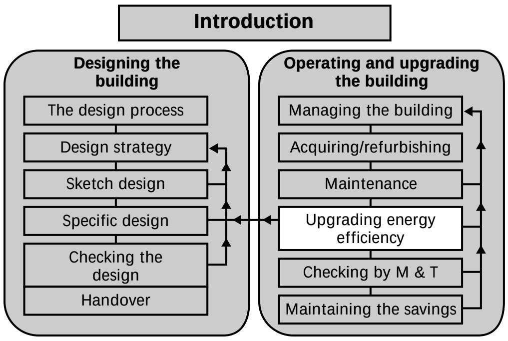
18 Retrofitting energy saving measures



This section provides an overview of the process of retrofitting energy efficiency measures when upgrading existing buildings (see the principles at the front of this Guide). It is aimed predominantly at the energy manager/consultant. Section 19 provides a checklist of specific measures that can be introduced. Where measures require significant amounts of design, reference should be made to the relevant section in Part A.

18.0 General

The key to retrofitting cost-effective measures in existing buildings is to:

— identify high energy users

— establish the potential for energy saving through measurement, audits etc.

— identify practicable measures to achieve these savings

— establish the financial case for introducing these measures, as well as other benefits

— implement the savings in a planned way with the least disruption to the building

— monitor the savings to confirm they have been achieved and to ensure they are maintained (see sections 20 and 21).

Energy consumption of existing buildings can often be reduced by about 20% by introducing simple and cost-effective measures, usually with payback periods of less than 5 years. Any cost savings add directly to the profitability of organisations once the initial capital cost has been repaid. Identifying and implementing retrofit energy saving measures can, therefore, be highly cost-effective often with significant spin-off benefits including reduced environmental emissions and higher productivity[1].

Measures range from changes to working practices through low cost/no cost items to more significant alterations to the building and its services[2,3]. Many of these measures may require little or no design input and can be implemented by the building manager using contractors. Refurbishment is an ideal opportunity to improve energy efficiency, as discussed in section 15.

18.1 Developing a programme

While it is possible to introduce *ad hoc* measures, it is usually more beneficial to develop a prioritised programme to ensure best use of the funds available and that supports the original design intent, while minimising disruption to the building.

18.1.1 Commitment and co-operation

An energy efficiency programme requires commitment from senior management. A senior member of staff must lead activities, and be responsible for ensuring the continued commitment and co-operation of management and staff (see section 14). The energy manager should initiate the following actions:

— Identify those measures and expected benefits that can produce energy savings with minimal expenditure.

— Produce a cost-benefit analysis for all measures that incur capital expenditure or changes in operational requirements.

— Obtain agreement on priorities, level of funding and economic criteria.

— Explain the impact of proposed energy efficiency measures on occupants and their work.

— In tenanted buildings, identify those aspects of the programme that are related to conditions in the lease and list the advantages to the owner and the tenants.

— Highlight the results achieved by others in the field of energy efficiency.

18.1.2 Planning

Since planning is essential, the first action should be to produce a fully costed plan of action, and obtain agreement to proceed with the programme, either as a whole or in stages.

All the original design information on the building and its services, plus the records, drawings, and maintenance and operating manuals, should be collected and reviewed in order to provide a good understanding of the original design intent (see section 14).

A simple audit of annual energy consumption based on invoices will establish if actual energy use is in line with expectations and targets (see section 20). It should then be possible to prepare an initial budget and action plan for discussion with maintenance and operations staff, for subsequent approval by owners and tenants. The action plan should include the following items:

— Preparation of a more detailed energy audit and building survey(3–7).

— Identification of measures where energy savings could be made.

— The effects of energy saving measures on the internal environment and activities within the building.

— Cost-benefit assessment of proposed measures.

— A list of priorities for the proposals.

— Involvement of maintenance staff and building occupants in additional activities.

— The implementation of the programme including timescales and disruptions which could occur to normal operation.

— Identification of external sources of information which could be needed in assessing the returns achieved in the programme, e.g. meteorological data, case studies of energy usage in similar buildings.

— The planning of a monitoring and recording system to assess the effect of the programme.

Figure 18.1 shows the main stages in the retrofit process and indicates where professional assistance might be considered.

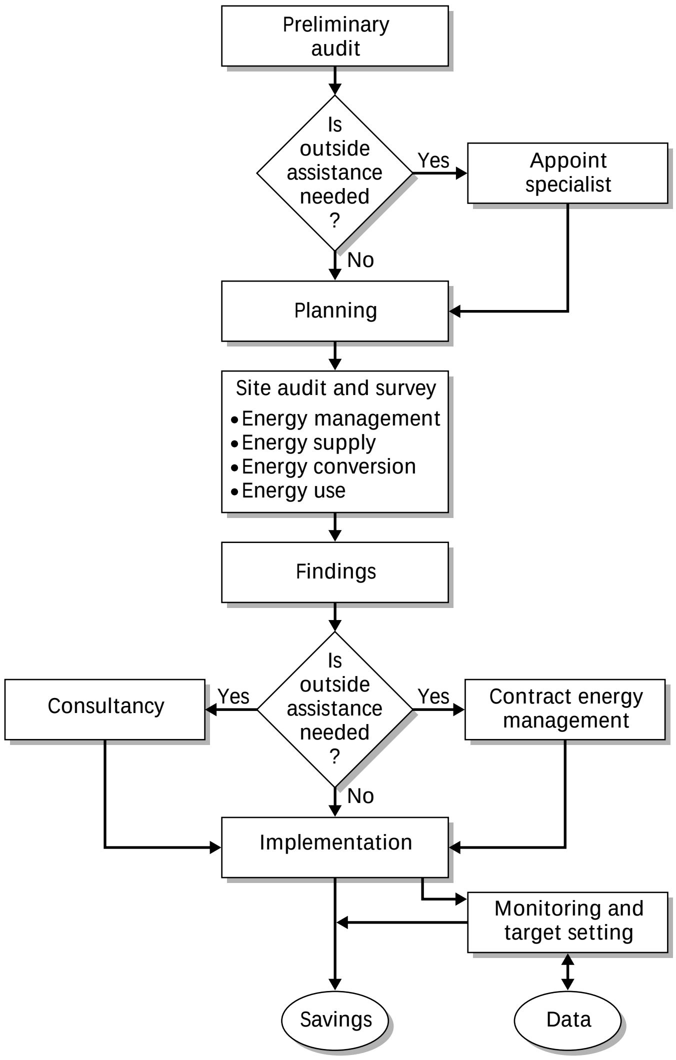


Figure 18.1 The retrofit process (adapted from CIBSE Applications Manual AM5(3))

18.2 Identifying measures

Energy audits and surveys provide the information needed to make decisions on which are the most cost effective measures(3–7).

18.2.1 Energy surveys and audits

18.2.1.1 Energy audits

Like a financial audit, an energy audit is an attempt to allocate a value to each item of energy consumption over a given period, and to balance these against overall energy use(3–7).

An energy audit, however imprecise, should be undertaken early in any energy efficiency programme to identify where energy is being used. It is then possible to direct energy efficiency action towards the highest consumers. Energy audits can bring to light and eliminate hitherto unknown mistakes (such as incorrect billing) and/or unnecessary uses of energy. Auditing should become progressively more accurate and can use all the analysis techniques shown in section 20.

Where a whole stock of buildings is being considered, simple performance indicators (e.g. (kW h)/m^2 for fossil fuel and electricity) can be used to set up league tables of the highest consumers. Investigations should then target the worst buildings first, ultimately leading to detailed energy surveys where high consumption can not be easily explained and rectified (see section 20).

18.2.1.2 Energy surveys

An energy survey(3–7) is an on-site technical investigation of the supply, use and management of energy to identify specific energy saving measures. Two basic levels of survey, concise and comprehensive, are shown in CIBSE Applications Manual AM5(3) with standard specifications

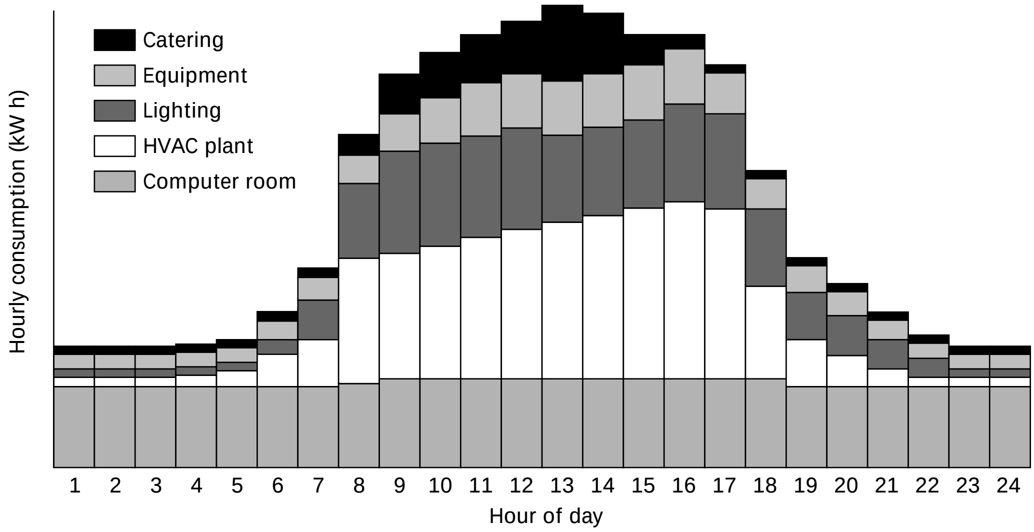


Figure 18.2 Identifying individual uses within the demand pattern[4] (reproduced from DETR Fuel Efficiency Booklet No.1. Crown copyright (1993))

of what a survey should cover. These can be used to brief the survey team.

The survey should cover the main items affecting energy use, including the following:

— the building: levels of insulation, ventilation, air infiltration etc.

— the pattern of use: periods of occupancy, the types of control, the temperatures and humidities maintained, the use of electric lighting, the activities and processes being undertaken, including their operating temperatures, insulation etc.

— the main building services: primary heating, cooling and air handling plant

— electric lighting: quality, illuminance, luminance efficiency, extent to which daylight could reduce energy use, flexibility of control etc.

— the transport of energy within the building: fans and pumps, insulation of hot water and steam pipes and air ducts, evidence of leakage etc

— the plant room: state and condition, insulation of boilers, tanks, pipe work, recovery of condensate, plant efficiency checks etc.

The survey should also assess energy management, determining who is responsible for energy management in each department. The assessment should include how energy consumption is reviewed, recorded and analysed. A check should be made as to whether the analysis correlates with departmental activity.

Measurements should be made systematically with correctly calibrated instruments. Guidance on instrumentation is given below. In the absence of instrumentation, it is possible to estimate energy use from nameplate and manufacturers' data, combined with an assumed proportion of full load operation. Such estimates are, however, second-best to actual measurement. Early in the energy efficiency programme, the larger energy-using systems should be instrumented, enabling actual energy consumption to be measured.

Comprehensive surveys should aim to reach a detailed breakdown of the constituent parts of typical load patterns. This allows the principal components to be identified and, in particular, the base load, as indicated in Figure 18.2. This is particularly helpful in indicating possible opportunities for reducing energy consumption.

Recent work[8] has emphasised the importance of accurate key data such as floor area, and the benefit of assessing the consumption of different energy sources separately, particularly electricity and fossil fuels. This work has provided a method for achieving a more accurate apportionment of end-uses by:

— using the most reliable data sources available

— reconciling the apportionment results with all useful metered data and avoiding *ad hoc* adjustments

— assessing the reliability of data and of the apportionment; if justified, seeking more data

— using specific techniques to obtain more details on uncertain loads.

These methods[8] require little or no extra work but can provide more useful and reliable information in understanding the building's detailed performance.

18.2.1.3 Instruments and measurements

Good instrumentation and measurement is an essential part of investigating and implementing retrofit measures. Measurements taken as part of energy surveys can indicate the potential for savings but it is also important to include metering in the implementation package in order to monitor the future savings achieved. A BMS can provide a useful source of measurements although the accuracy of any information needs to be assessed carefully. More detailed information on consumption can be obtained through spot check measurements, demand profile recording and metering selected items of plant[9].

Table 18.1[3] shows some common portable instruments found useful during surveys. All should have valid calibration certificates to ensure confidence in the results.

Table 18.1 Useful survey instruments

Instrument	Purpose/application
Electrical load profile recorder	Indicates pattern of overall building load or local use (e.g. 24 h, 7-day); recordings can include (kVA h), V, A, power factor, dependent on type; useful for analysis, auditing and tariff review.
Clip-on power meter	Useful for auditing and checks on lighting circuits, motor consumption and small power usage
Data logger (or chart recorder)	Inputs can include space temperature, duct air temperature, water temperature and relative humidity; pulsed outputs can also be used to provide gas/oil/water consumption, and indications of system and control performance
Boiler combustion test kit	Flue gas analysis; temperature, O_2, CO_2, CO, smoke number; spot check on boiler efficiency to highlight need for burner adjustment, boiler cleaning, etc.
Light meter	Spot checks on illuminance levels
Digital temperature indicator	Surface and immersion probes; spot checks on space/water/duct temperatures; surface temperatures for assessment of quality of pipework and vessel insulation
Sling hygrometer	Spot checks on wet and dry bulb space temperatures
Anemometer (or pitot tube and manometer)	Air flow rate to calculate supply/extract volumes, air change rates

Meters installed in an area or on an individual plant can be used to record consumption. The cost of sub-metering can usually be justified on major loads, particularly where little information on energy use is currently available (see section 4).

18.2.2 Level of detail required

The level and extent of an energy audit/survey should be determined by the likely potential for savings and the necessary investment in time and resources. In a small building with a relatively low energy bill, it may not be worth investing a great deal of time and effort in a survey. Large, complex buildings or sites will usually merit a detailed investigation of all areas of energy use(3).

A simple walkabout survey is often sufficient to identify some low-cost/no-cost measures and some areas requiring further study. A detailed survey will be required to identify and assess more complex and costly measures.

18.2.3 Integrating the measures

Energy analyses or surveys often identify stand-alone measures that will save energy on specific items. However, the wider effects of any measures should be considered carefully in relation to the whole building and the original design intent. Often, one set of problems can be exchanged for another. For example, turning off humidifiers on air conditioning plant to reduce electricity consumption may lead to control problems and complaints of dryness.

It is essential that these measures are co-ordinated so that they form an integrated package, avoiding conflict between one measure and another. For example, the introduction of fast response lighting controls alongside the introduction of high pressure discharge lamps with long strike-up times will result in significant problems. Equally, better building insulation without good heating controls may simply result in overheating.

Integration should also avoid double counting of savings. For example, if a boiler is upgraded and improved boiler controls are introduced then the savings from the controls should be based on the consumption expected after boiler replacement.

New measures should also be carefully integrated with the ability and resources of the existing management since additional burdens may prevent savings actually being achieved in practice.

18.2.4 Reporting the results

For action to be taken, recommendations for energy efficiency measures must reach the correct level of management, be presented in a form that assists, and offer a good case for investment. Energy analyses or survey reports should include:

- a management summary suitable for non-technical managers
- observations and data
- an analysis of costs and non cost benefits
- conclusions and interpretation of the findings
- clear recommendations.

The energy account is often best presented in tabular form in a similar manner to a financial account. A graphical presentation can also be adopted, e.g. a pie-chart or Sankey diagram as shown in Figure 18.3(3).

The audit and survey report should include future targets (see section 20), including emissions targets in (kg CO_2)/m^2 per annum (see 12.3).

Survey recommendations can range from simple non-technical measures to those needing major investment, and possibly more detailed investigation. A report can also include recommendations for savings solely in energy cost, e.g. tariffs or control of electrical maximum demand. Such recommendations can often help the supplier reduce their primary energy consumption.

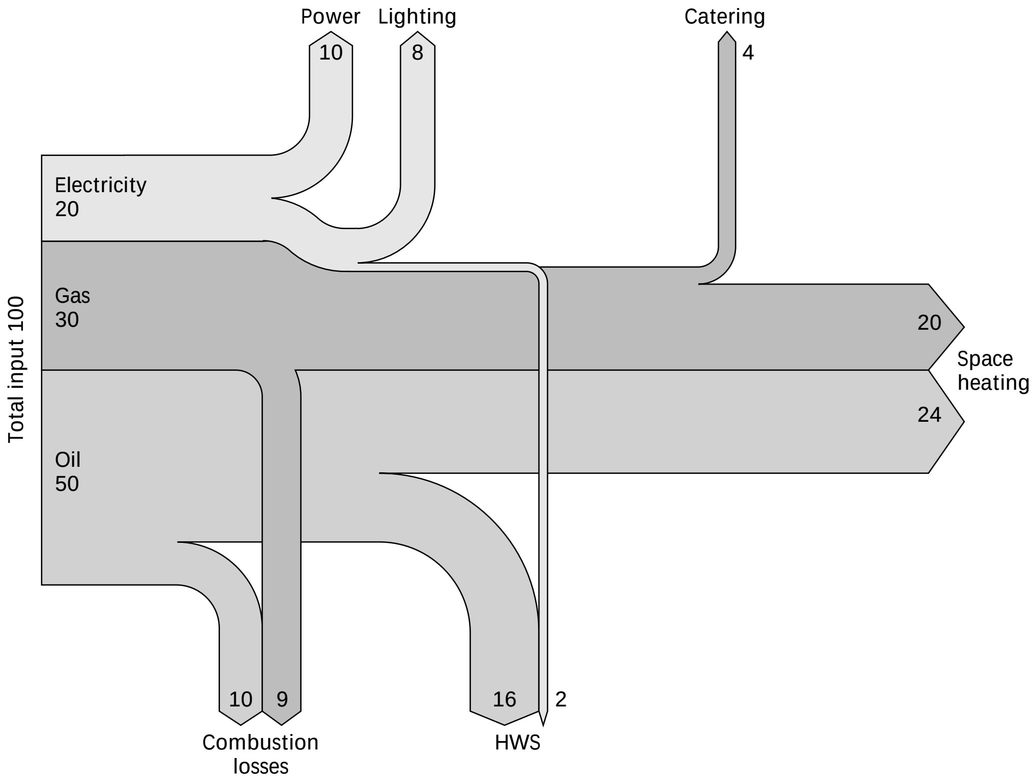


Figure 18.3 Sankey diagram showing where energy is being used[3]

Table 18.2 Specimen summary of recommendations

Ref	Location	Description of recommendation	Fuel type	Net annual savings		Implementation costs (£)		Simple payback (years)
				(£)	(GJ)	Extra study and design if applicable	Total	
Totals (and overall payback period)								

Measures can be summarised and ranked in as much detail as the data allows, as shown in the specimen summary illustrated in Table 18.2.

18.3 Assessing energy saving measures

18.3.1 Option appraisal

Before making a change to an existing system, it is important to consider all the available options, particularly where major investment is involved, e.g. new boilers or a BMS. A full option appraisal will ensure that the most cost-effective and efficient plant is chosen[10,11]. Option appraisal can provide a number of benefits:

— correct sizing of plant to meet the real demands of the building, often leading to lower capital costs

— improved comfort levels through increased levels of control taking account of the needs of staff

— lower running costs through the installation of more efficient plant with better controls

— easier maintenance and improved reliability by using modern plant and careful choice of systems

— higher environmental standards by considering the environmental benefits of each option

— a formal justification for the recommendations made, including a well researched fall-back option in case the first recommendation is rejected by management.

— an opportunity to investigate other forms of financing such as contract energy management.

Table 18.3 Example format for an option appraisal worksheet

Option appraisal worksheet			
	Option 1	Option 2	Option 3
Plant output (kW)			
Hours run			
Seasonal efficiency			
Energy consumption (kW h)			
Fuel cost (p/(kW h))			
Annual running cost			
Capital cost			
Payback period			
Environmental emissions			
Other benefits			

Option appraisal compares possible solutions to a particular problem in order to arrive at the optimum solution to provide the required comfort conditions. The appraisal includes capital and operating costs, and environmental impact, as well as practical issues like flueing and plant location and the flexibility to cope with changes in building use and occupancy.

Option appraisal is a highly iterative process. Some options will be eliminated during the process due to the constraints on the project, such as economics or practical problems like the size of the plant room. Conversely, others may become known during the analysis. It is important, therefore, to consider even what appear to be the most unlikely options. The appraisal should be treated as a flexible process of development; nothing should be fixed until final recommendations are made.

Strategic issues should be considered, including:

— Should the plant be centralised or decentralised?
— Where will the plant be located?
— What fuels are available on site?
— Is in-house maintenance available or will it be contracted out?
— Are there complaints from staff about comfort levels?

Future changes which may influence demand should also be considered, for example, use or occupancy patterns, alterations to the buildings including additions, refurbishments, demolitions etc.

The process starts by comparing the rough payback and non-cost benefits of each option. The worksheet shown in Table 18.3 illustrates a suitable format for estimating the paybacks and lists the information that will be required at this stage[10]. The aim is then to focus on the most feasible and economic options by gradually increasing the accuracy of costings and the engineering detail for those most favoured. The preferred options can be further refined by considering the practical problems e.g. flue heights, floor loadings etc.

18.3.2 Investment criteria

For low cost/low risk measures with quick returns, simple methods of appraisal are generally acceptable. Appraisals of large or long-term investments should take account of interest rates, inflation, project life and risk. Energy efficiency measures should be assessed on the same basis as other investments, taking into account the wider benefits that can accrue. Analysis of the sensitivity to changes in, for example, ambient temperature (as measured by degree-days), equipment performance or energy prices is also advisable.

The full implementation costs should always be considered including equipment, material and labour costs, consultants' fees, builders work and any disruption costs. In-house staff time, whether carrying out work directly or supervising the work of others should also be included.

Some of the methods used in investment appraisal are outlined below[12–14].

18.3.2.1 Simple payback

The crudest test of cost-effectiveness is simple payback period, which is the time taken for the initial capital expenditure to be equalled by the saving in energy cost.

This ignores interest rates and the benefit of continuing savings to the end of the life of the plant. A persistent and unthinking use of this method of testing cost-effectiveness may lead to under investment and a failure to seize good investment opportunities where payback periods are somewhat longer than anticipated.

The method is generally adopted for measures showing a return within five years, measures involving only minor investment, or for an initial assessment of measures that involve more substantial investment.

It should be made clear whether costs and savings are based on firm quotations or budget estimates. Where alternative measures are being compared, the marginal capital cost should be used to indicate the payback of one measure versus the other.

18.3.2.2 Discounted cash flow

Large projects and long term measures require the preparation of a cash flow statement to evaluate their true economic worth. Discounted cash flow (DCF) takes into account the timing of capital and revenue costs and savings. The decision on when to apply DCF methods should reflect normal business policy.

Such methods require the use of discount rates[12–14]. These discount rates differ widely between organisations but are usually between 5% and 20%. This is, in effect, saying that such a return on capital can be obtained by an alternative investment and an energy efficiency investment must yield a return no less than this. Discounted payback, or the break-even period, can be calculated in a similar way to simple payback except that discount rates are taken into consideration.

When the net annual saving is less than the real or notional interest charges, i.e. the discount rate, the capital can never be recovered. Some organisations may wish to take into account predictions of future energy prices. The discount rate should then be reduced by the predicted annual percentage increase of energy costs. Alternatively, they may wish to assess the effect of falling energy prices, in which case the discount rate would be increased.

18.3.2.3 Net present value

Net present value (NPV) indicates the discounted cash flow over the life of the project[12–14].

The effects of taxation and capital allowances can be taken into account, as can changes in energy prices. The true worth of the proposed measure can then be seen as a sum of money in present day values.

18.3.2.4 Internal rate of return

Internal rate of return (IRR) provides an alternative approach to NPV, representing the rate of interest that money would have to earn elsewhere to be a better investment; the higher the IRR, the better the project.

IRR is defined as the discount rate at which the net present value of the project reduces to zero. There is no direct way of calculating IRR. The interest rate at which the NPV becomes zero is determined by successive approximations[12–14].

18.3.3 Life cycle costing

In addition to direct financial returns, there are nearly always wider benefits that should be taken into account, including:

- improved manageability, for example through better control and monitoring
- reduced maintenance and staff costs after replacing or upgrading plant
- reduced harmful emissions to the atmosphere, e.g. less CO_2, NO_x etc; this is particularly important to organisations with environmental policies
- improved management information and decision making
- improved services, comfort and productivity.

The last point is often missed but is commonly one of the greatest benefits. Results from building surveys[1], have shown a combination of benefits comprising optimum levels of energy efficiency, people satisfied with their environment, and high productivity. This does not mean that installing measures will always directly improve productivity, but rather that well managed buildings tend to have satisfied occupants who pay attention to energy management.

Total life cycle costing involves evaluating all costs and benefits over the entire physical life of the asset, providing a more realistic basis for comparison. However, there is a risk of overestimating benefits and exposing the project to an unnecessary level of risk from market effects. In particular, it should never be used as a means of enhancing the value of a project that has a poor payback.

18.4 Implementing savings

A works programme, as shown by the example in Table 18.4, can help to prioritise measures and to assist in

Table 18.4 Example energy efficiency works programme

Proposed project	Location	Priority	Works order no.	Estimated cost	Estimated rate of return	Organisation actioned	Project manager	Date work ordered	Expected completion date	Comments

managing project implementation. It should show the cost, responsibility and timing of each recommended measure.

Large scale energy saving projects need significant supervision to an extent that an independent project manager may be required.

One effective method is the rolling programme in which savings from the first energy saving measures are re-invested to produce further savings. Part of the initial investment can sometimes be raised by capitalising fuel cost savings from good housekeeping measures that need little or no capital expenditure.

Energy managers should publicise the programme and explain its importance and implications. Implementation should be planned so that measures are introduced with minimum disruption to normal activities but achieve savings at the earliest opportunity. Repetitive solutions may benefit from pilot projects to provide valuable experience and identify any pitfalls. Monitoring equipment should be installed as part of implementation in order to quantify the savings actually achieved. The implementation programme should be regularly reviewed, and all personnel should be kept informed of progress and the results achieved.

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