# Energy Audit Manual for Use in the Operation of Buildings

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## Foreword

As developing countries become industrialized and their populations grow, the need for increasing amounts of energy is placing a heavy burden on energy−supply systems. The migration of workers from rural to urban areas creates a demand for housing and transport in cities, resulting in increased fuel consumption − especially of petroleum−based fuels. Hence, there is an urgent need for maximum conservation of existing energy supplies and maximum efficiency in their use. Energy conservation is a means by which the demand for energy can be significantly reduced without causing discomfort or diminishing the quality of life. It is estimated that approximately 15 per cent of energy per unit of output can be saved, with a correspondingly lowered level of expenditure, through sound energy−management practices. In fact, countries that have developed energy−conservation programmes have reported savings of up to 25 per cent per unit of output.

Energy auditing is an integral part of any energy−management programme and an essential step in the process of energy−conservation, since it facilitates the optimum use of available energy resources. It can be a valuable tool in developing countries where emphasis is being placed on reducing consumption of commercial and non−commercial energy through energy−conservation measures. Some governments of developing countries have already adopted energy−conservation measures but not always in accordance with a systematic national policy on energy conservation which would bring benefits through (a) a reduction of the load on overall energy−supply systems; (b) an increase in time available to develop new indigenous energy sources; (c) a reduction of foreign−exchange demand; and (d) a reduction in overall costs of operating human settlements.

With the purpose of examining the various aspects of energy conservation and energy management, the United Nations Centre for Human Settlements (Habitat) and the Regional Centre for Energy, Heat and Mass Transfer for Asia and the Pacific convened a Workshop on Energy Auditing in Human Settlements in Madras, India, in 1987. The Workshop noted that, in developing countries, per capita energy consumption is on the increase and that energy consumption in residential, commercial and public buildings constitutes a significant portion of total energy consumption in urban areas, thus justifying the implementation of energy−conservation measures. It concluded that there was scope for initiating energy−auditing procedures which would lead to energy conservation in these sectors and recommended, inter alia, the development of national and local−level energy−audit manuals, both for the user and the auditor, applying, with suitable modifications where necessary, the experience already gained by developed countries in the field.

This manual has been prepared in response to the recommendations of the Workshop. It is a local−level energy−audit manual and is addressed primarily to houseowners and managers of small, medium and large buildings in the public and private sectors. It deals with a practical methodology for reducing energy use in buildings and provides information on energy−auditing procedures in a non−technical manner. Application of the principles given in the manual will enable users to evaluate energy−use patterns and carry out energy−saving programmes at minimum cost, while helping national efforts at energy conservation. The manual should, therefore, be useful to policy−makers and planners concerned with the energy sector in the developing countries.

I wish to acknowledge the contribution of Mr. R. Walterson to the work of UNCHS (Habitat) in the preparation of this publication.

**Dr. Arcot Ramachandran**

Under−Secretary General
Executive Director

## Introduction

### A. Background

In developing countries, about 40 per cent of operational expenditure is estimated to be incurred in human settlements, and costs for supplying energy accounts for a significant portion of this expenditure. These costs place a severe strain on the national economy of almost all developing countries: hence, there is an urgent need for initiating sound energy management. This calls for innovative approaches to management aimed at energy conservation. Energy users need to be convinced of the financial benefits they can derive through energy management: it is often not realized that resources spent on conserving energy and on reducing energy waste are sound investments and that there are several measures which can be undertaken at minimal costs. This manual presents some of these measures.

The manual is addressed primarily to houseowners and managers and operators of small, medium and large buildings in the private and public sectors. It has, therefore, been written in a non−technical manner suitable for laymen who might not be very conversant with the field of energy technology but who could, nevertheless, benefit by following the methods and measures contained herein. This manual does not deal with renewable sources of energy, such as solar radiation and wind, nor with computerized management systems, in which the technology is developing rapidly.

Interspersed throughout the various sections of this manual are examples of possible savings that can be made by changing operating and maintenance procedures and, in many cases, by installing energy−efficient equipment. It should, however, be borne in mind that each building is unique. Its location in relation to prevailing winds, the number of its windows and many other factors influence how a building can be made energy−efficient. Implementing the ideas and suggestions presented in this manual will provide energy savings for most buildings, although the savings might not be the same as those cited in the examples.

### B. Purpose of the manual

This manual provides information on energy management both for houseowners and for building managers. It is designed to be used in the analysis of energy−consumption patterns of buildings, large, medium or small. It is not intended to be used in the design and construction of new buildings. The methods used are relevant to hot or cold climates, in developed or developing countries. Climatic differences will generally affect only the total amount of energy used and change the mix of fuel types consumed.

The manual assembles recent information on energy management and presents it in a non−technical manner that is understandable to building operators and houseowners who cannot consult in−house engineers or energy specialists. It proposes many no−cost and low−cost methods for reducing energy consumption. Procedures and techniques to eliminate energy waste and to reduce energy use, especially in large buildings such as hospitals, hotels and multistorey office buildings, are proposed.

The first part of the manual − the Energy Audit Manual − is, as the name implies, devoted to the energy audit or survey. A first step in undertaking an energy−management programme is to identify energy−consumption patterns, to determine: (a) where energy is used; (b) how energy is used; (c) what forms of energy are used; (d) how much energy is used; and (e) when energy is used. The energy audit will present an accurate picture of the premises' energy profile. The second part of the manual − the Energy Management Manual − provides suggestions and examples of possible savings. It has been broken down into three categories needed to develop an energy−management programme: (a) management; (b) operating procedures; and (c) maintenance procedures.

## C. Measuring the results of energy conservation

Before changes are carried out to improve the energy performance of a building or group of buildings, it is essential to have a starting point from which to evaluate the effect of proposed changes. The energy audit provides this starting point. The auditor selects a base year and measures that year's performance of energy−consuming units and corresponding financial cost. Then, the current year and future years are measured in an identical manner and compared with both the performance of the base year and the previous year. In this way, the owner/operator can evaluate, both in energy units and financial terms, the effects of a conservation programme, procedural changes required and the impact of the project on energy consumption. The historical energy audit is used to measure the overall energy performance of the complete building, whilst the diagnostic audit analysis is used to measure the energy−consumption pattern of energy−consuming equipment within the building, such as boilers, cookers and lifts. After completing the energy audit, the auditor should turn to the Energy Management Manual which proposes changes that can be made to energy−consumption patterns so that energy is used efficiently.

## D. Strategy for applying energy−conservation methodology

Generally speaking, the overall strategy for applying energy−conservation methodology in human settlements is to identify and eliminate wasteful practices, then look for ways of reducing energy consumption in items of energy−using equipment. The following gives a step−by−step strategic approach for achieving energy conservation. Although the approach generally applies to large buildings, individual houseowners can still make use of the same general approach to achieve reduced energy consumption in their premises.

### *1. Commitment*

Top−level commitment to start an energy−conservation programme should first be obtained. Without the owner's or building manager's involvement and commitment, the programme will have a poor chance of success.

### *2. Energy uses and losses survey*

In order to provide a trend in the use of energy in a building, a base year for the historical energy audit should first be established, and then a current historical energy audit should be carried out. A first survey, aimed at identifying energy wastage that can be corrected by maintenance or management attention, should be conducted. Another survey, to determine where additional instruments for measurement of energy flow are needed and whether there is economic justification for the cost of their application, should then be carried out. An energy balance (diagnostic) on each item of energy−using equipment, such as a boiler, a stove or a water heater, should be developed to determine energy−efficiency.

### *3. Setting targets*

Once the survey is complete, the findings should be reviewed, and consultations with the building manager or operator undertaken. Potential energy savings should be estimated, and reduction−targets for the first year set. Experience shows that it is possible to achieve a 10 to 15 per cent reduction in the first year of an energy−conservation programme. Further examination of energy−conservation options will show additional potential that will require, most likely, investments in energy−saving projects that will have large payback periods. It is advisable to establish a five−year target and measure, historically, each year's progress towards that goal. Each year's savings will become the justification and support for an ongoing programme and future investment.

### *4. Corrective actions to save energy*

Energy wastage should be eliminated or reduced, and energy−conservation projects that evolve from the surveys should be listed. Projects for implementation should be evaluated and selected, starting with projects having the shortest payback period.

### *5. Continuing energy conservation efforts*

The energy audit should be continued on a regular basis, and corrective action should be taken when unit energy−use deteriorates. It is important to report progress towards an established goal on a yearly basis.

## Part one – Energy Audit Manual

### I. Introduction to energy audit

An energy audit, sometimes referred to as an energy survey or an energy inventory, is an examination of the total energy used in a particular property. The analysis is designed to provide a relatively quick and simple method of determining not only how much energy is being consumed but where and when. The energy audit will identify deficiencies in operating procedures and in physical facilities. Once these deficiencies have been identified, it will be apparent where to concentrate efforts in order to save energy. The energy audit is the beginning of and the basis for an effective energy−management programme.

Human settlements encompass a variety of buildings. Regardless of the building involved, the audit procedure is basically the same. If more than one facility is involved (as in the case of apartment buildings), an audit of each will be necessary.

No two buildings are identical regarding energy usage. This is due to the possible variables affecting the buildings, e.g., occupancy rates, the building's size and orientation, its geographic location, the type of heating and cooling systems, the amount and types of equipment in use, the type of construction, the level of insulation and so on. Because each building is unique, it is difficult to generalize about energy−consumption patterns, and so it is necessary to conduct an energy audit for each building. Most buildings were probably designed, built and equipped when cheap energy was readily available. Little attention was paid to energy efficiency. Consequently, there is a great potential for improving operating costs of existing buildings.

The chapters that follow explain the procedures and computations necessary to understand all phases of energy consumption. The data compiled will be suitable for use in both manual and computer−assisted energy audits. The emphasis is on the do−it−yourself approach, and the worksheets have been designed accordingly.

#### Conducting the energy audit

In order to audit energy consumption, several steps are necessary. The basic procedures to be followed are:

(a) The historical audit summarizes all types and amounts of energy used in the past. Data should be compiled and analysed on the totals of both energy consumption and costs. This analysis, then, becomes the base with which future energy use will be compared.

(b) The diagnostic audit is carried out to identify the users of energy and to discover any deficiencies in operating and maintenance procedures as well as in physical facilities. This part of the audit is usually done in two parts: an equipment survey and a building survey.

(c) The financial evaluation determines the most cost−effective options. This will lead to the establishment of high−priority actions to be undertaken in the energy−management programme.

Each of these steps is explained in detail in the following pages, and sample worksheets are provided, where appropriate, to assist in recording the necessary data. Once the energy audit has been completed, there will be sufficient information upon which to establish an energy−management programme. However, the existing situation should be fully understood before any attempt is made at improvements.

### II. The historical energy audit

The historical energy audit or energy survey makes use of past utility bills to provide data on energy consumption and cost for the purpose of future comparisons. In order to provide a common base for comparison, all consumption figures should be converted into the metric thermal unit (Megajoules (Mj)). Table

1 lists useful conversion factors of different energy sources.

The objectives of the historical audit are: (a) to develop a common unit with which to compare future energy consumption (without such a unit, it becomes difficult to evaluate energy−conservation projects); and (b) to provide an energy utilization index (EUI) for each building. The latter will permit a comparison of current energy consumption of the building with those of previous months or years and with the consumption of similar buildings. (see section II.A).

The benefits associated with an historical energy audit are:

(a) The audit figures, once compiled, provide a management tool not previously available. Energy consumption patterns can be monitored monthly by making comparisons with those of earlier months, so that increases can be identified very quickly. Increases might indicate operational or mechanical problems in the building that would otherwise have gone undetected.

(b) Budgeting and cash−flow projections become easy, once basic energy−consumption patterns are known. Expected energy rates are simply applied to the quantity of energy used in the comparable previous period to provide a realistic estimate of future costs.

(c) As both energy−cost and energy−consumption figures have been recorded, ratios or relationships can be established which can be used for comparison purposes in both financial and energy−consumption terms. Energy costs and energy−consumption figures should be expressed (a) per unit floor area (e.g., per square metre) of the building area; (b) per hour of operation; (c) per unit volume of the building; (d) per occupied room; and (e) per occupant. Such relationships can be calculated on a monthly or yearly basis. In order to make the calculation accurate, data on climate should be incorporated to compensate for temperature variations.

Table 1. Thermal conversion factors

| To convert from | To equivalent Megajoules, multiply by |
|---|---|
| Cubic metres of natural gas | 37.0 |
| Kilograms of liquified petroleum gas (LPG) (butane) | 45.2 |
| Litres of kerosene | 3.8 |
| Litres of No.2 fuel oil F.O. 125 CST. | 3.8 |
| Litres of No.4 fuel oil F.O. 480 CST. | 4.0 |
| Litres of No.5 fuel oil, F.O. 580 CST. | 4.2 |
| Litres of No.6 fuel oil F.O. 680 CST. | 4.3 |
| Kilowatt−hours of electricity | 3.6 |
| Tons of bituminous coal | 28,000 |
| Tons of sub−bituminous coal | 21,000 |
| Tons of lignite coal | 16,060 |

*Note:* In some cases, thermal values vary from those given in the above table. The fuel supplier or local utility should be contacted for exact values.

#### A. Method for conducting an historical energy audit

The first step in conducting an historical energy audit is to record consumption and cost figures available from earlier utility bills. The local utility or supplier can be contacted if the records are incomplete or if the reading of utility bills or of meters are difficult to understand (see annex I. for detailed information on meter readings). Some sample worksheets (see tables 2 to 7) have been provided to assist in compiling the necessary data. Separate worksheets have been prepared for fuel oil, electricity, liquified petroleum gas (LPG − Butane), wood, coal and water. All worksheets have been prepared on a 12−month calendar−year basis. If the fiscal year is different, e.g., if June is the end of the fiscal year, the "month" column should be rearranged to start with July and end with June, so that comparisons can be made on the basis of the fiscal year rather than the calendar year.

On the various worksheets, figures should be compiled for at least the past year. However, an accurate assessment of energy−consumption patterns can only be developed if data are recorded for each of the past three consecutive years. The worksheets are designed to collect as much data as possible in a single attempt. Although the initial concern is to determine the total number of megajoules consumed, the monetary figures are also important and will be used in later analysis.

Once completed, the original worksheets should be kept as a base with which to compare future consumption and cost. A new set of worksheets should be prepared for each year. These records are easily kept up−to−date, as only one entry per month is required on each worksheet. A logical time to have these data updated is when the utility bills are being processed for payment.

When the figures have been recorded on the worksheets for the 12−month period and the conversions made, the appropriate columns should be totalled for the year. This will permit calculation of an average cost per megajoule for the entire year. When all the worksheets have been tallied, a comparison of costs between the various forms of energy is possible. This might influence decisions on the replacements or initial installation of equipment, such as the replacement of water heaters and kitchen and laundry equipment. This aspect is discussed in detail in chapter III.

Once tables 2 to 6 have been completed, the next step is to complete table 8. The energy cost in currency units and the energy consumption in megajoules should be recorded in the appropriate columns on the summary sheet. The figures necessary to complete the summary are taken directly from the energy audit worksheets (tables 2 to 6).

From the summary sheet, the total energy costs are entered on the energy costs − comparative analysis sheet (see table 9). Similarly, the total energy−consumption figures in megajoules are entered on the energy used in Mj − comparative analysis sheet (see table 10). These analysis sheets are designed to compare the current month with the same month of the previous year. Percentage columns are provided so that comparisons can be made in percentages as well as in monetary terms and in megajoule consumption figures.

The various forms should be updated each month, so that comparisons can be made on a current basis. It might be found that the weather, the number of persons residing, changes in hours of occupancy or the addition of new equipment will influence energy consumption. Notations regarding any significant changes should be made on the comparative analysis sheets, as these will help to explain fluctuations in energy usage.

Table 2. Energy−audit worksheet − monthly electrical energy consumption
Year: 19__

| | (1) kWh readings | | (2) Billed kWh | (3) Energy charges | (4) Maximum demand charges | | | (5) Total charges | (6) Equivalent megajoules | (7) Cost per Mj |
|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **Current (a)** | **Previous (b)** | **(1(a))−(1(b))** | | **(A)** | **(B)** | **(Total)** | **(3) + (4)** | **(2) x 3.6** | **(5)/(6)** |
| Jan | | | | | | | | | | |
| Feb | | | | | | | | | | |
| March | | | | | | | | | | |
| April | | | | | | | | | | |
| May | | | | | | | | | | |
| June | | | | | | | | | | |
| July | | | | | | | | | | |
| August | | | | | | | | | | |
| Sept | | | | | | | | | | |
| Oct | | | | | | | | | | |
| Nov | | | | | | | | | | |
| Dec | | | | | | | | | | |
| Total | | | | | | | | | | |

*Notes:*

Column 1. Enter the current and previous meter readings as shown on the electricity bill.

Column 2. This figure will be shown on the bill and should be the difference between the two readings recorded in column 1. It might be necessary to multiply this figure by a "constant" or "meter multiplier" to determine the actual consumption in kilowatt−hours. A common "constant" is 10, but this should be confirmed by the electricity utility, as this information is not usually shown on the bill.

Column 3. Enter the energy charges in currency units.

Column 4. Enter subtotal and total demand charges in currency units, if shown. Otherwise, ask the utility office to explain and/or provide this information. It is important that this information be recorded, because demand charges are often a large part of total energy charges, and there are ways of reducing them. This is explained further under "load shedding" or "peak shaving" (see annex I for details on demand management).

Column 5. Enter the total cost of electricity consumption (column 3 plus column 4 total).

Column 6. Convert the total number of kilowatt−hours consumed to megajoules by multiplying kWh by 3.6.

Column 7. Calculate the cost per megajoule by dividing the cost figure in column 5 by the megajoule figure in column 6. This will allow a comparison between the cost of electricity and other forms of energy, and between costs in different periods.

Table 3. Energy−audit worksheet − monthly fuel oil consumption
Year: ____

| **Month** | **(1) Cost/litre** | **(2) Quantity (litres)** | **(3) Total cost** | **(4) Equivalent Megajoules ((3) x Heating Value)[a/]** | **(5) Cost per Mj (Col. 3 – Col. 4)** |
|---|---|---|---|---|---|
| Jan | | | | | |
| Feb | | | | | |
| Mar | | | | | |
| April | | | | | |
| May | | | | | |
| June | | | | | |
| July | | | | | |
| August | | | | | |
| Sept | | | | | |
| Oct | | | | | |
| Nov | | | | | |
| Dec | | | | | |
| Total | | | | | |

*Notes:*

Column 1. Enter cost per litre.

Column 2. Enter total cost.

Column 3. Enter quantity in litres.

Column 4. Convert the quantity in litres to the metric equivalent by multiplying total litres by the appropriate megajoule (Mj) value per litre of fuel oil. Thermal value varies with the grade of oil used. Suppliers will provide the exact calorific value for the oil being used.

Column 5. Determine the cost per Mj by dividing the total cost figure in column 2 by the megajoule figure in column 4. This will enable a comparison to be made of the cost of fuel oil with other forms of energy and with costs incurred in previous periods.

[a/] Conversion factors and heating values (approximate):

No. 2 fuel oil = 38.68 Mj per litre
No. 6 fuel oil = 42.3 Mj per litre

Table 4. Energy audit worksheet – monthly liquified petroleum gas consumption
Year: ____

| **Month** | **(1) Meter readings Current[a/] Previous[a/]** | **(2) Consumption in kg[b/]** | **(3) Consumption charge[c/]** | **(4) Equivalent megajoules ((2) x 45.2)[d/]** | **(5) Cost per Mj (3–4)** |
|---|---|---|---|---|---|
| Jan | | | | | |
| Feb | | | | | |
| March | | | | | |
| April | | | | | |
| May | | | | | |
| June | | | | | |
| July | | | | | |
| August | | | | | |
| Sept | | | | | |
| Oct | | | | | |
| Nov | | | | | |
| Dec | | | | | |
| Total | | | | | |

*Notes:*

Column 1. Enter the current and previous meter readings as shown on the gas bill.

Column 2. The consumption figure shown on the bill should be in kgs. and should be the difference between the two readings in column 1.

Column 3. Enter the consumption charge in currency units, including any fixed charges.

Column 4. Convert the consumption in kilograms of LPG to megajoules. The thermal value of LPG may vary somewhat and should be confirmed by the local supplier. LPG contains approximately 45,200 Mj per ton or 45.2 Mj per kilogram.

Column 5. Determine the cost per megajoule by dividing the cost figure in column 3 by the Mj figure in column 4. This will provide a comparison of the cost of LPG with other forms of energy and a comparison of costs in different periods.

[a/] These columns apply to consumers supplied in bulk and whose consumption is metered.

[b/] For bulk consumers this is the difference between the two readings in column 1. Consumers supplied with cylinders should multiply the number of cylinders used during the month by the capacity of the cylinders (e.g., 12.5 kg, 54 kg.) to obtain monthly consumption.

[c/] Consumption charge including fixed charges.

[d/] Butane (LPG) = approximately 45.2 Mj per kg.

Table 5. Energy–audit worksheet – monthly wood consumption
Year: ____

| Month | (1) Cost/ton | (2) Quantity (ton) | (3) Total cost | (4) Equivalent Megajoules ((3) x heating value)[a/] | (5) Cost per Mj (3) – (4) |
|---|---|---|---|---|---|
| Jan | | | | | |
| Feb | | | | | |
| Mar | | | | | |
| April | | | | | |
| May | | | | | |
| June | | | | | |
| July | | | | | |
| August | | | | | |
| Sept | | | | | |
| Oct | | | | | |
| Nov | | | | | |
| Dec | | | | | |
| Total | | | | | |

[a/] Heating values (approximate):

Pinewood (dried) –13,600 Mj/ton
Hardwood (dried) – 9,300 Mj/ton

Table 6. Energy–audit worksheet – monthly coal consumption
Year: ____

| Month | (1) Cost | (2) Quantity | (3) Total cost | (4) Equivalent megajoules ((3) x Heating value[a/]) | (5) Cost per Mj (3) – (4) |
|---|---|---|---|---|---|
| Jan | | | | | |
| Feb | | | | | |
| Mar | | | | | |
| April | | | | | |
| May | | | | | |
| June | | | | | |
| July | | | | | |
| August | | | | | |
| Sept | | | | | |
| Oct | | | | | |
| Nov | | | | | |
| Dec | | | | | |
| Total | | | | | |

[a/] Heating values (approximate):

Charcoal (briquettes) – 28,900 Mj/ton
Lignite coal – 16,060 Mj/ton

Table 7. Energy–audit worksheet – monthly water consumption[a/]
Year: _____

| | (1) Meter readings | | (2) Consumption in cubic metres | (3) Consumption charges | (4) Cost per cubic metre |
|---|---|---|---|---|---|
| Month | Current (a) | Previous (b) | (1a – 1b) | | (3) – (2) |
| Jan | | | | | |
| Feb | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| March | | | | | |
| April | | | | | |
| May | | | | | |
| June | | | | | |
| July | | | | | |
| August | | | | | |
| Sept | | | | | |
| Oct | | | | | |
| Nov | | | | | |
| Dec | | | | | |
| Total | | | | | |

*Notes:*

Column 1. Enter the current and previous meter readings as shown on the water bill.

Column 2. Enter the consumption in cubic metres.

Column 3. Enter the consumption charge in currency units. This should include any sewer surcharge levied by the municipality.

Column 4. Determine the cost per cubic metre by dividing the cost figure in column (3) by the consumption in cubic metres in column (2). This will be the true cost per cubic metre, as it will include the sewer surcharge. It will not be possible to compare water costs on an ongoing basis but the information will be readily available for making some of the calculations required for water conservation and cost savings.

[a/] In order to determine the cost of water consumed, it will be necessary to record the cost of incoming water and the cost associated with wastewater. Often, the cost of wastewater is determined by adding a sewer surcharge to the cost of incoming water. The sewer surcharge can vary significantly from one municipality to another and might be as high as 100 per cent of the cost of water. The purpose of the Energy Audit Worksheet for Water Consumption is to record such data in a readily usable form.

Table 8. Summary sheet − total energy cost and consumption
Year: ____

| | **Energy Cost** | | | | | **Energy use (Mj)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **Gas** | **Oil** | **Electricity** | **Coal/wood** | **Total** | **Gas** | **Oil** | **Electricity** | **Coal/wood** | **Total** |
| Jan | | | | | | | | | | |
| Feb | | | | | | | | | | |
| Mar | | | | | | | | | | |
| Apr | | | | | | | | | | |
| May | | | | | | | | | | |
| June | | | | | | | | | | |
| July | | | | | | | | | | |
| Aug | | | | | | | | | | |
| Sept | | | | | | | | | | |
| Oct | | | | | | | | | | |
| Nov | | | | | | | | | | |
| Dec | | | | | | | | | | |
| Total | | | | | | | | | | |

*Note:* Figures for this summary sheet are taken directly from the energy−audit worksheets (tables 2 to 6).

#### B. Effects of climatic conditions on energy consumption

Obviously, additional energy and fuel are required when the weather is very hot or very cold. Some way of comparing energy consumption from one year to the next that will adjust for weather variations is, therefore, needed. Without such a comparison, the efficiency of the building and its cooling and heating systems cannot be accurately determined.

No system exists that can take into consideration all the factors that affect energy consumption (humidity, wind, sun, cloud cover, temperature etc.). There is, however, a convenient means of factoring climatic conditions into calculations in order to provide a reasonable comparison. This is the "cooling degree−day" concept which can be applied to both cooling and heating situations.

The term "cooling degree−days" is used to take into account the role of weather during the hot season. One cooling degree−day results for each degree that the daily mean outside temperature is above the base temperature (generally, 65°F or 18°C). No "cooling degree−day" is counted when the mean outside temperature is below the base temperature − this is counted as a "heating degree−day".

To calculate the number of cooling degree−days in any day, determine the day's mean temperature and add this figure to the base temperature. For example, if a summer day had a high of 42°C and a low of 28°C, its mean temperature would be 35°C (42 + 28 divided by 2), and the number of degree−days for this particular day would be 17 degree−days (35 − 18). In other words, the average temperature for the 24−hour period was 17°C more than the base temperature of 18°C.

Using this concept, month−to−month and year−to−year comparisons between the amount of energy used and the number of degree−days can be made. This will help to explain variations in energy use from one period to another and give an indication of the efficiency of the cooling system and the thermal characteristics of the building. One useful relationship is the quantity of energy consumed per degree−day. For example, if there were 760 degree−days recorded in a hot month and the energy consumption was 51,756 kWh, the energy consumption per degree−day would be 75.7 kWh. This figure could then be compared with the consumption in the same month of the previous year. This procedure can be used not only to account for variations in energy consumption but also to assess the effects of adding storm windows, upgrading building insulation or installing an advanced heating system.

Table 9. Energy costs − comparative analysis

| | **Total energy costs 19__19__** | **Percentage increase (decrease)** | **Energy cost per occupant 19__19__** | **Percentage increase (decrease)** | **Energy cost per room 19__19__** | **Percentage increase (decrease)** |
|---|---|---|---|---|---|---|
| Jan | | | | | | |
| Feb | | | | | | |
| March | | | | | | |
| April | | | | | | |
| May | | | | | | |
| June | | | | | | |
| July | | | | | | |
| August | | | | | | |
| Sept | | | | | | |
| Oct | | | | | | |
| Nov | | | | | | |
| Dec | | | | | | |
| Total | | | | | | |

*Notes:* Figures for "Total energy cost", are taken directly from the summary sheet−total energy cost and consumption (table 8). The analysis indicated is for illustrative purposes only. Any other relationships, such as cost per square metre, cost per hour of operation, can be used in the comparative analysis.

Table 10. Energy use in Mj − comparative analysis

| | Total energy use in Mj 19__19__ | Percentage increase (decrease) | Energy use/sq m. 19__19__ | Percentage increase (decrease) | Energy use per occupant 19__19__ | Percentage increase (decrease) | Energy use per room 19__19__ | Percentage increase (decrease) |
|---|---|---|---|---|---|---|---|---|
| Jan | | | | | | | | |
| Feb | | | | | | | | |
| March | | | | | | | | |
| April | | | | | | | | |
| May | | | | | | | | |
| June | | | | | | | | |
| July | | | | | | | | |
| August | | | | | | | | |
| Sept | | | | | | | | |
| Oct | | | | | | | | |
| Nov | | | | | | | | |
| Dec | | | | | | | | |
| Total | | | | | | | | |

*Note:* Figures for "total energy use, Mj" are taken directly from the summary sheet – total energy cost and consumption (table 8).

**III. The diagnostic energy audit**

The diagnostic energy audit helps to determine which item of equipment is a large energy user and where energy is being wasted. The historical audit dealt with overall or general energy consumption. The diagnostic audit deals with detailed specific uses of energy in all forms.

In order to produce the required information, a complete inventory of all energy−using systems must be prepared. The second step is to conduct a walk−through audit of the premises, in order to identify operational and physical problems. An example of an operational problem is a piece of equipment operating when it should be off. Physical problems include as leaking faucets, windows that fit poorly, and missing pipe insulation, among others. It is very important to understand the existing situation before attempts are made at improvements, for otherwise corrective efforts could be misdirected and ineffective and, hence, financially wasteful.

The objectives of the diagnostic audit are:

(a) To identify, by way of an equipment survey, the items of equipment that are the large users of energy, in order that action can be taken to reduce their energy consumption and cost of operation;

(b) To identify, by way of a building survey, areas that require upgrading or maintenance, so as to improve energy efficiency and, thus, reduce cost of operation;

(c) To obtain the best possible return for money and effort spent on energy management.

The benefits associated with the diagnostic energy audit are:

(a) By identifying the areas of energy use in the building, each area can be thoroughly investigated, and appropriate actions taken to reduce waste and unnecessary expense;

(b) Items of equipment that use a considerable amount of energy while in operation and systems that are operating round−the−clock can be closely monitored;

(c) The diagnostic energy audit will reveal the need for some equipment to be replaced, retrofitted or overhauled;

(d) The equipment inventory listing which must be prepared, if it does not exist, will be very useful for insurance and bookkeeping purposes (although these are not the main objectives of the audit, they are, nevertheless, valuable side benefits);

(e) The "walk−through" part of the diagnostic audit will quickly point out areas where the building and mechanical systems require attention, in the form of additions, upgrading or improved maintenance, so that problems can be easily and quickly corrected.

The completed walk−through energy survey should detail all apparent faults or shortcomings of the building and mechanical systems and make note of suggested improvements or remedies. This survey might provide the incentive necessary to set up a good preventive maintenance programme for the physical plant. The benefits of such a programme cannot be overemphasized, as poorly maintained equipment is never efficient.

#### A. Conducting a diagnostic energy audit

The diagnostic energy audit should be undertaken in two separate steps so as to avoid confusion. The first step should be an equipment survey, and the second a building and mechanical systems survey. Carrying out the two steps will be easy, if they are conducted by two people, one of whom should be familiar with the building and equipment. Drawings of the building, an instant camera and a portable tape recorder will prove useful in carrying out the survey work. If any information concerning the equipment is not available in−house, either from the equipment nameplates or manuals, it should be obtained from the equipment dealer or manufacturer.

In order to assist in recording the necessary data, some sample worksheets have been provided (tables 11 to 19). Where appropriate, provision has been made on the survey worksheets to record data in the metric system (see annexes III, IV and V which are devoted to conversion factors). The forms and procedures set out in this manual are meant for a "do−it−yourself approach to the diagnostic energy audit, however, if the building is large and contains a lot of equipment, it might be advisable to enlist the services of experienced professionals for this task.

The assistance and guidance of a qualified consultant can be worth the expense during this type of study, owing to the specialized knowledge needed to understand the operation of energy−using systems. A consultant, equipped with special instruments, can perform a thorough in−depth energy audit.

#### B. Instrumentation

Some instrumentation is required for carrying our energy audits and surveys. Generally speaking, measuring instruments are not needed to carry out the historical audit, as meters are normally supplied and permanently installed by the utility companies and need only to be read and recorded. The diagnostic energy audit relies mainly on the energy−consumption ratings and hours of operation of equipment and it does not verify actual performance against manufacturers' claims. The diagnostic audit does, however, identify the systems and equipment that are large consumers of energy.

Once the large consumers have been identified, their actual performance can be measured and energy efficiency determined. For example, in a large residential building, the air−conditioning system and the hot water heater would probably be the main users of electricity. Determination of the performance of these systems requires instrumentation and the services of a trained professional, equipped with the proper tools and instruments (see annex VII for a detailed list of instruments required). Untrained people should not attempt to measure electrical power consumption and flue−gas temperatures: such exercises can be hazardous, and the results, very likely, erroneous.

#### C. The building and mechanical systems survey

This part of the audit requires a "walk−through" survey of the premises, in order to identify operational and physical situations requiring attention. The auditor must be alert to such operational problems as lights left on in vacated rooms, kitchen equipment left on unnecessarily, excessive heating or cooling of unoccupied rooms and other similar situations. Problems of this nature can be quickly corrected through occupant awareness: it is often very effective to make specific persons responsible for each area. In order to remind employees of their responsibility to control costs, it might be helpful to place stickers, showing "on and off schedules, on each piece of equipment.

The walk−through audit will likely show that a number of physical problems have developed, owing to the lack of a good preventive maintenance programme. Many of these situations can be quickly and easily remedied and often at minimum expense. For example, dirty light fixtures, which should not take long to clean, can reduce lighting efficiency by as much as 50 per cent. Similarly, dripping faucets, which can be easily repaired with low−cost tap washers, can waste thousands of litres of water in a year, which can be very expensive, especially if it is hot water.

#### D. Evaluation of results

Once the historical and diagnostic portions of the energy audit have been completed, the necessary information is available to start the energy−management programme. The analysis of past records, together with the detailed survey of building and equipment, should have provided information as to how much energy is being consumed and where that energy is being used. Appropriate sections of this manual describe specific techniques and practices that will allow introduction of energy conservation in all departments.

These first three steps, i.e., the historical audit, the diagnostic audit and the programme implementation, are the most difficult and time−consuming parts of the auditing exercise. The programme is not complete, however, without some means of determining how effective energy−management efforts have been. This section describes briefly some of the procedures available to monitor the success of a management programme.

The historical energy audit has provided a set of figures with which to compare total future energy consumption. These figures can also be used to evaluate the effectiveness of steps taken to reduce energy use and to improve preventive maintenance programmes. Soon after the energy management programme has been started, a reduction in energy consumption should be noticed, as conservation measures take effect. Another use of the data is to develop an energy utilization index (EUI) for each building, which is the total number of Mj consumed per degree−day per square metre over a certain period of time. By tracking the EUI on a monthly basis, an understanding of the monthly and seasonal energy requirements of the building will be gained. It will also be possible to compare the building's EUI with that of other similar buildings, to judge its relative efficiency.

There are a number of statistical relationships that are useful in monitoring energy cost and consumption, and two tables, 9 and 10, were prepared to illustrate some of the comparisons that can be used for control purposes. The comparisons can be made in both monetary and energy−consumption terms, and the ones that are most meaningful in the operation of the particular building should be selected. The energy cost and consumption statistics should be prepared on a regular and current basis, preferably as often as once a week but not less than once a month, using the comparative analysis sheets (table 10).

Some managers of small properties have found it beneficial to have a member of the staff record meter readings each day at a set hour: this allows the manager to recognize a pattern of energy consumption in his establishment. Large fluctuations might be due to the level of activity, the weather or serious malfunctions in the system. Cases of malfunctions should be followed up, and the malfunctions located, e.g., steam leaks, water leaks, stuck valves, non−functioning pumps. If it is felt that certain systems need special monitoring, separate meters should be installed, so that exact energy consumption is recorded.

The aim of the monitoring process is to provide information on how to keep the energy−management programme effective and to identify situations where improvements can be made. Energy management must become routine and should not be a one−off or intermittent exercise. Every attempt should be made to stay abreast of current developments in both products and energy−conservation techniques. Governments, national associations and various trade publications can provide valuable information on energy conservation.

Table 11. Energy survey worksheet−electrical equipment

Location: ____________

| (1) Equipment description | (2) Equipment location | (3) Rated Input | | (4) Horsepower | (5) Kilowatts ((3)(a) x (3)(b)) 1000 | (6) Hours used daily | (7) Days used per month | (8) Kwh per month ((5) x (6) x (7)) | (9) Mj per month ((8) x 3.6) |
|---|---|---|---|---|---|---|---|---|---|
| | | (a) Amps | (b) Volts | | | | | | |
| | | | | | | | | | |
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| | | | | | | | | | |
| Total | | | | | | | | | |

*Notes:*

Column 1. Enter a brief description of the item of equipment (together with its identification number, if applicable)

Column 2. Indicate the location of the item of equipment, e.g., kitchen.

Column 3. Enter the rated input information. This information is usually found on the equipment nameplate but it may also be obtained from the equipment manual or the supplier.

Column 4. Enter the horsepower, if given. Horsepower (HP) may be converted to kilowatts by multiplying by 0.746

Column 5. Multiply column (3) (a) (amps) by column (3) (b) (volts) and divide by 1000 to get kilowatts. Normally, this should be multiplied by the power factor, which is generally not readily known and has, therefore, been assumed as 1.0.

Column 6. Enter the best estimate of the average number of hours of operation of the equipment on a typical day.

Column 7. Enter the number of days the equipment is used in an average 30−day month. If it is used every day of the week, then enter 30 days.

Column 8. Multiply column (5) by column (6) and by column (7) to determine the total kilowatt−hours consumed in an average month.

Column 9. Multiply the figure in column (8) by 3.6 to convert to megajoules, so as to provide a common base for comparison of various items of equipment. Once the kilowatt−hours consumed by an item of equipment have been determined (column (8)), the approximate cost of operating that piece of equipment for the month can be found by multiplying kWh by the cost per kWh available from the electricity bill.

Table 12. Energy−survey worksheet−gas equipment

Location: ____________

| (1) Equipment | (2) Equipment | (3) Equipment | (4) Kg per | (5) Hours used | (6) Days used | (7) Kg per | (8) Mj per |
|---|---|---|---|---|---|---|---|

| description | location | rating | hour | per day | per month | month | month |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |
| Total | | | | | | | |

Column 1. Enter a brief description of the item of equipment (together with its identification number, if applicable, e.g., gas boiler I.D. No. K.6).

Column 2. Indicate where the item of equipment is located, e.g., kitchen.

Column 3. Enter the rated input in Mj per hour from the equipment nameplate or manual.

Column 4. Enter consumption in kilograms per hour.

Column 5. Enter an estimate of the average number of hours the equipment is operated on a typical day.

Column 6. Enter the number of days the equipment is used in an average (30−day) month, e.g., if the equipment is in use every day of the week, enter 30 days.

Column 7. Multiply column (4) by column (5) and by column (6) to determine the total number of kilograms of gas consumed per month.

Table 13. Building energy−audit data

Name of building: ______________________________________________________

Address: _____________________________________________________________

Date audit completed: ____________________ Data compiled by: ________________

Year building constructed: ________________________________________________

Length of operating season in months: _______________________________________

Number of accommodation units: ___________________________________________

Total area of all accommodation units: __________________ square metres

Total area of building interior: _________________________ square metres
(include all hallways and public areas)

Number of floors: _______________________________________________________

Height of each floor: __________________________________ metre

Number of occupants: ____________________________________________________

Approximate occupancy rate: _____________________________________________

Remarks: ______________________________________________________________

*Note:* If possible, use construction drawings when completing this form.

Table 14. Central heating and air–conditioning data

| (1) System | (2) Type | (3) Number | (4) Fuel | (5) Rated (Mj/h) |
|---|---|---|---|---|
| Boiler | | | | |
| Unit heater | | | | |
| Furnace | | | | |
| Electrical | | | | |
| Air conditioner | | | | |
| Other | | | | |

*Distribution system*

Forced air: Yes/No[a/]
Radiators: Yes/No[a/]
Air recirculated: Yes/No[a/]
Air cleaner: Yes/No[a/]
Other (specify) ____________________________________

| Items to be checked | Suggested improvements: |
|---|---|
| Heating system not functioning properly | |
| Heating or cooling of unoccupied public space | |
| Excessive heating or cooling of storage areas | |
| Insulation of heating and cooling equipment | |
| Excessive exhaust fan speeds | |
| Dirty filters | |
| Obstructions to free flow of air | |

*Notes:* Central–heating and air conditioning data

Column 1. Record the various mechanical systems that are in operation in the building.

Column 2. Briefly describe the particular system, for instance, boiler would be described as "hot water" or "steam".

Column 3. Record the number of units in use.

Column 4. Record the fuel source, e.g., coal, natural gas, oil, electricity.

Column 5. Record the unit's energy output.

[a/] Circle as appropriate

Table 15. On–site uses of energy

| Code | Application | Code | Application |
|---|---|---|---|
| | Building heating | | Coolers |
| | Water heating | | Freezers |
| | Air conditioning | | In–house laundry |
| | Lighting | | Back–up generators |
| | Heated pools | | Fans/ventilators |
| | Pumps | | Outdoor lighting |

| | | | |
|---|---|---|---|
| | Cooking stoves | | Others |
| | Ovens | | Fryers |
| | Dishwashers | | |
| | Refrigerators | | |
| Remarks: | | | |

Code:

E = Electricity
C = Coal
O = Oil
W = Wood
G = Natural Gas
Oth = Other
P = Propane
N/A = Not applicable

Table 16. Building structure and insulation

| Building segment | Construction material | Thickness of construction material | Type of insulation (batts, rigid, value loose fill etc.)[a/] | Insulation "R"/"RSI" |
|---|---|---|---|---|
| Walls | | | | |
| Roof | | | | |
| Floor | | | | |

[a/] If there is no insulation, enter 'Nil'

*Note:* This table is convenient for recording some useful data about the basic construction and insulation of the building. If the building is single storey, only one table need be completed. However, if it is a multistorey building, it is advisable to complete separate tables for each floor, as the types of construction and insulating materials of different floors could be different. It is not always possible to determine the type and thickness of insulation present, especially inside the walls, and it might be necessary to refer to construction drawings and specifications to obtain this information. It might also be possible to remove receptacle covers or switchplates on exterior walls to determine the type and thickness of the insulation. Any section of the building that is uninsulated or underinsulated offers potential for worthwhile energy savings. These areas should be studied to determine the required financial outlay and the required payback. The last column in the table mentions "R" and "RSI". Please refer to chapter VI, which also includes a table comparing some of the common types of insulation, for an explanation of these insulation terms.

Table 17. Energy−survey worksheet − lighting
Year: ____

Location/area ______________

Type of lighting fixtures (incandescent, fluorescent, high−intensity discharge etc.)

| (1) Quantity | (2) Watts | (3) Total watts (1) x (2) | (4) Total kilowatts (kW) | (5) Hours used daily | (6) Days used monthly | (7) kWh per monthly | (8) Maintenance carried out |
|---|---|---|---|---|---|---|---|
| Month | | | | | | | |
| Jan | | | | | | | |
| Feb | | | | | | | |
| Mar | | | | | | | |
| April | | | | | | | |
| May | | | | | | | |
| June | | | | | | | |

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|---|---|---|---|---|---|---|---|
| July | | | | | | | |
| August | | | | | | | |
| Sept | | | | | | | |
| Oct | | | | | | | |
| Nov | | | | | | | |
| Dec | | | | | | | |
| Total | | | | | | | |

*Notes:* Location/area: Indicate the area being surveyed and its location. Guest bedrooms, guest bathrooms and corridors can all be recorded on one sheet, but rooms used regularly, dining rooms and kitchen should each be recorded on separate sheets.

Type of lighting fixtures. Indicate the source of light in each area, e.g., lighting fixtures incandescent, fluorescent, high−pressure sodium etc. This information will be useful to assess whether some bulbs and tubes now in use can be replaced by more efficient ones so as to effect energy cost savings, as suggested in chapter X.

Column 1. Record the quantity of each type of lamp in use.

Column 2. Record the wattage of each type of lamp in use.

Column 3. Multiply (column (1) by column (2)) to arrive at the total watts being used.

Column 4. This column is provided to convert watts to the standard unit of measuring electrical power, the kilowatt (kW) (1000 watts = 1 kW). When making the conversion, it is necessary to use a "lighting multiplier" to correct for what is called the ballast factor. Fluorescent and most high−intensity discharge (HID) lamps require a ballast which consumes some energy. An average figure of 0.0011 can be used to convert watts to kilowatts and adjust for the ballast factor. Hence, to obtain total kilowatts, multiply column (3) (total watts) by 0.0011.

Column 5. Record the estimated number of hours the lights are on in each area per day. For instance, hallway lights might be on 24 hours a day, whereas room lighting might be used for an average of only six hours per day.

Column 6. Record the estimated number of days per month the lighting is used.

Column 7. Multiply total kilowatts by hours used daily by days used per month to arrive at the total kilowatt−hour consumption for the month.

Column 8. Record any maintenance work carried out on the fixture to improve its efficiency.

Table 18. Energy−survey worksheet − windows

| **(1) Location and exposure (N, S, E, W, wall)*** | **(2) Approximate percentage of wall area covered by glass** | **(3) No. of single glazed windows** | **(4) Total area of single−pane glass** | **(5) No. of double−glazed windows (storm windows)** | **(6) Total area of double−pane glass (storm windows)** | **(7) No. of thermal−pane windows (sealed double−glass)** | **(8) Total area of thermal−pane windows (sealed double glass)** |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

*Notes:*

Column 1. Record the location (e.g., main dining room) and the direction (north, south, east or west) the window faces. The window exposure is important, because it affects the choice of appropriate window treatment. For example, in the northern hemisphere, heavy or insulated draperies might be appropriate for north facing windows, whereas some type of solar film or awning would be suitable for south−facing or west−facing windows.

Column 2. Record an estimate of the amount of glass in relation to the rest of the wall. It is sometimes possible to reduce the glass area, if the heating/cooling loss is too great.

Column 3. Record the window count. This will be used in calculating column (4).

Column 4. Record the total area of single−pane glass. This information is useful in determining seasonal heat loss and heat gain.

Column 5. Record the number of windows provided with storm windows, whether of the self−storing type or of the removable type.

Column 6. Record the total area of glass that has storm windows. This information will be useful in making heat−loss comparisons with efficient types of windows.

Column 7. Record the number of windows provided with sealed double glass. This type of window construction normally provides better insulating qualities than storm windows.

Column 8. Record the total area of sealed double glass. This will be useful when making comparisons to improved systems, such as triple glazing.

Column 9. Record the total area of triple−glazed windows now in place.

Column 10. Record the windows fitted with tinted glass, reflective glass or solar film. Consideration should be given to windows in the building that could benefit from use of tinted glass, reflective glass or solar film. All are considered more effective in relation to air conditioning than to heating problems, but they tend to reduce fading of fabrics, wall coverings, carpets etc.

Column 11. Record the condition of the caulking around the window frames as either satisfactory (S) or unsatisfactory (U). If the caulking is cracked, broken or missing, it should be replaced at once with a good grade of caulking. Some products are guaranteed for 10 years or more and are a good investment, taking into account the labour cost involved in replacing unsatisfactory caulking. The purchase of caulking is not a large expenditure, and the energy saved should quickly recoup the costs. Furthermore, poorly caulked wooden windows enable rot to set in, and, eventually, the entire window will have to be replaced.

Column 12. Actions necessary to improve each situation should be noted in this column. These can then be ranked on a cost−effective basis, and priority actions determined.

* It might be advisable to divide wall locations into "Street Level" and "Above Street Level".

Table 19. Energy−survey worksheet − exterior doors

| **(1) Location of each exterior door*** | **(2) Size of door** | **(3) Door insulated** | **(4) Double glazed door glass** | **(5) Storm door fitted** | **(6) Protected by vestible** | **(7) Door sweep condition** | **(8) Weather−stripping condition** | **(9) Adequate caulking around frame** | **(10) Door closer satisfactory** | **(11) Suggested improvemen** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

*Notes:*

Column 1. Identify the location (front, side, back) of each exterior door and also the direction of its exposure (N, S, E, W).

Column 2. Record the dimensions (width and height) of each door.

Column 3. Record a "Yes" or "No" for each door.

Column 4. Identify doors with double glass. If the door has no glass, as in the case of most emergency exits, just enter "No glass".

Column 5. Identify entrances already equipped with storm doors. If the storm door fits poorly, then a notation should be made in column (11).

Column 6. Identify doors already equipped with an enclosure. Ideally there should be sufficient space between the inside and outside doors so that one is closed before the other is opened.

Columns 7 and 8. Record the condition of the door sweep and the weather stripping along the sides and across the top of each door. The weather−stripping is subject to considerable wear and tear and must be replaced when it ceases to seal properly. It is wise to use the best quality of weather stripping available. Replacement is not a big job, but there is labour involved, and top quality products offer better wearing and performance characteristics.

Columns 9 and 10 Record a "Yes" or "No" for each door. If caulking is not adequate, then relevant notations should be made in column (11).

Column 11. Insert possible improvements for inadequacies or in columns (2) to (10)

* Each door should be identified as front, back, side, north, south etc.

### IV. The financial evaluation

The energy audit or survey will have revealed where energy inefficiencies and waste exist. It must now be decided not only what is to be done but also in what order actions are to be taken. The establishment of priorities is, most often, cost/benefit−related. Fortunately, many of the techniques and procedures essential to good energy management involve little or no capital outlay. It is, therefore, logical to implement the no−cost and low−cost actions first and, then, consider those items which involve significant capital outlays. In other words, all the staff training, housekeeping items and maintenance−related procedures should be attended to, before money is spent on such things as additional insulation, new windows, heat−recovery devices or automatic controls.

When establishing priorities for capital expenditure, it is necessary to assess options, in order to determine which will be the most effective in the long run. For example, if an old item of equipment is in need of an overhaul, it might be better to replace it than to repair it. When, even after an overhaul, it is expected that the item of equipment in question will still consume large amounts of energy, the repair−alternative might not be the best choice, and it might be financially advantageous, in the long run, to replace it with a new energy−efficient model that will have low operating costs throughout its life.

The energy survey will have identified the areas where energy use is the highest, and these areas offer the greatest potential for energy savings. Close examination can reveal that certain systems are easier to modify or control than others, and costs involved can vary significantly, depending on the changes to be made.

Financial considerations affect the opportunities to invest in energy−conservation technology. Hence, a financial evaluation of options is very important. An investment in energy conservation can be very attractive, when life−cycle cost−benefits are considered.

Life−cycle costing takes into account the total costs of owning and operating the building or equipment over the period of its estimated useful life. It includes the initial capital cost plus all maintenance and energy costs. This objective approach to new construction, renovations and equipment replacement or retrofitting is much more logical and realistic than the "first−cost" approach used frequently in the past. Any contract awarded strictly on the basis of lowest bid, as opposed to performance specifications, will, most likely, result in short−lived savings. That the costs of operating a building over its useful lifespan will far exceed the initial construction costs must not be overlooked at the design stage.

Many commercial buildings were built when energy was cheap and plentiful. As a result, most of these buildings waste large amounts of energy. Buildings constructed using modern technology could be several times more energy−efficient than those built in the past. For example, the Gulf Canada Square building in Calgary, Canada, spends only about 4.4 cents per square metre per year in energy costs, compared with an average of 20 cents per square metre for conventional 20−year−old buildings. It is estimated that energy savings alone will pay for the $75 million spent on the construction of the building in just 40 years. The additional cost of construction of this building, compared with conventional structures, is expected to be recovered in less than seven months through energy savings. The construction of this building is a good illustration of the application of life−cycle costing. Although the initial cost was considerably higher than the costs of conventional buildings, the additional cost was repaid quickly through low operating (energy) costs.

An in−depth financial evaluation of a proposed capital expenditure on energy systems can be quite complex and might be best left to an accountant or energy consultant. There are, however, several basic "screening" techniques that can assist the layman in the selection of options for evaluating capital expenditures. These screening techniques are: the payback method, the average rate of return method and the discounted cash−flow method. It is usually desirable to use more than one of these techniques in each situation, since no one method can provide all the answers needed for the evaluation.

#### A. The payback method

The payback method is popular, because it is quick and easy to understand. It measures the number of years required to "pay back", in cash, the initial investment. It is calculated by dividing the investment by the estimated average annual financial savings from the project (to be accurate, the investment should include the cost of financing, as interest rates cannot be ignored). The payback method, however, docs not show the cash savings subsequent to the payback period and, also, ignores the timing aspect of cash flows (the savings might vary from year to year).

This method is useful for screening proposed investments, insofar as they can be ranked on the basis of payback time. Another advantage of this method is that depreciation docs not enter into the calculation, and, hence, depreciation methods do not have any effect on the outcome.

#### B. The average rate of return method

The average rate of return method is a simple measurement of the anticipated profitability of an investment. The amount of net income (cost savings less depreciation) expected to be earned from the investment is stated as an annual average over the number of years the asset is to be used. This is divided by the average cost of the asset (average net book value).

A disadvantage of this method is that it ignores the time−value of money. It does not disclose whether the project will recover a high proportion of the investment early in its life or late. It is obviously desirable to have a high recovery as soon as possible, so that money can be reinvested.

#### C. The discounted cash flow method

The discounted cash−flow or net present−value method attempts to determine the present worth of cash flows to be received in the future. For example, a dollar received one year from now is worth less than a dollar received today: if the rate of interest is 18 per cent, one dollar which will be received a year from now is worth less than 85 cents ($1.00 − 0.18).

The present value of net annual benefits is determined by applying an appropriate discount rate. The discount rate can be arrived at by starting with the interest rate on loans (say 20 per cent) plus an amount for inflation (say 10 per cent) and another amount for desired profit (say 5 per cent), to give the discount rate (in this case, 35 per cent). A capital investment in energy savings is attractive only when the expected total return, after discounting by the selected rate, exceeds or equals the net investment required. Pre−calculated tables of present values at different discount rates, to simplify the process of calculation, are readily available.

#### D. Conclusion

Of the three methods, the discounted cash−flow method is considered to be best, because it takes into account the time−value of money, but these techniques for assessing capital expenditures have only been explained briefly, as detailed explanations are beyond the scope of this manual. Professional financial guidance should be sought when comparing energy−investment opportunities, so as to avoid committing scarce funds to projects that do not have a good financial return. It should also be remembered that there is a point beyond which financial evaluation cannot go and where managerial judgement has to take over.

## Part Two − Energy Management Manual

### V. Introduction to energy management

Part One of the manual has explained the necessity for and methods of carrying out historical and diagnostic energy audits, and explained briefly how to evaluate the cost of carrying out various energy−conservation schemes. Once energy auditing has been completed, the next step is to try to improve upon energy−consumption patterns. Part Two of the manual is designed to assist in carrying out changes in the energy−consumption patterns in buildings. It shows ways of reducing energy use and limiting waste of energy, taking into account the information gathered in the energy audits.

This Part is divided into the following sections:

(a) Building envelope;
(b) Employee involvement;
(c) Heating, ventilating and air conditioning;
(d) Lighting;
(e) Water.

The first three sections are specifically aimed at operators and managers of buildings which are heavy users of energy, such as hospitals, hotels and office buildings which have a large number of employees and generally use active air conditioning. However, it is hoped that some of the information contained in these sections will be of interest to household users of energy. The sections on lighting and water can benefit all users of these two forms of energy, from small houseowners to operators and managers of large buildings.

### VI. The building envelope

The roof, exterior walls, doors and windows of a building are called the building envelope. Preventing heat from flowing through the materials of the envelope (out in winter, in during hot weather) is an important step in an energy−conservation programme in buildings.

Heat moves through the building envelope in three ways:

(a) *Convection.* Heat transfer by convection is dependent upon the temperature of a surface and air. As air comes in contact with a hot (or cold) surface, it becomes heated (or cooled). Heat transfer relies primarily upon the removal of this warm (or cold) layer of air by natural or induced air currents.

(b) *Conduction.* Heat transmission in solids occurs by conduction. Whenever there is a temperature difference between two surfaces of a solid, heat flows from the surface at the higher temperature to the surface at the lower temperature. The rate at which heat is conducted is a characteristic property of the material and is related to the thermal conductivity of the material. Thermal conductivity is defined as the rate of heat conducted per unit surface area per unit temperature difference per unit thickness of the material. Materials such as copper and aluminium have high thermal conductivity and are called good conductors of heat, whereas materials such as wood and asbestos have low thermal conductivity and are referred to as thermal insulators.

(c) *Radiation.* All hot objects radiate heat, and heat transfer from a hot object to a cold object can take place by radiation, even if there is no medium between the two, i.e., *in vacuo.*

Several measures can be undertaken to reduce heat gain in a building in summer and reduce cooling expenses at minimal costs. These measures will also reduce heat loss in winter to some extent.

Examples of very inexpensive measures include weather−stripping and caulking. Weather−stripping should be applied to any external joint where two surfaces meet and move relative to each other (such as doors and windows). Caulking should be applied where two fixed surfaces meet. All operable windows and doors should be fitted with weather−stripping, and caulking should be done around every window frame in the gaps underneath baseboards, around wall receptacles where plumbing and wiring enter the building, and in any cracks on the inside surface of walls and ceilings. Openings that are too large to be plugged with caulking should be stuffed with insulation. Gaps around chimneys and openings where pipes, exhaust fans or ducts are cut through an attic floor should receive attention. Any roof openings or stacks that are no longer in use should be thoroughly sealed and insulated.

A check of the building might reveal that the insulation is insufficient. Cost is involved in adding insulation but, when balanced against reduced energy costs, it might be paid for within a very few years by the cost of energy saved. Some studies have indicated that savings in energy costs that can be effected through the use of insulation are as high as 90 per cent for roofs, 60 per cent for walls and 70 per cent for floors. Hence, many operators just assume that their current level is inadequate and upgrade their level of insulation.

When adding insulation, it is necessary to be sure that none of the existing insulation is wet. Insulation does not look or feel wet, as a rule, until its moisture content is greater than 45 per cent. By the time the insulation is visibly wet, it no longer qualifies as thermal insulation and must be removed and replaced with new dry material.

When choosing insulation, ensure that it is fire−retardant. Also, allow for air exchange in the attic and under roof areas, as insulation in the roof area, without an adequate flow of air, results in "back heat", causing asphalt roof elements to break down, eventually requiring the replacement of the entire roof. This heat build−up in attic areas makes it difficult to cool rooms directly below during summer. Proper ventilation in attic areas reduces moisture build−up during winter, as well. Vents should allow one square foot of unobstructed ventilation for every 300 square feet of ceiling area and should be so located as to provide cross−ventilation from top to bottom and from end to end of the attic space.

When dealing with heat loss or heat gain, two terms are frequently used, R−value and U−value. The R−value is a measure of a material's resistance to heat transfer, and, the higher the R−value, the less the amount of heat that will pass through the material. The U−value is a measure of a material's ability to transfer heat, and, the lower the U−value, the less the amount of heat that will be transferred by the material. The R−value is the reciprocal of the U−(thermal conductance)−value which is defined as the rate of heat transmitted through 1 square metre of a stated thickness of homogeneous material when a temperature difference of 1 °C exists between the two surfaces of the material. The International System of Units (SI) unit commonly used for R−value is called the RSI−value and is expressed as square metre Kelvin per Watt ($m^2K/W$). Table 20 shows the R and RSI values of different types of insulation and building components.

Recommended R−value levels for insulation have been rising steadily over the past few years, owing to the rising costs of fuels. Table 21 shows present recommended levels for different building components.

Single−glass windows generally lose a large amount of energy. If existing glass windows are snug−fitting and well−caulked, each square metre of window is still gaining as much as seven times the amount of heat gained per square metre through the floor, five times as much as a square metre of wall and four times as much as a square metre of ceiling. If existing windows are single glass but are in good condition, it is possible to install separate storm windows. These will provide a second layer of glass to form an insulating air space, and heat penetration will be reduced by up to 50 per cent. If existing windows are in poor condition, they should be replaced by thermalized ones. Most operators of buildings fitted with separate storm windows are now leaving them in place year−round, to reduce heat gain in summer and heat loss in winter.

External doors lose a large amount of energy. If at all feasible, consideration should be given to the installation of vestibules or entry ways. The outer doors should be far enough away from the inner doors for them to be closed before the inner ones are opened. Where appropriate, an alternative to construction of vestibules is the installation of revolving doors.

Table 20. R−value (heat resistance) of insulation materials[a/]

| Type | | | Description |
| --- | --- | --- | --- |

| | RSI−value per 25 mm[b/] | R−value per inch[b/] | |
|---|---|---|---|
| Glass fibre | .4675 – .6062<br>.4175 – .4930 | 2.7 – 3.5<br>2.4 – 2.8 | For blowing and pouring into cavity |
| Cellulose fibre (2.1−2.3 lb density) | .6062 – .6425<br>.4675 – .6250 | 3.5 – 3.7<br>2.7 – 3.6 | As above |
| Mineral fibre (2.0−5.0 lb density) | .4504 – .5550 | 2.6 – 3.2 | Fibres in loose form |
| Vermiculite 1 (7.0 lb density) | .3637 – .4325 | 2.1 – 2.5 | Expanded mica |
| Loose polystyrene | .5196 – .5716 | 3.0 – 3.3 | Shredded or beads |
| Batt or blanket−type insulation glass | .5023 – .6925 | 2.9 – 4.0 | "Fiberglass", thickness: 2−6 inches Both are available with backing |
| Mineral fibre | .5023 – .6925 | 2.9 – 4.0 | Specially needled matt |
| Rigid board extruded polystyrene | .7450 – .8676 | 4.3 – 5.0 | Styrofoam roofing or sheathing material |
| Expanded polystyrene | .5889 – .7275 | 3.4 – 4.2 | "Beadboard", white, lightweight when new |
| Rigid board phenolic foam | .7275 | 4.2 | With vapour barrier, flexible |
| Polyurethane slabs | .8675 – 1.04 | 5.0 – 6.0 | High fire resistance |
| Foamed−in−place polyurethane | .8142 – .8675 | 4.7 – 5.0 | Needs contractor for installation |

*Notes:*

[a/] The metric equivalent for R−value is RSI−value: as a rule of thumb, R x 0.176 = RSI.
[b/] 25 mm is lightly less than 1 inch

Table 21. Recommended RSI−values and R−values for building components in moderate zones

| Building components | RSI 2 (mK/W) | R ft.h.F/Btu |
|---|---|---|
| Ceilings | 5.4 | 31 |
| Walls | 2.6 | 15 |
| Floors | 4.9 | 28 |
| Basement walls (less than 50 per cent above ground) | 1.4 | 8 |
| Basement walls (more than 50 per cent above ground) | 2.6 | 15 |
| Floors over unheated garages, crawl spaces and overhangs | 3.5 | 20 |

*Note:* The values given above are for illustrative purposes only. RSI and R values are dependant on local energy costs, climate and cost of insulating materials. In tropical countries they will generally tend to be lower than the figures given above.

**VII. Employee involvement**

An important aspect of an energy−conservation programme which is often overlooked by building managers and operators is employee involvement. Without the cooperation and involvement of employees, even the best−designed energy−conservation programme can fail or, at best, achieve very little success. The following paragraphs explain some of the steps that can be undertaken to encourage employees to become involved in the programme.

As a first step, employees should be informed of actions they can take to conserve energy. For this, each department should be provided with an appropriate checklist to that effect for employees, and it is vital that employees involved with energy−using equipment, such as kitchen equipment and the HVAC system, be instructed in proper equipment use. Secondly, on−going training is important, and the training of new employees should stress the need for energy conservation. Thirdly, many organizations have found that sharing the savings obtained from energy conservation with staff serves as a strong motivation to the employees. A bonus paid at the end of a period of time, if goals are met, is a tangible sign to employees that the programme is important and that their contributions count. Making one individual responsible for a certain specific area or task, such as control of kitchen exhaust systems, is a good way of making the employee feel "part of the team".

If an energy audit calls for changes, it is important that the people who will be affected by the changes be actively involved. For example, if plans are to reduce the lighting in an area, they should be discussed with the people who work in that area, the rationale should be explained, and their ideas and suggestions should be solicited. If changes are made without the participation of occupants, there could be some resentment, but it will be easy to elicit co−operation from employees, if everyone is reassured that his/her comfort and well−being are not threatened. It must be remembered that old people or those with physical problems might need more light and/or heat than others. After the programme has started, staff should be kept posted with frequent progress reports, such as regular and simple energy newsletters. Short−term goals should be set, to maintain employees' interest. Also, credit should be given to individuals and to departments for accomplishments. It is useful to provide progress reports in terms of money saved, rather than kilowatt−hours or Mj which are not meaningful to most employees. An energy−conservation programme is not merely a short−term measure, and all employees should be made aware of this. Many organizations have discovered that, when employee training and reports on the conservation programme stop, energy costs tend to go up.

## VIII. Heating, ventilation and air conditioning (HVAC)

### A. Introduction

Energy management of a building is an art, and a good way to being mastering this art is to learn the characteristics of those systems in a building which use energy and their relationship to the building's operation. A thorough understanding of mechanical systems helps to avoid wasteful imbalances between systems. A wide variety of continuously changing factors influence the demand for heating, cooling and ventilation. The number of people in a room, the amount of heat−producing equipment in use (in kitchens, for example), the outside air temperature, the position of the sun and, even, the lighting levels in different areas must all be taken into account when assessing the equipment.

The basic functions of an HVAC system are to maintain the desired temperature by cooling (or heating), to control humidity and to provide ventilation, by removing and replacing stale air, cooking odours etc. In many commercial buildings, heating, ventilating and air conditioning are large energy users. The results of an energy audit will provide all the basic information about the HVAC system, and the audit process will, no doubt, bring to light a number of areas where equipment is not being used as efficiently as possible. Thermostats which are out of adjustment or inoperable and inadequately maintained equipment, such as filters, condenser coils and air dampers, can create situations where the HVAC system is using more energy than is necessary. Such problems are easily corrected and can be prevented with a good maintenance programme. Many operators have been using the "failure" or "breakdown" approach to HVAC maintenance − that is, waiting until a unit fails and then doing the minimum necessary to get it running again. Given the high energy costs at present, this approach should be strongly discouraged.

Much publicity has been given in recent years to computerized systems for energy management in buildings. While useful in some situations, they are not the answer to all problems. All systems in the building must be in top operating condition before the use of a sophisticated system is feasible. Even then, in most operations, savings realized through the use of a computerized system might not be large enough to offer a reasonable pay−back period. A computerized system can be programmed to operate equipment according to a predetermined schedule and load factor, but it cannot solve the problems of poorly maintained or operated equipment. The success of an energy conservation and management programme depends, to a large extent, on the co−operation and participation of maintenance personnel. Hence, staff should be made to understand the importance of controlling operating times and attaining and maintaining peak efficiency of equipment.

### B. HVAC management programme

It can be determined from the energy−audit reports which of the bigger energy users should be tackled first. In some instances, the audit results might indicate that new, energy−efficient equipment should replace existing equipment. In making decisions about replacement, it is important to take into account not only the initial cost but the long−term energy savings over the life of the equipment (see chapter IV for information about various methods used to analyse expenditures for replacing equipment).

The following are some of the areas which call for attention:

*Electrical connections.* Small items such as dirty connections on fan–coil units increase energy costs. For example, dirty connections consume about 2 watts each per hour; there are usually six connections per unit which add up to 12 watts per hour per unit, a total of 105,120 watt–hours per unit per year. In a 100–room building this totals 10,512,000 watt–hours or 10,512 kWh. At 5 cents per kWh, dirty connections would, thus, waste $525 annually.

*Dirty equipment.* A 1–ton cooling unit, operating with a plugged filter and dirty coils, might operate for 1 hour 25 minutes rather than 1 hour, to produce 1 ton of cooling. The energy cost for a 100–day cooling season (units operating five hours a day), with electricity at 5 cents per kWh, is $71.50 whereas for a clean unit it is $41.25. If the building has 100 such units in use, the cost in wasted energy is, thus, $3,025 per season.

*Manuals.* Operating and maintenance manuals for every item of equipment should be obtained, if possible, and maintenance staff should be instructed on ensuring that equipment or systems remain in peak operating form. The preventive programme should be put into effect only after top performance levels have been achieved. Staff should then begin the upgrading programme on items which are large or inefficient energy users and go through the list of equipment installed in the building.

It will take some time to get all equipment performing as efficiently as possible because, in addition to upgrading selected equipment, workers must still maintain other equipment. Some industry experts estimate that it takes two years from the time an energy–audit programme is started to the time the preventive maintenance programme is fully under way with all systems operating at the most efficient possible levels. At the end of this period, a reduction of about 30 per cent in energy costs and about 15 per cent savings in maintenance and repair bills can be expected.

*Task lists.* A part of any preventive maintenance programme should be the establishment of specific task lists for each system and item of equipment. These should include lubrication, current (amperage) checks, belt inspection, damper inspection, temperature–control calibration and adjustment, filter changes, and inspections to ensure that equipment is performing according to specifications. Tasks should be scheduled to be undertaken at an opportune time, e.g., the air–conditioning system should be overhauled in winter. Report forms, that must be signed and dated when work has been completed, should be prepared, and management should ensure that follow–up action is undertaken.

*Heating and cooling.* With some HVAC systems, it is possible to have the heating and air conditioning working at the same time, thus wasting an enormous amount of energy. Every possible step should be taken to avoid such occurrences. Professional engineering help should be sought, when necessary, to eliminate such possibilities. The expenses of the consultation will be covered quickly by energy savings.

Condenser coils for air–conditioning and refrigeration equipment are sometimes located out–of–doors, often on the roof. If they are located in direct sunlight, they are affected by solar heat and their effectiveness is, thereby, decreased. A simple and inexpensive sun–shield can eliminate this problem.

Ceiling fans, which are relatively inexpensive, pull warm air down from the ceiling to provide a comfortable floor–to–ceiling temperature during the heating season and can be used in summer to provide constant air circulation. Many have variable speed controls, and they are not expensive to operate. However, the controllers should be of solid–state and not resistor type, as the latter do not reduce power consumption, and the cost is the same for both types.

Cooling (and heating) replacement air is expensive. Dampers used to bring outside air into the building should be as leak proof as possible when closed. Outdoor air being introduced to the building, to be heated or cooled, should be reduced as much as possible. This can be accomplished partly by reducing the ventilation to the minimum required by international health standards and partly by reducing the minimum air settings of all outdoor air dampers (which should, however, conform to international health standards). The installation of air–to–air heat exchangers which make use of exhaust air to heat or cool incoming air should be considered.

Temperature settings of all thermostats which control room temperatures should be checked critically. These, normally set at 25°C during the hot season, can be raised by 2 or 3°C, without causing any discomfort to occupants. Similarly, thermostats can generally be lowered by the same values during winter. This simple exercise can result in considerable energy and financial savings.

If a steam boiler is being used, its distribution system should be examined. If it has grown gradually over the years with little long−range planning, it may have undersized pipe runs, insufficient pipe insulation or steam leaks. Steam lines that are no longer used should be physically removed. Areas that use intermittent or seasonal steam should be isolated with valves so that steam will be delivered only when needed. Steam leaks are often underestimated and ignored as an energy−conservation measure. The advantages of insulating the steam system should not be overlooked. All pipes should be insulated, and heating ducts passing through unheated areas should be rerouted to pass through heated areas.

## IX. Lighting

#### A. General lighting

The energy audit already carried out will have recorded the number of lamps being used, their wattage and the amount of light they are providing. The next step is to find out whether the lighting levels are adequate in the various areas and whether changes should be made either on account of under/over−lighting levels or energy wastage. Table 22 shows suggested light levels for various areas and tasks in different establishments. It should be used to determine which, if any, areas have inadequate or too much light. However, a maintenance programme should be carried out before any change in the lighting plan is envisaged.

The maintenance programme consists of (a) periodic cleaning of lighting fixtures and lamps (or bulbs); (b) regular cleaning of ceilings, walls and windows; and (c) group replacement of lamps. Dirty light fixtures can reduce lighting efficiency by as much as 50 per cent. Dirty walls and ceilings do not reflect as much light as clean ones, and clean windows allow maximum use of natural light. Lamps lose efficiency with age, whilst still consuming the same amount of energy as before: it is, therefore, sensible, both from the labour and lighting−efficiency points of view, to replace lamps when they have reached approximately 70 per cent of their rated life−expectancy. At this point, the remaining value of lamps is so small that discarding them means losing relatively little money. Life−tables on all types of lamps, which are available from manufacturers, should be consulted when deciding to replace lamps ("re−lamp"). Re−lamping should be incorporated in the preventive maintenance programme. All the lamps in a particular section of the building should be changed, and fixtures cleaned at the same time.

Cutting down lighting on a random basis, by, say, removing every other bulb or turning off some lights entirely, is not advisable. It can bring security problems and insufficient lighting levels. The ideal method is to devise a master lighting plan, guided by the lighting levels suggested in table 22.

If the master lighting plan calls for the purchase of new fixtures, ventilated−type ones should be purchased, as fixtures with closed tops collect dirt very quickly. With a ventilated fixture, dust and dirt can flow through instead of settling on the reflector and lamp. A study has shown that the efficiency of lamps in non−ventilated fixtures drops by 38 per cent in 12 months, compared with only 6 per cent in ventilated ones.

Installation of dimmer switches is also advisable, as they vary the amount of light (and energy) used according to need and prolong the life of the lamps they control. It is not uncommon for higher−than−needed−wattage lamps to be fitted, and dimmer switches used to maintain the desired light level. As the efficiency of lamps decreases with age, lighting can be maintained at acceptable level by changing the setting of the switches. However, only solid−state and not resistor type dimmers should be used, as the latter type of dimmer switches do not decrease the amount of wattage used but just reduce the voltage at the lamp. Special types of dimmer switches are also available for fluorescent tubes.

Lamp efficiency affects energy costs, and the light source that provides the most lumens per watt is the most efficient. Table 23 shows the efficiency of different types of light source. As shown in the table, incandescent lamps are the least efficient and should be replaced by other types of light source. Furthermore, replacement of incandescent lamps by fluorescent lamps reduces the energy consumed by the air−conditioning system, since about 90 per cent of the energy used by standard incandescent lamps is converted to heat. The comparisons in table 23 show that a 4−foot light fixture with two 40−watt fluorescent lamps is more efficient than one 150−watt incandescent or two 75−watt incandescent or three 60−watt incandescent lamps, whilst, at the same time, reducing the heat load in air−conditioned areas.

It is not always necessary to install new fixtures, as some fluorescent lamps can be used in incandescent fixtures with the addition of an adapter. It should also be noted that several lighting manufacturers produce fluorescent tubes that can be used in portable lamps and hanging fixtures as well as permanent ceiling receptacles, thereby increasing their versatility. "Full spectrum" fluorescent lamps are available which give the same colour effect as incandescent lamps.

The very efficient high−intensity−discharge (HID) lamps are suitable for most outdoor applications, such as parking lots, walkways and general building illumination. They are not used indoors, as the colour obtained from these lamps is usually not acceptable indoors.

In areas where it is not possible to switch over from incandescent lamps, consideration should be given to replacing pairs of small−wattage lamps by single large−wattage ones which are the more efficient. Where light level is not an important factor, extended−life lamps can be used to effect savings. For example, a 60−watt extended−life lamp provides less light than a regular 60−watt lamp but lasts more than twice as long as a regular one and uses only 54 watts, an energy saving of 10 per cent, as shown in the box on the next page.

| Lamp | Hours burned | kWh used | Cost @ 5c/kWh |
|---|---|---|---|
| 60−watt regular lamp | 2500 | 150 | $7.50 |
| 60−watt extended−life lamp | 2500 | 135 | $6.75 |

Additional savings can be effected by replacing low−efficiency lighting systems with low−wattage high−efficiency lamps. The following shows how to calculate the annual financial savings that can be achieved through the use of high efficiency lamps.

1. (Hours per day) x (Days per week) x (Weeks per year) = Total hours burned per year (*) (A)

2. (Number of lamps) x (Watts saved per lamp)/1000 = Kilowatt (kW) saved (B)

3. (B) (kW saved) x (A) (Hours burned per year) = (C) (Kilowatt hours (kWh) saved per year)

4. (C) (kWh saved per year) x (Cost of electricity & per kWh) = $ ________ Total savings per year

(*) Use 8760 hours if lamp is burning continuously for 365 days.

Table 22. Light levels for various areas and tasks

| Area | Light level in foot−candles |
|---|---|
| Entrance foyer | 30 |
| Corridors, lifts, stairs | 20 |
| Front office | 50 |
| Lobby | |
| – general | 10−20 |
| – reading | 40−70 |
| Offices | 70−100 |
| Dining areas | |
| – cashier | 50 |
| – intimate atmosphere | 3−10 |
| – quick−service type | 50 |
| Kitchen | |
| – preparation area | 70 |
| – clean−up area | 30−50 |
| Bedrooms | |
| – general | 10−20 |
| – bathroom mirror | 50 |
| – reading/desk areas | 40−70 |
| Laundries | |
| – general | 30 |

| | |
|---|---|
| – sorting, ironing | 50–70 |
| Exterior | |
| – entrance | 5 |
| – surroundings | 1 |
| – parking lots | 1–2 |

*Source:* Various codes specifying lighting safety regulations for work areas, passageways and stair wells.

Table 23. Lamp efficiency

| Light source | Lumens per watt |
|---|---|
| Incandescent lamps: | |
| – 40–watt general service | 11 |
| – 60–watt general service | 14.3 |
| – 100–watt general service | 7.4 |
| – 100–watt extended service | 14.8 |
| – 1000–watt extended service | 22 |
| Cool white fluorescent lamps: | |
| – 2 x 24–inch | 50 |
| – 2 x 48–inch | 67 |
| – 2 x 96–inch | 73 |
| HID (high density discharge) lamps: | |
| – 400–watt phosphor–coated mercury | 46 |
| – 400–watt metal halide | 74 |
| – 400–watt high pressure sodium | 100 |
| – 1000–watt metal halide | 85 |

#### B. Task lighting

Energy can also be saved by using appropriate amounts of light in the various areas of the building. For example, referring to table 22, bedrooms require 40 to 70 foot–candles of light in the reading/desk area but only 10 to 20 foot–candles in the general area. Providing illumination at the desk with a specific light will not only satisfy the occupants' needs but also keep the rest of the room at an appropriate light level and save energy in the process. The same holds true for lighting in other parts of the establishment. For example, cooking areas should be provided with 70 foot–candles of light, but, in the dishwashing area, only 30 to 50 foot–candles are needed. In some areas, lowering the light source can eliminate problems. For example, in a room with 10–foot high ceilings, suspending the light source can bring the fixture close to the area to be lit and permit the use of low–wattage lamps.

It should, however, be remembered that good lighting is essential for security, safety and comfort. Change is not beneficial if it saves money but decreases any of these factors. However, if these factors are not affected, existing lamps can be replaced by energy–saving ones, as shown in table 24.

Table 24. Lamp–substitution guide

| Existing light source | Replacement | Illumination | Power savings (watts) |
|---|---|---|---|
| 40–watt fluorescent | 34–watt fluorescent | Approx. same | 6 |
| 40–watt incandescent | 34–watt incandescent | Approx. same | 6 |
| | 22–watt screw–in fluorescent | Higher | 18 |
| 60–watt incandescent | 22–watt screw–in fluorescent | Same or higher | 38 |
| 75–watt incandescent | 27–watt screw–in fluorescent | Slightly less | 48 |
| 75–watt R30 flood | 50–watt ellipsoidal reflector | Same or higher | 25 |
| 100–watt incandescent | 90–watt incandescent | Approx. same | 10 |

| | | | |
|---|---|---|---|
| | 75–watt reflector | Up to 25 per cent higher | 25 |
| | 60–watt reflector | Same or higher | 40 |
| | 40–watt screw–in fluorescent | Approx. same | 56 |
| 150–watt R40 flood | 100–watt par 38 flood | Up to 133 per cent higher | 50 |
| | 90–watt ellipsoidal reflector | Up to 56 per cent higher | 60 |
| 250–watt mercury | 215–watt high pressure sodium | Up to 130 per cent higher | 35 |
| 400–watt mercury | 325–watt metal halide | Up to 40 per cent higher | 70 |
| 1000–watt mercury | 880–watt high pressure sodium | Up to 440 per cent higher | 120 |

**X. Water management**

The role water conservation can play in overall energy management is often ignored, probably because the water bills constitute a small portion of the overall energy bills paid by householders and building managers. Nevertheless, it should be realized that the cost of providing water supplies to urban centres has been increasing steadily over the years, and, at the same time, the amount made available to consumers has decreased in developing countries, owing to rapid increases in the urban population. Hence, a policy of water conservation by consumers is to be actively encouraged, not only because financial savings can be made by the consumers (which is not insignificant) but also because the policy also reduces the strain on existing water–supply facilities. The following pages describe some of the areas where possibilities exist for controlling water consumption in buildings. The financial savings through reduction in water consumption can be quite substantial, especially in large commercial buildings (hospitals, hotels, apartment blocks etc.)

One area where a considerable amount of water is used is the toilet. Old types of flushing toilets consume up to 30 litres of water per flush. This amount can be halved by making use of water–saving toilets. Alternatively, old types of tanks can be retrofitted with "flush–dams" which dam off part of the water normally used for flush, while still maintaining the original pressure–head in the tank, so that the bowl is cleaned as usual. Similarly, devices are available to retrofit certain types of pressure–flush–valve toilets. These are simple to install, require almost no maintenance and reduce water consumption by up to 50 per cent. Another cheap method is to reduce the volume of the tank by filling it with pebble–packed plastic bags. Whatever method is adopted, the reduction in water consumption and the financial savings can be substantial. For example, it can be shown that the reduction in water consumption through the use of efficient toilets in a 50–room apartment building, with an average occupancy per room of three people, can be up to 50,000 litres annually.

Another piece of equipment which is widely used in residential buildings and which wastes a considerable amount of water is the shower. Large families, hotels and guest–houses use a considerable amount of water with standard showerheads which consume up to 55 litres of water per minute. Assuming a 10–minute shower per day per person, over 200,000 litres of water are used on showers by a single person in one year.

Installation of water–saver showerheads or modification to existing showerheads can drastically reduce the water consumption. Inexpensive restrictors that can be inserted in existing showerheads to reduce the water–flow are generally available on the market. However, they do not always produce an acceptable shower. Water–saver showerheads are available which reduce the water flow to about 9 litres per minute while still producing a good drenching shower. There are two basic types of water–saver showerheads: the standard stream–spray type and the turbulating type which aerates the stream of water. Both produce satisfactory showers. Using the 10–minute shower as an example, water–saver showerheads will consume annually only about 33,000 litres of water compared with the 200,000 litres consumed by the conventional showerheads mentioned above.

A third piece of equipment which consumes a considerable amount of water, especially in public places, is the washroom tap. Here also, the flow of water can be reduced without inconveniencing the users, by installing flow restrictors on existing taps or by replacing existing faucets with spray–type faucets. Alternatively, spring–delay–type taps, which restrict flow and limit its time, can be fitted. The flow restrictors and the spray–type faucets reduce the water flow from about 27 litres per minute to about 9 litres per minute, and some spray–type faucets reduce the flow to less than 3 litres per minute.

All the above–mentioned examples illustrate the water–conservation aspect of the various items of equipment. However, since the water consumed by showers or taps is usually heated, reducing water consumption will reduce heat–energy consumption as well, and this aspect can be significant in the financial savings computation. Annex VIII, based on the 10– minute shower, shows the considerable amount of heat energy that can be saved and the financial benefits that can accrue from converting to efficient equipment.

Another priority in a water−conservation programme should be the insulation of hot−water tanks and all pipes carrying hot water. Heat loss through insufficient insulation leads to high energy use and also adds heat to areas that do not need it. Hot−water tanks should be located as close as possible to the areas of use, thus eliminating heat loss that occurs with transmission. For instance, if most of the hot water is used in the kitchen, the tank should be located in the kitchen and not in a far corner or the basement. Use of a single large hot−water tank rather than two small tanks is also recommended for economical water heating. Hot−water tanks should be drained and flushed at least every six months, to prevent scale build−up and deposits, since both reduce heating efficiency. The burners should be serviced regularly, if the tank is heated by gas or oil. Also, all thermostats should be checked frequently.

Solar water heating is gaining in popularity, especially in countries with tropical climates with long daylight hours. Solar water heaters are very effective and, when combined with a large well−insulated water tank, can supply most family needs quite adequately. The possibility of installing such heaters is, therefore, worth investigating. If necessary, an in−line, instant electric water heater, as supplemental heating in case of long periods without adequate sunlight or failure of the solar system, can be installed.

## Annexes

### I. Understanding utility meters and billings

This annex is aimed at helping users read utility meters and explaining some of the factors that influence utility bills.

#### Demand charges

The demand charge on electric bills is, very often, not clear to consumers. This charge is based on the amount of power consumed not the amount of energy consumed. It is calculated on the highest demand (in kW) for electricity over a specified time interval, and the highest demand in kW recorded during a month is charged. This charge may, sometimes, be a very large portion of the total electricity bill. The demand charge is imposed to ensure that each customer pays a fair share of the utility's costs in providing enough power capacity so that it is available upon demand by all consumers simultaneously. There are a number of ways of reducing high demand charges and saving money.

Peak−shaving or load−shedding are the terms most often used to describe techniques for reducing peak electricity demand. It is often possible to balance the demand (so avoiding high peaks and, hence, high demand charges) by developing a "start−up" and "load−spreading" schedule for electrically powered equipment. Obviously, if a number of electric ranges are starting up simultaneously, a high demand will be created at that time. Hence, this practice should be avoided. Similarly, if some equipment is due to come on in the building, other equipment that is already operating can often be shut off temporarily to reduce the peak demand. In some cases, certain activities can be rescheduled to "off−peak" hours. For example, electric water−heaters might be operated in off−peak hours to fill insulated storage tanks with hot water for use during high−demand periods.

Some load management can be achieved manually as suggested, but this is one area where automatic controls should be considered. There are a number of options available including load−shedding equipment, minicomputers and microprocessors. Most of these devices operate on the principle that some items of equipment can be shut down for short periods of time without adversely affecting either building occupants or equipment. For instance, it is unlikely that anyone will collapse from heat prostration if the air conditioning is shut down for brief periods during the day. Automatic controls can sense when the demand load is increasing and compensate by shutting down certain non−essential items of equipment as necessary, to avoid high peaks in demand.

This is a relatively new and rapidly developing area of technology, and the advice of experts in the field should be sought before any funds are committed to load−shedding or computerized controls. Each building has its own requirements and, therefore, has to be studied individually, so that equipment can be selected according to need. There are no off–the–shelf systems that can solve all the problems, but some well–engineered systems have reportedly had a pay–back period of less than one year, so the possibilities of load control should be seriously considered by large users of electricity.

#### Reading the electric meter

An electric meter is a measuring device used to determine the amount of electrical energy consumed, which it records in units of kilowatthours. A kilowatthour (kWh) is defined as being 1,000 watts of electricity consumed for one hour (for example, 10 100–watt bulbs burning for one hour). There are various types of meters in use – some new, some old – but they all operate on the same principles. Most meters are of the "direct" type and are not difficult to read, but assistance in reading the meter can be sought from the local utility company, in case of difficulty (e.g., in case of "dial" type meters). To determine the electrical consumption, simply take the difference between two readings and multiply this by the multiplier (if the meter has one).

As stated previously, the electrical billing might include a demand charge as well as a consumption charge. The electric meter will incorporate some type of volt–amp meter to record the demand in kilovolt–amperes (kVA). As the types of demand meters in use vary from one location to another, it is advisable to consult the local utility on how to read them.

#### Water meters

Most water meters are not difficult to read. The new meters are of the "direct" type and are as easy to read as the odometer in an automobile (e.g., 0 0 0 0 6 2 4 4). There might also be a pointer or a dial to indicate when water is flowing through the meter. Other types of water meters look similar to the electric ones and are read in the same way.

Water meters will likely record consumption in cubic metres ($m^3$), but there might be some that still read in cubic feet or gallons. Conversion factors are:

1 cubic metre = 35.314 cubic feet
1 cubic foot = 6.25 imperial gallons
1 cubic metre = 220.7 imperial gallons

In some urban areas, the municipality levies a "sewer surcharge" on the amount of water supplied to each residence or business. It is calculated as a percentage of the water charge and might be as high as 100 per cent. The basic reason for this surcharge is to compensate the municipality for costs associated with sewage treatment and disposal. The percentage might not be stated on the bill, but this information is easily obtained from the local public–utility authority.

## II. Abbreviations

| | |
|---|---|
| A | (amp) ampere |
| ac | (AC) alternating current |
| bhp | brake horsepower |
| Btu | British thermal unit |
| cd | candela |
| COP | coefficient of performance |
| cfm | cubic feet per minute |
| cu ft (cf) | cubic feet |
| dc (DC) | direct current |
| deg | degree |
| eff | efficiency |

| | |
|---|---|
| EUI | energy utilization index |
| ft | foot |
| gal | gallon |
| gmp | gallons per minute |
| h (hr) | hour |
| HID | high intensity discharge (lamps) |
| hp | horsepower |
| HPS | high pressure sodium (lamps) |
| HVAC | heating, ventilating and air conditioning |
| Hz hertz | (or cycles per second) |
| i.d. | inside diameter |
| in | inch |
| j | joule |
| K | degree Kelvin |
| kg | kilogram |
| kVA | kilovolt ampere |
| kVAR | kilovolt ampere reactive |
| kW | kilowatt |
| kWh | kilowatthour |
| lb | pound (weight) |
| LCC | life−cycle costing |
| lm | lumen |
| lx | lux |
| M | million or mega |
| MBtu | million Btu |
| min | minute |
| Mj | megajoule |
| mo | month |
| o.d. | outside diameter |
| oz | ounce |
| PF | power factor |
| psi | pounds per square inch |
| psia | pounds per square inch absolute |
| psig | pounds per square inch gauge |
| q | rate of heat transfer (Btu/h) |
| RH | relative humidity |
| rpm | revolutions per minute |
| sat | saturated |
| sec | second |
| sq ft | square feet |
| std | standard |
| t | temperature |
| V | volt |
| W | watt |
| wk | week |
| yr | year |

## III. Thermal conversion factors

| *To convert from* | *To* | *Multiply by* |
|---|---|---|
| Cubic feet, natural gas | therms | 0.01 |
| Cubic feet, natural gas | Btu | 1,000 |
| Cubic metre, natural gas | Btu | 35,000 |
| Therms, natural gas | cubic feet | 100 |
| Therms, natural gas | Btu | 100,000 |
| Gallons, No. 2 fuel oil | Btu | 166,200 |
| Gallons, No. 4 fuel oil | Btu | 173,000 |
| Gallons, No. 5 fuel oil | Btu | 180,000 |
| Gallons, No. 6 fuel oil | Btu | 182,000 |
| Kilowatt–hours | Btu | 3,413 |
| Kerosene | Btu 16 | 1,000 |
| Horsepower–hours | Btu | 2,544 |
| Horsepower–hours | kWh | 0.746 |
| Horsepower | Btu/minute | 42.4176 |
| Horsepower (boiler) | Btu/hour | 33.79 |
| Liquified butane (welding) | Btu/gallon | 103,300 |
| Liquified propane (superior) | Btu/hour | 12,000 |

## IV. Metric/imperial unit conversion factors

| *To convert from* | *To* | *Multiply by* |
|---|---|---|
| *Volume conversions* | | |
| Cubic feet | Cubic metres | 0.0283 |
| Cubic feet | Litres | 28.31685 |
| Cubic metres | Cubic feet | 35.314667 |
| Gallons (US) | Gallons (Imperial) | 0.80 |
| Gallons (Imperial) | Gallons (US) | 1.25 |
| Gallons (Imperial) | Litres | 4.546090 |
| Gallons (US liquid) | Litres | 3.785412 |
| Litres | Imperial gallons | 0.219969 |
| *Energy conversions* | | |
| British thermal units | Joules or | 1.05435 x 10 |
| (thermochemical) | Wattseconds | 1055.06 |
| British thermal units | Kilowatt–hours | 0.0002931 |
| Joules | British thermal units | 0.0009485 |
| Kilowatt–hours | British thermal units | 3409.52 |
| Kilowatt–hours | Horsepower | 1.34102 |
| *Power conversions* | | |
| British thermal units/hour | Kilowatts | 0.0002931 |
| Btu/pound | Joules/gram or Kilojoules/kilogram | 2.326 |
| Horsepower | Kilowatts | 0.746 |
| Horsepower | Joules/second | 746 |
| Horsepower (mechanical) | Horsepower (boiler) | 0.0760181 |

| | | |
|---|---|---|
| Horsepower (boiler) | Horsepower | 13.1548 |
| Horsepower (boiler) | Horsepower (electrical) | 13.1495 |
| Horsepower (electrical) | Watts | 746 |

*Lighting conversions*

| | | |
|---|---|---|
| International candela | Lumens/steradian | 1 |
| Foot−candles | Lumens/square foot | 1 |
| Foot−candles | Lumens/square metre | 10.7639 |
| Foot lamberts | Candela/square metre | 3.4263 |
| Lamberts | Candles/square centimetre | 0.3183 |
| Lumens | Spherical candlepower | 79.5774 |
| Lux | Foot−candles | 0.0929 |

**V. Energy conversion factors**

The following typical values for conversion factors can be used when actual data are unavailable. Hydrocarbons are shown at the high heating value, i.e., on the wet basis. Some items listed are typically feedstocks but are included for completeness and as a reference source. The conversion factors for coal are approximate, since the heating value of a specific coal is dependent on the particular mine from which it is obtained. Consistent factors must be used when calculating base year and current year energy usage.

| *Energy Type* | *Metric* | *British* |
|---|---|---|
| **Coal:** | | |
| Sub−bituminous | 22,100 megajoules/ton | $19.0 \times 10^6$ Btu/ton |
| Lignite | 16,700 megajoules/ton | $14.4 \times 10^6$ Btu/ton |
| Metallurgical | 29,000 megajoules/ton | $25.0 \times 10^6$ Btu/ton |
| Anthracite | 30,000 megajoules/ton | $25.8 \times 10^6$ Btu/ton |
| Bituminous | 32,100 megajoules/ton | $27.6 \times 10^6$ Btu/ton |
| **Coke:** | | |
| Raw | 23,300 megajoules/ton | $28.0 \times 10^6$ Btu/ton |
| Metallurgical | 30,200 megajoules/ton | $26.0 \times 10^6$ Btu/ton |
| Calcined | 32,600 megajoules/ton | $28.0 \times 10^6$ Btu/ton |
| **Pitch:** | 37,200 megajoules/ton | $32.0 \times 10^6$ Btu/ton |
| **Oil:** | | |
| Crude | 38.5 megajoules/litre | $5.8 \times 10^6$ Btu/bbl |
| No. 2 | 38.68 megajoules/litre | $5.88 \times 10^6$ Btu/bbl |
| | | $0.168 \times 10^6$ Btu/IG |

| | | |
|---|---|---|
| No. 4 | 40.1 megajoules/litre | 6.04 x $10^6$ Btu/bbl |
| | | 0.173 x $10^6$ Btu/IG |
| No. 6 (C) | | |
| 1.0% sulphur | 40.5 megajoules/litre | 6.11 x $10^6$ Btu/bbl |
| | | 0.174 x $10^6$ Btu/IG |
| 2.5% sulphur | 42.3 megajoules/litres | 6.38 x $10^6$ Btu/bbl |
| | | 0.182 x $10^6$ Btu/IG |
| Kerosene | 37.68 megajoules/litre | 0.167 x $10^6$ Btu/IG |
| Diesel fuel | 38.68 megajoules/litre | 0.172 x $10^6$ Btu/IG |
| Gasoline | 36.2 megajoules/litre | 0.156 x $10^6$ Btu/IG |
| Natural gas | 37.2 megajoules/m3 | 1000 x $10^6$ Btu/MCF |
| Butane | 45.2 megajoules/Kg | .01945 x $10^6$ Btu/lb |
| Propane | 50.3 megajoules/kg | .02165 x $10^6$ Btu/lb |
| | 26.6 megajoules/litre | 0.1145 x $10^6$ Btu/IG |
| LPG | 45,200 megajoules/ton | 38.9 x $10^6$ Btu/ton |
| | 24.51 megajoules/litre | 0.1055 x $10^6$ Btu/IG |
| **Wood (air-dried):** | | |
| Hardwood | 9,300 megajoules/ton | 8.0 x $10^6$ Btu/ton |
| Pine | 13,600 megajoules/ton | 11.7 x $10^6$ Btu/ton |
| **Charcoal:** | | |
| Briquette | 28,900 megajoules/ton | 24.9 x $10^6$ Btu/ton |
| Bagasse (39% moisture) | 12,600 megajoules/ton | 10.8 x $10^6$ Btu/ton |
| Coffee husks | 15,080 megajoules/ton | 13.0 x $10^6$ Btu/ton |
| Nut shells | 19,700 megajoules/ton | 16.9 x $10^6$ Btu/ton |

## VI. Definitions

*Air changes (AC).* The number of times that the air volume of a given space is replaced in a one-hour period.

*Ambient air.* The air surrounding an object.

*Ambient temperature (of a light).* The temperature immediately surrounding a lamp or luminair (knowledge of the ambient temperature of a light is only crucial in high heat environments).

*Ampere.* A unit of measurement of the flow of electrical current.

*Attic.* Refers to any section of a roof area which is large enough to admit a person (see roof space).

*Ballast.* A device used with gaseous discharge lamps, such as fluorescent tubes, to limit current flow and to provide voltage at proper design levels. Ballasts consume low amounts of energy (6−10 watts).

*Base load (heating system).* Load on heating system which occurs regardless of outside temperatures, due to hot water, laundry, kitchen equipment etc.

*Billing demand.* The charge on electrical bill for the maximum demand called for during a billing period.

*Billing load.* The maximum peak load in any billing period.

*Blow down.* The discharge of water from a boiler or cooling−tower sump that contains a high proportion of total dissolved solids.

*Boiler capacity.* The rate of heat output in Btu/hr or boiler hp, measured at the boiler outlet under rated conditions.

*British thermal unit (Btu). A* unit of heat energy defined as the amount of heat required to raise one pound of water by one degree Fahrenheit.

*Building envelope.* All exterior parts of a building, such as walls, windows and roofs, that are subjected to elements of the weather.

*Coefficient of utilization (light).* The ratio of lumens on the work surface to the total amount of lumens emitted by a lamp.

*Condensate.* Water caused by changing the state of water vapour that is steam or moisture in air from a gas to a liquid, usually caused by cooling.

*Condenser. A* heat exchanger that removes heat from a vapour, changing it to its liquid state. In a refrigeration system, this is the component that enables the refrigerant vapour, that has passed through the compressor, to give up heat and condense back to a liquid.

*Conduction. A* method by which heat is transferred through a material or between different materials as a result of their direct contact.

*Convection.* Heat transfer between two objects by means of an intermediate medium, such as air.

*Cooling load.* Rate of heat removal necessary for maintaining a space at a desired temperature, usually offset by supplying air at a temperature below that desired. Heat is removed from the space as the supply air is warmed up to the space temperature.

*Damper.* A device capable of altering the amount of air passing through a duct, air outlet or inlet.

*Degree−day, cooling. A* measure of the need for air−conditioning based on the outdoor temperature. Cooling−degree−days are expressed as the outdoor mean temperature minus 18 degrees Celcius (65 degrees Fahrenheit). For example, a day with an average temperature of 22 degrees Celcius would result in 22 degrees Celcius −18 degrees Celcius = 4 degree−days.

*Degree−day, heating. A* measure of the coldness of the weather experienced, is expressed as the difference between 18 degrees Celcius (65 degrees Fahrenheit) and the outside mean daily temperature.

*Demand (electrical).* Peak rate of electric−power consumption in kilowatts, during a monthly billing period. It is usually averaged over a specific time period, such as 30 minutes.

*Demand scheduling (load factor).* The ratio of the average and peak demands. The load factor can be calculated by dividing the total demand in kilowatt hours by the peak demand (kW) and then dividing this figure by the number of hours in the month.

*Dew point.* The temperature at which moisture would begin to condense out of the air when the air is cooled.

*Economizer cycle. A* method of operating a ventilation system to reduce refrigeration load. Whenever the outdoor air conditions are more favourable (lower heat content) than return air conditions, outdoor air quantity is increased.

*Energy.* The capacity for doing work. It takes a number of forms that may be transformed from one into another, such as thermal (heat), mechanical (work), electrical and chemical. In customary units, it is measured in kilowatt−hours (kWh) or British thermal units (Btu).

*Energy efficiency ratio (EER).* The ratio of net cooling capacity, Btu/h, to total rate of electric input, in kilowatt−hours under designated operating conditions.

*Energy utilization index (EUI).* A reference that expresses the amount of total energy consumed in a building over a certain period of time. If the weather (degree−days) is included, it determines the number of Mj consumed per degree−day per square metre per year.

*Evaporator.* A heat exchanger that adds heat to a liquid, changing it to a gaseous state. In a refrigeration system, this device would absorb the heat.

*Foot−candle.* A measure of illumination. General rate class. A type of electrical billing used by some utility companies to offer their customers a lower billing rate, by separating into different groups industrial, commercial and residential users.

*Heat exchanger.* A device designed to transfer heat between two physically separated fluids or gases, most often used to scavenge heat from waste hot water or hot air being exhausted from a building.

*Heat gain.* The amount of heat gained by a space from all sources, including people, lights, machines and sunshine. The total heat gain represents the amount of heat that must be removed from a space in order to maintain indoor comfort conditions.

*Heat, latent.* The amount of heat needed to produce a change in state, e.g., from a liquid to a gas.

*Heat loss.* The amount of heat lost by a building when the outside temperature is lower than the inside temperature. Heat loss represents the amount of heat that must be provided to a space in order to maintain indoor comfort conditions.

*Heat pump.* A refrigeration machine capable of either heating or cooling by reversing its flow. When used for heating, it extracts heat from a low−temperature source and raises its temperature to the point at which the heat can be used.

*Heat, sensible.* Heat resulting in a temperature change without a change in state.

*Heating value.* The energy content of a fuel per unit weight or unit volume − sometimes, referred to as calorific values. Some typical heating values are:

(a) Liquified petroleum gas−butane: 4,031 Mj per kg
(b) No. 2 heating oil: 32.0 per Mj per litre
(c) Electricity: 3.6 Mj per kilowatt−hour

*Horsepower (hp).* A measurement of the rate of doing work by a mechanical instrument (fan, motor, boiler etc.). It is the amount of work required to raise 550 pounds one foot in one second.

*Humidity (relative).* A measurement of the amount of moisture in the air.

*Humidistat.* A device used to control relative humidity automatically.

*HVAC.* Abbreviation referring to heating, ventilating and air conditioning.

*Infiltration.* The process whereby outside air enters (or leaks) into a building by natural forces, through cracks in the building envelope and around windows and doors.

*Insolation.* Solar radiation that arrives at the earth's surface.

*Kilovolt−amps (kVA).* Product of volts X amps divided by 1,000 (for single−phase power). For three phase power, this would also be multiplied by a factor of 1.73.

*Kilowatt (kW).* Standard unit for measuring electrical power: equal to 1000 watts.

*Kilowatt−hour (kWh).* Standard unit for measuring electrical energy consumption, obtained by multiplying the number of kilowatts consumed by the number of hours.

*Lamp life.* An estimate of the number of hours a lamp can be expected to burn.

*Lamp−lumen depreciation.* A reduction of light output of a lamp as it ages. This is an inherent characteristic of all lamps but varies significantly with the type of lamp. Incandescent lamps, for example, depreciate in lumen output at a much faster rate than high−pressure sodium lamps. Dirt−accumulation on lamps also reduces their lumen output.

*Life−cycle cost.* The cost of equipment, including initial purchase price and operating and maintenance costs, over its entire life.

*Load profile.* Usually in graph format, this represents a building's heating, cooling and electrical load over time.

*Lumen.* A measure of the amount of light produced by an electric lamp. The amount of lumens (or light) per watt will vary among lamps of different rated wattages and also among lamps having the same rated wattage. For example, 100W lamps can produce between 1000 and 1750 lumens.

*Luminaire.* A complete lighting unit, consisting of a lamp or lamps, together with the pans designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.

*Make−up air.* Air required to replace air exhausted through the ventilation system. Problems with insufficient make−up air most often occur with kitchen exhaust systems.

*Make−up water.* Water supplied to a system to replace that lost by blow down, leakage, evaporation etc.

*Orsat apparatus. A* device for measuring the combustion components of furnace or boiler flue gases.

*Outside air.* Air taken from the outdoors and not previously circulated through the system.

*Payback−period (for energy−saving devices).* The length of time taken by energy savings to recover the money spent on a project designed to save energy. To calculate the payback period, the cost of the investment is divided by the expected energy savings in one year.

*Power.* The time−rate of doing work, as applied to machines. In connection with the transmission of energy of all types, power refers to the rate at which energy is transmitted. In customary units, it is measured in watts (W) or British thermal units per hour (Btu/h).

*Power factor.* Ratio of kW to kVA. Utility companies charge a penalty for poor power factor of motors (usually when they operate below 0.9 power factor).

*Rate schedule.* The list of charges that the utility applies to its customers for the provision of energy.

*Recovered energy.* Energy used that would otherwise be wasted from an energy−utilization system.

*Reflectance.* The ratio of the light reflected by a surface to the light falling upon it.

*Reheat.* The application of sensible heat to supply air that has been previously cooled below the temperature of the conditioned space, by either mechanical refrigeration or the introduction of outdoor air to provide cooling.

*Resource impact factor (RIF).* The social and environmental issues resulting from the use of certain fuels in particular regions of the country. An example is acid rain generated by the burning of coal, which eventually "kills" lakes and streams.

*Resource utilization factor (RUF).* The relation of energy used in a building to the gross amount of energy required to generate, convert and transport raw energy from the sources to the building. For example:

| *Fuel* | *RUF* |
|---|---|
| Natural gas | 1.0 |
| Furnace oil | 1.2 |
| Electricity | 3.08 |

*Roof space.* Refers to any section of a roof area which is not large enough to admit a person (see attic).

*Roof−top unit.* An HVAC system located on the roof and connected to ducts.

*RSI−value.* R−value of material expressed in metric (SI) units.

*R−value.* The thermal resistance value of a material. The higher the R−value, the better the resistance to transferring heat. R−values are most commonly used in insulation products: however, every type of material (glass, brick, wood) has an R−value.

*Specific heat.* The amount of heat (e.g., Btu) that must be added to one pound of a substance, in order to raise its temperature one degree. For example, water has a specific heat of 1.0 Btu/lb/degree F.

*Stratification.* A persistent pattern of uneven temperatures in still or moving air. In a room, the pattern occurs when warm layers of air remain near the ceiling and cool air settles near the floor. In ventilating duct systems, it results when warm and cold air streams are inadequately mixed.

*Temperature differential.* The temperature difference between inside and outside temperatures.

*Terminal device.* The means by which the transformed energy from a system is finally delivered, for example, registers, diffusers, lighting fixtures and faucets.

*Therm.* Unit for measuring quantity of natural gas. One therm equals 100,000 Btu.

*Thermal break (or barrier).* Generally refers to a separation between the inner and outer frames of a metal window frame. The separation is usually made of a plastic material and reduces the conductivity or heat loss through the metal frame.

*Thermal conductance (U−value).* The rate of heat transmitted through one square metre of a stated thickness of homogeneous material when a temperature difference of 1°C exists between the two surfaces of the material.

*Vapour barrier.* A moisture impervious layer used in the building structure. When insulating, it is necessary to install a vapour barrier to prevent moisture from migrating through the insulation and causing damage, such as wood rot.

## VII. Instrumentation

| Type of measurement | Description of instrument | Typical price ($US) | Comments |
|---|---|---|---|
| Temperature | Thermometer | 5−30 | Glass type thermometers can measure room temperature. Metal dial thermometers are ideal for stack temperature. Accuracy + 5 degrees adequate. |
| | (Thermocouple and digital) readout | 200−500 | |

| | | | |
|---|---|---|---|
| | | | Easy to read, remote indicating, accurate. |
| Flue gas composition | Orsat for measuring carbon−dioxide and oxygen | 400 | The Orsat is extremely accurate but it is not readily portable. The Orsat requires care in operation. |
| | Electronic oxygen and combustibles Indicator | 2,000 | Almost instant response portable, accurate, very handy for boiler tuning needs calibration often. |
| | Smoke spot test for measuring unburned of smoke fuel | 15 | Good qualitative indication concentration. |
| | Carbondioxide and oxygen indicators (commonly called "dumb bells" due to shape.) | 75 each | Easy to use, but not precise. Errors of + 1 percentage point in reading can occur. Good to get "ball park" figure in short time. |
| | CO Indicator. Consists of accurate metering pump to draw sample through a tube containing a chemical which undergoes a colour change. Length of chemical in the tube undergoing colour change indicates concentration of CO. | 150 | Relatively accurate, compact, portable, cheap, sufficient for boiler tuning. |
| Water Quality | Apparatus for measuring concentration of hardness, sulphite, alkalinity, TDS, and amines by titration. | 3−30 (per test) | Drop set kits available for rapid, rough determination of end points. |
| | | | Measuring burrettes are available for accurate end−point determination. |
| | | | Reagents are available in tablets − count tablets for end points |
| | Apparatus for measuring phosphate and pH by color comparison. | 15 (per test) | Accurate and fast |
| | Conductivity meter for measuring TDS. | 100−400 | Accurate and fast |
| Steam leaks | Ultrasonic detector | 500−900 | Accurate |
| Humidity | Hygrometer (sling psychrometer) | 10−20 | A precision pocket−size instrument |
| | Hygrometer (electric psychrometer) | 30−50 | Provides extremely accurate wet and dry bulb temperatures for determining relative humidity and low point |
| Air flow | Simple air−flow meters (velometers) usually consists of a meter, measuring probes, range selector and connecting hoses. | 100−150 | Using the probes the air−velocity in heating, ventilating or air−conditioning systems can be accurately measured. |

**VIII. Water savings using water saver showerhead**

Water use (calculations based on one 10−minute shower per day)

| | |
|---|---|
| Conventional showerhead | |
| 55 litres per minute | = 550 litres |
| Water−saver showerhead | |
| 9 litres per minute | = 90 litres |
| Savings (one shower) | = 460 litres |
| Annual savings | = 460 litres x 365 days<br>= 167,900 l/yr. |

At least half of this water (83,950 litres.) would be hot water. If water enters the building at about 20°C, it must be raised to about 70°C. The following computation shows the number of Mj required to raise the temperature of the water by 50 °C (70 ° – 20 ° = 50 °C; 1 litre of water weighs 1000 grams; and 1 cal = 4.187 j):

50 x 1000 x 83,950 x 4.187 = 17,575,000,000 j = 17,575 Mj

**Cost to heat the water:**

Using the following conversion:

| | |
|---|---|
| 1 kilowatt–hour | 3.6 megajoules. |
| 1 gallonheating oil | 32 megajoules per litre |
| 1 cubic foot natural gas | 45.2 megajoules per kg |

**Using electricity:**

$$\frac{17{,}575\ \text{Mj}}{3.6\ \text{Mj}} = 4881.94\ \text{kilowatt-hours} @ \$.05/\text{kWh}^{a/} = \$244.10$$

**Using oil:**

$$\frac{17{,}575\ \text{Mj}}{32\ \text{Mj}} = 549.22\ \text{litres} \times \$0.31/\text{litre}^{a/} = \$170.25$$

**Using gas:**

$$\frac{17575\ \text{Mj}}{45.2\ \text{Mj/kg}} = 388.82\text{kg butane} \times \$0.25/\text{kg}^{a/} = \$97.20$$

[a/] These unit costs, although taken from real costs, are purely illustrative. Actual costs would vary, depending upon location.

**Cost of water saved:**

| | |
|---|---|
| Cost of purchasing 200,000 litres at $0.044/litre[a/] | = $88.00 |
| Add 60 per cent[1/] sewer surcharge | = $52.80 |
| Total | = $140.80 |

**Summary of savings:**

| | *Electricity* | *Oil* | *Gas* |
|---|---|---|---|
| Cost of heating water | $244.10 | $170.25 | $97.20 |
| Cost of water including sewer surcharge | $140.80 | $140.80 | $140.80 |
| Potential annual savings | $384.90 | $311.05 | $238.00 |

**The variables:**

The above calculations contain several variables:

(a) Many existing showers have a flow rate different from the 55 litres per minute mentioned in the example;

(b) The average shower might take more than 10 minutes (e.g., hair washing may lengthen the shower time considerably);

(c) The percentage of hot water might be more than 50 per cent (some estimates are as high as 70 per cent hot water);

(d) Water temperature might be raised more than 50 °C;

(e) Sewer surcharges in some cities are much higher than the 60 per cent figure used in this example;

(f) The effectiveness of restrictors to ensure a good spray pattern is very dependent on water supply pressure.

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