
Sep 10	1,134.60	1,398.60	264.00		3,168,000.00	717,846.70							717,846.70
Oct 10	1,398.60	1,546.00	147.40		1,768,800.00	405,892.70							405,892.70
Nov10	1,546.00	1,630.00	84.00		1,008,000.00	228,070.30							228,070.30
Dec 10	1,630.00	1,717.24	87.24		1,046,880.00	237,478.10							237,478.10
TOTAL					21,096,240.00	4,856,180.33							4,856,180.33

* In January 2010, additional consumptions added to real consumption and first index is accepted as zero by TEDAS.

Table J.3. Electricity consumptions in 2011

Billing Period	BALCALI HOSPITAL						FACULTY OF MEDICINE						Total TL
	First Index	Last Index	Difference	Multiplier	Consumption kWh	Consumption TL	First Index	Last Index	Difference	Multiplier	Consumption kWh	Consumption TL	
Jan 11	1,717.24	1,814.13	96.89	12,000	**1,162,680.00**	**262,217.60**	7,060	7,326.6	267	400	**106,640.00**	**26,166.70**	**288,384.30**
Feb 11	1,814.13	1,893.07	78.94		**947,280.00**	**213,240.50**	7,326.6	7,538	211		**84,560.00**	**20,748.30**	**233,988.80**
Mar 11	1,893.07	1,988.13	95.06		**1,140,720.00**	**256,639.90**	7,538	7,814	276		**110,400.00**	**27,088.60**	**283,728.50**
Apr 11	1,988.13	2,068.70	80.57		**966,840.00**	**216,324.90**	7,814	8,051	237		**94,800.00**	**23,198.30**	**239,523.20**
May 11	2,068.70	2,181.76	113.06		**1,356,720.00**	**308,232.60**	8,051	8,287	236		**94,400.00**	**23,100.50**	**331,333.10**
June 11	2,181.76	2,364.52	182.76		**2,193,120.00**	**498,897.30**	8,287	8,594	307		**122,800.00**	**30,050.30**	**528,947.60**
July 11	2,364.52	2,593.44	228.92		**2,747,040.00**	**621,906.90**	8,594	8,937	343		**137,200.00**	**33,573.10**	**655,480.00**
Aug 11	2,593.44	2,840.79	247.35		**2,968,200.00**	**669,556.30**	8,937	9,247	310		**124,000.00**	**30,343.00**	**699,899.30**
Sep 11	2,840.79	3,066.58	225.79		**2,709,480.00**	**613,204.80**	9,247	9,494	247		**98,800.00**	**24,176.50**	**637,381.30**
Oct 11	3,066.58	3,176.00	109.42		**1,313,040.00**	**357,261.50**	9,494	9,649	155		**62,000.00**	**17,949.00**	**375,210.50**
Nov11	3,176.00	3,272.52	96.52		**1,158,240.00**	**315,771.60**	9,649	9,825	176		**70,400.00**	**20,493.40**	**336,265.00**
Dec 11	3,272.52	3,376.42	103.9		**1,246,800.00**	**339,238.44**	9,825	10,027	202		**80,693.00**	**23,489.66**	**362,728.10**
TOTAL					**19,910,160.00**	**4,672,492.34**					**1,186,693.00**	**300,377.36**	**4,972,869.70**

Table J.4. Electricity consumptions in 2012

Billing Period	BALCALI HOSPITAL First Index	BALCALI HOSPITAL Last Index	BALCALI HOSPITAL Difference	BALCALI HOSPITAL Multiplier	BALCALI HOSPITAL Consumption kWh	BALCALI HOSPITAL Consumption TL,	FACULTY OF MEDICINE First Index	FACULTY OF MEDICINE Last Index	FACULTY OF MEDICINE Difference	FACULTY OF MEDICINE Multiplier	FACULTY OF MEDICINE Consumption kWh	FACULTY OF MEDICINE Consumption TL,	Total TL
Jan 12	3,376.42	3,481.17	104.75	12,000	**1,257,000.00**	**341,910.30**	38	273	235	400	**94,000**	**27,434.60**	**369,344.90**
Feb 12	3,481.17	3,580.13	98.96		**1,187,520.00**	**322,793.70**	273	468	195		**78,000**	**22,772.40**	**345,566.10**
Mar 12	3,580.13	3,682.03	101.9		**1,222,800.00**	**332,211.80**	468	674	206		**82,400**	**24,052.20**	**356,264.00**
Apr 12	3,682.03	3,756.49	74.46		**893,520.00**	**265,461.10**	674	812	138		**55,200**	**17,604.20**	**283,065.30**
May 12	3,756.49	3,888.08	131.59		**1,579,080.00**	**473,674.00**	812	964	152		**60,800**	**19,450.50**	**493,124.50**
June 12	3,888.08	4,090.44	202.36		**2,428,320.00**	**727,198.40**	964	1,192	228		**91,200**	**29,173.20**	**756,371.60**
July 12	4,090.44	4,369.32	278.88		**3,346,560.00**	**998,053.90**	1,192	1,457	265		**106,000**	**33,906.70**	**1,031,960.60**
Aug 12	4,369.32	4,638.85	269.53		**3,234,360.00**	**965,750.20**	1,457	1,677	220		**88,000**	**28,149.80**	**993,900.00**
Sep 12	4,638.85	4,878.64	239.79		**2,877,480.00**	**860,469.20**	1,677	1,936	259		**103,600**	**33,139.10**	**893,608.30**
Oct 12	4,878.64	5,048.08	169.44		**2,033,280.00**	**654,374.00**	1,936	2,121	185		**74,000**	**25,448.20**	**679,822.20**
Nov12	5,048.08	5,151.72	103.64		**1,243,680.00**	**400,114.60**	2,121	2,305	184		**73,600**	**25,424.60**	**425,539.20**
Dec 12	5,151.72	5,254.96	103.24		**1,238,880.00**	**396,221.70**	2,305	2,579	274		**109,600**	**37,858.20**	**434,079.90**
TOTAL					**22,542,480.00**	**6,738,232.90**					**1,016,400.00**	**324,413.70**	**7,062,646.60**

Table J.5. Electricity consumptions in 2013

Billing Period	BALCALI HOSPITAL						FACULTY OF MEDICINE						Total TL,
	First Index	Last Index	Difference	Multiplier	Consumption kWh	Consumption TL,	First Index	Last Index	Multiplier	Difference	Consumption kWh	Consumption TL,	
Jan 13	5,254.96	5,359.18	104.2		1,250,640.00	399,116.70	2,579	2,854		275	110,000	37,996.30	437,113.00
Feb 13	5,359.18	5,451.07	91.89		1,102,680.00	351,580.60	2,854	3,027		173	69,200	23,905.00	375,485.60
Mar 13	5,451.07	5,546.80	95.73		1,148,760.00	365,956.70	3,027	3,223		196	78,400	27,082.40	393,039.10
Apr 13	5,546.80	5,650.04	103.2	12,000	1,238,880.00	397,255.70	3,223	3,385	400	162	64,800	22,422.20	419,677.90
May 13	5,650.04	5,818.86	168.8		2,025,840.00	651,722.60	3,385	3,597		212	84,800	29,344.10	681,066.70
June 13	5,818.86	6,009.34	190.48		2,285,760.00	737,919.30	3,597	3,821		224	89,600	31,004.70	768,924.00
July 13	6,009.34	6,277.68	268.34		3,220,080.00	1,029,310..40	3,821	4,107		286	114,400	39,576.20	1,068,886.60
Aug 13													
Sep 13													
Oct 13													
Nov13													
Dec 13													
TOTAL					12,272,640.00	3,932,862.00					611,200.00	211,330.90	4,144,192.90

Table J.6. Electricity consumptions at day, peak and night time periods in 2009

Billing Period	DAY (06:00-17:00)				PEAK (17:00-22:00)				NIGHT (22:00-06:00)			
	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh
Jan 09	1,836.10	1,879.36	12,000	**519,120.00**	743.14	761.67	12,000	**222,360.00**	1,032.04	1,057.59	12,000	**306,600.00**
Feb 09	1,879.36	1,919.87		**486,120.00**	761.67	779.20		**210,360.00**	1,057.59	1,081.88		**291,480.00**
Mar 09	1,919.87	1,965.63		**549,120.00**	779.20	799.00		**237,600.00**	1,081.88	1,109.68		**333,600.00**
Apr 09	1,965.63	2,005.13		**474,000.00**	799.00	815.69		**200,280.00**	1,109.68	1,133.20		**282,240.00**
May 09	2,005.13	2,059.62		**653,880.00**	815.69	840.76		**300,840.00**	1,133.20	1,164.50		**375,600.00**
June 09	2,059.62	2,158.25		**1,183,560.00**	840.76	884.61		**526,200.00**	1,164.50	1,221.32		**681,840.00**
July 09	2,158.25	2,283.78		**1,506,360.00**	884.61	939.03		**653,040.00**	1,221.32	1,296.11		**897,480.00**
Aug 09	2,283.78	2,401.41		**1,411,560.00**	939.03	991.86		**633,960.00**	1,296.11	1,369.16		**876,600.00**
Sep 09	2,401.41	2,497.72		**1,155,720.00**	991.86	1,035.24		**520,560.00**	1,369.16	1,428.45		**711,480.00**
Oct 09	2,497.72	2,574.77		**924,600.00**	1,035.24	1,070.88		**427,680.00**	1,428.45	1,474.87		**557,040.00**
Nov09	2,574.77	2,610.74		**431,640.00**	1,070.88	1,086.76		**190,560.00**	1,474.87	1,496.28		**256,920.00**
Dec 09	2,610.74	2,660.03		**591,480.00**	1,086.76	1,108.72		**263,520.00**	1,496.28	1,526.49		**362,520.00**
TOTAL				**9,887,160.00**				**4,386,960.00**				**5,933,400.00**

Table J.7. Electricity consumptions at day, peak and night time periods in 2010

Billing Period	DAY (06:00-17:00)				PEAK (17:00-22:00)				NIGHT (22:00-06:00)			
	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh
Jan 10 *	0.00	27.56	12,000	**567,000.00**	0.00	10.27	12,000	**228,120.00**	0.00	15.10	12,000	**329,400.00**
Feb 10	27.56	71.58		**528,240.00**	10.27	27.25		**203,760.00**	15.10	40.30		**302,400.00**
Mar 10	71.58	116.44		**538,320.00**	27.25	44.62		**208,440.00**	40.30	66.01		**308,520.00**
Apr 10	116.44	159.50		**516,720.00**	44.62	60.97		**196,200.00**	66.01	89.59		**282,960.00**
May 10	159.50	224.62		**781,440.00**	60.97	84.98		**288,120.00**	89.59	123.07		**401,760.00**
June 10	224.62	325.00		**1,204,560.00**	84.98	121.00		**432,240.00**	123.07	175.00		**623,160.00**
July 10	325.00	450.53		**1,506,360.00**	121.00	168.50		**570,000.00**	175.00	243.18		**818,160.00**
Aug 10	450.53	588.28		**1,653,000.00**	168.50	222.44		**647,280.00**	243.18	323.90		**968,640.00**
Sep 10	588.28	723.06		**1,617,360.00**	222.44	275.04		**631,200.00**	323.90	400.45		**918,600.00**
Oct 10	723.06	801.00		**935,280.00**	275.04	305.00		**359,520.00**	400.45	440.00		**474,600.00**
Nov10	801.00	843.00		**504,000.00**	305.00	322.00		**204,000.00**	440.00	465.00		**300,000.00**
Dec 10	843.00	888.42		**545,040.00**	322.00	339.11		**205,320.00**	465.00	489.71		**296,520.00**
TOTAL				**10,897,320.00**				**4,174,200.00**				**6,024,720.00**

* In January 2010, additional consumptions added to real consumption and first index is accepted as zero by TEDAS.

Table J.8. Electricity consumptions at day, peak and night time periods in 2011

Billing Period	DAY (06:00-17:00)				PEAK (17:00-22:00)				NIGHT (22:00-06:00)			
	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh
Jan 11	888.42	938.51	12,000	**601,080.00**	339.11	357.83	12,000	**224,640.00**	489.71	517.79	12,000	**336,960.00**
Feb 11	938.51	978.84		**483,960.00**	357.83	373.15		**183,840.00**	517.79	541.08		**279,480.00**
Mar 11	978.84	1,027.26		**581,040.00**	373.15	391.61		**221,520.00**	541.08	569.26		**338,160.00**
Apr 11	1,027.26	1,068.46		**494,400.00**	391.61	407.00		**184,680.00**	569.26	593.24		**287,760.00**
May 11	1,068.46	1,127.95		**713,880.00**	407.00	429.48		**269,760.00**	593.24	624.33		**373,080.00**
June 11	1,127.95	1,225.28		**1,167,960.00**	429.48	465.58		**433,200.00**	624.33	673.66		**591,960.00**
July 11	1,225.28	1,346.33		**1,452,600.00**	465.58	510.11		**534,360.00**	673.66	737.00		**760,080.00**
Aug 11	1,346.33	1,473.67		**1,528,080.00**	510.11	558.85		**584,880.00**	737.00	808.27		**855,240.00**
Sep 11	1,473.67	1,590.11		**1,397,280.00**	558.85	603.94		**541,080.00**	808.27	872.53		**771,120.00**
Oct 11	1,590.11	1,647.00		**682,680.00**	603.94	626.00		**264,720.00**	872.53	903.00		**365,640.00**
Nov11	1,647.00	1,695.97		**587,640.00**	626.00	645.55		**234,600.00**	903.00	931.00		**336,000.00**
Dec 11	1,695.97	1,749.18		**638,520.00**	645.55	665.71		**241,920.00**	931.00	961.53		**366,360.00**
TOTAL				**10,329,120.00**				**3,919,200.00**				**5,661,840.00**

Table J.9. Electricity consumptions at day, peak and night time periods in 2012

Billing Period	**DAY (06:00-17:00)**				**PEAK (17:00-22:00)**				**NIGHT (22:00-06:00)**			
	First Index	**Last Index**	**Multiplier**	**Consumption kWh**	**First Index**	**Last Index**	**Multiplier**	**Consumption kWh**	**First Index**	**Last Index**	**Multiplier**	**Consumption kWh**
Jan 12	1,749.18	1,803.27		**649,080.00**	665.71	685.96		**243,000.00**	961.53	991.94		**364,920.00**
Feb 12	1,803.27	1,853.97		**608,400.00**	685.96	705.17		**230,520.00**	991.94	1,020.99		**348,600.00**
Mar 12	1,853.97	1,906.40		**629,160.00**	705.17	724.80		**235,560.00**	1,020.99	1,050.83		**358,080.00**
Apr 12	1,906.40	1,944.21		**453,720.00**	724.80	739.61		**177,720.00**	1,050.83	1,072.67		**262,080.00**
May 12	1,944.21	2,013.23		**828,240.00**	739.61	765.81		**314,400.00**	1,072.67	1,109.04		**436,440.00**
June 12	2,013.23	2,119.26	12,000	**1,272,360.00**	765.81	805.78	12,000	**479,640.00**	1,109.04	1,165.40	12,000	**676,320.00**
July 12	2,119.26	2,262.29		**1,716,360.00**	805.78	860.92		**661,680.00**	1,165.40	1,246.11		**968,520.00**
Aug 12	2,262.29	2,399.02		**1,640,760.00**	860.92	915.19		**651,240.00**	1,246.11	1,324.64		**942,360.00**
Sep 12	2,399.02	2,522.35		**1,479,960.00**	915.19	963.15		**575,520.00**	1,324.64	1,393.14		**822,000.00**
Oct 12	2,522.35	2,609.67		**1,047,840.00**	963.15	998.19		**420,480.00**	1,393.14	1,440.22		**564,960.00**
Nov12	2,609.67	2,662.00		**627,960.00**	998.19	1,019.60		**256,920.00**	1,440.22	1,470.12		**358,800.00**
Dec 12	2,662.00	2,714.75		**633,000.00**	1,019.60	1,040.03		**245,160.00**	1,470.12	1,500.18		**360,720.00**
TOTAL				**11,586,840.00**				**4,491,840.00**				**6,463,800.00**

Table J.10. Electricity consumptions at day, peak and night time periods in 2013

Billing Period	DAY (06:00-17:00)				PEAK (17:00-22:00)				NIGHT (22:00-06:00)			
	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh	First Index	Last Index	Multiplier	Consumption kWh
Jan 13	2,714.75	2,768.54	12,000	**645,480.00**	1,040.03	1,060.19	12,000	**241,920.00**	1,500.18	1,530.45	12,000	**363,240.00**
Feb 13	2,768.54	2,814.87		**555,960.00**	1,060.19	1,078.35		**217,920.00**	1,530.45	1,557.85		**328,800.00**
Mar 13	2,814.87	2,862.40		**570,360.00**	1,078.35	1,097.50		**229,800.00**	1,557.85	1,586.90		**348,600.00**
Apr 13	2,862.40	2,914.93		**630,360.00**	1,097.50	1,118.11		**247,320.00**	1,586.90	1,617.00		**361,200.00**
May 13	2,914.93	3,003.00		**1,056,840.00**	1,118.11	1,151.44		**399,960.00**	1,617.00	1,664.42		**569,040.00**
June 13	3,003.00	3,104.79		**1,221,480.00**	1,151.44	1,188.70		**447,120.00**	1,664.42	1,715.85		**617,160.00**
July 13	3,104.79	3,242.38		**1,651,080.00**	1,188.70	1,241.00		**627,600.00**	1,715.85	1,794.30		**941,400.00**
Aug 13												
Sep 13												
Oct 13												
Nov13												
Dec 13												
TOTAL				**6,331,560.00**				**2,411,640.00**				**3,529,440.00**

APPENDIX K: Lighting System of Balcalı Hospital

Table K.1. 18 W armature lamps in corridors

Floor name	Departments	# of 2x or 4x lamp armature	# of total lamp armature	Total capacity (Watt)
Ground	Polyclinic-Endocrine corridor	25	100	1800
Ground	Polyclinic outdoor corridor	80	160	2880
Ground	Obstetrics corridor	56	224	4032
First	Emergency Information corridor	91	364	6552
First	Bill check corridor	121	484	8712
First	Orthopedics corridor	69	138	2484
Second	Surgical operating room corridor	69	138	2484
Second	Central sterilization corridor	74	296	5328
Third	Coroner intensive Care-Cardiology corridor	22	88	1584
Fourh	Thoracic Surgery corridor	20	80	1440
Fifth	Emergency Urology corridor	35	140	2520
Sixth	Hematology-Eye polyclinic corridor	16	64	1152
Seventh	Psychiatry corridor	21	84	1512
Total number and installed capacity		**699**	**2360**	**42480**

Table K.2. 36W armature lamps in corridors

Floor name	Department	# of 1x lamp armature	# of total lamp armature	Total capacity (Watt)
Ground	Obstetrics polyclinic	30	30	1080
Ground	Delivery room	19	19	684
First	Infectious Diseases	32	32	1152
First	Pediatric Neonatal	20	20	720
Second	Obstetrics and Gynecology clinic-1	34	34	1224
Second	Obstetrics and Gynecology clinic-2	35	35	1260
Third	Hematology clinic	20	20	720
Third	Pediatric Oncology clinic	20	20	720
Third	Child service-1	20	20	720
Third	Child service-2	20	20	720
Fourth	Dermatology clinic	40	40	1440
Fourth	Nephrology clinic	20	20	720
Fourth	Endocrine clinic	20	20	720
Fifth	Ear-Nose-Throat clinic	38	38	1368
Fifth	Urology clinic	41	41	1476
Sixth	Plastic and reconstructive surgery clinic	40	40	1440
Sixth	Brain Surgery clinic	41	41	1476
Seventh	VIP clinic	44	44	1584
Seventh	Infant clinic	22	22	792
Seventh	Rehabilitation clinic	24	24	864
Total number and installed capacity		**580**	**580**	**20880**

Table K.3. 4x18W armature lamps in corridors

Floor name	**Department**	**# of 4x lamp armature**	**# of total lamp armature**	**Total capacity (Watt)**
Ground	Obstetrics and Gynecology polyclinic	9	36	648
Ground	Delivery room	1	4	72
Second	Obstetrics and Gynecology clinic-2	9	36	648
Third	Child service-1	3	12	216
Fourth	Dermatology clinic	4	16	288
Fifth	Ear-Nose-Throat clinic	4	16	288
Fifth	Urology clinic	5	20	360
Sixth	Plastic and reconstructive surgery clinic	4	16	288
Sixth	Brain Surgery clinic	4	16	288
Seventh	VIP clinic	4	16	288
Seventh	Infant clinic	3	12	216
Seventh	Rehabilitation clinic	4	16	288
Total number and installed capacity		**54**	**216**	**3888**

Table K.4. 4x18W armature lamps in the rooms at ground floor

Department	**# of 4x lamp armature**	**# of total lamp armature**	**Total capacity (Watt)**
Polyclinic daily patient	28	112	2016
Endocrine	86	344	6192
Cardiology	13	52	936
Internal Diseases allergy polyclinic	9	36	648
Nephrology polyclinic	17	68	1224
Nurse taking blood	2	8	144
Central laboratory	30	120	2160
Burn service	62	248	4464
Radiology	67	268	4824
Ultrasonography	18	72	1296
Hematology	13	52	936
Endoscopy	7	28	504
Rheumatology	29	116	2088
Physical Medicine and Rehabilitation	17	68	1224
Hospital information management system	4	16	288
Delivery room	25	100	1800
Total number and installed capacity	**427**	**1708**	**30744**

Table K.5. 2x18W armature lamps in the rooms at ground floor

Department	**# of 2x lamp armature**	**# of total lamp armature**	**Total capacity (Watt)**
Polyclinic daily patient	3	6	108
Central laboratory	9	18	324
Hematology	15	30	540
Physical Medicine and Rehabilitation	33	66	1188
Total number and installed capacity	**60**	**120**	**2160**

Table K.6. 2x36 W armature lamps in the rooms at ground floor

Department	**# of 2x lamp armature**	**# of total lamp armature**	**Total capacity (Watt)**
Central laboratory	3	6	216
Radiology	50	100	3600
Endocrine	4	8	288
Hematology	24	48	1728
Endoscopy	13	26	936
Delivery room	6	12	432
Electric maintenance service	11	22	792
Biomedical	9	18	648
Total number and installed capacity	**120**	**240**	**8640**

Table K.7. 18W armature lamps in the rooms

Floor name	Department	# of 2x lamp armature	# of total lamp armature	Total capacity (Watt)
First	Adult emergency service	7	28	504
First	Central emergency laboratory	56	224	4032
First	Neurology	30	120	2160
First	Gastroenterology	6	24	432
First	Cardiology	2	8	144
First	Dermatology	7	28	504
First	General Surgery	46	184	3312
First	Orthopedics polyclinic	18	72	1296
First	Eye polyclinics	34	136	2448
First	Urology polyclinics	46	184	3312
First	Pediatric Infectious	23	92	1656
First	Adult Infectious	40	160	2880
First	Pediatric Neonatal intensive care	31	124	2232
Second	Psychiatry	35	140	2520
Second	Ear-Nose-Throat	43	172	3096
Second	Menopause polyclinic	48	192	3456
Second	Infectious	16	64	1152
Second	Anesthesia	18	72	1296
Second	Neurology intensive care	85	340	6120
Second	Pediatric Neonatal intensive care	24	96	1728
Second	Central sterilization	22	88	1584
Second	Pathology	67	268	4824
Second	Drugstore	21	84	1512
Second	Pediatric Surgery	57	228	4104
Second	Pediatric Neurology	25	100	1800
Second	General Pediatric	12	48	864
Second	Urology polyclinics	27	108	1944
Second	Plastic and reconstructive surgery	22	88	1584
Third	Pediatric clinic	43	172	3096
Third	Cardiovascular Surgery	22	88	1584
Third	Coronary intensive care	54	216	3888
Fourth	Hematology	45	180	3240
Fourth	Rheumatology	34	136	2448
Fourth	Gastroenterology	28	112	2016
Fifth	General Surgery-1	73	292	5256
Fifth	General Surgery-2	38	152	2736
Sixth	Orthopedics and traumatology clinic	33	132	2376

Sixth	Eye Diseases	59	236	4248
Seventh	Psychiatry	46	184	3312
Total number and installed capacity		**1343**	**5372**	**96696**

Table K.8. 2x36W Armature lamps in the rooms

Floor name	**Department**	**# of 2x lamp armature**	**# of total lamp armature**	**Total capacity (Watt)**
First	Adult emergency service	2	4	144
First	EEG-EMG	3	6	216
First	Neurology	4	8	288
First	Gastroenterology	2	4	144
First	Cardiology	9	18	648
First	Neurosurgical	17	34	1224
First	Chest Diseases	6	12	432
First	General Surgery	10	20	720
First	Orthopedics and Traumatology clinic	14	28	1008
Second	Psychiatry	32	64	2304
Second	Ear-Nose-Throat	6	12	432
Second	Menopause polyclinic	20	40	1440
Second	Infectious	14	28	1008
Second	Anesthesia	8	16	576
Second	Pediatric Surgery	35	70	2520
Second	Pediatric Neurology	15	30	1080
Second	General Pediatric	8	16	576
Third	Cardiology service	20	40	1440
Third	Cardiovascular Surgery	17	34	1224
Fourth	Chest Diseases	17	34	1224
Fourth	Hematology	16	32	1152
Fourth	Dietetics	9	18	648
Fourth	Emergency Medicine clinic	12	24	864
Sixth	Apheresis	11	22	792
Seventh	Psychiatry	25	50	1800
Seventh	Psychiatry clinic	16	32	1152
Total number and installed capacity		**348**	**696**	**25056**

Table K.9. Armature lamps in surgical operating room and other places

Floor name	Department	2x or 4x lamp armature number	Total lamp armature number	Total capacity (Watt)
First	Emergency central laboratory	27	108	3888
Second	Operating room, 18 W	65	130	2340
Second	Operating room, 36 W	280	560	20160
Second	Operating room, 18 W	12	48	864
Second	Operating room, 18 W	88	176	3168
Second	Reanimation intensive care, 36 W	138	276	9936
Total number		**610**	**1298**	**40356**

Table K.10. Building at outside of Balcalı Hospital

Floor name	Department	2x or 4x lamp armature number	Total lamp armature number	Total capacity (Watt)
	Nuclear Medicine Building 18W	92	368	6,624
	Nuclear Medicine Building 36W	24	48	1,728
	Archive 18 W	5	10	180
	Archive 36 W	152	304	10,944
	Radiation Oncology 18 W	97	388	6,984
	Radiation Oncology 36 W	25	50	1,800
	Internal Oncology 18 W	129	516	9,288
	Internal Oncology 36 W	183	366	13,176
	Blood Center Ground Floor 18 W	73	292	5,256
	Blood Center First Floor 18 W	73	292	5,256
	Additional Service Building 18 W Ground Floor	311	1,244	22,392
	Additional Service Building 18 W First Floor	311	1,244	22,392
	Additional Service Building 18 W Second Floor	311	1,244	22,392
	Additional Service Building 36 W Ground,First and Second Floor	240	480	17,280
Total number		**2,026**	**6,846**	**145,692**

Table K.11. Environment lighting of Balcalı Hospital

Place/Pcs.	**Mercury vapor (125 W)**	**Mercury vapor (250 W)**	**Metal halide (750W)**	**Compact fluorescent (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**				

Table K.12. Lamp Armatur with electromagnetic ballast at Balcalı Hospital

Place	**Pieces**	**Armatur Type**	**Total Capacity (Watt)**
*Old Intensive Care	220	2x40	**17,600**

*At the Balcalı Hospital, Fluoresan lamps with electronic ballast have only been used in old intensive care.

APPENDIX L: Heat Center and Fuel Oil Consumptions

Table L.1. Boilers and burners at Balcalı Hospital

Properties		Number 1	Number 2	Number 3	Number 4
BOILERS	**Furnace height**	3,10 meters	3,10 meters	3,10 meters	2,20 meters
	Furnace diameter	1,05 meters	1,05 meters	1,05 meters	0,80 meters
	Flame, smoke pipe number	80 pcs	80 pcs	80 pcs	52 pcs
	Chimney diameter	0,55 meters	0,55 meters	0,55 meter	0,40 meter
	Chimney height	19 meters	19 meters	19 meters	19 meters
	Water volume	6,49 m^3	6,49 m^3	6,49 m^3	3,10 m^3
	Steam volume	2,52 m^3	2,52 m^3	2,52 m^3	1,00 m^3
	Capacity	5500 Kg/h	5500 Kg/h	5500 Kg/h	2500 Kg/h
	Trade mark	Erensan	Erensan	Erensan	Erensan
	Type	Natural gas Fuel Oil Steam Boiler	Natural gas Fuel Oil Steam Boiler	Natural gas Fuel Oil Steam Boiler	Natural gas Fuel Oil Steam Boiler
	Model	HDR 550	HDR 550	HDR 550	HDR 250
	Serial number	106	108	107	105
	Production date	01.11.2002	01.11.2002	01.11.2002	01.11.2002
	Testing date	11.11.2002	11.11.2002	11.11.2002	11.11.2002
	Tse number	377	377	377	377
	Process pressure	6 Bar	6 Bar	6 Bar	6 Bar
	Construction pressure	6,3 Bar	6,3 Bar	6,3 Bar	6,3 Bar
	Testing pressure	9,45 Bar	9,45 Bar	9,45 Bar	9,45 Bar
BURNERS	**Trade mark**	Ecostar	Ecostar	Ecostar	Ecostar
	Type	Eco 8 Osc 3	Eco 8 Osc 3	Eco 8 Osc 3	Eco 6 Osc 2
	Used fuel oil	Fuel Oil 5-6	Fuel Oil 5-6	Fuel Oil 5-6	Fuel Oil 5-6
	Capacity	165-500 Kg/h	165-500 Kg/h	165-500 Kg/h	90 -270 Kg/h
	Factory number	02631	03634	03633	0214763
	Fuel nozzle	Capacity with 450 Kg, 45 ^{0}C Fuel Oil Pump Pressure 22 bar	Capacity with 450 Kg, 45 ^{0}C Fuel Oil Pump Pressure 22 bar	Capacity with 450 Kg, 45 ^{0}C Fuel Oil Pump Pressure 22 bar	First Step is 9 and Second Step is 12 Gallons

Table L.2. Fuel oil consumptions in 2009

Consumption period	**Fuel oil consumption**		**The amount of steam (kg)**		**The amount of steam (kg/hour)**	
January 2009	520	tonnes	7.020.000,00	kg	9.435,48	kg/h
February 2009	430	tonnes	5.805.000,00	kg	8.340,52	kg/h
March 2009	360	tonnes	4.860.000,00	kg	6.532,26	kg/h
April 2009	155	tonnes	2.092.500,00	kg	2.906,25	kg/h
May 2009	135	tonnes	1.822.500,00	kg	2.449,60	kg/h
June 2009	120	tonnes	1.620.000,00	kg	2.250,00	kg/h
July 2009	120	tonnes	1.620.000,00	kg	2.177,42	kg/h
August 2009	120	tonnes	1.620.000,00	kg	2.177,42	kg/h
September 2009	120	tonnes	1.620.000,00	kg	2.250,00	kg/h
October 2009	125	tonnes	1.687.500,00	kg	2.268,15	kg/h
November 2009	275	tonnes	3.712.500,00	kg	5.156,25	kg/h
December 2009	385	tonnes	5.197.500,00	kg	6.985,89	kg/h
TOTAL	**2865**	**tonnes**	**38.677.500,00**	**kg**	**4.403,18**	**kg/h**

Table L.3. Fuel oil consumptions in 2010

Consumption period	**Fuel oil consumption**		**The amount of steam (kg)**		**The amount of steam (kg/hour)**	
January 2010	420	tonnes	5.670.000,00	kg	7.620,97	kg/h
February 2010	380	tonnes	5.130.000,00	kg	7.370,69	kg/h
March 2010	270	tonnes	3.645.000,00	kg	4.899,19	kg/h
April 2010	145	tonnes	1.957.500,00	kg	2.718,75	kg/h
May 2010	115	tonnes	1.552.500,00	kg	2.086,69	kg/h
June 2010	105	tonnes	1.417.500,00	kg	1.968,75	kg/h
July 2010	105	tonnes	1.417.500,00	kg	1.905,24	kg/h
August 2010	110	tonnes	1.485.000,00	kg	1.995,97	kg/h
September 2010	110	tonnes	1.485.000,00	kg	2.062,50	kg/h
October 2010	132	tonnes	1.782.000,00	kg	2.395,16	kg/h
November 2010	150	tonnes	2.025.000,00	kg	2.812,50	kg/h
December 2010	360	tonnes	4.860.000,00	kg	6.532,26	kg/h
TOTAL	**2402**	**tonnes**	**32.427.000,00**	**kg**	**3.691,60**	**kg/h**

Table L.4. Fuel oil consumptions in 2011

Consumption period	**Fuel oil consumption**		**The amount of steam (kg)**		**The amount of steam (kg/hour)**	
January 2011	450	tonnes	6.075.000,00	kg	8.165,32	kg/h
February 2011	400	tonnes	5.400.000,00	kg	7.758,62	kg/h
March 2011	355	tonnes	4.792.500,00	kg	6.441,53	kg/h
April 2011	205	tonnes	2.767.500,00	kg	3.843,75	kg/h
May 2011	140	tonnes	1.890.000,00	kg	2.540,32	kg/h
June 2011	130	tonnes	1.755.000,00	kg	2.437,50	kg/h
July 2011	120	tonnes	1.620.000,00	kg	2.177,42	kg/h
August 2011	120	tonnes	1.620.000,00	kg	2.177,42	kg/h
September 2011	125	tonnes	1.687.500,00	kg	2.343,75	kg/h
October 2011	130	tonnes	1.755.000,00	kg	2.358,87	kg/h
November 2011	330	tonnes	4.455.000,00	kg	6.187,50	kg/h
December 2011	480	tonnes	6.480.000,00	kg	8.709,68	kg/h
TOTAL	**2985**	**tonnes**	**40.297.500,00**	**kg**	**4.587,60**	**kg/h**

Table L.5. Fuel oil consumptions in 2012

Consumption period	**Fuel oil consumption**		**The amount of steam (kg)**		**The amount of steam (kg/hour)**	
January 2012	540	tonnes	7.290.000,00	kg	9.798,39	kg/h
February 2012	496	tonnes	6.696.000,00	kg	9.620,69	kg/h
March 2012	360	tonnes	4.860.000,00	kg	6.532,26	kg/h
April 2012	165	tonnes	2.227.500,00	kg	3.093,75	kg/h
May 2012	135	tonnes	1.822.500,00	kg	2.449,60	kg/h
June 2012	125	tonnes	1.687.500,00	kg	2.343,75	kg/h
July 2012	126	tonnes	1.701.000,00	kg	2.286,29	kg/h
August 2012	123	tonnes	1.660.500,00	kg	2.231,85	kg/h
September 2012	120	tonnes	1.620.000,00	kg	2.250,00	kg/h
October 2012	135	tonnes	1.822.500,00	kg	2.449,60	kg/h
November 2012	210	tonnes	2.835.000,00	kg	3.937,50	kg/h
December 2012	400	tonnes	5.400.000,00	kg	7.258,06	kg/h
TOTAL	**2935**	**tonnes**	**39.622.500,00**	**kg**	**4.510,76**	**kg/h**

Table L.6. Fuel oil consumptions in 2013

Consumption period	**Fuel oil consumption**		**The amount of steam (kg)**		**The amount of steam (kg/hour)**	
January 2013	486	tonnes	6.561.000,00	kg	8.818,55	kg/h
February 2013	387	tonnes	5.224.500,00	kg	7.774,55	kg/h
March 2013	325	tonnes	4.387.500,00	kg	5.897,18	kg/h
April 2013	176	tonnes	2.376.000,00	kg	3.300,00	kg/h
May 2013	125	tonnes	1.687.500,00	kg	2.268,15	kg/h
June 2013	125	tonnes	1.687.500,00	kg	2.343,75	kg/h
July 2013	115	tonnes	1.552.500,00	kg	2.086,69	kg/h
August 2013						
September 2013						
October 2013						
November 2013						
December 2013						
TOTAL	**1739**	**tonnes**	**23.476.500,00**	**kg**	**32.488,87**	**kg/h**

APPENDIX M: Cooling Systems at Balcalı Hospital

Table M.1. Existing cooling system capacities, compressors

No	Units	Output Power of Cooling System
1	Surgery operating room	660 kW
2	Y1,Y2,Y3 blocks	2415 kW
3	Y4,Y5,Y6 blocks	1680 kW
4	Intensive Cares	262 kW
5	Burn unit	222 kW
6	Internal Oncology (outside of hospital)	240 kW
7	Emergency Medicine	276 kW
8	Refectory	240 kW
9	Coroner Intensive Care	30 kW
10	Dialysis	104 kW
11	Radiation Oncology (outside of hospital)	67.5 kW
	TOTAL	**6,196.5 kW**

Table M.2. Required cooling capacity at Balcalı Hospital

Units	Area	Required Cooling Capacity
Surgery Operating Room	5,472 m²	2.487.272 BTU/h
Emergency Medicine	3,550 m²	1.613.636 BTU/h
Daily Patient unit	1,000 m²	454.545 BTU/h
Polyclinics	24,000 m²	10.909.090 BTU/h
K1 block	3,312 m²	1.505.454 BTU/h
K2 block	2,808 m²	1.276.363 BTU/h
Y1,Y2,Y3 block	22,400 m²	10.181.818 BTU/h
Y4,Y5,Y6 block	22,400 m²	10.181.818 BTU/h
Central laboratory	1,270 m²	577.272 BTU/h
Archive (outside of hospital)	1,135 m²	515.909 BTU/h
Radiation Oncology (outside of hospital)	920 m²	418.181 BTU/h
Nuclear Medicine (outside of hospital)	1,100 m²	500.000 BTU/h
Internal Oncology Building (outside of hospital)	4,650 m²	2.113.636 BTU/h
Burn unit	750 m²	340.909 BTU/h
Intensive Cares	1,200 m²	545.454 BTU/h
Conference Building (outside of hospital)	1,700 m²	772.727 BTU/h
TOTAL	**97,667 m²**	**44.394.084 BTU/h**

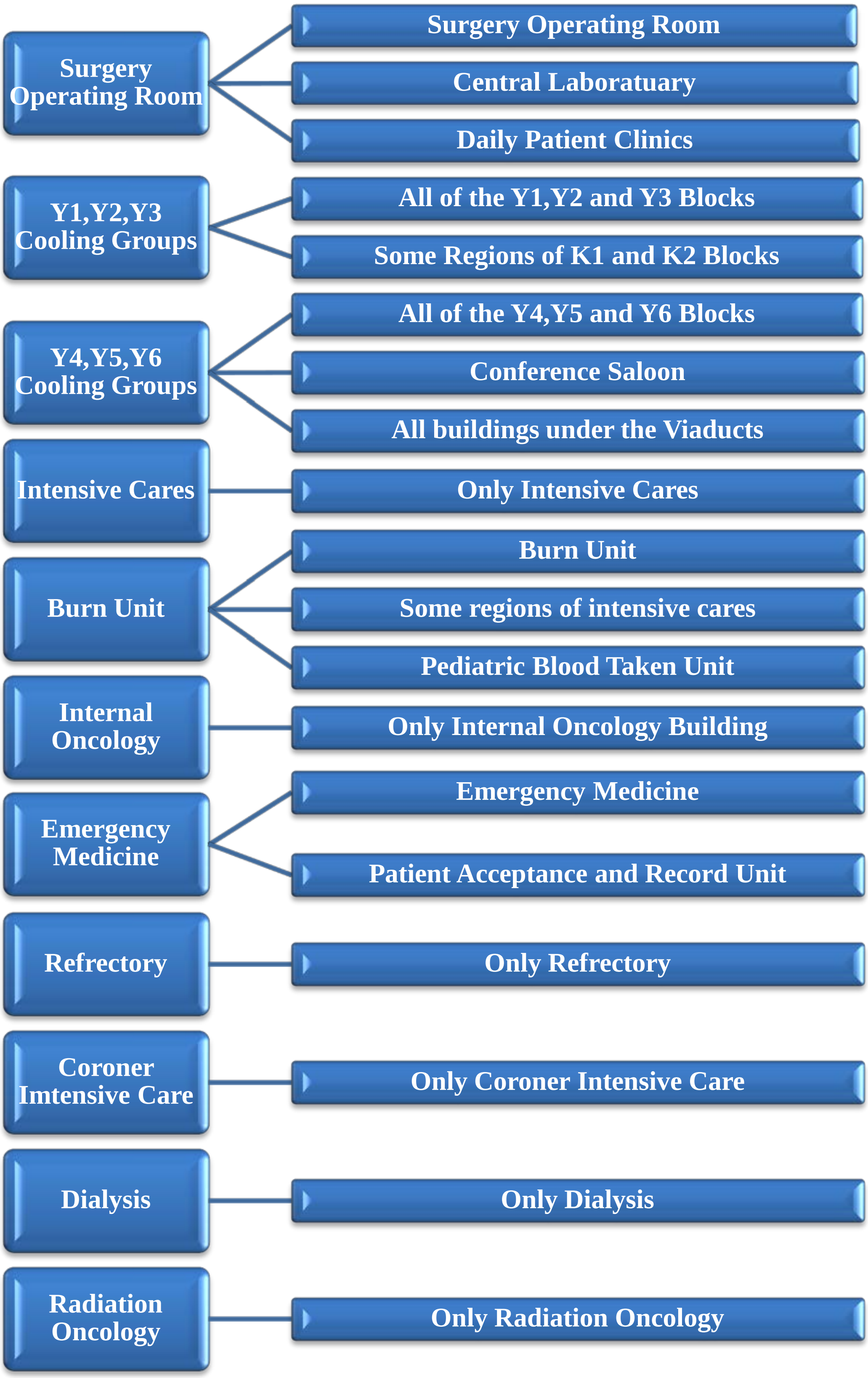


Figure M.1. Conditioning areas of cooling groups

Table M.3. Existing cooling system capacities details, compressors

Units	Pcs	The Number of Motors and Capacity	Output Power of Cooling System	Liquid Type
Surgery operating room	1	2x45=90	660 kW	R22
	2	2x65=130		
	3	2x45=90		
	4	2x65=130		
	5	2x45=90		
	6	2x65=130		
Y1,Y2,Y3 blocks	1	3x161=483	2415 kW	R134
	2	3x161=483		
	3	3x161=483		
	4	3x161=483		
	5	3x161=483		
Y4,Y5,Y6 blocks	1	6x40=240	1680 kW	R134A
	2	6x40=240		
	3	6x40=240		
	4	6x40=240		
	5	6x40=240		
	6	6x40=240		
	7	6x40=240		
Intensive Cares	1	2x131=262	262 kW	R22
Burn Unit	1	2x111=222	222 kW	R134A
Internal Oncology	1	4x60=240	240 kW	R134A
Emergency Medicine	1	2x138=276	276 kW	R134A
Refectory	1	2x60=120	240 kW	R134A
	2	2x60=120		
Coroner Intensive Care	1	2x7.5=15	30 kW	R134A
	2	2x7.5=15		
Dialysis	1	4x13=52	104 kW	R134A
	2	4x13=52		
Radiation Oncology	1	3x7.5=22.5	67.5 kW	R410
	2	3x7.5=22.5		
	3	3x7.5=22.5		
TOTAL			**6,196.5 kW**	

Table M.4. Condenser motors in cooling system

Unit	Condenser Motors and Pumps	Condenser Motor Power (KW)	Condenser Motor Revolution (rpm/m)	Pump Flow (m^3/h)	Pump Revolution (rpm/m)	Discharge Head (m)	Fan Diameter (mm)	Total Capacity (kW)
Surgical Operating Room	1	20	1455	120	1400	82	370	**80**
	2	20	1455	120	1400	82	370	
	3	20	1455	120	1400	82	370	
	4	20	1455	120	1400	82	370	
Y1,Y2,Y3 Blocks	1	22	1460	260	1450	33.5	270	**260**
	2	22	1460	260	1450	33.5	270	
	3	22	1460	260	1450	33.5	270	
	4	22	1460	260	1450	33.5	270	
	5	22	1460	260	1450	33.5	270	
	6	30	1460	260	1450	33.5	270	
	7	30	1460	260	1450	33.5	270	
	8	30	1460	260	1450	33.5	270	
	9	30	1460	260	1450	33.5	270	
	10	30	1460	260	1450	33.5	270	
Y4,Y5,Y6 Blocks	1	22	1450	210	1400	33.5	295	**242**
	2	22	1450	210	1400	33.5	295	
	3	22	1450	210	1400	33.5	295	
	4	22	1450	210	1400	33.5	295	
	5	22	1450	210	1400	33.5	295	
	6	22	1450	210	1400	33.5	295	
	7	22	1450	210	1400	33.5	295	
	8	22	1450	210	1400	33.5	295	
	9	22	1450	210	1400	33.5	295	
	10	22	1450	210	1400	33.5	295	
	11	22	1450	210	1400	33.5	295	
Intensive Care	Because there is no cooling tower, there is no condenser motor							
Burn Unit	Because the cooling system is air cooled system, there is no condenser							
Internal Oncology	Because the cooling system is air cooled system, there is no condenser							
Emergency Medicine	Because the cooling system is air cooled system, there is no condenser							
Refrectory	Refrectory hasn't got any condenser motors and chiller motors							
Coroner Intensive C.	Coroner Intensive Care hasn't got any condenser motors							
Dialysis	It has small internal condenser motors							
Radiation Oncology	It has small internal condenser motors							
TOTAL								**582 kW**

Table M.5. Chiller motors in cooling system

Unit	Condenser Motors and Pumps	Condenser Motor Power (KW)	Condenser Motor Revolution (rpm/m)	Pump Flow (m³/h)	Pump Revolution (rpm/m)	Discharge Head (m)	Fan Diameter (mm)	Total Capacity (kW)
Surgical Operating Room	1	30	1670	150	1400	32	320	**120**
	2	30	1670	150	1400	32	320	
	3	30	1670	150	1400	32	320	
	4	30	1670	150	1400	32	320	
Y1,Y2,Y3 Blocks	1	30	1455	165	1400	32	325	**261**
	2	30	1455	165	1400	32	325	
	3	30	1455	165	1400	32	325	
	4	30	1455	165	1400	32	325	
	5	30	1455	165	1400	32	325	
	6	37	1455	165	1400	32	325	
	7	37	1455	165	1400	32	325	
	8	37	1455	165	1400	32	325	
Y4,Y5,Y6 Blocks	1	35	1455	163	1400	33	320	**385**
	2	35	1455	163	1400	33	320	
	3	35	1455	163	1400	33	320	
	4	35	1455	163	1400	33	320	
	5	35	1455	163	1400	33	320	
	6	35	1455	163	1400	33	320	
	7	35	1455	163	1400	33	320	
	8	35	1455	163	1400	33	320	
	9	35	1455	163	1400	33	320	
	10	35	1455	163	1400	33	320	
	11	35	1455	163	1400	33	320	
Intensive Care	1	5.5	1450	160	1460	32	270	**11**
	2	5.5	1450	160	1460	32	270	
Burn Unit	1	7.5	1450	162	1450	22	277	**35**
	2	7.5	1450	162	1450	22	277	
	3	5	1450	162	1450	22	277	
	4	5	1450	162	1450	22	277	
	5	5	1450	162	1450	22	277	
	6	5	1450	162	1450	22	277	
Internal Oncology	1	11	2890	162	2890	32	270	**33**

	2	11	2890	162	2890	32	270	
	3	11	2890	162	2890	32	270	
Emergency Medicine	1	15	1455	150	1455	20	262	**30**
	2	15	1455	150	1455	20	262	
Refrectory	Refrectory hasn't got any condenser motors and chiller motors							
Coroner Intensive Care	Coroner Intensive Care hasn't got any condenser motors and chiller motors							
Dialysis	It has small internal chiller motors							
Radiation Oncology	It has small internal chiller motors							
TOTAL								**875 kW**

Table M.6. Cooling tower fan motors

Unit	**Number of Cooling Tower**	**Number of Fan Motors on Each Cooling Tower**	**Capacity of each motor**	**Calculation**	**Total Capacity (kW)**
Surgical Operating Room	2	3	7.5	2x3x7.5	**45**
Y1,Y2,Y3 Blocks	5	3	11.8	5x3x11.8	**177**
Y4,Y5,Y6 Blocks	7	2	7.5	7x2x7.5	**105**
Intensive Care	There is no cooling tower				
Burn Unit	There is no cooling tower because this system is air cooled.				
Internal Oncology	There is no cooling tower because this system is air cooled				
Emergency Medicine	There is no cooling tower because this system is air cooled				
Refrectory	There is no cooling tower				
Coroner Intensive Care	There is no cooling tower				
Dialysis	There is no cooling tower				
Radiation Oncology	There is no cooling tower				
TOTAL					**327 kW**

Table M.7. Vantilator and Aspirator motors in air conditioners

Unit	Vantilator				Aspirator		
	Place	Number	Power kW	Internal Aspirator	Place	Number	Power kW
Surgery Operating Room		1	**7.5**	-		1	**5.6**
		2	**7.5**	-		2	**5.6**
		3	**11.2**	-		3	**5.6**
		4	**11.2**	-		4	3
Y1,Y2,Y3 Blocks	Y1 Roof	1	**11**	-	Y1 Roof	1	4
	Y1 Roof	2	**30.5**	-	Y1 Roof	2	**5.5**
	Y1 Roof	3	**15**	-	Y1 Roof	3	**5**
	Y1 Roof	4	**14**	-	Y1 Roof	4	**5**
	Y1 Basement	5	**7**	-	Y1 Roof	5	3
	Y1 Basement	6	**15**	-	Y1 Roof	6	1.1
	Y1 Basement	7	**7**	-	Y1 Roof	7	3
	Y1 Basement	8	**7.5**	5.5	Y1 Roof	8	**15**
	Y1 Basement	9	**11**	-	Y1 Roof	9	4
	Y1 Basement	10	**11**	-	Y1 Roof	10	4
	Y2 Roof	11	**11**	-	Y1 Roof	11	3
	Y2 Roof	12	**15**	9	Y1 Roof	12	4
	Y2 Roof	13	**11**	7.5	Y2 Roof	13	3
	Y3 Roof	14	**5.5**	3	Y2 Roof	14	3
	Y3 Roof	15	**7.5**	5.5	Y2 Roof	15	4
	Y3 Roof	16	**11**	4	Y2 Roof	16	4
	Y3 Roof	17	**11**	5.5	Y2 Roof	17	4
	Y3 Roof	18	0.75	0.75	Y3 Roof	18	**5.5**
	Y3 Roof	19	4	5.5	Y3 Roof	19	4
	Y3 Roof	20	**5.5**	5.5	Y3 Basement	20	**5.5**
	Y3 Basement	21	**7.5**	5.5			
	Y3 Basement	22	**15**	-			
	Y3 Basement	23	**15**	15.5			
	Y3 Basement	24	4	4			
Y4,Y5,Y6 Blocks	Y4 Basement	1	**30**	-	Y4 Basement	1	**11**
	Y4 Basement	2	**18.5**	3	Y4 Basement	2	4
	Y4 Basement	3	**15**	-	Y4 Basement	3	3
	Y4 Basement	4	**11**	-	Y4 Basement	4	**5.5**
	Y4 Basement	5	**11**	-	Y4 Roof	5	**11**
	Y4 Basement	6	**16**	-	Y4 Roof	6	**11**

	Y4 Basement	7	**11**	**-**	Y4 Roof	7	**7.5**
	Y4 Basement	8	**11**	-	Y4 Roof	8	**7.5**
	Y5 Basement	9	**11**	5.5	Y4 Roof	9	**11**
	Y5 Basement	10	**11**	5.5	Y6 Basement	10	**11**
	Y6 Basement	11	**5.5**	-	Y6 Roof	11	**11**
	Y6 Basement	12	**15**	-	Y6 Roof	12	**11**
	Y6 Basement	13	**15**	1.1	Y6 Roof	13	**11**
	Y6 Basement	14	**15**	2.2	Y6 Roof	14	**15**
	Y6 Basement	15	**7.5**	-	Y6 Roof	15	**15**
	Y6 Basement	16	**11**	-			
	Y4.Y5.Y6 Roof	17	**11**	5.5			
		18	**18**	2.2			
		19	**15**	3			
		20	**15**	4			
		21	**15**	4			
		22	**15**	5.5			
		23	**15**	-			
		24	**15**	3			
		25	**15**	3			
		26	**11**	4			
		27	**15**	3			
		28	**11**	3			
		29	**15**	11			
		30	**15**	-			
Intensive Cares		1	**11**	-		1	**7.5**
		2	**11**	-		2	**7.5**
		3	**7.5**	-		3	**5.5**
		4	**7.5**	-		4	**5.5**
Burn Unit		1	**18.5**	-		1	**7.5**
Internal Oncology		1	**15**	-		-	-
Emergency Medicine		1	**7.5**	-		1	3
		2	**5.5**	-		2	1.5
		3	3	-		3	1.1
		4	**5.5**	-		4	1.1
		5	**5.5**	-		5	2.2
		6	3	-		6	2.2
Refrectory		1	3.5	-		-	-
		2	3.5	-		-	-

Coroner Intensive Care		1	3.5	-		There is a very small aspirator motor	
		2	3.5	-			
Dialysis	There is a very small vantilator motor and a very small aspirator motor						
Radiation Oncology	There is a very small vantilator motor and a very small aspirator motor						
Kitchen		1	**15**			1	**30**
> 5.5 KW Motors		66	**806.4**			28	**260.3**
<5.5 KW Motors		9	28.75			23	69.2
TOTAL		**75**	**835.15**			**51**	**329.5**

* In the kitchen, 30 kW Aspirator motor runs with the variable speed drive. Motor measurements were performed with VSD or without VSD.

Table M.8. Conditioning areas of Vantilator and Aspirator motors

No	Conditioning Areas	Motor Power (kW)	Motor Revolution (rpm)	Vantilator/ Aspirator
1	Radiology and Administrative Rooms Vantilator motor	7,5	3000 rpm	Vantilator
2	Surgical Operating Room Secretarial, Patient Waiting Room, Staff Locker Rooms and Doctor's Locker Rooms (Vantilator)	7,5	1500 rpm	Vantilator
3	Intensive Care and Resuscitation	5,5	3000 rpm	Vantilator
4	Adult Observation and Child Observation	3	3000 rpm	Vantilator
5	Surgical Operating Room Numbers 1,2,3,4,5,6,7 and Hand Cleaning Room, A Block Corridors	7,5	1500 rpm	Vantilator
6	Central Laboratory	11,2	3000 rpm	Vantilator
7	Pediatric Emergency Unit	5,5	3000 rpm	Vantilator
8	Surgical Operating Room Numbers 17,18,16,20,21,22 and 23, Hand Cleaning Room, A Block Corridors	11,2	1500 rpm	Vantilator
9	Surgical Operating Room Numbers 8,9,10,11,12,13,14,15 and 16, Hand Cleaning Room, Corridors	11,2	1500 rpm	Vantilator
10	Blood Collection Center, Daily Patient and Child Healty Department	18	1500 rpm	Vantilator

11	Emergency Department Inlet	5,5	3000 rpm	Vantilator
12	Adult Emergency Department and Trawma Department	3	3000 rpm	Vantilator
13	Radiology and Administrative Rooms	3	1500 rpm	Aspirator
14	A Block Aspirator motor	5,6	1439 rpm	Aspirator
15	A Block Aspirator motor	5,6	1439 rpm	Aspirator
16	A Block Aspirator motor	5,6	1439 rpm	Aspirator
17	Pediatric Emergency Unit	3	1500 rpm	Aspirator
18	Emergency Department Inlet	1,5	1500 rpm	Aspirator
19	Label values hasn't read exactly	-	-	Aspirator
20	Adult Emergency Department and Trawma	1,1	1500 rpm	Aspirator
21	Adult Observation and Child Observation	1,1	1500 rpm	Aspirator
22	Intensive Care and Resuscitation	2,2	1500 rpm	Aspirator
23	A Block Aspirator motor	3	1418 rpm	Aspirator
24	Coroner (K1 Block Aspirtor Motor)	3	3000 rpm	Aspirator
25	Coroner (K1 Block Vantilator Motor)	11	3000 rpm	Vantilator
26	Neotanal Intensive Cares	3	3000 rpm	Aspirator
27	Neurology Intensive Cares	4	3000 rpm	Aspirator
28	Coroner Intensive Cares	5,5	1500 rpm	Vantilator
29	Coroner Intensive Cares (East)	4	1500 rpm	Vantilator
30	K1 Block Vantilator Motor	11	3000 rpm	Vantilator
31	K1 Block Vantilator Motor	11	3000 rpm	Vantilator
32	Pediatric Intensive Cares	11	3000 rpm	Vantilator
33	Brain Surgery Intensive Cares	11	3000 rpm	Vantilator
34	Brain Surgery Intensive Cares	7,5	3000 rpm	Vantilator
35	Internal Intensive Cares	7,5	3000 rpm	Vantilator
36	Label values hasn't read exactly	-	-	Aspirator
37	Burn Unit	18,5	3000 rpm	Vantilator
38	Burn Unit	7,5	3000 rpm	Aspirator
39	Kitchen Aspirator Motor with VSD	30	3000 rpm	Aspirator
40	Y1 6 Number Air Conditioner (Blood Center and Sterilaziton Unit)	7	3000 rpm	Vantilator
41	Y1 8 Number Air Conditioner (Laundry and Sterilization Unit)	11	3000 rpm	Vantilator
42	Y1 7 Number Air Conditioner (Urology)	15	3000 rpm	Vantilator
43	Y1 General Surgery Intensive Cares	7	3000 rpm	Vantilator
44	Y1 Kitchen	15	1500 rpm	Vantilator
45	Y3 Aspirator (0,1,2,3 Public Lavatory)	3	1500 rpm	Aspirator
46	Y3 Number 9 Air Conditioner (Mortuary and Forensic Medicine)	7,5	3000 rpm	Vantilator

47	Y2 Building, K3 Section, Y2 on floor 0,1,2 at front of lifts	-	-	Vantilator
48	10 of the Air Conditioning at Y3	15	3000 rpm	Vantilator
49	11 of the Air Conditioning at Y3, Patology and Hospital Pharmacy	4	3000 rpm	Vantilator
50	Y4 Building, Floor 1,2,3 middle space area	11	1165 rpm	Aspirator
51	Delivery Room	30	3000 rpm	Vantilator
52	Delivery Room Aspirator	11	1165 rpm	Aspirator
53	Y4 Building, 1,2,3 floors	18,5	972 rpm	Vantilator
54	7 of the Air Conditioning, Patient Rooms on the South Side	15	970 rpm	Vantilator
55	Y4, 6 of the Air Conditioning, at Floor 0,1 Patient Rooms on the North Side	11	1165 rpm	Vantilator
56	Y4, 5 of the Air Conditioning, At Floor 2,3 on the North Side	11	1165 rpm	Vantilator
57	Neotanal Intensive Care 1	16	1465 rpm	Vantilator
58	Y4 Intensive Care	4	940 rpm	Aspirator
59	Y5 Building, 6 of the Air Conditioning, Corridors on floor 0,1,2,3	11	960 rpm	Vantilator
60	Y4, Test-Tube Baby Air Conditioning	5,5	1500 rpm	Vantilator
61	Y4, Test-Tube Baby Aspirator	3	1500 rpm	Aspirator
62	Y5 Building, 7 of the Air Conditioning, Floors 0,1,2,3	11	960 rpm	Vantilator
	Y5 Building, 7 of the Air Conditioning Aspirator, Floors 0,1,2,4	5,5	960 rpm	Aspirator
63	Y6 Building, 12 of the Air Conditioning, Patient Rooms, Second Floor on the North Side	15	960 rpm	Vantilator
64	Y6 Building, 11 of the Air Conditioning, Corridors on Floor 0,1	15	970 rpm	Vantilator
65	Y5,Y6 Building, 13 of the Air Conditioning, Corridors on Floor 0,1 on the North Side	11	960 rpm	Vantilator
66	Y6 Building, Floor 0,1,2,3	5,5	960 rpm	Vantilator
67	Y6 Building, 10 of the Air Conditioning, Corridors on Floor 2,3	15	960 rpm	Vantilator
68	Y6 Building, 15 of the Air Conditioning, Patient Rooms on Floor 0,1 on the South Side	7,5	965 rpm	Vantilator
69	Y1 Building, 2 of Aspirator at the roof	3	960 rpm	Aspirator
70	Y1 Building Roof, Laundry Aspirator	15	1450 rpm	Aspirator
71	Internal Oncology and General Surgical	1,1	960 rpm	Aspirator

72	Y1 Building Roof, 5 of the air conditioning. (Internal Oncology and General Surgery Clinic)	11	3000 rpm	Vantilator
73	Y1 Building Roof, 1 of the air conditioning. (Orthopedics and Psychiatry Clinics on the north side of building)	30,5	3000 rpm	Vantilator
74	Y1 Cell Aspirator Number 1	3	960 rpm	Aspirator
75	Y1 Aspirator for Middle Section	4	960 rpm	Aspirator
76	Y1 Old Aspirator	4	1425 rpm	Aspirator
77	Y1 3 of Aspirator	3	960 rpm	Aspirator
78	Y1 General Intensive Care Aspirator	4	960 rpm	Aspirator
79	Y1 4 of Aspirator, Internal Hematology and General Surgery Clinics on the south side of building	15	1450 rpm	Aspirator
80	Y1 6 of Aspirator	4	960 rpm	Aspirator
81	Y1 Building for Middle Section of Building	5,5	1425 rpm	Aspirator
82	Y1 2 of the Air Conditioner	14	1460 rpm	Vantilator
83	Y1 4 of Aspirator	5	1460 rpm	Aspirator
84	Y1 Public Lavatory	5	1425 rpm	Aspirator
85	Y2 Building, 5 of Aspirator	3	1425 rpm	Aspirator
86	Y2 Building, 4 of Aspirator, Public Lavatory	3	960 rpm	Aspirator
87	Y2 Building,Number 1 Corridor, 6 th and 7 th Floor (Air Conditioner)	15	3000 rpm	Vantilator
88	Y1 5 of the Air Conditioner	5	1425 rpm	Vantilator
89	Y2 Building, 7 of Aspirator	4	1425 rpm	Aspirator
90	Y2 Building, 8 of Aspirator	4	1425 rpm	Aspirator
91	Y2 Building, 2 of Air Conditioning, Y2 Corridors on Floor 3,4,5	11	1425 rpm	Vantilator
92	Y2 Building, 6 of Aspirator	4	960 rpm	Aspirator
93	Y3 Building, 8 of Air Conditioning, Pediatric Surgery Clinic	5,5	3000 rpm	Vantilator
Int.	Y3 Building, 8 of Aspirator, Pediatric Surgery Clinic	3	3000 rpm	Aspirator
94	Y3 Building, 4 of Air Conditioning, Floor 3,4,5 and Romatology, General Surgery 2 Clinic	7,5	3000 rpm	Vantilator
Int.	Y3 Building, 4 of Aspirator, Floor 3,4,5 and Romatology, General Surgery 2 Clinic	5,5	1500 rpm	Aspirator
95	Y3 Building, 5 of Air Conditioning, Floor 6 and 7, Neurology and Eyes Clinics	11	3000 rpm	Vantilator

Int.	Y3 Building, 5 of Aspirator, Floor 6 and 7, Neurology and Eyes Clinics	4	1500 rpm	Aspirator
96	Y3 Building, 6 of Air Conditioning, Floor 3,4,5	15	1500 rpm	Vantilator
Int.	Y3 Building, 6 of Aspirator, Floor 3,4,6	5,5	1500 rpm	Aspirator
97	Y3 Building, 7 of Air Conditioning, Eyes Clinic Surgical Operating Room	0,75	3000 rpm	Vantilator
Int.	Y3 Building, 7 of Aspirator, Eyes Clinic Surgical Operating Room	0,75	3000 rpm	Aspirator
98	Y3 Building, 3 of Air Conditioning, Floor 6,7	4	1500 rpm	Vantilator
Int.	Y3 Building, 3 of Aspirator, Floor 6,8	5,5	1500 rpm	Aspirator
99	Y3 Building, 1 of Air Conditioning, Floor 6,7 South Side	5,5	3000 rpm	Vantilator
Int.	Y3 Building, 1 of Aspirator, Floor 6,7 South Side	5,5	1500 rpm	Aspirator
100	Y3 Building, 2 of Air Conditioning, Floor 3,4,5 South Side	7,5	1500 rpm	Vantilator
Int.	Y3 Building, 2 of Aspirator, Floor 3,4,5 South Side	5,5	1500 rpm	Aspirator
101	Y3 Building, 1 of Aspirator, Public Lavatory on Floor 2,3,4,5,6,7	4	1500 rpm	Aspirator
101	Y3 Building, 2 of Aspirator, Kitchen and Bathroom on Floor 3,4,5,6,7, North Side	5,5	1500 rpm	Aspirator
102	Y6 Building, 5 of Air Conditioning, Block 4 and 5	11	1665 rpm	Vantilator
Int.	Y6 Building, 5 of Aspirator, Block 4 and 6	5,5	1660 rpm	Aspirator
103	Y6 Building, 7 of Aspirator South Side of Y5 and Y6	11	1665 rpm	Aspirator
104	Y6 Building, 9 of Air Conditioning (Vantilator)	18	965 rpm	Vantilator
Int.	Y6 Building, 9 of Aspirator	2,2	1440 rpm	Aspirator
105	Y6 Building, 8 of Air Conditioner, Patient Rooms on the South Side of Y5 and Y6	11	1665 rpm	Vantilator
106	Y6 Building, 8 of Air Conditioner, North Side of Y5 and Y6	15	1665 rpm	Vantilator
Int.	Y6 Building, 8 of Aspirator, North Side of Y5 and Y7	3	1165 rpm	Aspirator
107	Y6 Building, 3 of Air Conditioner, Block 4,5,6 and 7	11	1665 rpm	Vantilator
108	Y6 Building, 6 of Air Conditioning, North Side of Y5 and Y6	15	1165 rpm	Vantilator
109	Y6 Building, 9 of Air Conditioning, Block 4,5, North Side	15	970 rpm	Vantilator

Int.	Y6 Building, 9 of Aspirator, Block 4,5, North Side	4	1490 rpm	Aspirator
110	Y6 Building, 5 of Aspirator,Y5 and Y6 North Side	15	1665 rpm	Aspirator
111	Y6 Building, 11 of Air Conditioning, Fourth Floor on Y5 and Y6, South Side	15	970 rpm	Vantilator
Int.	Y6 Building, 11 of Aspirator, Fourth Floor on Y5 and Y6, South Side	4	1490 rpm	Aspirator
112	Y6 Building, 10 of Air Conditioning, Floor 6,7 South Side	15	970 rpm	Vantilator
Int.	Y6 Building, 10 of Aspirator, Floor 6,7 South Side	5,5	1660 rpm	Aspirator
113	Y4 Building, 2 of Air Conditioning, North Side	11	1165 rpm	Aspirator
114	Y6 Building, 8 of Air Conditioning, Floor 6,7	15	970 rpm	Vantilator
Int.	Y6 Building, 8 of Aspirator, Floor 6,7	3	1165 rpm	Aspirator
115	Y4 Building, 1 of Air Conditioning, Floor 6,7	15	1665 rpm	Vantilator
Int.	Y4 Building, 1 of Aspirator, Floor 6,7	3	970 rpm	Aspirator
116	Y4 Building, 1 of Aspirator, Block 4,5,6 and 7	11	965 rpm	Aspirator
117	Y4 Building, 1 of Aspirator, North Side	7,5	1165 rpm	Aspirator
118	Y4 Building, 1 of Air Conditioning, Floor 6,7, Patient Room on North Side	11	965 rpm	Vantilator
119	Y4 Building, Patient Rooms with Number 3,South Side	7,5	960 rpm	Aspirator
120	Y4 Building, 2 of Air Conditioning, Floor 4,5	15	1665 rpm	Vantilator
Int.	Y4 Building, 2 of Aspirator, Floor 4,5	3	965 rpm	Aspirator
121	Y4 Building, 4 of Aspirator, South Side Patient Rooms	11	1665 rpm	Aspirator
122	Y4 Building, 3 of Air Conditioning, South Side Patient Rooms	11	970 rpm	Vantilator
Int.	Y4 Building, 3 of Aspirator, South Side Patient Rooms	3	1440 rpm	Aspirator
123	Y4 Building, 4 of Air Conditioner, Floor 4,5 South Side Patient Rooms	15	970 rpm	Vantilator
124	Y4 Building, 4 of Aspirator, Floor 4,5 South Side Patient Rooms	11	1660 rpm	Aspirator
125	K1 Roof. Fiveth, Sixth and Seventh Floor	-	-	Vantilator
126	K1 Roof. Fiveth, Sixth and Seventh Floor	-	-	Vantilator
127	K1 Roof. Fiveth, Sixth and Seventh Floor	-	-	Vantilator

132	Conference Building	-	-	Vantilator
133	Conference Building	-	-	Vantilator

Int. means internal aspirator.

Table M.9. The matching of cooling groups and air conditioners

Cooling Groups	Air Conditioners (AC)		
Surgical Operating Room (6 Air Conditioners)	AC 2	AC 5	AC 6
	AC 8	AC 9	AC 10
Y1,Y2,Y3 Blocks Cooling Group (26 Air Conditioners)	AC 40	AC 41	AC 42
	AC 43	AC 46	AC 47
	AC 48	AC 49	AC 53
	AC 54	AC 60	AC 63
	AC 66	AC 69	AC 72
	AC 74	AC 75	AC 76
	AC 77	AC 78	AC 79
	AC 80	AC 81	AC 11
	AC 3	AC 9	
Y4,Y5,Y6 Blocks Cooling Group (31 Air Conditioners)	AC 85	AC 87	AC 88
	AC 89	AC 90	AC 91
	AC 93	AC 94	AC 96
	AC 97	AC 98	AC 99
	AC 101	AC 102	AC 103
	AC 105	AC 107	AC 110
	AC 112	AC 113	AC 115
	AC 116	AC 119	AC 121
	AC 123	AC 124	AC 125
	AC 126	AC 127	AC 132
	AC 133		
Intensive Cares (4 Air Conditioners)	AC 32	AC 33	AC 34
	AC 35		
Burn Unit (1 AC)	AC 37		
Internal Oncology (1 AC)	AC 131		
Emergency Medicine (6 Air Conditioners)	AC 1	AC 3	AC 4
	AC 7	AC 11	AC 12
Refrectory (2 ACs)	AC 134	AC 135	
Coroner Intensive Care (2 ACs)	AC 28	AC 29	
Dialysis	There is a very small AC.		
Radiation Oncology	There is no AC		

Table M.10. The numbers of split air conditioners at Balcalı Hospital

Place	BTU (British Thermal Unit)								Total Pcs	Total BTU
	9.000	12.000	15.000	18.000	24.000	36.000	50.000	60.000		
Radiology	8	16	0	10	35	2	5	3	79	1,786,000
Physical Medicine and Rehabilitation Polyclinic	4	7	0	0	9	0	0	0	20	336,000
Adult Infectious Diseases	0	15	0	2	6	0	0	0	23	360,000
Internal Diseases Hematology and Rheumatology Polyclinic	6	8	0	2	7	0	0	0	23	354,000
Orthopedics and Traumatology	0	0	0	0	3	0	5	0	8	322,000
General Surgery Polyclinic	7	9	0	1	6	0	0	0	23	333,000
Child Health and Diseases	13	11	0	1	10	0	3	0	38	657,000
Brain Surgery and Thoracic Surgery Polyclinics	10	10	0	2	4	0	0	0	26	342,000
EKO & EEG	5	7	0	0	6	0	0	0	18	273,000
Dermatology and Cardiology	10	10	0	0	9	1	0	0	30	462,000
Neurology and Gastrology	12	6	0	0	7	0	0	0	25	348,000
Thoracic Diseases and Internal Diseases Polyclinics	7	7	0	1	7	0	0	0	22	333,000
Nuclear Medicine	1	1	0	6	8	0	2	0	18	421,000
Infection and Pediatric Surgery	4	9	0	0	1	4	0	1	19	372,000
Mental Health and Diseases	6	5	0	2	2	4	0	1	20	402,000
Ear-Nose-Throat	9	1	0	0	5	4	0	0	19	357,000
Obstetrics and Gynecology	8	5	0	0	6	2	1	0	22	398,000
Urology Polyclinic	7	5	0	0	1	1	0	0	14	183,000
Plastic, Reconstructive and Aesthetics Surgery Polyclinic	5	0	1	0	3	1	1	0	11	218,000
Infection Diseases Polyclinic	11	0	0	0	1	3	0	0	15	231,000
Anesthesiology and Pain Polyclinic	8	3	0	0	0	2	0	0	13	180,000
Archive Department	0	3	0	0	1	0	2	0	6	160,000
Administration of Hospital	0	0	0	1	1	0	2	0	4	142,000
Blood Bank	0	0	0	0	3	0	1	0	4	122,000
Pediatric Hematology and Oncology Polyclinics	3	4	0	0	3	0	0	0	10	147,000
Forensic Medicine	0	3	0	0	0	0	0	0	3	36,000
Information	0	4	0	0	0	0	0	0	4	48,000
TOTAL	**144**	**149**	**1**	**28**	**144**	**24**	**22**	**5**	**517***	**9,323,000**

* This value doesn't include air conditioners of rooms of faculty members, teaching assistants and expert doctors. Balcalı Hospital has approximately 777 (517+260 = 777) air conditioners.

APPENDIX N: Boosters, Elevators, Compressors and Other Devices

Table N.1. The features of boosters at Balcalı Hospital

Location	Type of elevators	Power		Quantity		Capacity kW
Old building Y1,Y2,Y3	Soft water booster	7.5	kW	2	Pcs	15
		11	kW	1	Pcs	11
	Hard water booster	7.5	kW	2	Pcs	15
		11	kW	1	Pcs	11
Y4,Y5,Y6	Hard water booster	15	kW	5	Pcs	75
Fire booster	Fire booster	7.5	kW	2	Pcs	15
TOTAL						142 kW

Table N.2. The features of elevators at Balcalı Hospital

Location	Types of elevators	Power		Quantity		Capacity kW
Y1,Y2,Y3 and polyclinics	Personnel elevator	6.6	kW	1	Pcs	6.6
	Visitors elevators	13.2	kW	3	Pcs	39.6
	Goods and patient moving elevators	11	kW	2	Pcs	22
	Policlinics' elevators	11	kW	2	Pcs	22
Y4,Y5,Y6	Personnel elevator	8.5	kW	1	Pcs	8.5
	Visitors elevators	22	kW	3	Pcs	66
	Goods and patient moving elevators	22	kW	2	Pcs	44
Surgical operating room	Surgical operating room patient elevator	5.5	kW	2	Pcs	11
Kitchen	Kitchen goods elevator	3.5	kW	2	Pcs	7
TOTAL						226.7

Table N.3. The features of compressors at Balcalı Hospital

Place	Pcs.	Compressor motor(kW)	Vacuum motor(kW)	Total(kW)
Basement floor	2	15	5,5	41
Burn unit	3	7,5	4	34,5
Oxygen room	4	5,5	-	22
Painting	2	3,5	-	7
TOTAL				104,5 kW

Table N.4. The features of UPSs used at Balcalı Hospital

No	**Power Fed Areas**	**Location of UPS**	**Model Year**	**With Generator or not**	**Power**	
1	Emergency Medicine lighting and wall plugs, Spare of Central Laboratory	Emergency Medicine Panel Room	2011	Yes	**2x120**	kVA
2	Blood Center, MR 2, Old building K,Y Blocks HIMS machines, Biomedical, General Surgery, Sterilization Unit	Old Building K and Y Blocks Panel Room	2009	Yes	**200**	kVA
3	Computers and Environments Devices of HIMS and MR 1 device	Emergency Medicine Panel Room	2011	Yes	**2x100**	kVA
4	Emergency Rontgen and Tomography Devices	Emergency Medicine Panel Room	2012	Yes	**160**	kVA
5	Internal Intensive Care, Brain Surgery Intensive Care, Reanimation and Pediatric Intensive Care Units	Intensive Cares Panel Room	2001	Yes	**120**	kVA
6	Radiology Angio Unit	Emergency Medicine Panel Room	2013	Yes	**120**	kVA
7	Neurology Intensive Care and Neonatal Intensive Care II	Neurology Intensive Care Panel Room	2010	Yes	**120**	kVA
8	Eyes diseases policlinic, Pediatric Surgery Polyclinic and Clinics, Pathology	Mortuary Panel Room	2010	Yes	**120**	kVA
9	Nuclear Medicine Siemens Mark PET CT Device	Nuclear Medicine Panel Room	2011	Yes	**100**	kVA
10	Burn Unit	Burn Unit Panel Room	2009	Yes	**80**	kVA

11	Radiology Unit Tomography device	Radiology Rontgen Film Bathroom	2009	No	**80**	kVA
12	Central Laboratory	Central Laboratory Panel Room	2009	Yes	**80**	kVA
13	Additional Service Building HIMS machines	Additional Service Building Panel Room	2012	Yes	**80**	kVA
14	Cardiology and Pulmonology Clinics	Cardiology Clinics Panel Room	2011	Yes	**80**	kVA
15	Radiology Unit	Radiology Panel Room	2010	Yes	**60**	kVA
16	New Building (Y4,Y5 and Y6) HIMS machines, HIMS technical services, test-tube baby and obstetrics and gynecology polyclinics	New Building, Y4,Y5 and Y6 water facilities	2006	Yes	**60**	kVA
17	Internal Oncology and Pediatric Hematology Policlinics Lab.	Internal Oncology Panel Room	2012	Yes	**60**	kVA
18	Hemapheresis - Bone Marrow Transplant and Transplantation Units	Transplantation Unit Panel Room	2013	Yes	**60**	kVA
19	Coroner Angio	Coroner Intensive Care Panel Room	2007	Yes	**60**	kVA
20	HIMS Room	HIMS Room	2010	Yes	**40**	kVA
21	The Salons of Surgical Operating Room, Lighting and wall plugs	The roof of the Surgical Operating Room	2005	Yes	**15**	kVA
22	Nuclear Medicine	Camera 3 Room	2007	Yes	**15**	kVA
TOTAL					**2030**	**kVA**

Table N.5. The features of generators used at Balcalı Hospital

Number	Location	Power	kVA	Coupled with
1	Near the Y4 TR building (Yellow color)	750	kVA	Coupled with 1600 kVA Y1,Y2,Y3 Central Air Conditioners TR
2	Near the Y4 TR building (White color)	750	kVA	Coupled with 1600 kVA Laundry TR. It supplies to Y1,Y2,Y3 Lighting systems
3	In the Y4 TR building	500	kVA	Coupled with Y4 TR
4	In the Y5 TR building	500	kVA	Coupled with Y5 TR
5	In the Y6 TR building	500	kVA	Coupled with Y6 TR
6	Under the kitchen	250	kVA	Coupled with 1600 kVA Surgical Operating Room TR
7	Under the kitchen	250	kVA	Coupled with 1000 kVA Kitchen TR. It supplies to polyclinics and K Blocks
8	Under the kitchen	120	kVA	Coupled with 1600 kVA Surgical Operating Room for Coroner Devices.
9	Under the kitchen	250	kVA	Spare Generator (the spare of 2 number of 250 kVA and 229 kVA of Intensive Care Generator
10	Nuclear medicine	105	kVA	Coupled with 630 kVA Nuclear Medicine TR for Petct Device
11	Radiation Oncology and Nuclear Medicine	150	kVA	Coupled with 630 kVA Nuclear Medicine TR
12	Near the heat center	100	kVA	Coupled with Heat Center TR
13	The opposite sides of Intensive Cares	229	kVA	Coupled with 1000 kVA Intensive Care 1 TR
14	The opposite sides of Intensive Care 1	1600	kVA	Coupled with 1600 kVA Intensive Care 2 TR. It supplies to New Intensive Cares, Burn Unit and Emergency Medicine
15	Additional service building	400	kVA	Coupled with 1000 kVA Additional Service Building TR.
TOTAL		**6454**	**kVA**	
MEDICINE FACULTY DEANERY BUILDING				
16	Medicine Faculty Deanery Building	500	kVA	Coupled with 1000 kVA Deanery TR
TOTAL VALUE		**6954**	**kVA**	

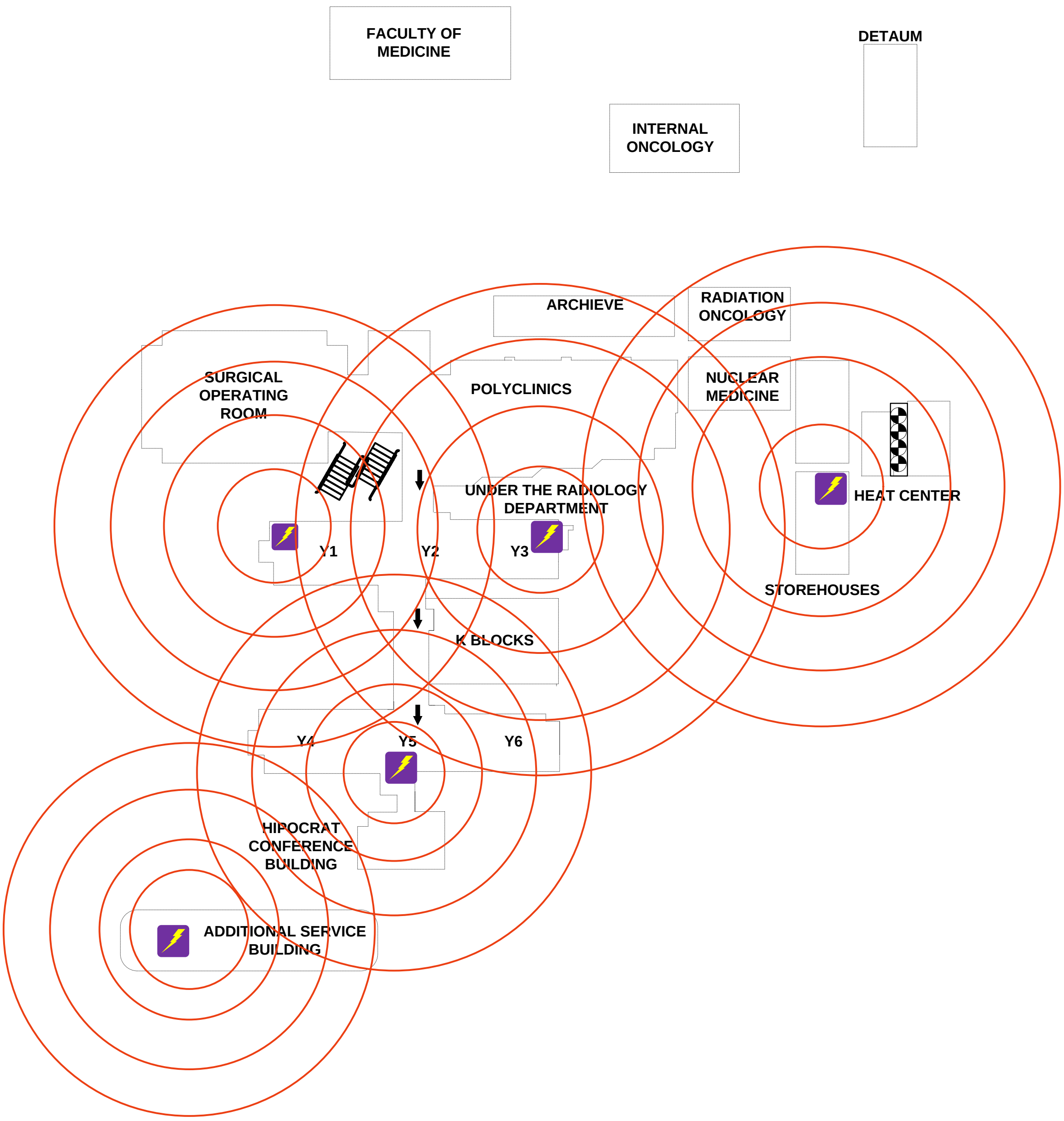


Figure N.1. Lightning rods at Balcalı Hospital

APPENDIX O: Energy Use Analysis and Tariff Optimization Software

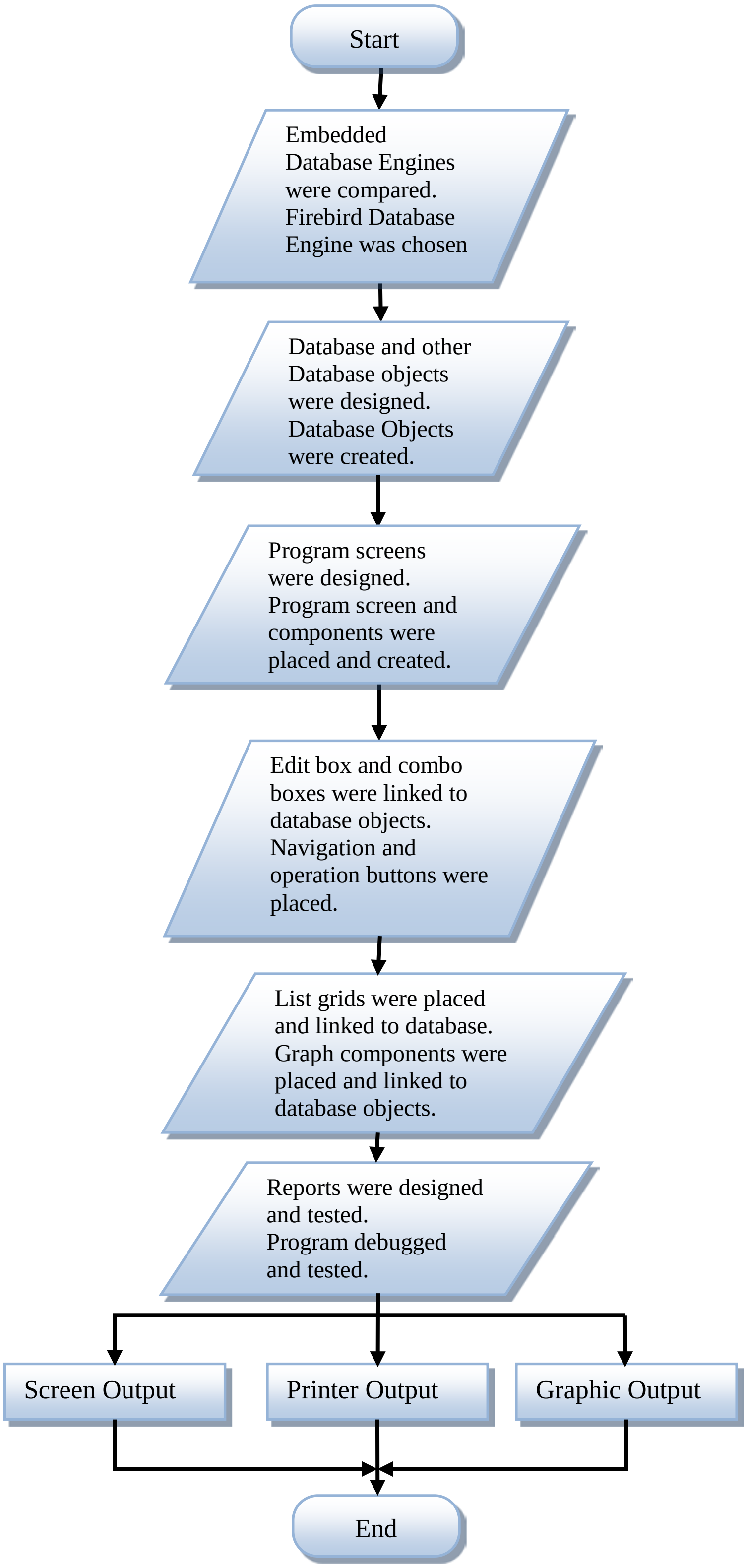


Figure O.1. Flowchart of proposed program

The proposed software program has the following features and algorithmic view is shown at Figure O.1:

- Calculates the electric bills for different tariffs and shows which tariff is more economical for users
- Calculates and monitors the consumption of active and reactive electric power and warns the user for the high level of reactive power consumption
- Prepares a detailed report for the energy consumption, bill rates and tariff efficiency with graphical charts and tables
- Enables the users to checks the validity of the given electric bill by electric power supplier

This project operates under the Windows desktop environment. At the beginning, this project can be used by one user but our project may be used more than one user at the near future. Because this project is designed to use only by one user for the present, development environment, database engine, user interface and the other factors are selected for one user.

I. Choosing the Right Software Application Development Environment

This software project and its database can be operated under 32 bit Windows and 64 bit Windows environment. In the windows environment, different development environments can be used such as Microsoft based or others. Microsoft based development environment is named as Microsoft Visual Studio Integrated Development Environment. Visual Studio is a multi language development platform. By this platform, some applications can be designed by using C, C# and Visual Basic. C and C based languages are a bit complex to develop visual application for the Borland users which used Pascal in the past. Visual Basic is easy but limited language for development of this project. Java and its development environments are less efficient than Windows development environment because they have to run under Java virtual machine. Because of java virtual machine, java has limited program resources and usability. Delphi language is preferred for proposed software project. Delphi is an easy development language and has powerful development environment. Its development environment has easy debugger. In addition it can be installed to another computer easily. Delphi is a development environment which can produce direct executable program files.

It was created by Borland Software Company in 1992. First version of Delphi was running under Windows version 3.1. Since the first version, Borland Software Company has aimed powerful database connectivity, easy language features, simple but powerful debugger in a one package. From the beginning of Delphi, it has easy language, very fast compiler and easy usable debugger and most powerful database design, connections, management and development features. Delphi is based on Pascal. Pascal is a powerful development language. First Apple Macintosh operating system was developed by this language. At the first 10 years, Pascal was major development language at Apple Macintosh platform. Photoshop first releases are developed by Pascal also. Because of superior properties of Delphi with integrated development environment, it was chosen to develop for the proposed software project.

The proposed software project is written by Delphi XE3 developer version which can be developed excellent applications running under 32 bit and 64 bit Windows desktop environment with same codes. Code development feature of XE3 is powerful. Delphi has allowed for connecting to most known databases such as Oracle, IBM DB2, PostgreSQL, Interbase/Firebird, MySQL, Microsoft SQL server, SQLite and etc.

II. Choosing a Database Engine

Most of the computer programs have a database to store data. The proposed software program needs to store electricity consumption values, calculated power losses, comparison results, tariff values and etc. Because of storing data, database which has vital features such as fast processing, portable and less disc size has required. The selected database should be run under the Windows operating systems. It must be easy installable and portable. It should be run either 32 or 64 bit Windows environment. When the huge amount of data demands at the future, it should be met this demand by scalable feature.

Most of the enterprise class databases meet these requirements but they are very expensive products and not portable. Because of this situation, embedded database solutions can be met the requirements of proposed project instead of the enterprise class databases. Embedded databases are portable, fast and easy manageable products. Additionally, they use less disc size. Some embedded database products and all enterprise class databases have a license fee. Because proposed project is a thesis project, open source database engine has been chosen.

At this paragraph, the embedded databases are compared among themselves. One of the most known database named MySQL was started by an open source project and used by millions of web based project. MySQL has license fee but individual user can’t buy license of MySQL. Embedded MySQL database should be only licensed by traditional company. Because of this situation, MYSQL is not selected for proposed project.

Some embedded databases do not support SQL (Structure Query Language) SQL is important for generating reports, filter and searching of the record. When the huge amount of data is processed, application processing speed is the most important factor. Because SQL has been developed for big data store, it is fast and efficient.

Borland software has a database which is called Interbase also. It was produced at mid of 80’s. Borland is deploying the source codes of Interbase version 6.0.to public. Firebird was developed by using these deploying codes. Because of this, firebird is most compatible open source database engine for Borland development environments. Firebird is an open source, fast, portable, near zero maintenance, scalable database engine. Firebird is used less disc space. It can be run in different platform such as Windows, Linux, Macintosh and Solaris. Data which is produced by firebird can be transferred from the one platform to another. There are three main versions of Firebird. First of them is Super Server version which is built for Windows environment. Second is Super Classic version which is developed for multi user. It can be run different operating system such as Windows and Linux. Third of firebird version is embedded version which is portable, small and power full database engine. All Firebird versions have support SQL 92 standards. In the proposed project, the required features are completely met by Firebird Embedded Database Engine.

III. User Interface Design

In the proposed project, user interface was designed like Microsoft Office 2003. Most of people have used Microsoft Office applications. Generally, Office applications have one main window and a lot of child windows. The design of these windows is called as MIDI by authors. This design has a main menu bar at the top of main window and a toolbar located top of the child window. Windows sometimes have tabbed child screens as the proposed project. This tabbed design has increased the usability and accessibility. Everything is as far as a mouse click. Delphi has a form design appearance manager which is based on objective. The views of the application can be chosen and changed by using this appearance manager.

IV. Miscellaneous Programs

Some miscellaneous programs were used at the development stage. One of them is IBExpert software. IBExpert is software to create database. It is used for maintenance and management to Firebird database engine. Database objects can be created such as database, table, index, view etc… At the same time, database object properties can be changed by using IBExpert. The maintenance of the database is executed by this program. Briefly, proposed project has required creating and managing of the database structure on the disk.

Unidac is a component of Delphi. It is provided most known database engine connection components. Every database objects have logical components in Delphi environments.

Quick Report is a report builder component in Delphi. You can create very detailed reports automatically from the database table. Reports can be previewed at the screen, printed to printer or saved to disk by using this component.

Teechart is a graphic drawing component in Delphi. By this component, stored data in the database can be drawn graphic directly. Graphic types, series colors and etc. can be chosen. Drawing graph can be previewed, printed or saved.

In this project database design is prepared after determining the development environment, database engine and other development tools.

V. Database Design Basics

Database design procedure has two stages: One of them is logical database design and the other is physical database design.

At the logical database design stage is decided which variables represent and which database areas use. At the same time, variable types and sizes are decided (Decide Process).

At the physical stage logical objects are created. (Realize Process)

At the proposed project, database object was created which is named ENERGY.FDB. Energy.fdb database file has five database tables.

One of them is COUNTER table. It stores the electricity meter values. Active and reactive power values should be followed by daily.

Second table is PARAMETER table. It stores the upper and lower limit values of reactive power loses.

Third table is TARIFF table. It stores the tariff values.

Fourth table is ACCOUNT table. It stores the bill values by calculated the program based on the COUNTER table data

Last table is TARIFF_COMPARATOR table. It stores the different bill values calculated by different tariff values stored on TARIFF table.

Firstly, main database file ENERGY.FDB was created by IBExbert miscellaneous program as shown in Figure O.2.

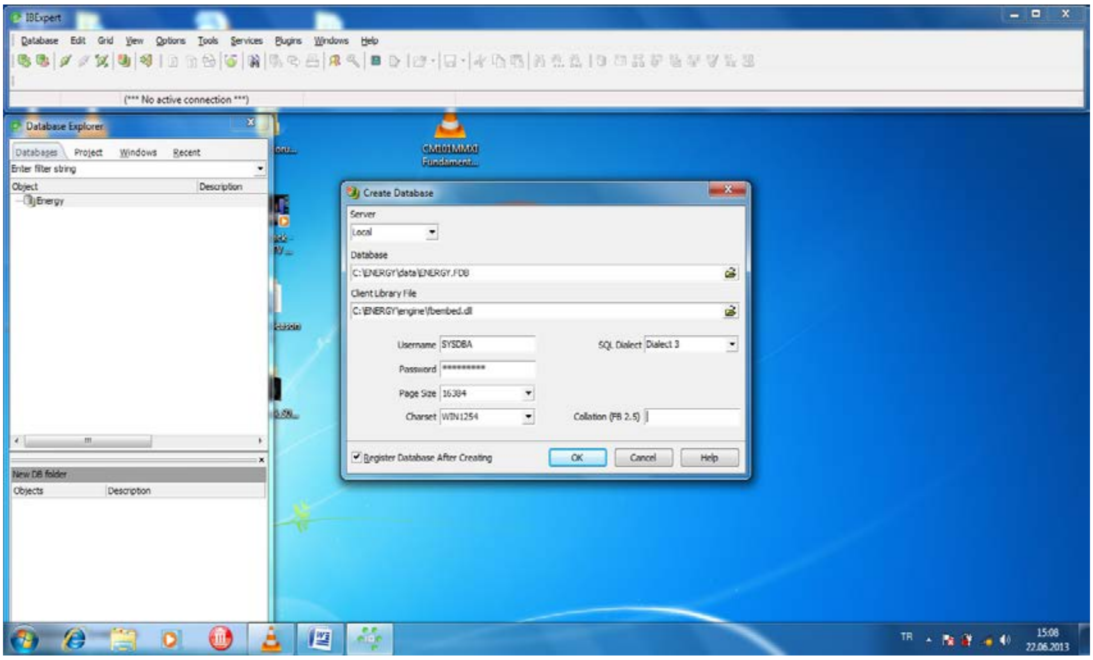


Figure O.2. Database creation stage with IBExbert tool

After this process, the creations of database tables and other database objects (domains, index etc.) were started to design. Column name, size, type and other parameters in the table were defined and created as shown in Figure O.3. At the table, for quick access to data, indexing should be used.

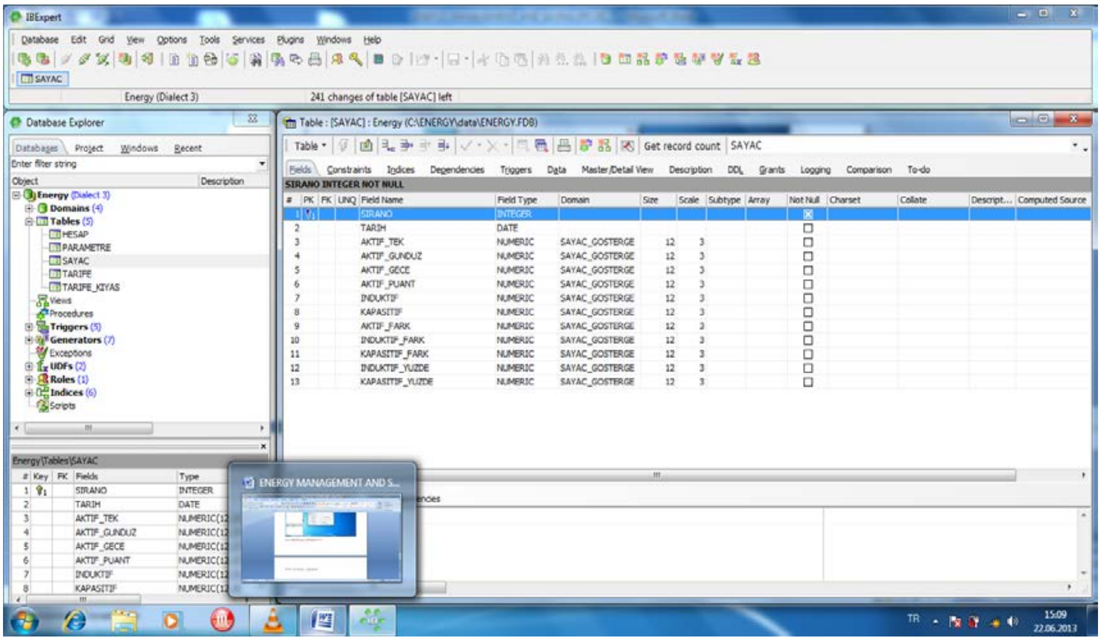


Figure O.3. Table creation stage

After the all database table creation, application screen should be designed and program source codes should be written. In Figure O.4, Embarcadero RAD Studio XE3 has been used for the designing of user screen and writing of the source codes.

Figure O.4. Delphi integrated development environment (IDE)

The project was developed under the Delphi IDE (Integrated Development Environment). Delphi IDE has a code editor to write program code, a project manager to manage the project files, a component pallet to store the Visual Component Library (VCL), an object inspector to see and change the object properties and assign the code block the object events and of course integrated debugger to find and debug the logical or structural program bugs. In Figure O.5, Delphi IDE with its all components is shown together.

In Delphi development environment, processed data in the database tables can be seen and run practically. It is very useful and important feature. It is easy way to design and test the designed program.

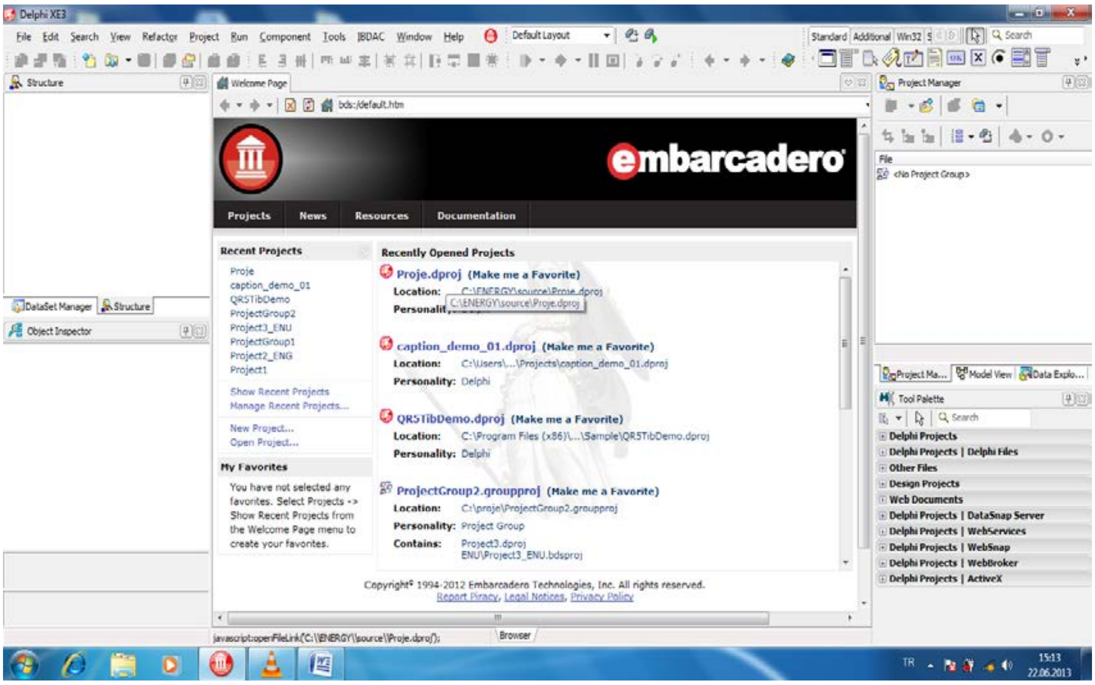


Figure O.5. Delphi development environment

Firstly, startup screen was designed for application as shown in Figure O.6. This screen has a background image, and two labels. One of labels stores the application name and the other one stores the project owner.

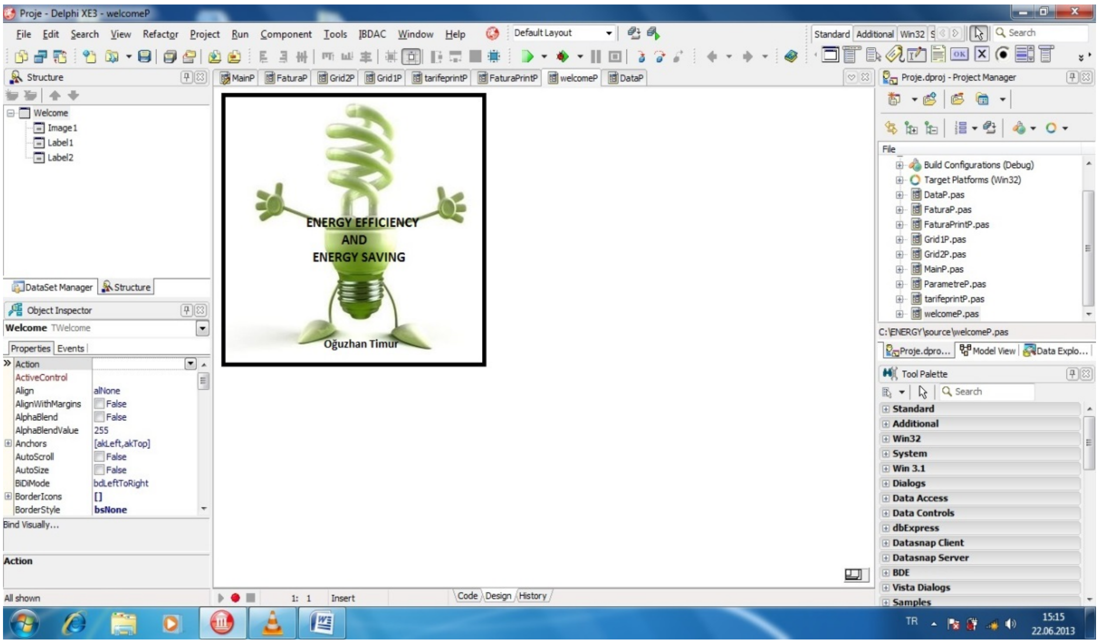


Figure O.6. Welcome screen of the proposed program

After this stage, database form which holds the all database object was designed as shown in Figure O.7.

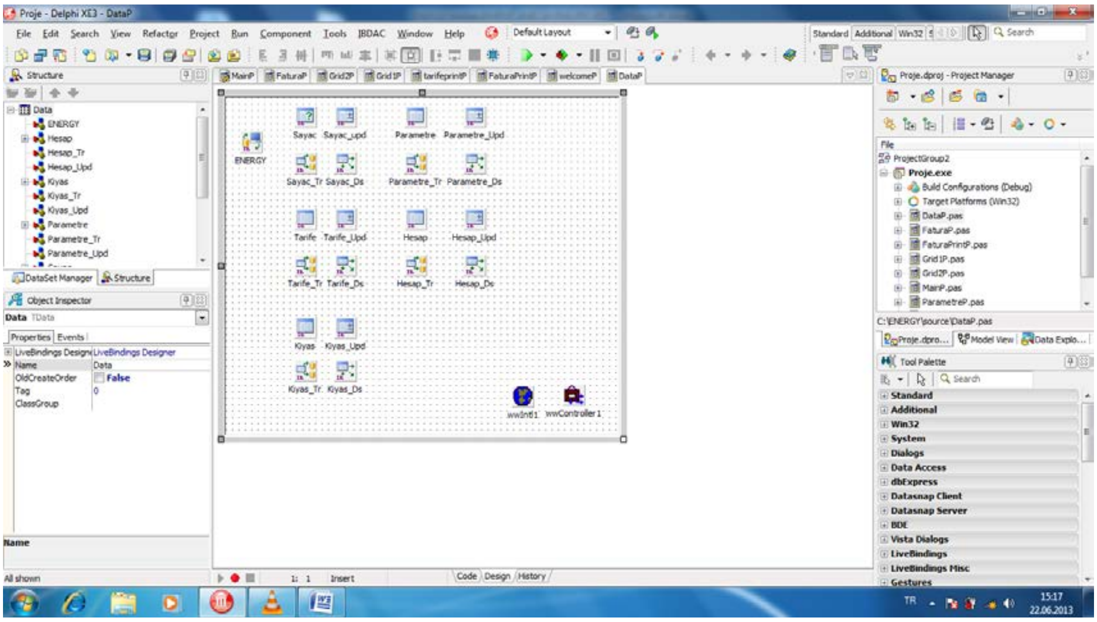


Figure O.7. Database objects screen

This form has a database component named as ENERGY which represents physical database file on the disk. Every database table represents by four database components. First component is a table component that represents the physical database table in the database file. Second is a transaction component that is responsible for management the every read or write operation to the table object. With this component really write the data which is entered or changed the physical disk file or rollback the operation. Third component is an update component that is responsible for store the SQL sentences for every operation (Insert, Update, Cancel, Delete, Save and Refresh). When the user click the button on the form start or finish the database operation (start data entry, edit the record or delete the record etc.) table components take the SQL sentences form this components and add the some parameters and send it to the database engine for processing. Fourth component is data source component that is responsible for linking the table component and every other database enabled components. It works as a bridge between the components and table objects.

After this stage, main screen, electric meter readings screen, print preview screens and the other screens were designed as shown in Figure O.8.

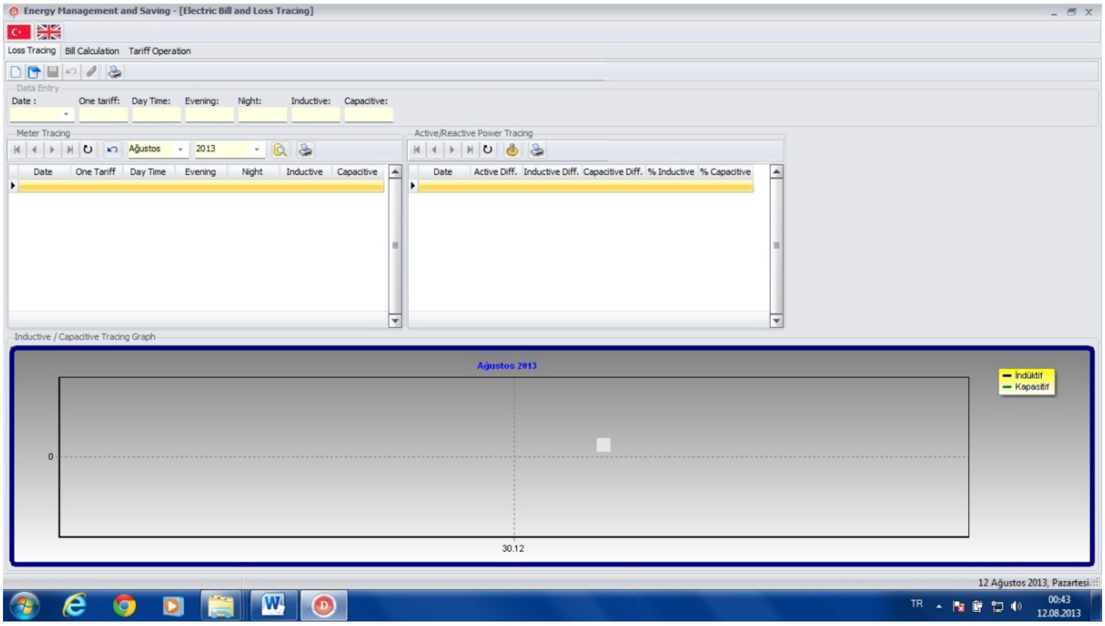


Figure O.8. Meter readings screen

The Proposed project screen has three tabs. First tab is losses tracing. In this tab, the screen has four areas. First area is data entry area. This area has seven data entry box for input data values. Second and third areas are list areas. Second area lists the entered values ordered by date. Active and reactive values by date basis are seen at this second area. In third area, active, inductive and capacitive losses and their percentage can be seen. Forth area is graphic area. In this area, inductive and capacitive losses as a graph by day basis can be seen.

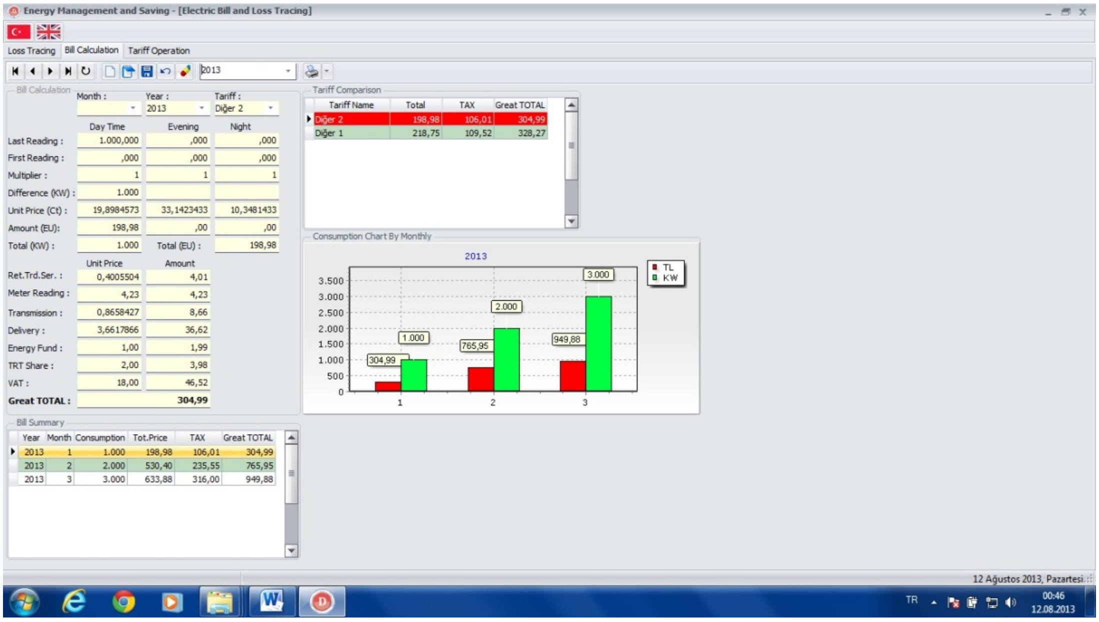


Figure O.9. Bill calculation screen

Second tab is named as bill calculation. In this tab, bill consumption values can be entered for bill calculation and then program can be calculated bill amount automatically. Every calculated bill amount and values can be saved and can be listed in the second area in this tab. In the third area, the bill calculation can be compared each other, according to defined tariffs. It can be decided which tariff is effective for this bill calculation. At the last area, bill comparison can be seen as graphically. In this graphics, bill amount and consumption can be showed at the same time by month basis. Third tab and its contents are shown in Figure O.9.

Third tab is named as tariff operation. This tab has two areas. First area is data entry area. The tariff values can be defined for every tariff type and can be stored defined values or can be retrieved all defined data for looking and fixing. In second area, tariffs can be seen in a list form. First and second areas are shown in Figure O.10.

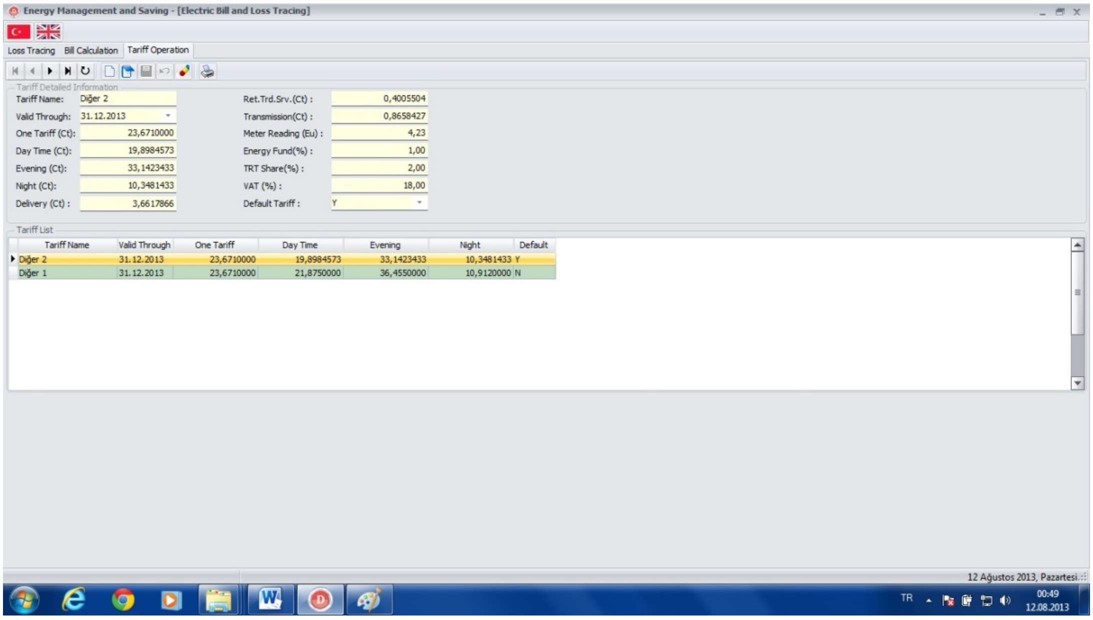


Figure O.10. Tariff operation screen

After the screen design and component linking stage are finished, program coding stage can be started. In Figure O.11, Delphi code editor to write program code are shown. Code editor has many important features;

One of them is code compilation. Code editor underlines the wrong code when the code is written. In Delphi development environment can add a breakpoint to wanted lines. The program debugger can be run. The program debugger traces all writing codes and the line which has a break point compiler stops the operation and code editor shows the breakpoint lines or code writing errors. Delphi Debugger is shown in Figure O.12. The code can be followed and can be examined the variables values. In Addition, the codes can be changed the variables values and can be run the program step by step (or line by line). It is easy way to find the wrong code or logical design errors.

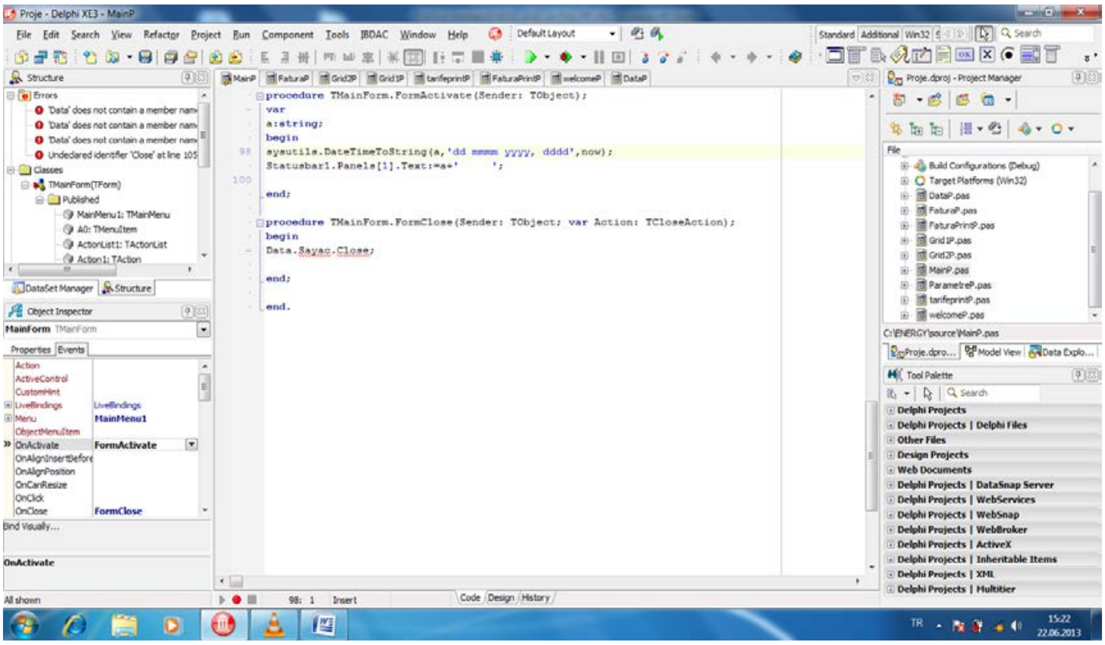


Figure O.11. Delphi development environment: Code editor

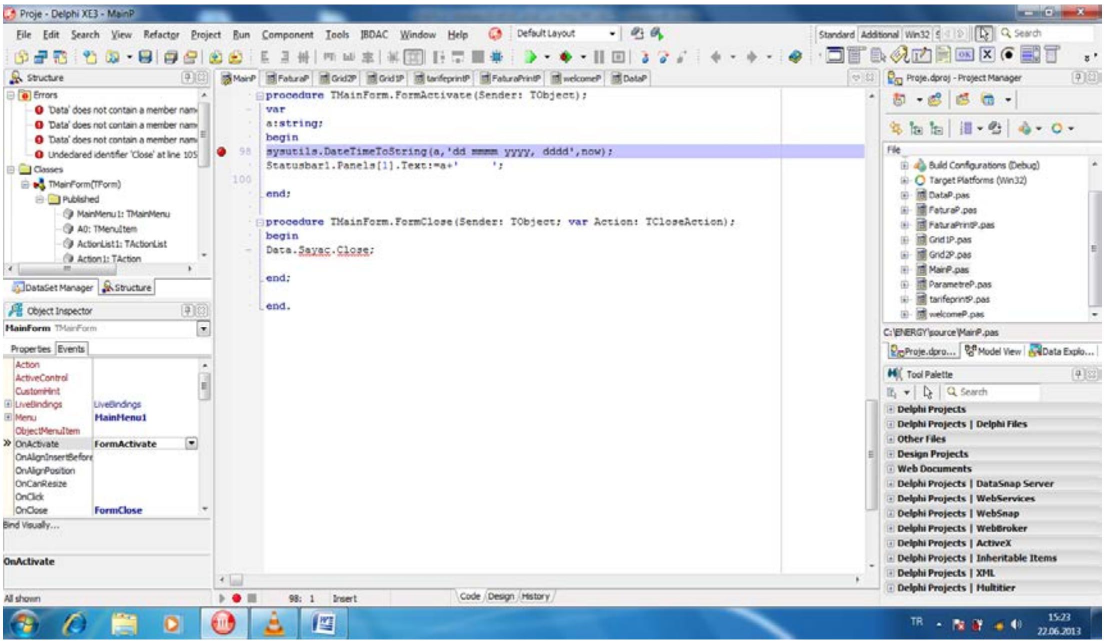


Figure O.12. Delphi development environment: Just in time debugger

After the full form designed and writing code, the proposed project program can be run without any problems.

APPENDIX P. Energy Efficiency Laws and Regulations in Turkey

- In 2007 “Energy Efficiency Law” no 5627 was enacted.
- By Prime Ministry Circular dated 15/02/2008 numbered 2008/2 “National Energy Efficiency Action” was started.
- The year of 2008 was announced as “Year of Energy Efficiency”.
- By Prime Ministry Circular dated 13/08/2008 numbered 2008/19 replacing incandescent filament lamps with saving light bulbs is required.
- On 25/10/2008 "Regulation of Increasing Efficiency on Energy Sources and Energy Use" was published.
- On 05/12/2008 “Regulation of Energy Performance on Buildings” was published.
- On 25/02/2012 “Energy Efficiency Strategy Document 2012-2023” was published by High Planning Council and measures were taken to improve the efficiency were planned to do until 2023.
- According to regulation of increasing efficiency on energy sources and energy use, public buildings which have total construction area of 10.000 m^2 or total annul energy consumption is at least 250 TOE have to charge an energy manager or have to take energy manager service.

250 TOE = 2,906,977.5 kWh

Even electricity consumption of Balcalı Hospital is 22,542,480.00 kWh in 2012.

- The Regulation of Energy Performance on Buildings which was published in the Official Gazette No. 27075 dated 5 December 2008 is legally enforced the current new and larger than 1000 m^2 buildings to take Identification of Energy.
- It is obligated to arrange an Identification of Energy for current buildings and the buildings under construction which has not yet received permission to use, up to 10 years from the date of the publication of Energy Efficiency Law (up to date 02/05/2017).