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Overview of Energy Savings and Efficiency Strategies at the Hospitals

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***Abstract*—**Hospitals represent approximately 6% of total energy consumption in the utility buildings sector. Heating, Ventilation and Air Conditioning (HVAC) systems are the major part of electrical energy consumption at the hospitals. The air-conditioning system is responsible for around 70% of total electricity consumption. Electric motors and lighting systems in a hospital represent approximately 19% and 21% of the total energy consumption, respectively. In this paper, profiles of hospital energy end-use consumption and an overview of energy saving areas at the hospitals are presented.

***Keywords*—**Energy efficiency, energy saving, healthcare energy consumption, hospital.

I. Introduction

ENERGY is a vital input for social and economic development of any nation, [1]. According to International Energy Agency (IEA) data, final energy consumption of the building sector in the world has risen to 2,794 millions of tons of oil equivalent (Mteo) in 2007 as shown in Fig. 1. The building sector represents around 34% of the world final energy consumption and hence is the first consumer sector, [2].

According to the reference scenario of IEA, the building sector will remain the first consumer with in 2030 with consumption share of 32% (3639 Mteo). Its energy demand will grow with an average of around 1.2% per year against 1.4% for the whole final energy consumption, [2]. 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, [1]. 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. All fossil fuels should peak within about the next half century and the obtained results are, [3]:

- World crude oil and natural gas liquids: assuming a global ultimate in the range 2250-3000 Gb, the peak was estimated to be in the range 29.2-31.6 Gb/year and occurs between 2009 and 2021.
- World (dry) natural gas: assuming a global ultimate in the range 9500-15400 Tcf, the peak was estimated to be in the range 121-135 Tcf/year and occurs between 2024 and 2046.
- World coal: assuming a global ultimate in the range 550-750 Gtoe, the peak was estimated to be in the 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, [4]. Installed renewable energy capacity of Turkey is shown in Fig. 2.

- Hydroelectric dams 19,600 MW
- Thermal power plants 35,000 MW
- Geothermal 162 MW
- Wind 2,260 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, [5];

- 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

The paper is therefore organized as follows: After this introductory section, energy savings and efficiency areas at the hospitals are discussed in Section II. Energy cost controls and energy management at the hospitals are presented in Section III. And finally, the main points and significant results of the study are summarized in conclusions.

II. Energy Savings and Efficiency Areas at the Hospitals

There are currently several developments worldwide that focus on the implementation of policies and strategies to

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sustain the promotion of energy use efficiency, [6]. The benefits of energy efficiency are, [7]-[9]:

- 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, [10]. Energy savings potential end-use sectors in 2020 are shown in Fig. 3, [11]. Buildings sector energy savings by sector and end-use is shown in Fig. 4, [12].

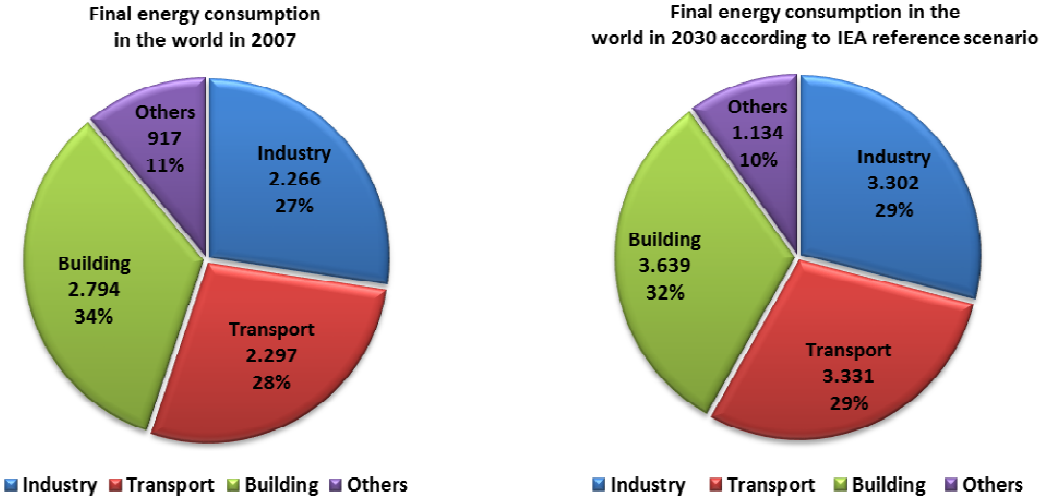


Fig. 1 Final energy consumption prospective in the world in 2007 and 2030

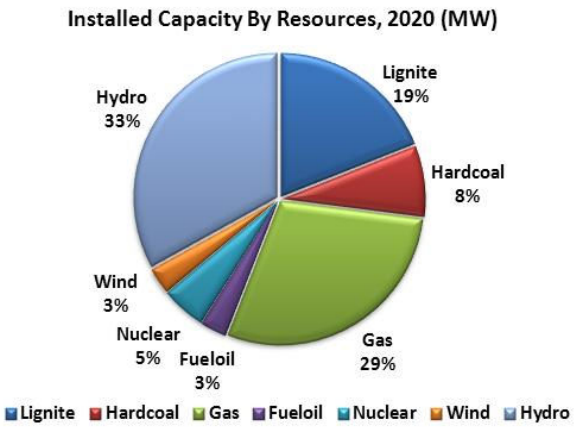


Fig. 2 Installed energy capacity of Turkey in 2012

Energy efficiency opportunities for healthcare organizations can find energy savings through multiple efforts as in [13], [14].

Low-Cost Measures

- 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 variable speed drives (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
- Turning off computers, lights, air handling units
- Turning down operating-room air-handling setbacks and room temperature setbacks
- Cleaning and maintenance of economizer, air conditioning temperatures, filters, cabinet panels, condenser coils and airflow

Cost-Effective Investments

- 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

- Maximizing the usage of natural light during the day through corridors
- Continuously monitoring a building's energy systems
- Upgrade to more-efficient lighting and electric motors

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 I, [15]. 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, [16].

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 ft² annually (Data are calculated using a 2003 U.S. Energy Information Administration survey of commercial buildings).

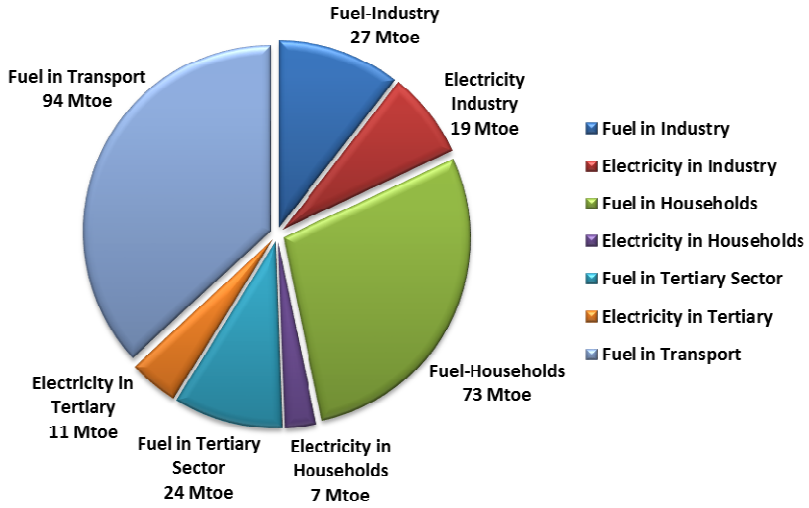


Fig. 3 Energy savings potential end-use sectors in 2020

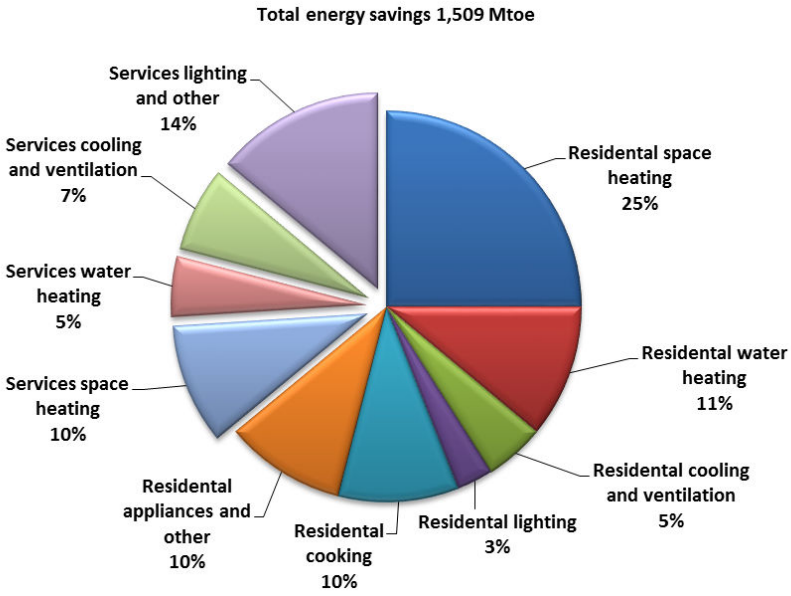


Fig. 4 Buildings sector energy savings by sector and end-use

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TABLE I
THE MOST 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 ▪ 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 and seal ductwork to minimize leaks ▪ Repair or replace malfunctioning variable-speed drives
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

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. Fig. 5 details healthcare energy consumption by end use in the U.S, [17].

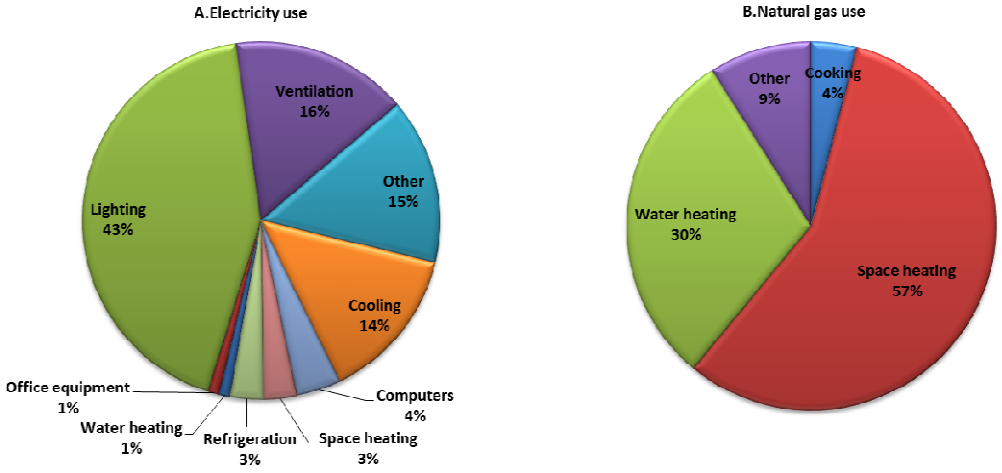


Fig. 5 Healthcare energy consumption by end use in the U.S

Table II 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.

There are some examples in the area of energy saving studies at the hospitals. 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 tons 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 tons/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 tons, [18].

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TABLE II
AN OVERVIEW OF ENERGY SAVING AREAS AT THE HOSPITALS

Heating system	▪ Room thermostats and 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

Reference [19] 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, [20].

III. ENERGY COST CONTROLS AND ENERGY MANAGEMENT AT THE HOSPITALS

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 [21]:

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:

- Organization
- Implementation of an energy management program
- Energy audit
- Prioritizing possible measures implementation of measures

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- Maintenance and follow-up

Energy management programs are useful because, [16]:

- 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

Before embarking on an energy management program it is important to have sufficient knowledge of the building, so that quotations received can be compared properly as shown in Fig. 6 [10]. 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.

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%) [22].

III. Conclusions

Maximizing the energy efficiency at the hospitals is the first step to reduce the energy use, to achieve sustainability, to decrease the fossil fuel consumption percentage and to implement the renewable energy cost-effectively. Energy related costs typically represent 2-5% of a hospital's total operating budget and up to at least 15% of their annual profits. Energy efficiency opportunities can be realized with low cost measures or cost effective investments. Hospitals can achieve savings of between 20% and 40% of their current energy use. HVAC, lighting systems and motors are typical candidates for energy efficiency applications as in [14], [23]:

- 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. 20% 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.
- Continuously monitoring a building's energy systems can lead to reductions of 10 to 15% in annual energy bills

Comprehensive energy management program and strategy should be also developed to control energy use, perform maximum energy efficiency and maximum energy savings at the hospitals. These applications can increase the numbers of energy smart hospitals that aim the followings, [24];

- Promote 20% improved efficiency in existing buildings and 30% in new construction over current standards
- Increase renewable energy applications in hospitals
- Reduce energy use and operating costs
- Create healthier healing and work environments
- Maximize successful hospital upgrades and design strategies
- Ensure reliable backup power during disasters

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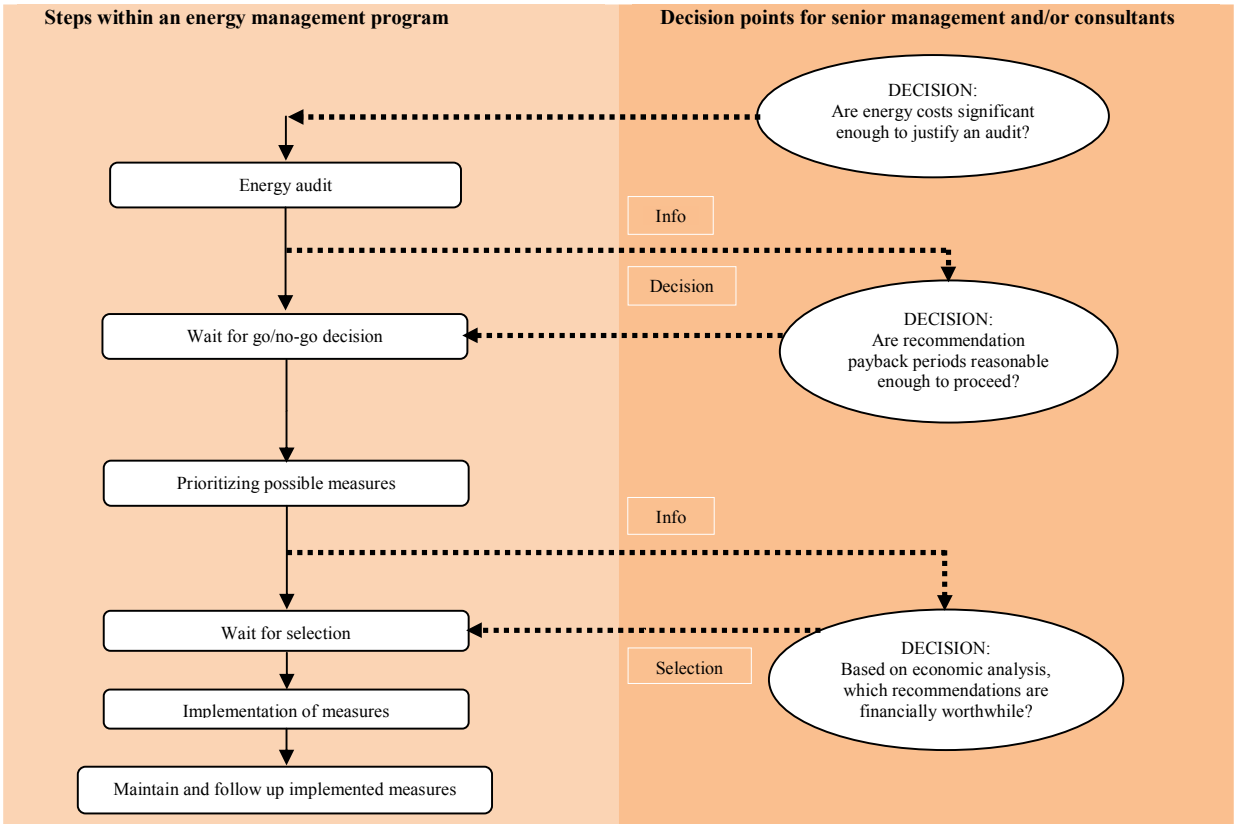


Fig. 6 Implementation of an energy management program

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