Saving energy with

Energy Efficiency in Hospitals

Maxi Brochure 05

CADDET energy efficiency

IEA
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CENTRE FOR THE ANALYSIS AND DISSEMINATION OF DEMONSTRATED ENERGY TECHNOLOGIES

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Centre for the Analysis and Dissemination of Demonstrated Energy Technologies - was founded in 1988. In 1993 CADDET was expanded and now has two branches: CADDET Energy Efficiency and CADDET Renewable Energy. This brochure is a bi-annual publication issued by CADDET Energy Efficiency in Sittard, the Netherlands.

OECD (Organisation for Economic Cooperation and Development)
IEA (International Energy Agency)
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CADDET Energy Efficiency
P.O. Box 17, 6130 AA Sittard
The Netherlands
Tel.: +31-46-420-2224, Fax: +31-46-451-0389
E-mail: nlnovcce@ibmmail.com
Internet: http://www.caddet-ee.org

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Summary

Hospitals and hospital buildings everywhere are large consumers of energy, which they use in many different ways. They have a high potential for energy savings, estimated to range from 20% (Germany) up to 44% (Netherlands).

Around 10% primary energy savings are often achievable within a single year (for which no special budget should be needed). Depending on the hospital's energy practices, a simple walkthrough inspection may reveal areas where lighting, equipment etc. are left on when unattended, or where lighting, ventilation or other service levels can be reduced without detriment to comfort or health care.

Other simple measures include cleaning lamps and luminaires regularly, replacing lamps and filters at the recommended time intervals, regularly checking for and repairing leaks, checking that thermostats and timers are accurate and correctly set, and that automatic controls are functioning properly.

More fundamental measures require a separate budget and modification to the energy system. When considering such measures, it should be borne in mind that hospitals have complex energy systems, and alterations to the performance usually have an impact on other aspects. For example, increasing insulation may reduce the need for heating, but is also likely to increase the need for cooling.

Before introducing energy-saving measures, an energy management programme should be set up, and an energy manager appointed. A well-managed energy management programme enables correct decisions to be taken, gives the appropriate feedback from currently implemented measures and initiates the implementation of new measures.

Introduction

This Maxi Brochure is primarily based on the CADDET Energy Efficiency Analysis Report "Learning from experiences with Energy Savings in Hospitals" [1], but is intended to give a quicker and more direct introduction to the subject. The full-length report is recommended reading for anyone requiring more in-depth information.

In order to benefit from energy-saving measures there are a number of steps that should be taken to ensure maximum effect. The measures must be well thought out before implementation. After implementation there should be a follow-up to see what has been achieved. Over a longer period a maintenance schedule should be followed to ensure that the energy savings are not decreasing over time. All these steps form part of an energy management programme. Therefore, this brochure concentrates on the energy management side of the implementation of energy saving measures in hospitals. More about energy management can be found in the CADDET Energy Efficiency Analysis Report "Learning from experiences with Energy Management of Commercial Buildings" [2].

BACKGROUND

Hospitals are institutions for the care of the sick or injured and are usually occupied 24 hours per day, all year round. They usually consist of large buildings, and careful control of their internal climate is necessary. A high level of heat is normally generated internally. This, combined with good insulation, usually reduces a hospital's sensitivity to the outside weather compared to less demanding building types. They also require standby generators to ensure a continuous supply of power in emergencies.

The typical hospital building is designed for long-term use and, in practice, is often used for longer periods than its builders ever intended. The actual lifetime is frequently over 50 years. During this period the building will be retrofitted and renovated many times. Reasons for this include the shorter life of technical equipment, the development of new types of equipment, new regulations, new energy-saving technologies and the ageing of the building itself.

When considering energy-saving measures to be applied in hospitals, it must be stressed that it is not the end-use of energy, but the need to control the indoor climate which is the principal requirement. The indoor climatic requirements are determined by the activities in, and the function of, the building. Once these are established, it is necessary to provide the required climate, ideally in the most economical way. In practice, energy efficiency is an increasingly important requirement, but medical considerations remain the top priority.

This brochure focuses primarily on existing hospitals, and the improvements in energy efficiency that can be made. However, it is generally true that newer hospitals consume more energy than older facilities. This is mostly due to the more sophisticated type and extent of the services provided by more modern hospitals, as a result of which their buildings may offer greater scope for energy and cost savings. Most energy efficiency measures undertaken in hospitals are appropriate for other kinds of buildings, but the severe constraints typical of hospitals do not usually apply.

The cost of energy used in hospitals, as in other types of premises, is subject to market forces such as supply and demand, variation in prices and taxes, and the form of energy used. It is anticipated that the cost of energy will generally increase over the long term. Several countries are also facing environmental taxes according to the type and amount of energy used.

Many reports present statistics on the expected availability of energy resources, and show varying degrees of optimism. Although there are different ideas and views, it is clear that for economic or environmental reasons, all of us should make every reasonable effort to reduce energy consumption, especially where this depends on non-renewable resources. Hospitals, as large consumers of energy, have high bills for electricity and fuels, although they often represent a small proportion of the hospital's total operating budget.

Figure 1 shows how energy consumption can be broken down according to its major applications in a hospital. The thick line through the pie chart tries to separate electricity use from thermal energy use (fuels). The precise split depends upon the type of hospital and the extent and complexity of equipment and services. New hospitals often have proportionately more air conditioning, with its associated chiller plant, and more extensive ventilation systems.

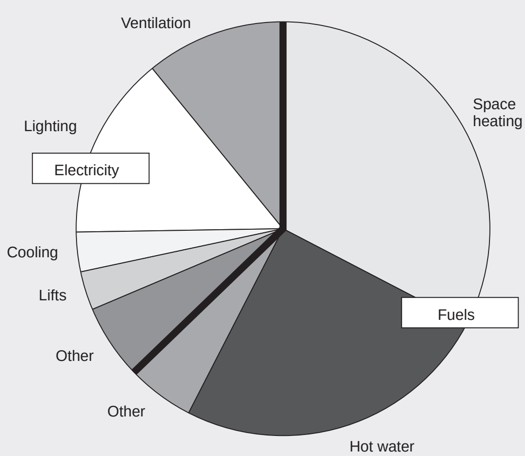


Figure 1: Breakdown of energy usage for a hospital at a northern location.

Fuel is mainly used for space heating and to produce domestic hot water, while the two major applications for electricity are seen as lighting and ventilation. These four applications may represent some 75% of a hospital's total energy consumption.

Heat to provide space heating and domestic hot water is often the largest application, at least in countries with a cold (usually northern) climate. Energy used to provide heat can be of thermal or electrical origin although, for most countries, thermal energy is predominant. Heating is closely followed by electricity used for lighting and ventilation. These two applications together often account for 50-60% of the total electrical energy consumption.

INDOOR CLIMATE REQUIREMENT

All hospitals and hospital buildings are unique in design and size, and the different specialised services they provide. Their technical systems must be designed and adjusted to meet the requirements and needs of each individual environment. Most countries have regulations that outline how these requirements may be fulfilled, through proper design and operation of technical systems and the building itself. This is mainly accomplished by regulations for thermal insulation, ventilation, lighting, and indoor temperature levels [3].

- *Thermal insulation*
  The thermal properties of the building envelope are very important, as a hospital often requires a minimum temperature level of 21-22°C throughout the year, but is limited to a maximum of around 26°C during the warmer months. Different countries' regulations are usually in the form of mandatory maximum levels for U-values (coefficients of thermal transmittance) for the entire building envelope, including walls, foundations, roof and windows.

- *Ventilation*
  For hospitals, it is not always the heat surplus that decides the ventilation rates (as is normal for commercial buildings, such as offices), but the hygiene considerations. As indoor air is contaminated by occupants and activities in the hospital, it must be renewed in order to eliminate odours and pollutants.

  Room ventilation levels typically range from 35-140 m^3 per person/hour depending on the function of the room (e.g. general or intensive-care). Operating theatres are usually among the rooms having the highest demands, with ventilation rates around 30-55 m^3 per square metre/hour.

- *Lighting*
  Daylight is, of course, by far the most comfortable type of illumination for the human eye. Design of areas used by patients should always provide for large windows. Their size, orientation and position in rooms must provide sufficient lighting levels, and should give a view of the outside surroundings and the sky. This adds to a patient's feeling of contact with the outside world, which is important, psychologically, in healing.

  Often in conflict with the above benefits are the unwanted effects of glare and overheating. These, if not avoided, result in considerable discomfort for the patients, and an increased need for cooling energy. For this reason sun shades and blinds should be fitted to affected windows. Maximum utilisation of daylight is best provided by having sun shades and blinds automatically controlled by sensors triggered by sunshine and wind, but manual controls should always be available for individual adjustment. Hospitals also usually contain a substantial number of windowless rooms, in which daylight is, of course, not a practical solution. In these cases, artificial lighting which maintains comfort levels must be employed.

- *Temperature*
  To maintain comfort levels for patients, the indoor temperature in hospitals is usually 1-4°C higher than for other building types. A typical temperature for patients' rooms is 22°C. This minimum value should be maintained during the colder part of the year, but is often allowed to rise to 26°C during the warmer months.

  When temperature discomfort is identified, it is usually more efficient to localise the sources of discomfort and treat these, rather than to increase or decrease the room temperature. This can be done, for example, by covering cold walls, erecting screens against cold drafts from windows, window frames and badly positioned air vents, and minimising insolation by installing sun shades.

- *Indoor air humidity*
  Indoor air should neither be too dry (which causes dehydration) nor too humid (which causes perspiration and increases the risk of fungal growth). The comfort range covers relative humidities of 35-70%, at temperatures normal for hospitals (22-26°C).

Humidification (due to operating costs), and especially dehumidification (due mainly to initial costs), are expensive. For this reason it is often acceptable to allow humidity levels to fall below the supposed comfort level. Strict hygrometric controls are often only applied in rooms where conditions are more critical, i.e. in operating theatres, intensive-care wards etc.

International Outlook

When comparing energy consumption data, it is important to treat different energy types separately, and to relate performance figures to their location and the prevailing climate. Therefore, the energy consumption statistics below are presented as overall annual consumption figures, broken down into electrical and thermal energy. To facilitate comparison of energy performance, data is presented for a number of variables, number of beds, $m^2_{\text{heated floor area,}}$ and $m^2_{\text{gross floor area.}}$

This section shows average annual energy consumption data for a number of countries, collected with the help of the CADDET National Teams of those countries. Although these energy consumption statistics have been analysed, there are no simple or obvious reasons why certain countries have a higher or lower consumption than the average. Therefore, only the most major differences are pointed out. A few suggestions are made as to possible reasons for exceptional values. Note that where statistics for gross and heated volumes have been reported for a country, they have been converted to equivalent gross and heated floor areas by assuming an average room height of 2.85 m.

Figure 2 shows electrical and thermal energy consumption for typical hospital stock in six CADDET countries. Statistics are presented as MWh/bed for the annual average.

Electricity consumption per bed varies from 5.1 MWh (Italy) to 28.1 MWh (Australia), with an average consumption of 16.1 MWh. The thermal energy consumption is more uniform, varying between 23.3 MWh (Italy) and 42.8 MWh (Canada), with an average of 33.9 MWh.

What is most noticeable is the broad variation in electricity consumption. Australian hospitals consume almost six times more electricity than hospitals in Italy. This may be due to climatic differences, the degree of sophistication and age of energy systems, or the hospital buildings themselves. The rather high consumption for Sweden and Canada (20-40% higher than average) may be due to their rather low electricity prices.

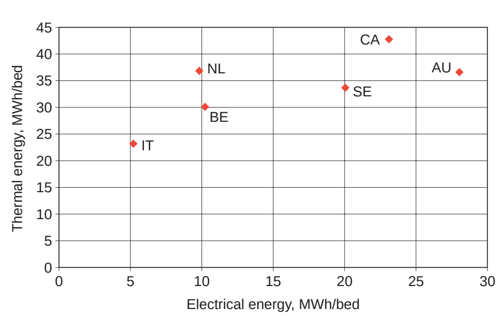
Electricity consumption per $m^2_{\text{gross floor area}}$ varies between 61 kWh (Switzerland) and 339 kWh (Canada), with an average consumption of 145 kWh. Thermal consumption varies between 168 kWh (Sweden) and 690 kWh (USA), with an average of 367 kWh (see **Figure 3**).

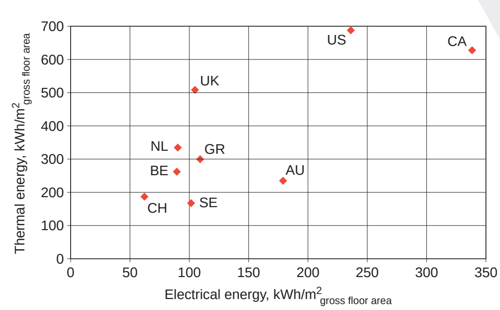
The only exceptional value is for Canada, which has an electricity consumption almost six times higher than Switzerland, and 2.5 times higher than the average. A simple reason for this may be that Canadian hospitals are, on average, smaller than those in the other countries. Their high thermal energy consumption could be due to the climate.

Also noticeable are the rather low thermal energy consumption levels for Sweden and Switzerland, especially since these two countries have fairly cold climates.

Figure 2: Average annual electrical and thermal energy consumption per bed, for typical hospital stock in six CADDET countries.

Figure 3: Average annual electrical and thermal energy consumption per gross floor area, for typical hospital stock in nine countries. Data is presented as $kWh/m_{\text{gross floor area}}$ for the annual average.





Energy Management of Hospitals

In a wider sense, energy management 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 maintening the building in a way that sustains the energy efficiency gains achieved.

Even at the design stage of a building, as well as considering its energy-efficient design and that of the installations, attention should also be paid to the future energy management needs of the building. These needs include the ability to measure and monitor energy consumption of the different energy end-uses.

There are a number of steps that must be taken to introduce and implement energy management programmes.

ORGANISATION

Since any serious energy conservation programme will continue over a long period of time (ideally throughout the building's lifetime), an energy manager should be appointed to be responsible for the energy management of the building or buildings. To give energy management the relevant priority, and to make it effective, it should be given the same importance as the management of other cost centres in the organisation. It should, of course, also have its own budget and be held accountable like other cost centres. The budget for energy management can normally be allocated as a percentage of the annual energy costs [4].

When appointing a person to be responsible for energy management, it is natural to first look within the existing organisation. If such a person is found, it is important and necessary to release this person from his/her other duties as far as possible, since energy management should not be an additional task assigned to a person already fully occupied. If such a person is not found within the organisation, then a new manager should be recruited.

The person responsible for energy management should be adequately trained for this purpose, unless someone with the necessary qualifications is already employed at the hospital. An effective energy manager should possess a number of skills - computer abilities, an understanding of building energy systems, familiarity with utility data and tariff structures, building energy survey skills etc.

A positive attitude towards energy management programmes by the hospital's top management is a vital factor in the success of such programmes.

The introduction of an energy management programme can be realised in many different ways. This depends on the type and size of the hospital, its location and the existing organisation structure. However, with every energy management programme it is important to monitor daily performance and to clearly define the responsibilities of each level in the management hierarchy.

There are a number of general steps to be taken which are applicable to every energy management programme. These steps are described below.

IMPLEMENTATION OF AN ENERGY MANAGEMENT PROGRAMME

Before embarking on an energy management programme, 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. 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 programme is viable according to the potential energy/economic savings that can (reasonably) be achieved (see **Figure 4**). If the conclusion is positive, then the energy manager should now be appointed.

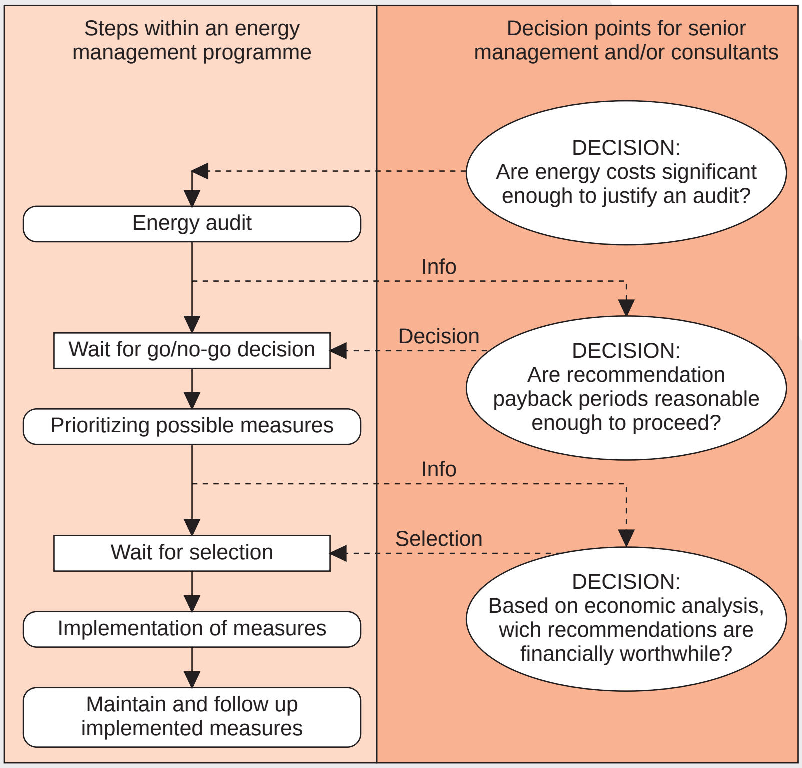


Figure 4: Implementation of an energy management programme.

ENERGY AUDIT

The practical work within each energy management programme should start with an energy audit.

An energy audit:

- identificaties all energy end-uses within the buildings under investigation;
- estimates how much energy is used by each end-use;
- determines the amount of energy used in relation to the budgeted or designed values.

As already mentioned, it is usually necessary to contract a consultant to assist with the energy audit. Additionally, the more information the building manager can supply to the consultant, the more helpful this will be, and the lower the price of the energy audit.

There are a number of questions which are of interest to the consultant, and which could be investigated before requesting an estimate. Examples include:

- how is the building used i.e. operating hours, number of occupants, etc.?
- are there any architectural drawings available to obtain a better understanding of the building envelope?
- is the electricity used measured on each floor, or at one single point, and what installations do the meters serve?
- what energy tariff or tariffs are used (supplemented with last year's energy accounts)?
- is there a history of prior retrofits?

The energy audit can be accomplished at different levels, each new level being more detailed than the previous one, and can be terminated after each level if so desired. Before requesting quotes from consultants, the termination level of the audit should be defined.

Independent of the level at which the energy audit is carried out, the audit will always result in a certain amount of detailed information about different energy end-uses, and should also indicate potential energy savings for the end-uses investigated. It is important that overall goals are set at the beginning of the energy management process. These goals should be tough, but achievable and measurable. In addition, a deadline for achieving these goals should be set. The goals can be expressed as key numbers (for example as kWh/m^2, year etc.). **CADDET Energy Efficiency Maxi Brochure No. 4** contains more information on the use of key numbers in terms of energy performance ratios and energy targets.

Once the energy audit is completed, the second major decision is made: whether the energy management programme should continue, or if it should be restructured in any vital way. A decision against an investment based on the energy audit results could be based, for example, on an assessment that the payback period would be too long for all of the energy conservation alternatives found.

Once the decision to continue with the energy management programme has been made, the next phase of the programme is to prioritise the measures that will be implemented.

PRIORITISING POSSIBLE MEASURES

The simplest way to prioritise energy conservation measures is by cost-effectiveness. When calculating the cost-effectiveness, some kind of economic model is required. There are a number of different models that can be used, but when studying different alternatives the model used should adequately take into account the savings throughout the lifetime of the measure. However, the simple payback period for any investment should not be too long.

There are two steps in dealing with a maximum payback period. First, select measures with the simple payback method. Then, prioritise these measures by using another, more detailed, economic model.

Note that the simple payback period does not measure profitability, nor does it take into account the lifetime of the assets. It is, however, commonly used and well understood and gives the decision makers a tool for quickly approving or rejecting investments, according to company policy.

After selecting and prioritising energy conservation measures, a third major decision needs to be made, i.e. which measures are to be implemented?

IMPLEMENTATION OF MEASURES

Once it has been decided which energy conservation measures are to be implemented, the energy management continues with the practical work of implementing them. At this stage of the process, agreements with manufacturers should be made and, depending on the complexity of the measure, consultants hired to assist with the design work. If consultants are necessary at this stage, then their costs should have been taken into account when prioritising the measures.

MAINTENANCE AND FOLLOW-UP

Once the measures have been implemented it is time to start maintenance and follow-up procedures. Maintenance is important to maintain high efficiency and to prevent breakdowns. The monitoring of the measures and, as far as possible, other energy end-uses in the building(s) give the energy management staff overall control of the energy usage. This control will be very useful if malfunctions occur in the energy system. Sometimes, when one part of the system is not operating correctly, this can be disguised by other functions compensating for the failure. A typical example of this is when more heat than necessary is delivered to an area while, at the same time, the temperature is controlled by the cooling system. This leads to both excessive heating and cooling being delivered unnecessarily to the same place.

The process of energy management is by no means finished after all the steps shown in Figure 4 have been carried out for the first time. These steps are repeated in cycle, perhaps with emphasis on different steps each time. Using this continuous energy management process major and lasting energy savings will be found.

Technology Advances

Table 1 summarises 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. Readers requiring further information should consult the CADDET Energy Efficiency Analysis Report “Learning from experiences with Energy Savings in Hospitals” [1].

Table 1: An overview of energy saving areas in hospitals.

Heating system	Combined heat & power	Building fabric & air-conditioning	Lighting	Mechanical ventilation	Building energy management systems	Maintenance	Services
Room thermostats	Start with careful check of heating and electricity needs	Insulate roof	Replace incandescent tungsten lamps with compact fluorescent lamps	Install variable speed control on fans and large pumps	Explore all possibilities to make better use of systems installed	Regular inventories of systems, equipment and components	Laundry; typically potential for heat and water savings
Thermostatic radiator valves	Usually most cost-effective when all heat and electricity can be used within the hospital area	Draught proofing	Replace old fluorescent tubes with new low-energy ones	Increase the temperature as much as possible when cooling is required	If no BEMS is installed, consider installation	Time schedule for inspection and mainten-ance	Kitchen; typically large potential for reduction of heat usage
Insulation of hot water tanks and boilers	etc.	Window shading	Replace old electromagnetic ballasts with electronic	Check the present system, especially its control settings	Make use of system within the energy management programme	Inventory of stock kept for critical repairs	etc.
Installation of local water heaters		etc.	Check applicability for time controls, presence detectors and daylight compensators	Use outside air for “free cooling”	etc.	Data and supply of equipment parts	
Boiler replacement etc.			etc.	Explore opportunities for heat recovery from the exhaust air etc.		etc.	

Demonstration Projects

UK

Energy efficiency in hospitals by good housekeeping, UK [5]

Programmes similar to this can be implemented in other hospitals. They can provide valuable energy cost savings, provided they are well structured and managed, as the capital investment requirements are minimal. As well as reduced costs, service can be improved.

In 1987 Somerset Health Authority embarked upon a programme aimed at reducing its annual energy bill of GBP 2.1 million by 25% over a five year period, whilst maintaining or improving on the standards of service and comfort required by the Department of Health. The target savings were to be achieved by a combination of good housekeeping measures and a parallel programme of capital investment in energy cost reduction projects.

Initially, a policy statement set out the saving objectives and the methods to be used to achieve them. An Energy Management Group was set up for each of the three units, consisting of members of the unit management team and chaired by the unit General Manager.

Energy "Monitors", appointed from existing staff in each department, were given the task of maintaining a watch on the day-to-day use of energy-using equipment and identifying opportunities for savings.

Allowing for changes in energy costs, the original five year target saving of 25% was achieved within the first three years. The cumulative net cost savings by the end of the third year were GBP 1,015,000, of which GBP 331,000 had come from the good housekeeping measures.

The GBP 619,000 annual rate of saving, achieved in the third year, will increase as the effects of the Authority's estate rationalisation programme appear. Energy consumption will reduce further as building space is used more effectively and older premises are relinquished.

Within the programme, training and appreciation sessions were arranged for:

- departmental managers;
- energy monitors.

Early morning sessions lasting about half an hour, conducted by the Chairman of the Authority and the Director of Estate Management and Capital Works, were undertaken to inform departmental managers about the energy cost-reduction programme and the means by which it would operate. Energy monitors received training to enable them to understand the consumption and cost of running equipment, and to assist them to identify cost-saving opportunities. Because of the numbers involved, no training was given to the remainder of the staff, but all new employees now receive a brief description of the programme at their induction.

To launch the programme, posters were produced to promote ideas for reducing waste. Most of these used humour to attract attention and to create a more lasting effect. A 10-page Handbook, also humourous, was produced and given to all employees. It contained many examples of wasteful practices and encouraged staff to "Catch the Energy Bug". An ideas scheme was launched to encourage staff to submit further ideas for cost saving, with small awards being given to winners and runners-up in the various competitions. Colouring competitions using energy posters were introduced for children and patients. At the end of the first year posters were produced to inform staff of the programme's achievements. These were supplemented by regular features in the Authority's internal newspaper "The Herald".

For senior managers, cost reduction is part of the management performance indicators used to assess performance. Energy is seen as one of the best opportunities for cost reduction. Motivation has been provided for departmental staff by arranging for the achieved revenue savings to be re-allocated to development funds and thereby contribute towards the provision of additional equipment and facilities. This general incentive is seen by the Authority as an essential feature of their approach. In addition, there is normally a positive response by staff and users to the "greening" of their hospital.

To take advantage of the increased levels of staff interest, brief surveys were undertaken of each department to identify all the opportunities to reduce energy through good housekeeping. These surveys also identified scope for reducing energy costs through minor capital expenditures e.g. the provision of more light switches, which would give staff better local control. The outcome of the surveys reinforces the benefits of linking a good housekeeping programme to a project-based programme, to obtain the best of both worlds.

Heat pump used in a hospital dishwasher, Belgium [6]

BE

The St. Norbertus Hospital (Duffel, Belgium) needed to replace its old dishwasher and decided to use a modern dishwasher with an integrated heat pump. The reason the hospital chose this dishwasher was its ability to save energy. The dishwasher has been operational since October 1993 (5,530 hours) and was financed by the Flemish government. The hospital has 215 beds and serves 630 meals each day.

An electrically-driven air-to-water heat pump is used to heat the cold water in the dishwasher's storage tanks and preheat water for rinsing. An electric resistance water heater is used to heat the warm rinsing water to the required temperature. An extra advantage of this heat pump is that the air from the evaporator can be used for cooling purposes.

The dishwasher is equipped with two storage tanks with a total volume of 490 litres. The heat pump's compressor has an electric power of 9.5 kW and auxiliary appliances take 0.9 kW, according to the supplier. The coefficient of performance (COP) of the heat pump is indicated by the supplier as 4.1, and the working fluid is HFC 134a, which is a non-ozone -depleting refrigerant.

In the evaporator the heat pump extracts the waste heat from the environment (26°C) and recovers waste heat from drying the dishes (electric resistance heater of 10.5 kW with fan). Cold water in the dishwasher's storage tanks is heated and maintained at a constant temperature of 63°C by the heat pump. This warm water is used in the pre-rinsing and rinsing cycles. The heat pump is also used to preheat the rinsing water up to 70°C in a superheat heat exchanger. This water is then further heated up to 85°C by an electric resistance water heater (18 kW).

A temperature of 64°C is needed in the storage tanks before the dishes can be washed. Pumps then spray the heated water over the dishes. This water is filtered and flows back into the storage tanks. It can be used for two washing processes depending on the number of dirty dishes. The dirty water is drained and the storage tanks are refilled with clean cold water twice a day.

Dishes are washed with water at 85°C. The water is then captured and used again for rinsing. Finally, it is recirculated to the storage tanks. Air from the outlet of the evaporator (19°C) partially replaces and cools the air in the kitchen to improve working conditions for personnel.

Installation of variable frequency drives on air-handling unit fan motors at Royal Darwin Hospital, Australia [7]

The Royal Darwin Hospital has a capacity of 360 beds and is the sole public hospital serving Darwin (population 85,000) and the surrounding region.

A study of the chilled water-based air-conditioning system serving the hospital highlighted the large energy cost savings associated with controlling the fan speed on five large air-handling units (AHUs) in the Main Ward Block. All five AHUs are operated 24 hours per day.

At the time of the study internal temperature and humidity conditions within the Ward Block were maintained by modulating the chilled water control valve on each AHU, according to the highest demand for cooling as signalled by room temperature sensors. Reheat energy was provided to zones requiring less cooling, in the form of hot water generated by steam calorifiers.

Each AHU also incorporated a humidity sensor in the return air stream to override the temperature sensors should the mean relative humidity rise. Over-cooling and re-heating can be avoided, while maintaining humidity control, if the air quantity over the cooling coil of each AHU is reduced as the sensible cooling load on the space reduces.

This was achieved by installing variable frequency drives (VFDs) on each supply and return air fan motor within each AHU. Concurrently, the room setpoint conditions were raised from 24+1°C and 50+5% RH (relative humidity), to 25+1°C and 55+5% RH.

The end result of the project was not only the energy cost savings associated with the elimination of over-cooling and re-heating, but also significant electricity cost savings derived from the reduced electrical load of each supply and return air fan.

A direct digital control (DDC) system was supplied to provide enhanced control of each AHU. Also included in the project were new temperature sensors in each zone, electrical surge diverters for each VFD and software within the DDC to allow rolling starts and automatic restarts of fans after power failures (common to the area). Outside air measuring devices were installed which enabled the accurate measurement and control of fresh air to each AHU. The speed of each VFD was limited by the DDC to a minimum of 50% of full speed.

In 1994, control of the air-handling units was integrated into a new building management system installed throughout the hospital.

The variable frequency drives have been in continuous service for periods ranging from three to five years. Reliability of each drive has been excellent. At commissioning a number of malfunctions occurred through lightening-induced electrical surges. This problem has been rectified through installation of surge diverters.

Theoretical analysis of the project indicated that at average heat load conditions, fan speed would be reduced by 42%. Performance monitoring has shown an average reduction in fan speed ranging between 34 and 40%.

The total cost of the project was AUD 119,932. Direct electricity cost savings resulting from reduced fan electrical load are estimated at AUD 129,000 per annum. Diesel fuel cost savings associated with eliminating reheat are estimated at AUD 181,000 per annum. A further saving, estimated at AUD 140,000 per annum, result from raising room conditions by 1°C.

All savings calculations are based on the 1989 electricity tariff rate and diesel fuel contract price. The electricity tariff rate has since increased by 12.3 %.

Power line carrier lighting controls demonstration at Adelaide Dental Hospital, Australia [8]

A demonstration of a power line carrier (PLC) system for controlling lighting was carried out at the Adelaide Dental Hospital.

The 9-floor building is of clay brick and precast concrete construction. External walls have a window-to-wall ratio of about 30%. Windows are double-glazed with a transmission factor of 65%.

Minimum daylight factor at the work area is about 1%. The building is generally occupied between the hours of 8.00 am and 6.00 pm.

Lighting on all floors is activated by using manual rocker switches. The lighting system consists of luminaires with 1-5 fluorescent tubes in each, mostly 40 W but with some 20 W lamps in corridors. Total lighting capacity in the building is 260 kW, but actual installed lighting capacity is about 225 kW.

A PLC system was chosen for the demonstration as it was the most suitable system in the prevailing circumstances. The system comprised one microprocessor programmable time controller, equipment for transmitting and receiving signals along the existing mains distribution system, wall reset switches, pull-cord reset switches, area control switches and 60 minute override devices. The equipment incorporated a "fail-on" action in the event of a malfunction and was designed not to interfere with the operation of computers and other equipment.

The system was demonstrated in two sections of the building which offered a sufficient range of utilisation patterns to indicate scope for energy saving if the system was expanded throughout the building. The basement has a lighting capacity of 23 kW and a maximum measured load of 12 kW; the third floor has a lighting capacity of 39 kW and maximum measured load of 33 kW). Electricity consumed before and after installation of the lighting control system was measured by a portable clamp-on power tester (3-phase, 4-wire "HIOKI") . A portable power integrator was connected to the power tester to yield total energy used (kWh) over any measured period. A portable chart recorder was used to yield a continuous load profile over the metered period. Lighting times were monitored using a portable data logger (Squirrel, Grant Instruments).

Installed cost was AUD 13,500 (USD 8,900). Annual energy savings were 47,840 kWh.

At AUD 0.08/kWh (USD 0.053), savings amounted to AUD 4,000 (USD 2,640), giving a simple payback period of 3.4 years.

The level of savings generated was found to vary significantly from one controlled area to another.

A procedure was therefore developed for assessment of the maximum savings which could be expected in a given area. This is dependent upon factors such as the availability of daylighting, behaviour of occupants and the operation of the organisation involved.

Annual energy saved was 47,840 kWh. Should the system be extended to other similar areas in the building, additional energy savings of 33,100 kWh/year could be expected.

Pilot energy management programme in Florida hospital, USA [9]

The Florida Energy Pilot Programme Initiative (FEPPI) was implemented in response to an Executive Order issued by Florida's Governor to reduce energy consumption by 30% in state facilities. The Energy Office at the Florida Department of Community Affairs sponsored the programme and provided start-up funding. The Facilities Resource Management Company (FRM) provided guidance to achieve the programme's goals.

The Florida State Hospital in Chattahoochee, Florida, was selected as the pilot site to represent the Department of Health and Rehabilitative Services (DHRS) in the pilot programme. The hospital saved nearly USD 662,000 in energy during the programme's first 18 months.

This project has received a "Best in Category" Award from the US Department of Energy's National Awards Programme for Energy Efficiency and Renewable Energy in 1995.

Florida State Hospital is DHRS' largest facility, consisting of more than 150 buildings totalling approximately 170,000 m^2 (1.8 million ft^2) . These buildings house patients and staff and provide clinical and administrative spaces, laundry facilities, and other support services needed for a residential campus community. The River Junction Correctional Institution is located on the hospital's campus and depends on the hospital for steam, chilled water, water treatment, and other utility services.

The hospital's utility systems include a central power plant that generates steam for the campus from three oil-fired boilers with a total generation capacity of 81,647 kg (180,000 pounds) of steam per hour. Chilled water is produced from two satellite chilled-water plants, which together provide 10,250 kW (2,910 tonnes) of cooling capacity. A number of independent split systems and package units support special programme needs or areas of the hospital that are not connected to the central utility systems.

The energy management programme used by FRM is framed around six energy subsystems. These subsystems include accurate data monitoring, economical procurement of energy, efficient energy generation and distribution, improved end-use energy consumption and development of community involvement.

Energy savings largely occurred as a result of changes to the operation of the primary steam and chilled-water generation systems, revised management practices for the steam and chilled-water distribution system, and modifications to building equipment schedules.

Working closely with FRM, which provided technical guidance, programme performance measurement techniques and personnel training, hospital personnel have been actively involved at the site level in shaping a programme that is distinctly their own.

During the period from June 1993 through December 1994, fuel oil consumption was reduced by more than 4.5 million litres (1.2 million gallons), or 27%. Electricity consumption was reduced by approximately 3.5 million kWh or 7%.

The energy savings amounted to USD 661,700 over the first 18 months of the programme. A portion of the documented FEPPI savings has been reinvested to continue the energy management programme and to fund additional projects to further accelerate utility savings and the phase-out of deferred mechanical maintenance. The remaining savings are reallocated to other needs within the hospital's operating budget.

Energy savings in Newcastle Health Authority, UK [10]

To reduce the energy consumption and costs of several major hospitals in the district of Newcastle, the Newcastle Health Authority (HA) has initiated a range of energy-saving measures.

Starting with simple good housekeeping practices that cost almost nothing to implement, a long-term energy efficiency programme was developed in Newcastle, from which outstanding results have been achieved.

Following the successful introduction of good housekeeping measures, the HA appointed a full-time energy officer and prepared an energy policy document for discussion and approval by hospital board members. The policy provides individual hospitals with objectives and targets, guidance on energy issues, and a framework for rationalising future energy use.

Energy audits provide the basic information for each hospital's energy plan, with the HA offering energy and engineering support via an independent trading agency, plus short-term loans for energy efficiency projects.

Both monitoring and targeting are essential for the success of the programme. Monitoring by visual inspection has been superseded by building energy management systems (BEMS) at some locations. Targets seek to reduce boiler fuel use and hold electricity consumption increases at less than 2-3% per year. BEMS is also used to control boiler and ventilation plant operation.

Other measures include tariff analysis and optimisation to reduce electricity costs, boiler decentralisation on dispersed or remote sites and where plant replacement is needed, reduced ventilation levels in operating theatres when these are not in use, ventilation plant heat recovery, and a programme of improved building insulation as part of any general retrofitting and utility mains insulation upgrades.

Since 1979 energy consumption of the Newcastle Health Authority has fallen by more than 26% from 931,000 GJ to 686,000 GJ.

As well as reduction of the energy consumption and the associated monetary savings, there is the added benefit that carbon dioxide emissions have been reduced by about 25,000 tonnes per year.

The reduction in energy consumption has led to estimated annual savings of about GBP 1 million in energy alone.

Hospital lighting refurbishment paid for by energy savings in Wellington Public Hospital, New Zealand [11]

The Clinical Services Building, at 12-storeys high and covering almost 2,000 m^2 per floor, was constructed in the late 1970s and contained some 3,450 recessed troffer-type fluorescent luminaires, together with the usual special purpose fittings. The principal luminaires were equipped with rapid-start ballasts and 38 mm tubes, both of which are now difficult to obtain, expensive to replace, and inefficient by present-day standards.

The energy audit showed that retrofitting could be highly cost-effective. The measures carried out on the lighting system covered the removal and disposal of all obsolete fluorescent tubes and control gear, replacing these with highly-efficient componentry, within the existing ceiling-recessed "bodies". Surface-mounted types were either upgraded in situ or replaced with brand new luminaires.

The new componentry included customised reflectors, low-loss ballasts, dimmable electronic ballasts, and 4,000 K triphosphor tubes. The resulting increase in efficacy enabled the numbers of fluorescent tubes to be reduced by 4,000 without sacrificing performance. All lampholders, PFC capacitors and internal wiring have been renewed, leaving the luminaires in "as new" condition.

The results have been nothing short of spectacular. Luminaires in corridors that used to have three tubes now have only one tube, with energy savings of 75%, yet illuminance has improved around 300 lux. The X-Ray rooms have new cornice fittings with angled reflectors, enabling one tube to do the job formerly done by two, yet providing a higher level of illumination that is more evenly distributed across the room, with full dimming control. The illuminance levels on the staircases are twice what they were, improving safety yet reducing energy consumption by 35%.

The eleven operating theatres have benefitted enormously. The general or "background" illuminance has now been increased at least threefold, from 500 lux to more than 1,500 lux, in line with current European recommendations. The astonishing thing is that this has been achieved with a decrease in electricity consumption of about 33%. The surgical team also have perfect control of illuminance levels via the dimmable ballasts.

An updated calculation shows that the energy saving across-the-board is of the order of 62% compared with the former lighting energy usage. This calculated figure has now been checked against actual kWh meter readings and has been found to agree within a very small "margin of error". This can be accounted for in terms of increased use of the building and the general running-down of the lighting installation in the months preceding the retrofitting.

Annual electricity savings, originally estimated at 750 MWh, are expected to exceed 1,000 MWh, with a reduction in connector load of 400 kW. Simple payback on the investment is estimated at 3.5 years, based on the price currently paid for electricity at the hospital, and taking into account savings in maintenance as well as energy.

Conclusions

Although there are many technical methods for improving energy efficiency, a hospital's energy auditors should begin by considering the more simple measures. Very often, moderate investment and improved maintenance and operation procedures will provide immediate, and continuing, energy and cost savings. No-cost opportunities that are easy to identify and implement include altering time switches, temperature controls, and thermostats. Other no-cost measures, such as switching off equipment (lights, heaters, etc.) when rooms are unoccupied normally require the cooperation of staff. Not all types of equipment can be switched off, e.g. networked computers and many other items of hospital equipment require proper shutdown procedures to be followed. Motivation, cooperation and involvement of staff at all levels is of the utmost importance.

Improvements or changes made in one energy system can often affect other energy systems (e.g. heat generated by lighting will affect the need for cooling). Therefore, thorough systems analysis and consideration is necessary before any modifications are implemented. This must be kept in mind by the hospital's technical staff who perform and contract such modifications.

To implement energy-efficiency measures cost-effectively, they are best installed in new or retrofitted buildings, or when replacing old equipment. It is generally cheaper to introduce additional energy-saving measures when retrofitting work is already being carried out on a building than at other times when the hospital is operating normally. By choosing times carefully, interference with normal hospital routines can be kept to a minimum, and capital expenditures may be substantially reduced. Advantage should always be taken of these rare opportunities to carry out energy-saving measures.

If an installation or item of equipment has to be replaced anyway, it is only the extra cost (the over-cost compared to a conventional system) which needs to be taken into consideration when calculating the payback period for a new, more energy-efficient installation.

Monitoring, as much as control of the energy situation, is the key to success. It will provide information from which the technical management can detect malfunctions and make recommendations for further improvements.

Glossary

Efficacy
The visible light output of lighting in relation to power input, expressed in lumens per watt (lm/W). The higher the efficacy, the more energy efficient the lamp or lighting system.

Illuminance
The amount of light (measured in lumens) incident on a surface or plane.

Insolation
Solar radiation through windows, etc., generally leading to heat gain.

Hygrometric control
Control of relative humidity

References

This Maxi Brochure was compiled from information in the CADDET Energy Efficiency Register (R), and also from information published in Technical Brochures (T) and newsletter articles (N). Further reference was made, with thanks, to other publications as indicated.

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Maxi Brochures are written for the benefit of energy managers, engineers or anyone with responsibility for energy efficiency. They are split into a number of short sections which lead the reader through the basics of the topic covered. Firstly, the reasons why there is a need to make energy savings are examined. This is followed by an assessment of the potential for savings. After a brief description of the main features of the technologies involved, recent technological advances within the relevant fields are discussed. Finally, a number of demonstration projects illustrate how such technologies have already been successfully applied in practice around the world.

When reading this Maxi Brochure, a basic technical knowledge on the part of the reader has been assumed. However, no specific background expertise is required.

Swentiboldstraat 21, 6137 AE Sittard
P.O. Box 17, 6130 AA Sittard
The Netherlands
Tel: +31-46-420-2224
Fax: +31-46-451-0389
E-mail: nlnovcce@ibmmail.com
Internet: http://www.caddet-ee.org

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