GOOD PRACTICE GUIDE 292

Energy in plastics processing – a practical guide

JOULE-THERMIE

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GOOD PRACTICE GUIDE 292

ENERGY IN PLASTICS PROCESSING – A PRACTICAL GUIDE

This Guide is no. 292 in the Good Practice Guide series and is intended to assist owners and operators of plastics manufacturing facilities to save energy and improve the cost effectiveness of their operations. The Guide is intended to point out areas where improvements can be made and to signpost other publications in the series which can provide more detailed help.

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First published October 1999

LIST OF RELEVANT GOOD PRACTICE GUIDES

2. ENERGY SAVINGS WITH ELECTRIC MOTORS AND DRIVES
14. RETROFITTING AC VARIABLE SPEED DRIVES
31. COMPUTER AIDED MONITORING AND TARGETING FOR INDUSTRY
42. INDUSTRIAL REFRIGERATION PLANT: ENERGY EFFICIENT OPERATION AND MAINTENANCE
48. REDUCING ELECTRICITY USE IN INJECTION MOULDING
69. INVESTMENT APPRAISAL FOR INDUSTRIAL ENERGY EFFICIENCY
84. MANAGING AND MOTIVATING STAFF TO SAVE ENERGY
85. ENERGY EFFICIENCY TRAINING AND DEVELOPMENT
91. MONITORING AND TARGETING IN LARGE MANUFACTURING COMPANIES
92. REDUCING ELECTRICITY USE IN EXTRUSION-BLOW MOULDING OF THERMOPLASTICS
112. MONITORING AND TARGETING IN LARGE COMPANIES
125. MONITORING AND TARGETING IN SMALL AND MEDIUM-SIZED COMPANIES
126. COMPRESSING AIR COSTS
141. WASTE HEAT RECOVERY IN THE PROCESS INDUSTRIES
168. CUTTING YOUR ENERGY COSTS
169. TOTAL QUALITY MANAGEMENT
178. CUTTING THE COST OF REFRIGERANT LEAKAGE
181. ENERGY EFFICIENT CRUSHING AND GRINDING SYSTEMS
197 ENERGY EFFICIENT HEAT DISTRIBUTION
213. SUCCESSFUL PROJECT MANAGEMENT FOR ENERGY EFFICIENCY
214. MAKING USE OF BUSINESS STANDARDS
215. REDUCING ENERGY COSTS IN INDUSTRY WITH ADVANCED COMPUTING AND CONTROL
216. ENERGY SAVING IN THE FILTRATION AND DRYING OF COMPRESSED AIR
217. CUTTING ENERGY LOSSES THROUGH EFFECTIVE MAINTENANCE (TOTALLY PRODUCTIVE OPERATIONS)
218. FUEL-EFFICIENT FLEET MANAGEMENT
225. INDUSTRIAL COOLING WATER SYSTEMS
231. INTRODUCING INFORMATION SYSTEMS FOR ENERGY MANAGEMENT
235. MANAGING PEOPLE, MANAGING ENERGY
236. REFRIGERATION EFFICIENCY INVESTMENT
238. HEAT RECOVERY FROM AIR COMPRESSORS
239. ENERGY EFFICIENT THERMOPLASTICS EXTRUSION
241. ENERGY SAVINGS IN THE SELECTION,CONTROL AND MAINTENANCE OF AIR COMPRESSORS
242. PROCESS INTEGRATION
249. ENERGY SAVINGS IN INDUSTRIAL WATER PUMPING SYSTEMS
251. MAINTAINING THE MOMENTUM : SUSTAINING ENERGY MANAGEMENT
260. OPTIMISATION OF INDUSTRIAL PAINT AND POWDER COATING
262. PRACTICAL TIPS FOR ENERGY SAVING IN THE RUBBER PROCESSING INDUSTRY
277. SAVING MONEY WITH REFRIGERATED APPLIANCES

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FOREWORD

This Guide is part of a series produced by the Government under the Energy Efficiency Best Practice Programme. The aim of the programme is to advance and spread good practice in energy efficiency by providing independent, authoritative advice and information on good energy efficiency practices. Best Practice is a collaborative programme targeted towards energy users and decision makers in industry, the commercial and public sectors, and building sectors including housing. It comprises four inter-related elements identified by colour-coded strips for easy reference:

— *Energy Consumption Guides:* (blue) energy consumption data to enable users to establish their relative energy efficiency performance;

— *Good Practice Guides:* (red) and *Case Studies:* (mustard) independent information on proven energy-saving measures and techniques and what they are achieving;

— *New Practice projects:* (light green) independent monitoring of new energy efficiency measures which do not yet enjoy a wide market;

— *Future Practice R&D support:* (purple) help to develop tomorrow's energy efficiency good practice measures.

If you would like any further information on this document, or on the Energy Efficiency Best Practice Programme, please contact the Environment and Energy Helpline on 0800 585794. Alternatively, you may contact your local service deliverer – see contact details below.

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CONTENTS

Section **Page No.**

Page No.

Figures

TABLES

1. INTRODUCTION

1.1 Who is This Guide For?

This Guide is designed to provide managers and operators in the plastics industry with easy access to a wide range of information about energy reduction. It is designed as a resource handbook and not as a textbook on energy reduction, and will help companies to save energy and thus reduce a key variable cost. Using this Guide, any person dealing with energy should be able to find ways of improving operating practices and procedures, and to reduce energy use and costs.

There are many technologies used to process polymers, and many share common techniques, but the one thing that they all have in common is that they use significant quantities of energy. Although energy may only be a small proportion of the total cost of plastics processing, unlike the cost of raw materials, it is controllable.

This Guide aims to provide a general resource for the whole polymer processing industry. All aspects of energy use in the plastics industry are covered and references are given to other related energy publications. These include Good Practice Guides (GPG), Good Practice Case Studies (GPCS), Fuel Efficiency Booklets (FEB) and Energy Consumption Guides (ECG). Copies can be obtained free of charge through the Environment and Energy Helpline (freephone 0800 585794), where free advice on all energy and environmental matters can also be obtained.

1.2 Best Operating Practices

There are many reasons why the average site will have room to improve their energy efficiency. In the main, the priority of processors is to produce as much high quality product as quickly as possible. As a result, manufacturing costs are often considered as secondary while companies remain competitive. Even in highly competitive markets, where production margins are vital, the focus is likely to be on reducing staff and material costs. Energy is often regarded as an uncontrollable overhead, or considered to be a low priority.

In fact, energy efficiency should be a key contributor to good productivity, not a competing priority or add-on extra. When integrated within the company’s management system, energy efficient operation is not time consuming and is an essential part of good management.

1.3 Energy in Plastics Processing

In addition to the energy used in processing thermoplastics, as Fig 1 shows, energy is used in every section of the plastics industry.

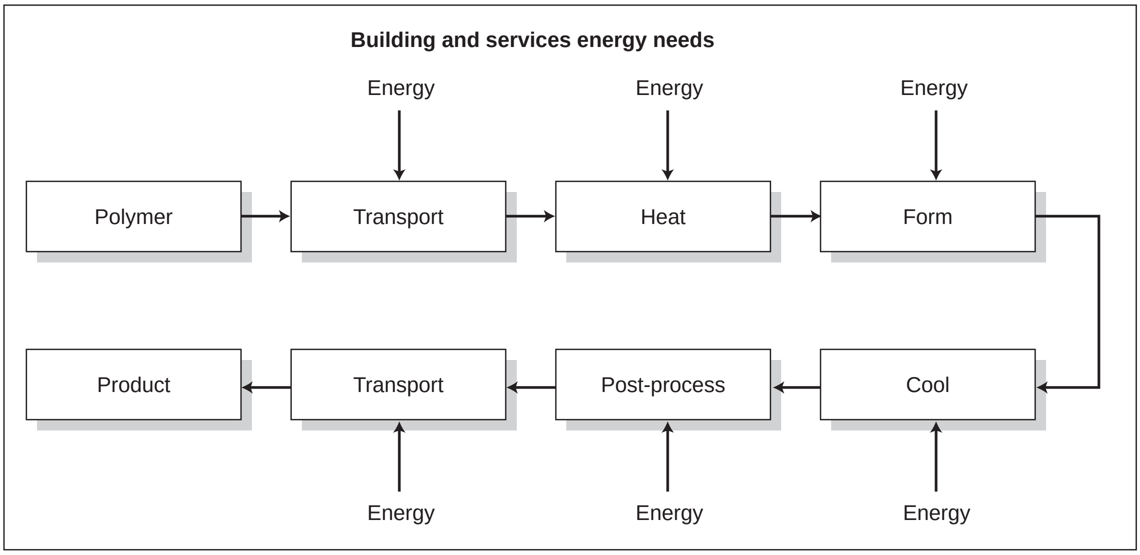

Fig 1 Energy used in the plastics industry

One of the major assets of plastics is their combination of good heat and electrical insulation properties. Unfortunately, this also means that they transfer heat poorly and are difficult to heat and cool. The slow rate of heat transfer limits the speed of processing, making the process very energy intensive. As a result, energy use can be a critical hidden factor in the industry's profitability.

Fig 1 shows that there is potential to save energy and money at almost every stage of the process chain. For example, if it takes energy to heat the plastic and more energy to cool it later, it is fairly obvious that optimising the initial heating energy will reduce later cooling costs. As energy is consumed at almost every stage of the process, it makes sense to control it in the same way as any other variable costs.

1.4 Energy Awareness in the Organisation

The experience of the Energy Efficiency Best Practice Programme over many years has shown that an organisation's attitude to energy management has a fundamental effect on the way that it uses energy. Although it is possible to save energy through technical 'fixes' alone, in the long-term, it is the attitude of the people working in the organisation that has the biggest impact. An initial assessment of an organisation's attitudes to energy management can be made by completing the self-assessment questionnaire (see Appendix 1). The questionnaire can also be used as the basis of an energy management plan.

Action Points:

- Attitudes are worth more than technology. The best technology will not reduce energy use unless attitudes are right – new equipment badly run is less effective than old equipment well run.
- Staff involvement and consultation should be the first priority – with an enthusiastic work-force, the rest is easy.
- A well-run suggestion scheme can pay big financial dividends.

2. UNDERSTANDING ENERGY

2.1 The Initial Survey

The first point to emphasise is that sophisticated and expensive automated systems are not required to start an initial site survey – the Checklist for an Initial Site Survey (see Appendix 2) is a good starting point. A ‘rough sketch’ of energy use based on easily available data can rapidly demonstrate the areas where rapid improvements can be made at no- or low-cost. One tip to ensure that the energy-saving campaign gets off to a good start is to concentrate efforts where the most immediate impact can be made. Quick results help to demonstrate that energy management is both worthwhile and cost-effective, and will provide encouragement and motivation to all levels of staff.

In the initial survey, the key questions are:

- Where is energy being used?
- When is energy being used?
- Why is energy being used?
- How much energy is being used?

Measuring energy is often seen as a difficult, expensive exercise that has little or no bearing on practical production. However, as the old adage says: *If it cannot be measured it cannot be controlled*, and nowhere is this truer than in energy management. Many people are under the impression that measuring energy requires costly and sophisticated equipment. However, much can be achieved using relatively simple hand-held instruments, such as those used by maintenance engineers. In fact, it costs very little to start managing energy, and worthwhile savings can be made with little or no additional expenditure. As the management programme is developed, some additional expenditure will be needed, but experience shows that the payback on this investment is usually rapid and can be estimated from the initial surveys.

Case Study 1

A small injection moulding plant operated 12 machines in a new factory, with new equipment, planned to run proven jobs. There was local maintenance staff for machine servicing; there were setters and machine minders. Machines were all fitted with pick and place handling gear. There was one electricity meter - the supply meter. Sub-metering was installed at a cost of £1,864. Staff were made more aware of where energy was being used. An energy manual was prepared and given to all staff, and their participation in making savings was encouraged via an energy notice board. In the first year, savings of £21,000 were made.

Good Practice Case Study GPCS 252

Case Study 2

This study looked at an older manufacturing unit, with some 50 moulding machines of varying ages and condition. The company had a full complement of technical, tooling and maintenance staff on site. The buildings were not ideal and had been adapted to suit the company as it developed. To make staff immediately aware of the possible savings, the factory lighting was refurbished. New fluorescent fittings with high efficiency reflectors were installed. One tube was needed to provide an improved lighting level where two were previously required. Immediate savings of £47,750/year were made for an outlay of £9,640. A monitoring exercise, using portable equipment, suggested that about 20% of total energy was being wasted running idle equipment. The methods used in this study were chosen because of their low initial investment cost and their capability to create an awareness of energy management in staff. They have worked effectively and provided an incentive for further energy efficiency activities.

Good Practice Case Study GPCS 253

2.2 Where is Energy Being Used?

There are four major users of energy in polymer processing:

- Motors and drives (on extruders, grinders air compressors etc.).
- Heaters (on extruder barrels, driers etc.).
- Cooling systems and (on extrusion cooling troughs, injection moulds, drives etc.).
- Lighting.

It is worth making a simple diagram of site energy distribution, such as that shown in Fig 2. This will help to ensure that no part of the site is overlooked.

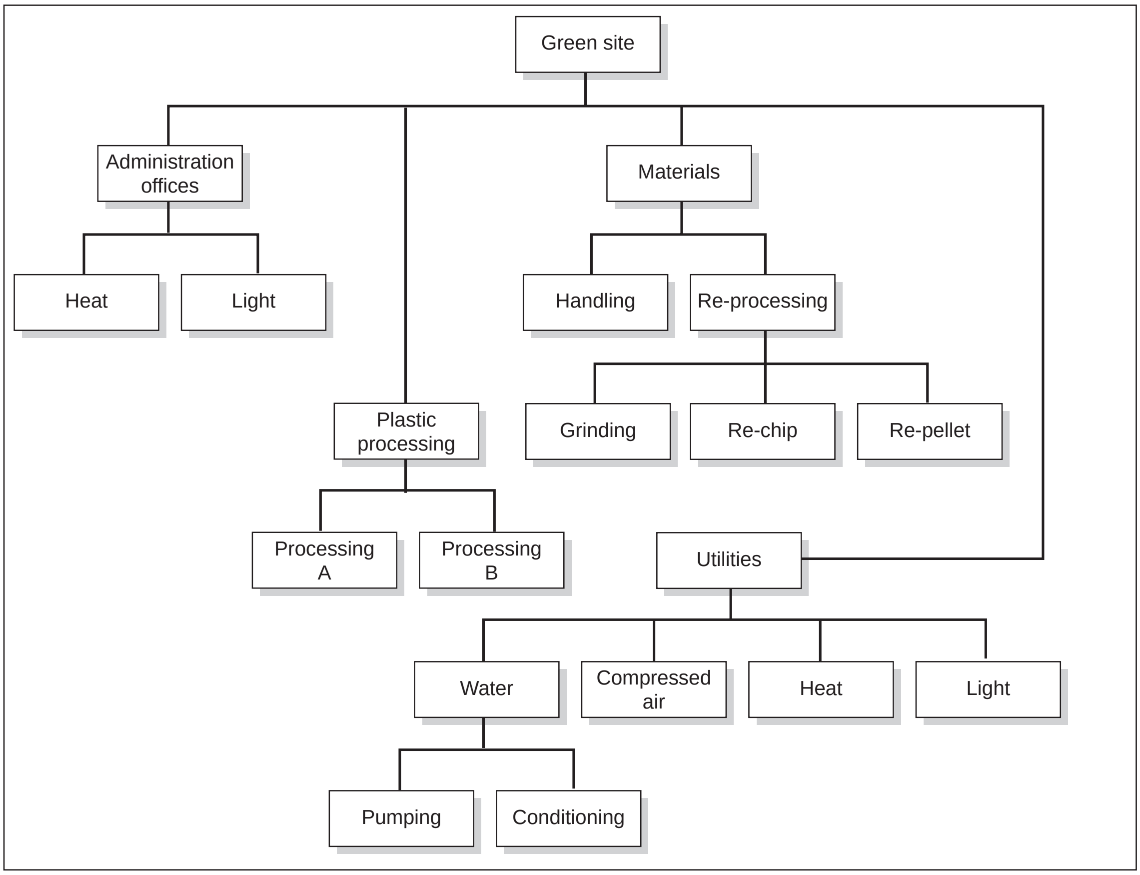

Fig 2 A typical site energy distribution plan

Initially, an energy manager needs to get a feel for the operation before any attempt is made to improve it. Although a checklist for a detailed site survey is given in Appendix 2, the important thing is to get a feel for where, when, why and how energy is used as quickly as possible.

The quickest way to achieve this is to walk around the site and look at the four major energy users. For example, look at the location and size of the various motors and heaters, and ask operators and factory staff (particularly the maintenance staff) how the electrical and other energy inputs are laid out. Make a note of existing loads, how long they are used for and how the power is distributed, as this information will provide a base from which to start improvements. Look at lighting, as this is an area that is always likely to give a quick return on investment. On most sites, it is quite easy to identify unoccupied areas where lights are left on (see Section 4.4 for more specific guidance on lighting).

At this stage, it is not worthwhile trying to make accurate measurements, as the purpose of the initial survey is to gain a general impression of the way that energy is consumed (and often wasted) on site. Try repeating this informal survey at different times of the day and night, such as during a lunch break and after normal working has ceased. Only when this activity has been carried out several times is a general pattern of energy use (and waste) likely to be revealed.

Action Point: Ask some simple questions to quickly reveal areas of high consumption and places where savings could easily be made

- Which areas have the largest electrical load?
- Where are the largest machines with the largest motors?
- Is the insulation in good condition on all machines?
- Which motors are left running when not in use?
- Do machines need to be kept idling to be ready for the next production run?
- Does the compressed air pressure need to be so high, or the vacuum so low?
- Which lights and machine heaters are left on when not needed?
- At quiet times, can steam and compressed air leaks be heard?
- Which cooling water pumps (and chillers) and vacuum pumps are still running?
- Is the lighting dirty or broken?
- Are all motors the correct size or would a smaller motor be more efficient?
- Are basic maintenance activities carried out?

Analysing the Results of the Initial Survey

The initial site survey should enable a rough estimate of site energy utilisation to be made and allow site energy utilisation per activity to be plotted on a bar chart. Plotting initial estimates of site energy may identify some areas that require further investigation to find out where excess energy is being used, and whether there is wastage that can be quickly eliminated. Fig 3 shows an example of typical site energy distribution.

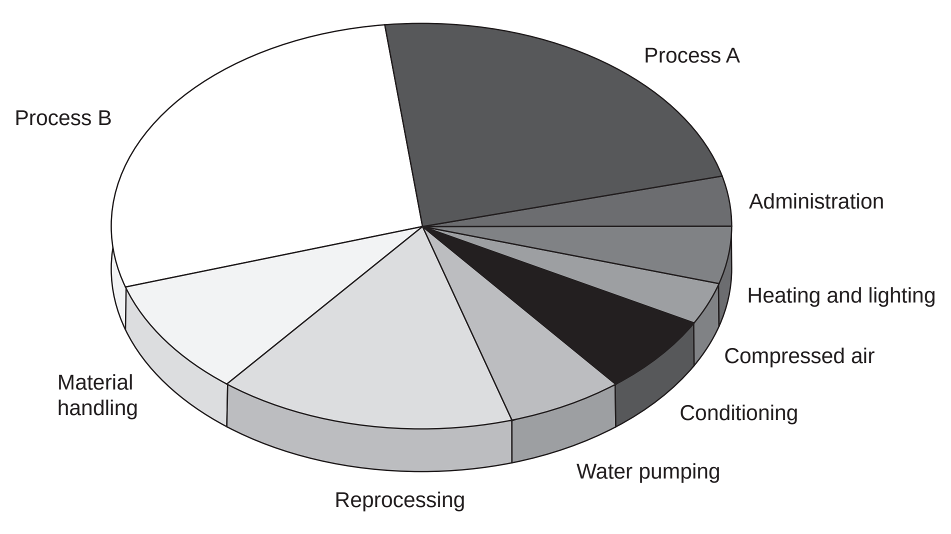

Fig 3 Typical site energy distribution

When the major areas of energy use have been identified, the next step is to make a rough calculation of the cost of energy per area, using real data from the company's energy bills. From the initial survey, it should be possible to estimate approximate levels of wastage in each area, and to calculate the potential financial benefits from the introduction of a systematic energy management system. Undoubtedly, dividing energy use into functional areas will start to reveal areas of waste and the areas with potential for improvements and reductions.

A careful examination of the way that the electricity distribution system is laid out is likely to reveal opportunities for measuring consumption more accurately. For example, in many cases, the motors, heaters, and ancillaries for an individual machine are supplied from the same substation, distribution board, or main feeder cable. In such a case, it would be possible to install metering to measure the precise energy use per machine and, subsequently, the energy cost of the items produced on that machine. This is the first step in enabling energy to be quantified in the same way as any other bought-in raw material.

This type of survey will also reveal the level of metering appropriate for the site. Meters on all of the possible measuring points are unlikely to be cost effective, as the cost of installation is likely to exceed possible gains. For example, spending £500 to install a meter on a motor using £1,000/year of electricity is unlikely to provide a payback over a realistic timescale. However, it is worth remembering that measuring energy consumption can also lead to other benefits, such as improved process control, better product specification or a reduced level of rejects.

2.3 When is Energy Being Used?

The Energy Demand Cycle

Plastics processing involves a cycle of energy demand, with peaks and troughs occurring at different stages of production. Most plastics processing machines require a period of running before 'good' production can begin, so there is a period when energy is wasted while machinery is 'warming up'. Similarly, as most polymer processes use electricity to provide direct heat, the heaters must have sufficient time to reach the required temperature and for the machine to reach steady state. Conversely, when production stops for any reason, there is often a time gap before the machine is switched off. Such stop/start situations mean that machinery is often idling under power, without being productive.

The energy demand cycle can be illustrated by plotting a graph of the instantaneous load at intervals during the day (see Fig 4). The electricity supplier can generally supply half-hourly electricity demand data to larger companies, over an extended period. Companies that do not have such an arrangement with their supplier can take manual readings from meters, borrow or hire a portable meter, or have an external company measure demand. Fig 4 illustrates the electricity demand in a factory that is nominally working two eight-hour shifts but with some staff working days and some overtime being worked (a situation common to many processors).

Fig 4 is based on a company operating a two-shift system. The shifts each have 12 people: 8 on day work and 6 on the 'twilight' shift (from 18.00 - 22.00), while supervisors and office staff work only day shifts.

When the chart is analysed, a number of key issues emerge. For example:

- Why did the load increase before the start of production at around 07.30?
- What happened during the lunch break for the day workers - were machines left running or were some machines late in starting?
- Were machines left running between 22.00 and 23.00 and, if so, who was there to switch them off?

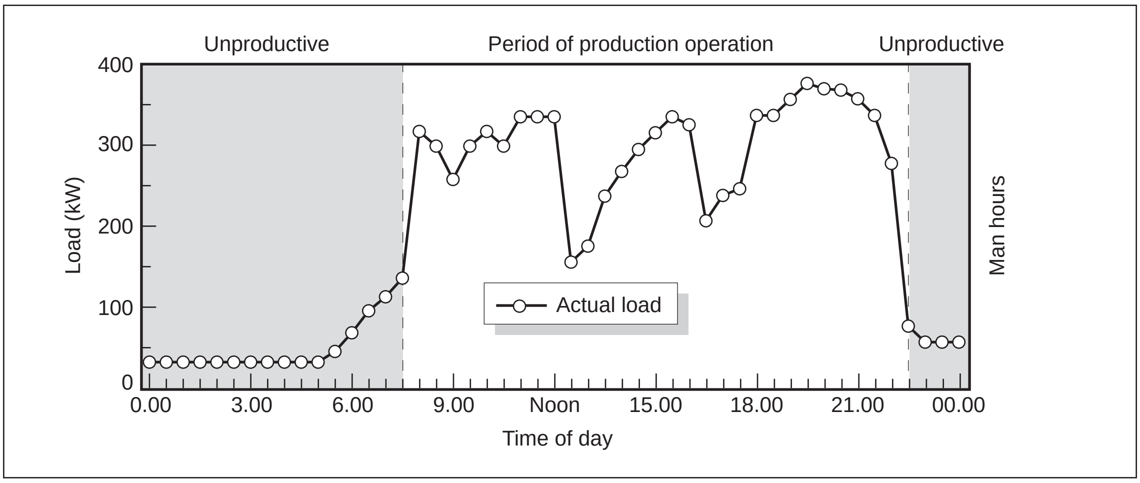

Fig 4 Half-hourly electricity demand plotted against staffing levels

Time of Day Conditions

Some electricity contracts have 'time-of-day' conditions that affect electricity costs. It is worth checking whether the current working pattern is the most financially advantageous, or whether the advantage is being outweighed by other factors. Supply contracts are usually based on production load demand, but this can change over a period of time and a review of present conditions may reveal the need to re-negotiate arrangements with suppliers. This is yet another example of the way that energy needs to be considered as simply another bought-in raw material, subject to changing needs and market conditions.

The Base Load

Once the load at various times of day has been identified, it is possible to start to isolate the **base load**. The base load is the load that is used only for services and does not relate to production. It is a good starting point for reducing overall energy consumption as it is the 'overhead' energy that is used **irrespective** of production levels and/or quality.

On Fig 4, the troughs in demand (at around noon and 17.00) represent non-productive periods. In this case, it would be worth checking to see why the demand has not returned to base load conditions. Of course, while the site is operating, some services cannot be avoided, such as lights in gangways, outside the factory, in offices, etc. However, the chart suggests excessive use in a non-productive period.

One way to find the base load is to note meter readings and production volumes at the end of shifts in order to build up a history of total site electricity use. Energy consumption (in kWh) and production volume should be plotted on a graph. The range of scatter will depend on factors such as the range of products and the efficiency of energy management. Draw a best-fit line through the points to see if there is a pattern to the points above and below the line. An example of this process is shown in Fig 5.

Significantly, the best-fit lines have a substantial intercept on the y-axis and not at the origin. This indicates the factory base load; that is, the electricity used whether there is production or not. While items such as lights possibly can not be reduced, other activities such as water pumping, compressed air leaks, machines with pumps running when no production is planned, etc., certainly can be avoided.

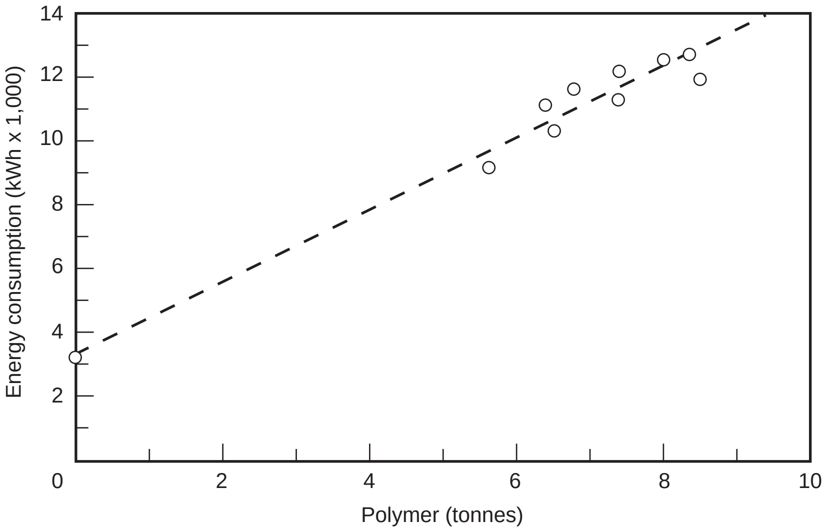

Fig 5 Example of standard daily performance

Action Point: Reducing the base load is a sure way of making savings

1. Regularly read the main supply meter at the same time each day.
2. Measure the production for each day (tonnes of polymer issued is probably the best measure, but other measures are possible - number of mouldings, weight of scrap, etc.).
3. Plot the tonnage produced against energy used on a graph, such as that shown in Figure 5. Extend the line to cut the 'Y' axis to give an estimate of the base load.

Further information can be found in Good Practice Case Study 354, *An energy management and monitoring system.*

The Peak Demand

In order to understand the importance of calculating the base load, it is also important to understand how **peak demand** can affect energy costs. Usually, some of the electricity bill is based on an allowed site **maximum demand**. These costs can sometimes be reduced by scheduling machine operation so that all the potential individual maximum demands do not coincide, thus avoiding a **spike** in total factory demand.

There are several ways to avoid spikes. For example, motors are often oversized for the actual demand profile to avoid possible overtaxing and subsequent burnout. However, such a built-in safety margin is a very expensive option. Electric motors have an efficiency curve which falls off very rapidly from the design rating. Significant savings can be made by either fitting variable speed controllers or by replacement with a smaller motor (see Section 5.2).

2.4 Why is Energy Being Used?

Average Processing Costs

In the previous Section, we looked at the base load in order to identify the amount of energy used on each day or shift. Once the process of measuring the amount of energy used per day or shift has been mastered, it is a fairly simple step to calculate the energy use per kg of good product (in kWh/kg). Data on energy use per kg of good product can be compared to industry averages, where available, to provide some useful targets for energy use. It might take a few minutes at the end of each shift to note the meter reading along with the production data, and to build up a history of total site electricity use. However, in the long-term, this information can be very useful.

The results should reveal patterns of energy use for specific products, processes and operating procedures. The analysis should reveal:

- which products or plastic types use more energy to process;
- whether particular shifts use more energy than other shifts;
- the machines that particularly affect energy use;
- what the factory was doing on low energy use days and how these activities can be maintained;
- what the factory was doing on high energy days and how these activities can be prevented;
- performance compared to industry averages; and
- where energy is used unnecessarily during lunch breaks, production run changes, overnight, and over weekends.

On a world-wide basis, the plastics processing sector is becoming increasingly competitive. In order to survive, companies need to carefully investigate areas for cost savings. Companies with energy costs significantly in excess of industry averages will find survival increasingly difficult.

When energy use in the plastics sector was audited by the Energy Efficiency Best Practice Programme, the non-productive energy use was about 50% of the total! (see Energy Consumption Guide 55, *Extrusion of thermoplastic pipes and profiles*). An analysis of energy used in one company showed that non-productive energy comprised 20% of all energy use (see GPCS 253, *Energy management at a large plastics injection moulding plant*). A subsequent energy management campaign saved 50% of this wastage, or 10% of overall energy use, and made a significant contribution to improving the company’s overall financial performance.

Monitoring and Targeting

Monitoring and targeting (M&T) was introduced earlier in this section as a way of putting accumulated data to practical use. M&T is a disciplined approach to energy management that ensures energy resources are used to the maximum economic advantage. M&T programmes provide the control that will lead to energy savings. It is generally accepted that energy savings of around 5% are achievable in the year following the introduction of an M&T programme.

M&T has two principal functions:

- It allows ongoing control of energy use.
- It allows planned improvements in the efficiency of energy use.

Monitoring enables the continuing control of energy use and measures any improvements or backward steps. Targeting allows achievable performance improvements to be set. As a technique, M&T utilises measured energy data to set achievable but challenging performance targets and can be applied equally in companies, departments or for individual machines.

There are three main ways to set targets:

- Using internal results previously achieved.
- Using results from research information.
- Using benchmark information from other manufacturers.

Each method has its pros and cons. For example, although the data to set internal targets can be easily obtained, the targets themselves may not be very challenging. On the other hand, while external targets from machinery manufacturers and research associations will give theoretical ‘minimum’ values for energy consumption for particular product types, polymers, and processes, there may be no hard evidence that these are either achievable or challenging. External comparison targets or benchmarks are very difficult to define because of the variety of operations and products, and the difficulty in defining an industry ‘standard’. However, a good range of information on industry performance is contained in the relevant Energy Consumption and Good Practice Guides available free of charge through the Energy Efficiency Best Practice Programme.

In the final analysis, the choice of target type will depend on a number of internal issues. What is important is that, whichever target type is chosen, it is both challenging and achievable, and forms part of a systematic and integrated energy management programme.

Quality failures

Experience shows that the root cause of most quality failures can be predicted by changes in energy levels, although measurement and identification of the underlying cause is not always easy. On most occasions, there will be more than one contributory cause and the real problem may be masked, but it is there to be found.

It is worth starting with electric motors, as extensive studies of motor failure have been made. Failure usually results from a few simple problems, such as bearings, windings and controlling gear, and most of these electro-mechanical problems can be identified by simple condition monitoring.

Much equipment failure can be avoided by checking:

- component wear and mechanical alignment;
- bearing condition;
- bearing lubrication;
- water, steam, and air leaks;
- thermal insulation;
- electrical insulation integrity;
- condition of motor commutators, slip rings and brushes;
- general cleanliness;
- transmission arrangements.

2.5 How Much Energy is Being Used?

The plastics industry is comprised of a large number of processing companies. Overall, there are many companies that contract out some or all of their electrical site-work. In-house technical staff are rarely involved in checking electricity bills, and these are routinely passed by accounts staff and never questioned. But, if energy is to be managed, it is essential for staff to acquire sufficient knowledge to check energy bills. Supply companies generally bill industrial users monthly, with the final sum dependent on both the supply contract and the quantity of electricity consumed.

Statutory provisions require the quantity supplied to be metered, and this is done as the supply cable enters the site. The meter is the property of the supply company who must maintain it in an accurate state, and it must be read at appropriate intervals. Meters are generally very reliable and give accurate readings over many years. So, unless a metered reading is obviously wrong, the accuracy of the metering equipment is unlikely to be checked.

However, minor errors can occur and can easily remain undetected. Therefore, companies should take their own regular readings and check these against electricity bills. It is worth accompanying the supplier’s meter reader when a meter reading is taken and recording the meter reading and the time that it was made. This activity can be incorporated within an M&T programme.

How to Buy Electricity

It is now possible for all companies to purchase electricity and gas competitively from a range of suppliers, each with a number of different options and tariffs. Although the way energy is purchased does not actually save energy, it can save money. When considering the introduction of an energy management programme, it is essential to look carefully at the options offered by the various suppliers. Energy efficiency measures can give a smoother electricity demand profile with fewer peaks and troughs, and can lead to reductions in charges based on maximum demand and power factor. More details on buying electricity can be found in Section 6.1.

Tariffs

Tariffs are designed to encourage users to consume electricity at the times when the supplier is likely to have the greatest spare capacity. Careful tariff selection can ensure that users achieve the best deal for their particular work pattern.

Tariffs usually consist of a price per unit, (pence/kWh) and a number of additional charges. These generally depend on factors such as:

- Maximum Power Requirement (MPR);
- Maximum Demand (MD);
- Power Factor (PF); and
- Load Factor (LF).

An explanation of these terms is given in Fig 6.

Peak demand lopping

Some processors use ‘peak demand lopping’ to reduce the MPR and MD and overall costs, or to remain within the constraints of the existing electrical connections. Solutions include the standard option of staggered start-up of machinery and the use of supplementary diesel generators, which cut in to provide site generated power if the total demand approaches that of the MPR or MD. Although the initial investment for the generator equipment can be high, it may provide a favourable option when compared with the cost of upgrading the MPR and the additional costs that the upgraded MPR brings.

Maximum Power Requirement (MPR) (kVA) Tips: Stagger start-ups to avoid exceeding MPR. Match MPR to real requirements to reduce costs. Get the MPR right for new premises to avoid costly charges. Consider negotiating an annually based MD instead of an MPR charge.	This is the maximum current that a site is able to draw at the supply voltage without triggering the main circuit breakers and trips. If a site exceeds the MPR, the trips will operate. This can mean an extended interruption to production, and the supplier will usually levy a charge for the overload. A site will be charged to increase its MPR, since the supplier has to upgrade the distribution system. Energy efficiency measures can minimise the additional demand caused by an expansion in production capacity, and avoid the cost of increasing the MPR.
Maximum Demand (MD) (kVA or kVAh) Tips: Stagger start-ups to avoid exceeding MD. Give machinery time to stabilise before starting up new processes.	This is a measure of actual current drawn at the supply voltage, usually averaged over half an hour. MD meters measure the cumulative value (kVAh) of instantaneous actual energy use, (kWh) divided by Power Factor. These are reset to zero after half an hour, and record the maximum value reached over all the half hour periods since the pointer was last reset. The MD is noted at each billing period and the MD pointer is reset to zero.
Power Factor (PF) Tips: Run electric motors energy efficiently to get power factors close to 1. Some supply areas make an additional charge if the PF is below a given value; PF correction can be applied to rectify this.	Electrical machinery induces a phase shift between supply voltage and current if it has a high reactive impedance (inductance or capacitance). Lightly loaded machinery tends to have a high phase shift and thus a low power factor. The chargeable units of electricity consumption are kWh. Electricity suppliers don't like low power factors because they must have a high distribution network capacity for a low consumption charge. Low power factors can cause problems with running the distribution network.
Load Factor (LF) Tips: Running for longer than a single 8 hour shift will reduce load factors. Can certain operations be run outside the main shift pattern? (e.g. regrinding)	This is a measure of the number of hours a day that the user draws from the supply. A 9-hour single shift working pattern gives a load factor of 9/24, i.e. 37.5%. Variable 'peaky' aggregate electricity demand forces the supplier to have standby capacity that runs only on peak demands. The supplier has the same fixed costs maintaining a distribution system that is used for 8 hours/day as for one that is used for 24 hours/day, but less consumption revenue to offset them.

Fig 6 Factors in an electricity bill

3. PRACTICAL MEASURES

3.1 Introduction

In Sections 1 and 2, we have looked at the general background to energy use in the plastics processing industry. In this section, guidance is provided on practical ways to use energy more efficiently.

This section will look at various ways of reducing energy use through:

- motivation & training;
- polymer preparation;
- machine choice;
- machine settings; and
- performance records.

Experience has shown that technical fixes alone rarely provide the answer. Without the ongoing commitment of the workforce, it is unlikely that even the most carefully planned energy management programme will succeed. As a result, motivating and training staff in energy awareness should be a priority in any energy management programme.

The most rapid returns on investment in energy reduction generally occur where no- or low-cost people-based measures are applied in practical situations, such as preparation and machine operation.

Although investment in energy awareness programmes is generally relatively low, success invariably depends on adopting a long-term view to ensure continuity. Every step that is taken to save energy involves a change in habit for someone and, unless energy awareness programmes are constantly maintained, they are likely to lose impetus rapidly. Before making changes to working practices, carefully consider:

- how the change will be introduced;
- how training and re-training is to be arranged; and
- the need to remind and reinforce the change until it is accepted as part of the normal routine.

The previous sections identified where, when and why energy is used, and highlighted the key areas for savings. The following sections show the various practical measures that can be adopted in each area.

3.2 Motivation and Training

The long-term success of any energy management programme will be ultimately dependent on the people who operate it. Sustaining the momentum of an energy management programme is a continuing challenge and depends to a large extent on maintaining a general ethos of energy *awareness* throughout the organisation. Top level *commitment* to the challenge is an essential component, providing the driving force behind any campaign. Without the full backing of management, little is likely to be achieved in the long-term. In addition to commitment, *leadership* is required at all levels - high level leadership to authorise necessary resources and to act as a corporate ‘champion’, and throughout the organisation to champion individual energy campaigns. However, for energy management to be truly effective, energy reduction needs to be the responsibility of everybody.

If an ‘energy awareness’ assessment has been carried out (see Section 1.4 and Appendix 1), this will provide useful information on the attitude of the organistaion to energy management.

A study carried out by the Energy Efficiency Best Practice Programme (see GPG 251, *Maintaining the momentum - sustaining energy management*) shows that there are six critical factors for successful, sustained energy management:

- Awareness.
- Commitment.
- Leadership.
- Communication.
- Empowerment.
- Recognition.

The mix of factors that is effective in one organisation may prove totally ineffective in another, as the successful implementation of an energy management programme involves understanding the culture of the individual organisation and adapting the mix to fit that culture. However, what is clear is that the key to success is the integration of energy management activities with the organisation's corporate objective, as is shown in Case Study 3. Although this case study was carried out on a large chemicals processing site, the basic principles are applicable to the plastics industry.

Case Study 3
The benefits of integrating energy management into company culture

Savings
Over £$^1/_2$ million in six months, out of total utility bill of around £6 million/year.

Costs
£100,000 in first year, including employment costs for energy manager, training, & capital costs.

Performance indicator
1996: cost of utilities to production lowest since start of programme - estimated that resource conservation currently saves site over £1m/year.

Key factors/activities:

- Director level **commitment** and **leadership.**
- Appointment of an **empowered** energy manager.
- Energy management **integrated** with corporate objectives.
- **Awareness** training for energy manager and staff from each business unit.
- Action based programme.
- Effective **communications** through an information cascade from energy manager.
- Good housekeeping measures and M&T procedures implemented in each business unit.
- On-going **commitment.**
- Energy conservation **integrated** with environmental issues.

Good Practice Case Study GPCS 165

As in all other management activities, energy management will not be successful unless somebody is made responsible for it and *empowered* to ensure that agreed practices are carried out. Although some organisations will not be able to justify the cost of a full-time post, the responsibility of both full-time and part-time energy managers is the same - to co-ordinate and advise members of staff at all levels. The real challenge for the energy manager is to achieve an integrated energy policy within the organisation as a whole. Empowerment is one of the key issues facing the energy manager, particularly in the case of staff at lower levels who may not have access to resources or the authority to change working practices. Often, they simply will not have the time to spend on energy issues and, thus, the challenge is to make energy management an integral part of everyday working life.

Measuring the level of energy management activity and its integration within the organisation is a critical step forward. The results of this analysis will provide the information needed to take the next step forward which is raising awareness. *Awareness* is an essential success factor - if staff are not aware that energy is an issue, how can they do anything about it? In fact, it is worth repeating the measurement and analysis process at regular intervals, both to measure progress and to help maintain interest in the campaign.

Raising and maintaining energy awareness will depend on a number of factors, the most important probably being training. Earlier, we said that organisations would differ in their needs and, therefore, their approaches to energy management. Strategically, it is critical that energy awareness training is targeted at the people who can make a real difference to energy consumption, and will ensure that the programme has an immediate impact. The information on initial energy cost savings should be widely broadcast in order to demonstrate that energy management actually works. The next stage is to spread the training across the organisation, using training packages customised to the needs of individual groups, but keeping in mind the key energy awareness issues:

- environmental impact;
- financial and other benefits;
- how the organisation uses energy;
- what the organisation can do to save energy; and
- contribution of individual staff members.

Finally, like all training, energy awareness training is not a one-off activity. Staff move on to other tasks and people forget things, particularly when they are not seen as essential. Awareness needs to be maintained through ongoing training and effective *communication* - one of the key features of effective energy management.

Although reducing energy consumption should not be a covert activity, many organisations are surprisingly secretive about their efforts, both in their internal and external communications. Sustaining successful programmes will require the use of the widest range of communication techniques, including reports, newsletters, posters, competitions, flyers, notice boards, meetings, workshops and briefings. Successful energy management is good news for everyone, and publicity for successful energy campaigns will help to sharpen up the environmental profile of the organisation - a major selling point in today’s market place.

Recognition of staff effort is an essential factor in successful energy awareness programmes. Energy management is rarely seen by the majority of staff as a core activity, and some additional motivation can help to kick-start programmes. At the corporate level, the tangible benefits of energy management should be self-evident in reduced operating costs and improved profits but, for individuals, the benefits are often not apparent. More personal and tangible rewards can be used to initiate and sustain activity, such as reallocating a percentage of the energy cost savings to improving staff facilities. Alternatively, effort can be rewarded by donations to charities chosen by the staff.

Action Point: Carry Out an Initial Assessment of Energy Management Awareness

The initial assessment of energy management skills and awareness (Appendix 1) is a simple but useful tool for assessing where a company stands.

Company Energy Policy

The Company Energy Policy should, as with any policy document, provide a road map for the company operations. An energy policy can stand alone, but it is more effective when integrated into wider business strategy, such as an **Environment** or **Total Quality Management** programme.

The Energy Efficiency Best Practice Programme has a wide range of publications dealing with awareness, training and motivation. Good Practice Guide 172, *Marketing energy efficiency – raising staff awareness,* is a useful starting point for any new energy efficiency programme as it contains a wide range of practical activities and resources to kick-off a new campaign. Good Practice Guide 186, *Developing an effective energy policy*, takes the campaign further, while Good Practice Guide 200, *A strategic approach to energy and environmental management*, enables energy managers to plan campaigns from a broader, long-term viewpoint.

3.3 Preparation and Handling

Preparation

Polymer is normally purchased ‘ready to use’ in compound form but there are exceptions, and some companies compound in-house to reduce costs or increase flexibility. Whilst many polymers require no special handling, certain specific types readily pick up moisture and require drying before they can be processed. The activities involved in compounding, drying and delivery to the machines all use energy and all present an opportunity to save time, energy and polymer. A well organised preparation and handling area will save all three and increase profits.

In many factories, polymer purchasing records are the only record of material weight as, traditionally, it is not the practice to dispatch finished products by weight. Material yield within the preparation department should be very near to 100% and is easily confirmed. Such a check has been found to sharpen the approach to the entire operation and identify any hidden waste.

Blenders and mixers are energy intensive machines, and extended cycle times waste energy, reduce plant capacity and can lower the quality of the compound. Excessive polymer drying can also waste both energy and time. In the case of expensive polymers, some processors are able to justify 100% polymer drying as an insurance against machine stoppages. However, this is a policy thats needs careful evaluation as it is very energy intensive.

Drying technology is extremely complex, with a number of different techniques available. These tend to have significantly different energy requirements and different levels of efficiency. Studies of traditional oven drying techniques reveal that they are both ineffective and inefficient. If drying is important, a rigorous study of the various techniques is essential in order to save time and energy.

Polymer Handling

During the time taken to deliver polymer to the machine, it is possible to undo all the energy and effort that has been applied in drying the polymer. Where possible, it is generally cost effective to automate both the feed of raw materials to machines and the removal of finished products. Movement of both materials and product adds to manufacturing costs and, in the ideal situation, polymer would be delivered direct to the machine and the product would eject direct through the despatch bay. However, the full financial implications of automation need to be analysed in detail before both capital resources and energy are used unnecessarily.

Action Point:

Compressed air is very useful for actuating, but its use as a blast for conveying granules or product may be very costly. Check the rate of use and alternative methods of transport.

Product quality can be affected by processing parameters and the qualities of the polymer supplied to the machines. Polymer supply companies have high standards of manufacture and the quality of raw materials is usually consistent. However, it is recommended that records of suppliers and batch properties are kept for quality control purposes. This can help to identify rogue batches and differences in product supplied by different suppliers, and their effect on specific operations. However, bought-in raw polymer is handled and, sometimes, pre-processed and master-batched with additives before it reaches the machine. This can introduce a degree of variability into the polymer, particularly when recycled polymer from an out-of-specification product is used.

Two key properties of the polymer feed that affect energy consumption are:

- particle size; and
- moisture content.

Both of these factors affect the flow characteristics of the polymer, as a stiffer polymer is harder to process and needs more energy input. This usually requires more mechanical work, which needs to be dissipated as extra heat in the machine (e.g. in the extruder throat). In turn, this puts a greater demand on the cooling system to maintain acceptable operating temperatures for machine and polymer, and increases energy consumption.

In order to combat the problem of moisture, it is worth investigating whether small quantities of polymer can be fed via a central vacuum system to maintain dryness. Employing a smaller dryer at each machine is sometimes less expensive and provides additional operational flexibility. There is also less opportunity for moisture to be picked up after the drying process.

It is worth considering drying only materials “on demand” rather than drying all materials, as this can give greater consistency and avoids moisture take-up after drying and before processing.

Product Handling

All product handling systems use electricity or compressed air, and it is worth investigating alternative, cheaper and less energy intensive ways of product handling. Product handling systems can use large quantities of energy whilst handling no product at all. As a priority, check that handling systems are being used productively, and consider using systems that operate “on demand” only. Although compressed air blasts are sometimes used for conveying finished products, this is an extremely costly method. Compressed air actuators may require careful design and set-up, but they can lead to significant savings in operational costs.

Action Point: Reorganising product handling to reduce energy use

- Drying immediately before processing gives greater control and can significantly reduce energy use.
- Avoid indiscriminate use of compressed air, as it costs ten times as much to generate as an equivalent amount of electrical power at the point of use.

Fig 7 shows how the handling process can be reorganised to reduce energy use.

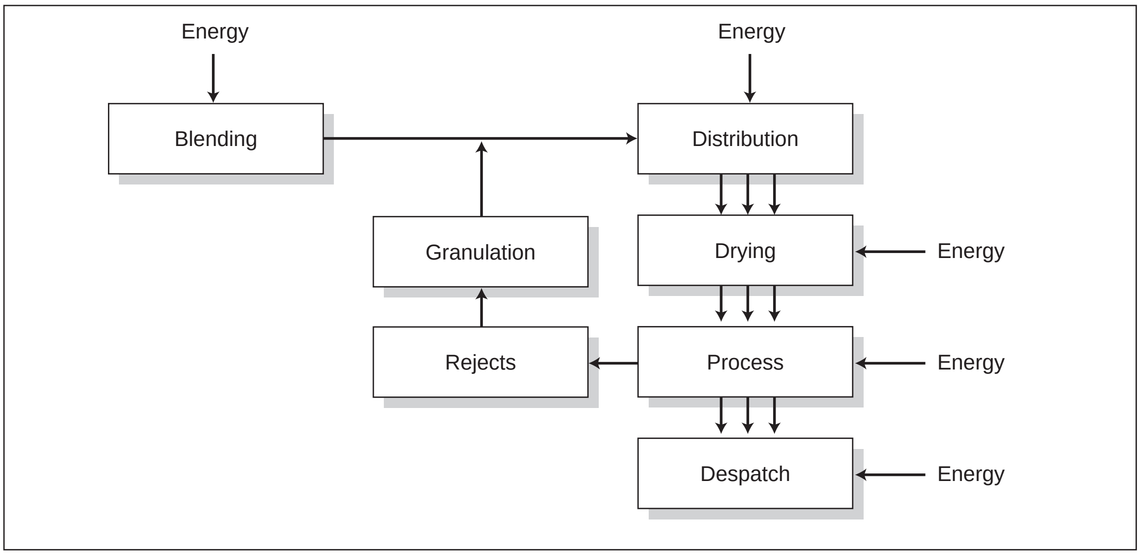

Fig 7 Product handling reorganised to reduce energy use

3.4 Choice of Machine and Process

It may surprise many to learn that only 5 to 10% of the energy used by injection moulding machines is actually input to the polymer, with the remaining 90 to 95% used only to operate the machine.

Energy measurements have been made in four of the main plastics processes. Table 1 compares the energy used by some of the lesser used processes with that used in the more widely practised processes.

Table 1 Energy intensity of plastics processes

Process element	**Blend compound**	**Plasticise**	**Expand surface area**	**Heated mould**	**Cooled mould**	**Cure**	**Total process intensity**
Main processes							
Extrusion	4	2	–	–	2	–	8
Blown film	4	2	3	–	3	–	12
Injection moulding	3	2	–	2	2	–	9
Compression moulding	–	1	1	3	–	5	10
Lesser used processes							
Thermoforming	1	–	1	3	2	–	7
Foam	1	1	2	–	–	2	6
GRP lay-up	1	1	–	–	–	3	5
Dough moulding	2	1	2	3	–	3	11
Compounding	3	1	–	–	2	–	6
Rotational moulding	2	1	1	2	2	–	8
Calendering	3	1	–	–	1	–	5
Spreading	2	2	–	–	2	–	6

For example, injection moulding is at its most efficient for well designed lightweight mouldings, and this application has been shown to require between 1.3 and 1.6 kW/kg, whereas heavy duty mouldings use between 3.0 and 4.0 kW/kg. Many mouldings are made on machines that are not ideal choice and use between 3 and 4 kW/kg. Variations exist in every process but these values are suggested as starting points for initial benchmarking.

Typically, an injection-moulding machine will use between 1.2 and 2.2 kW/kg of polymer processed. To put this into context, we can look at the way that energy is used in a machine used for moulding a 500 grams television cabinet. The process takes around 90 seconds, which means that, over 10 years at £0.045/kWh, electricity worth around £100,000 will be used to process £1,000,000 of polymer. These costs highlight the importance of making energy efficiency an important criterion when selecting machinery, as operating costs can rapidly outstrip initial investment costs if the process is inefficient.

There are a number of factors that can determine whether a machine is operating efficiently, including:

- motor size – many machines have oversized motors;
- excessive holding pressure applied for longer than is needed;
- an inefficient screw;
- barrel temperature set too high;
- over-large barrels - can result in excessive material being purged or purging occurring too frequently.

When considering any investment in new machinery, it is essential that these factors should be considered when selecting the machine and process parameters for a particular task. It is essential to look at the total life cost of any new equipment, including operating costs.

Which Machine?

Before investing scarce resources in new plant and equipment, it is worth making a survey of existing machinery. Quite often, an analysis of existing use patterns will reveal areas for improvement and, at the very least, it will provide a good guide to future purchase criteria.

Most sites have more than one processing machine and these usually vary in capacity, age, design and manufacturer, with each factor affecting the efficiency of operation. In fact, even nominally similar machines can have different energy efficiencies as a result of different degrees of wear or differing patterns of maintenance over a period of time.

Few machines are exclusively dedicated to a particular product and, over a period of time, most companies will process a mixture of polymers and products, according to customer demand. It is important to be aware of the different options available and the benefits and costs associated with each. This means that effective records of machine settings and performance are essential.

Action Point: Purchasing machinery

- Always consider whole life costing of machinery – steady state and peak energy demands, time between failures, time between maintenance, the liftetime of consumables such as oil, etc.

3.5 Machine Settings

Action Point: Improving the process

Every process used in plastics processing presents opportunities for energy reductions. It is worth taking some time to look at the various processes in use to see whether improvements may be possible.

Vacuum forming
Vacuum forming needs the plastic sheet to be heated to a sufficient temperature to be flexible enough to form over the mould. Careful control of the heating cycle can reduce the amount of heat put into the sheet, and thus reduce both the energy costs and the cycle time of the machine.

Blow moulding (both injection and extrusion)
Reducing the melt temperature of the plastic in blow moulding can significantly reduce the energy requirements and also improve the cycle times for the process. The compressed air used in blow moulding is an extremely costly production input – check that the pressure is set at the minimum level for machine performance and product quality.

Calendering
Calendering introduces large amounts of heat from the shearing of the material. Controls to regulate the calender roll temperature within tight limits can often have short payback periods, as well as improve the output of the process.

Machine controls and microprocessors have combined to make tool changes easy and to make optimisation of process conditions rapid. Repeatability is also easy to determine. However, even where advanced control techniques are not used, performance improvements are possible. Experience has shown that, when properly set, older machines are capable of an energy performance equal to that of more modern equipment. Although they are generally less easy to change, and may present a problem for work scheduling staff, the end product can be equally valid.

Even the most modern machines are very often not equipped with instrumentation to monitor power consumption. However, portable metering equipment is available and can be easily moved from machine to machine. For example, retrofit current transducers can measure power, and it is also likely that existing software on the moulding machines, suitably re-programmed, could be used to allow power optimisation as a routine facility.

Between Jobs – Reducing Set-up and Maintenance Times
The four key guidelines to efficient job changes and essential planned maintenance are:

- Issue clear instructions *before the previous job ends* so that staff are allocated and the appropriate preparations can be made. Starting preparations before the previous job ends allows time to make good any breakage, or change plans before machines are stopped.
- Locate and check all necessary tools, equipment and material, and have them available at the machine. Pre-warm dies or moulds away from the machine. Check to see if there are any records of previous settings for the product in order to minimise optimisation time.
- Make sure that fitters or machine setters do not get called away to deal with problems on other machines. Setting or maintaining a machine requires the full attention of the setter, and interrupted or hurried work can waste energy and materials.
- Make sure that Quality Staff are on hand in the latter stages of changes so they can issue approval as soon as the product has been made within specification. Material can be recycled, but the energy used in producing out of specification products is lost forever.

Between Jobs - Switching Off Barrel Heating

The only time that many barrel heaters are switched off is when the machine breaks down. This may make good technical sense for larger machines, but it does mean that electricity is used when machines are idling. Other energy wasting practices include setting up lines in readiness to avoid operators being idle if one line stops, and barrel temperatures being kept high (albeit at reduced levels) when there are no immediate plans to use specific machines.

Utilities

Utility energy use will be considered in detail in Section 4. However, there are three key points that should be considered in this section:

- Is cooling water still running through the system when the machine is not making product?
- Is compressed air still leaking from the machine when it is not making product?
- Is the vacuum system still running when the machine is not making product?

Recording Machine Settings

It is essential that all the settings of a machine are recorded as alterations are made. It is also good practice to record the final settings at shutdown to give the next operator a better chance of starting the machine quickly and efficiently. Although some of this information may be routinely recorded for Quality Assurance purposes, much of the rest tends to be kept only in the operator's head. For a site with a wide range of products, it is vitally important to record this data, as optimum settings will change with time and as machine components wear.

A comprehensive set of historical records will improve the understanding of machine operation and should result in efficiency improvements. This will facilitate the selection of the most appropriate machine for a particular job and will enable scheduled replacement of components and maintenance.

Experience has shown that machine 'tweaking' by individual operators - usually intended to improve production levels - causes more lost time and energy than almost any other cause. The lesson is, get machines set right, record the settings and do not change them unless absolutely necessary.

The Tools for the Job

It is worth investing in specific tool kits which should be kept adjacent to each machine. The tool kit can contain all the necessary tools for repairing the machine and its proximity will reduce the time taken to put machines back into production. This is particularly important for 'bottleneck' machines, where production losses will directly affect output.

Maintenance time is negative production time - it too must be done at speed and Right First Time!

Case Study 4

A case study of maintenance in one company illustrated the value of having machine-specific tool kits. In one instance, a moulding press shed one of its pillars, pushing the platens askew. Ten minutes after the incident occurred, a fitter arrived with a large tool case. Having examined the press, he spoke into his mobile phone and opened the case, which contained all the tools necessary to repair the machine.

After disconnecting the press and releasing the mounting bolts (about ten minutes work), two forklifts arrived, obviously the result of the phone call. Within 30 minutes of the stoppage, the press was in the workshop and three days later was back in production.

Action Point: Recording machine settings

It is vital to monitor and keep good records of all aspects of performance of each machine for particular product and polymer runs. Record:

- machine configuration (e.g. serial numbers of dies, calibrators, moulds used);
- machine specification (e.g. theoretical settings to achieve polymer characteristics);
- actual machine settings;
- time since last major overhaul (replacement of each major item, e.g. extruder screw);
- setting up time needed to reach acceptable product specification;
- production rate;
- product specification;
- polymer type;
- polymer batch and supplier;
- polymer additives (particularly proportion of recycled material);
- polymer moisture content (if available);
- polymer particle size distribution (if available);
- direct energy consumption;
- indirect energy consumption (use of central utilities);
- percentage of scrap product;
- range of actual production tolerances versus specification.

Remember that:

- a machine 'throttled down' to low production compared to capacity is inherently inefficient; and
- a machine is wasting energy making product to a higher specification than needed.

3.6 Performance Records

In Section 3.2, we said that the key to success in energy management is the complete integration of energy management activities within the organisation's business strategy. This means that energy reduction and efficiency improvements should become part of the business process, and not a special event. Energy results should be reported within normal reporting procedures to emphasise that energy management is simply good management.

Of course, the results of specific energy efficiency projects should be widely promoted, both internally and externally. However, the effect on operating performance should be apparent, and operational returns, where necessary, existing reporting methods and standards should be adapted to facilitate this process.

Process Performance Records

Performance records need to be kept for all processes (see Section 3.5) to maintain and improve control, and this should include records of process energy use to enable energy monitoring. Experience has shown that even the most basic attempt to reduce energy consumption can often show significant energy reductions and cost savings.

People Performance Records

In Section 3.2, the critical role of staff in reducing energy consumption was stressed. However, it is not enough to simply exhort staff to save energy and, as we saw earlier, more positive and systematic approaches are required. People only tend to react when their performance is being measured and some assessment of results is carried out. Simply issuing instructions from management to staff to save energy is generally ineffective, particularly when results or performance are not fed back.

3.7 The Asset Register

Another useful tool is the factory plant record or asset register. This is usually held by the finance manager or the company secretary, and contains the written down value of the company assets, including all machinery. It will state when and where plant was purchased and the initial purchase price. These are important to the maintenance engineer, particularly when plant is old and prone to failure, as they enable equipment to be assessed and potential replacement to be justified.

In fact, it is worth investigating the possibility of factory plant records being held and maintained by the engineering manager, in conjunction with the finance manager. This will enable the records to be updated with details of equipment performance and lifetime costs, including the full costs of breakdowns.

Action Point: Consider Fitting Additional Oil Filters in Hydraulic Systems

An additional bypass filter will:

- reduce oil contamination;
- increase life of oil;
- reduce wear and tear on components;
- improve system energy efficiency;
- reduce maintenance costs;
- reduce losses due to breakdown.

4. PRACTICAL MEASURES - UTILITIES

4.1 Introduction

This section deals with the design, installation and management of factory support services such as:

- water;
- compressed air;
- building services.

Often, factory support services are supplied without any attempt to quantify costs because they are thought of as essential. In many companies, allocation of utility costs to production is difficult due to a lack of suitable metering. The absence of financial controls is often accompanied by a lack of control of supplies and, when they occur, breakdowns can prove extremely expensive.

However, costs can be controlled and breakdowns can be avoided by taking a few simple actions. Generally, supply failures are preceded by a deterioration in energy performance and, where monitoring systems are in place, this can be detected. As with most things, prevention is better than cure.

The two major utilities used in plastics processing are water and compressed air, and both can be expensive to generate or buy. A careful analysis of the use of water and compressed air can pay dividends in reduced costs and increased reliability.

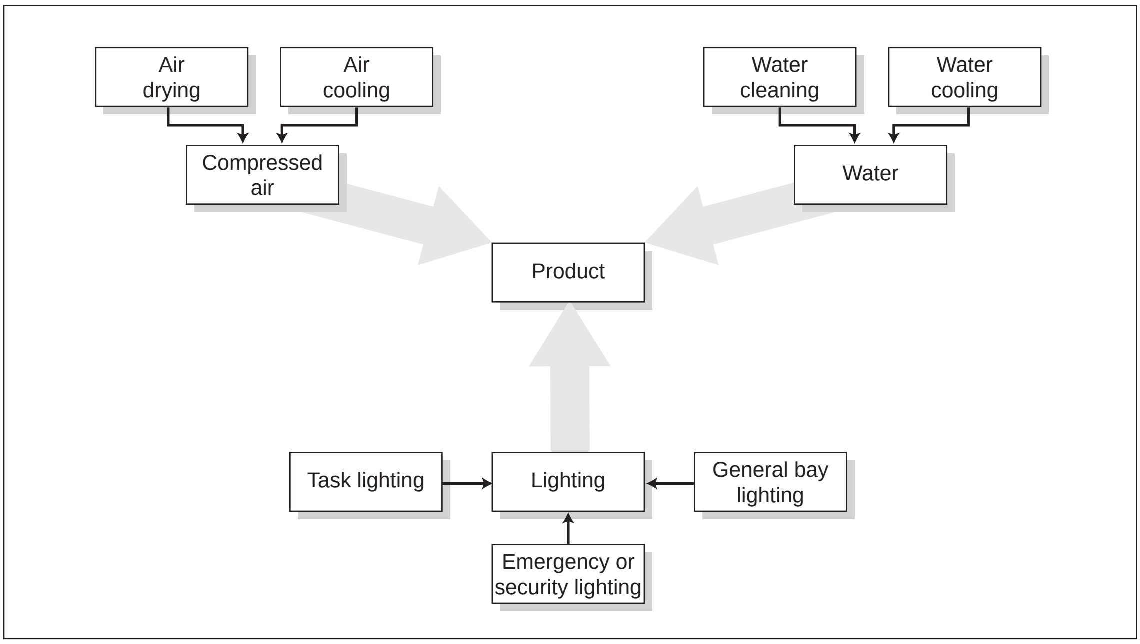

Fig 8 The use of utilities

4.2 Water

Reducing water costs starts by looking at water bills. Once overall costs have been established, future consumption targets and budgets can be set. Initially, a 10% reduction target can be set - in many companies, this could save up to £5,000/year.

Fig 9 shows the way that water flow is organised on a typical plastics processing site.

Delivering and applying the water has its associated costs. For example, water is usually pumped around the site or process area from a central sump. This is normally either temperature controlled or is of sufficient capacity to allow normal ambient cooling conditions to maintain a satisfactory supply. Frequently, electrically powered cooling towers or refrigeration units are used to remove the process heat. Invariably, these units are on-line throughout the working week, irrespective of plant operational demand. In this case, savings can be made by arranging for operation to match production demand.

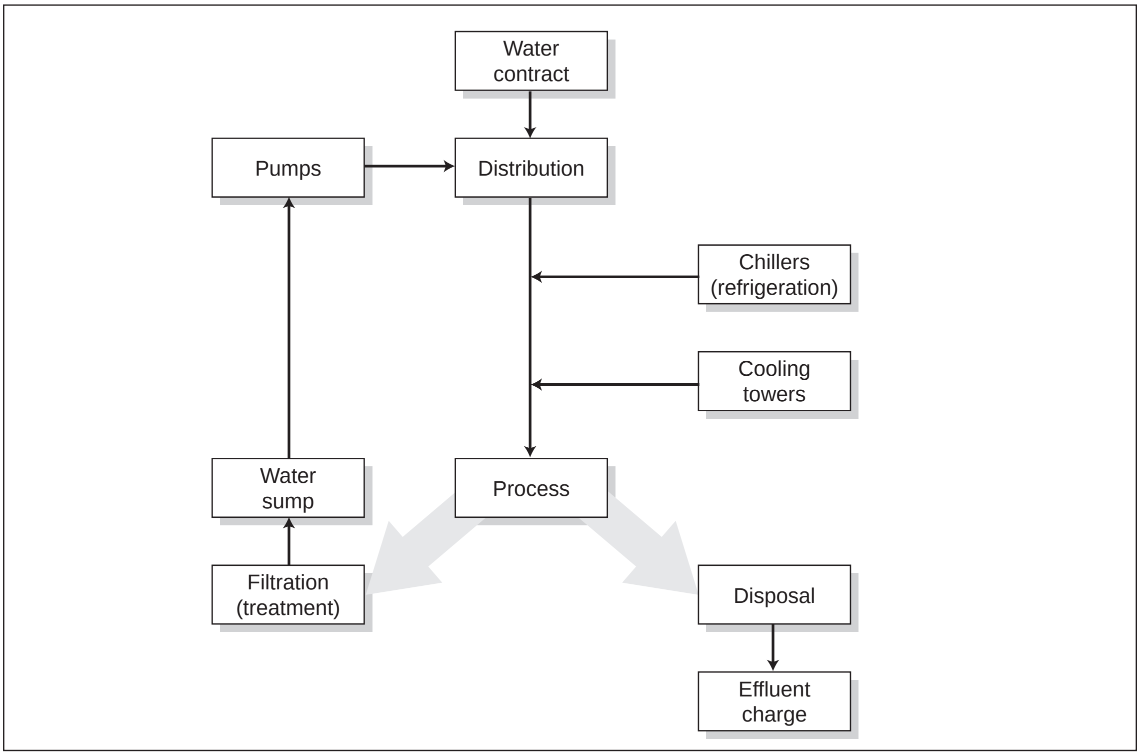

Fig 9 Water flow diagram for typical process activity

However, there are other options to central cooling systems. Some injection moulding machines are fitted with built-in closed circuit cooling systems, which reduce the danger of contamination. As these systems only operate when that machine is in use, they generally reduce energy and utility costs.

A typical example of the way that water is used in the plastics industry can be seen in the extrusion process, where large quantities of cold water are applied to the accessible extruded surfaces. Although large quantities of water are used in extrusion, few companies have thoroughly analysed and evaluated the process. In practice, there are significant variations from company to company between quantity, temperature, pressure, filtration methods and discharge procedures. Although there are no hard rules, each of these variables provides opportunity for experimentation and economy.

Extrusion sites apply water to the extrudate in a variety of ways. The simplest way involves passing the extrudate through a trough of flowing water, which is returned to a sump by gravity flow. The rate of heat removal is dependent upon:

- temperature difference between the extrudate and the water;
- rate at which the water is changing;
- degree of contact between plastic and water (N.B. Air bubbles on the plastic reduce the rate of cooling considerably).

Some cooling troughs are totally enclosed and fitted with vacuum pumps to provide a reduced atmosphere, which encourages any air bubbles to escape. Vacuum pumps are expensive to buy and costly to run. Usually, the pumps are larger than needed for normal operation to ensure that, when seals leak, there is sufficient capacity to allow operation to continue.

Sprays are fitted in some troughs in an attempt to move the water away more quickly from the hot extrudate, but there is little data to confirm the cost effectiveness of this methodology.

Size control by vacuum assisted metal sleeves can make a major contribution to the initial cooling of the extrudate. This is due to improved thermal contact as the extrudate is sucked on to the surface of the sleeve.

Action Point: Reducing water use

Check:

- for water leaks – including dripping taps or leaks in pipelines;
- that water temperatures in domestic systems are at appropriate levels;
- hoses are used carefully and are not left running when not in use - consider using high pressure hoses;
- water use in toilets and other facilities – they cost more to run than is usually appreciated!

Action Point: Reducing cooling costs

- A large sump will naturally cool down to ambient temperatures overnight and reduce cooling costs. Consider reducing energy bills from costly chillers by using this process.

Table 2 shows the specific heat capacities for various materials. Materials with a low heat capacity take on heat more readily but quickly become saturated. Polymers with a large heat capacity can take on greater quantities of heat but less readily. Therefore, in the cooling water circuit, it is important to make the maximum use of natural cooling by using a very large sump and by using artificial cooling as little as possible.

Table 2 Specific heat capacities of various materials

	J/kg °C
Copper	380
Aluminium	880
UPVC	1,700
PMMA	1,900
PPVC	2,800
PP	2,850
Nylon	3,000
HDPE	3,400
Water	4,200

4.3 Compressed Air

Compressed air is a convenient and often essential utility, but it is very expensive to produce. In fact, most of the energy used to compress air is turned into heat, which is then lost. As compressed air costs ten times more than the equivalent quantity of electrical power at the point of use, it should only be used when necessary and should certainly not be wasted. Air also needs to be treated to remove moisture, oil and dirt - the higher the quality required, the greater the energy consumed by the treatment system.

It is very important to make all end users aware of the cost of generating compressed air, and to enlist their help in reporting leaks.

However, although it is expensive, up to 30% savings can be made by some simple and inexpensive good housekeeping measures. The cost of generating compressed air can be calculated quite easily, using the following formula:

Compressor motor size x cost of electricity per unit x hrs per day x days per week x weeks.

For example, in a typical 24-hour day, five and half day week, a 100kW motor will use energy worth around £30,000 per year, assuming the cost of electricity to be £0.045/unit.

Maintenance and good housekeeping give a very rapid payback. In the UK, cost of compressor ownership over ten years is 10% capital cost, 15% maintenance and 75% electricity. Therefore, it is important to look at efficiency when buying a compressor.

Leakage

A significant amount of energy is wasted through leakage. Typically, leak rates can be nearly 40% - that’s 40% of generating power wasted in feeding leaks. The cost of a 3mm leak at 7-bar (g) is 11 litres/sec, which is a cost of £1,000 per year and, as a system can have numerous leaks, the cost can multiply rapidly. The cost of leaks can be calculated using the following formula:

Costs of leaks = compressor efficiency x hrs worked during year x
leakage rate x electricity costs

Fortunately, simple leak surveys can produce dramatic results. In some cases, rigorous leak reporting and repair programmes have enabled companies to shut down individual compressors for all or most of their operating time.

Action Point: Leakage reduction

Simple and repeated walk-round surveys, with leaks tagged in terms of severity and repaired as soon as possible, will make a significant contribution to reducing leakage rates. Load/no load tests will help to assess the leakage rate (for further information, see GPG 126, *Compressing air costs,* p5).

Use and Misuse of Compressed Air

Compressed air is often misused just because it’s there and everyone assumes it’s cheap. Check each application and note whether it is essential or convenient.

Action Point: Reducing compressed air usage

- Cut out the use of compressed air for ventilation or cooling - fans are more effective and far cheaper.
- Replace home made air nozzles with higher efficiency air nozzles - payback periods can be as short as four months.
- Consider the use of electric tools instead of compressed air.
- Do not use compressed air for conveying granules or products.

Action Point: Reducing Generation Costs

- Check that compressed air is not being generated at a higher pressure than required.
- Switch off compressors during non-productive hours, as they are often only feeding leaks in this time.
- Check that compressors are not idling when not needed – they can draw up to 25% of their load power consumption when idling.
- Arrange for air inlets to be outside, if possible - it is easier to compress cold air.
- If there is just one machine or area that requires compressed air longer than the rest, consider having a dedicated compressor so that others can be switched off.
- Investigate using electronic sequencing to minimise the number of times compressors go on and off-load – this can save substantial amounts of energy.
- Don’t neglect maintenance - missing a maintenance check costs more in energy consumed through reduced power output.

Action Point: Improving Distribution

- Make sure that the pipework is not undersized (see GPG 126, *Compressing air costs*, p9), as this causes resistance to air flow and hence pressure drop.
- Use a ring main arrangement in each building - air can converge from two directions, which reduces pressure drop and makes future alteration/extension of the distribution system easier.
- Make sure that there are no drops in pressure as these can compromise performance of equipment that relies on compressed air for its operation.
- Isolate any redundant pipework, as this can often be a source of leaks.
- When designing pipework systems, avoid sharp corners and elbows in pipework as these cause turbulence and hence pressure drops.

Action Point: Reducing Treatment Costs

- Treat the bulk of air to the minimum quality necessary, e.g. 40-micron filters are usually sufficient. Specifying 5 micron will increase filter purchase cost, replacement frequency, and pressure drop.
- Test filters regularly to make sure pressure drop does not exceed 0.4 bar – if the pressure drop is higher than 0.4 bar, replace filters, since the cost of power to overcome this drop is usually greater than the cost of a filter.
- Consider fitting electronic condensate taps - manual taps are often left open and act as leaks.

Heat recovery
90% of the energy used to operate a compressor is converted into heat, which is usually wasted. It is worth investigating whether this waste heat can be used as pre-heating for another process, or space heating in winter.

4.4 Building Services

The previous sections have concentrated on production-related energy use. Although buildings-related energy use is often seen as secondary, it actually represents an average of 17% of total energy costs. It can present good opportunities for energy savings simply because changes do not impact on production.

In recent years, there have been significant improvements to polymer processing sites. This is due in some part to the introduction of quality initiatives and general improvements in process systems, all of which have contributed to a general improvement in working conditions and standards.

Improvements have included:

- recognition of the need for cleanliness (e.g. for floors, machines, etc.);
- avoidance of oil and polymer spillages;
- improved control of scrap products;
- immediate clearance of waste; and
- established routines for disposing of ‘out of spec’ products and purgings.

The general upgrading of conditions has lead to significant improvements in all-round site efficiency, and this has resulted in a general reduction in levels of energy, utilities and waste. However, significant opportunities still remain for energy savings in areas such as lighting, space heating and domestic hot water supplies. Many plastics processes generate a lot of excess heat, so it is worth looking at whether this excess heat could be used for other purposes, such as space heating.

Lighting
Although they consume only a relatively small part of the overall energy budget, lighting systems offer opportunities to save energy in a way that is easily demonstrable to staff. For example, replacing normal tungsten bulbs with compact fluorescent lighting saves money in the long-term - although they cost ten times more than conventional bulbs, fluorescent tubes last about ten times longer and reduce maintenance costs for replacing bulbs. Compact fluorescent lights also use only 25% of the electricity of tungsten types.

It is worth paying close attention to areas with:

- high lighting levels and no people;
- continuous lighting and only occasional occupation; and
- fluorescent tubes fitted at high level without reflectors.

EEBPP publication ECG 18, *Energy efficiency in industrial buildings and sites,* includes the results of a survey conducted on sites across all UK industry. The data on **average** annual delivered energy use and cost for the plastics industry is shown in the box. The main figures represent those of an average working day cycle of 2.3 eight-hour shifts, and the bracketed figures give the values for an eight-hour shift. This data can be used to benchmark the performance of any site against the national average.

Table 3 Site survey results

Site Survey Results

	Average annual energy use kWh/m^2	**Average annual energy cost £/m^2**	**% total energy use**	**% total energy cost**
Process	532 (231)	26.60 (11.56)	61.0	82.9
Buildings total[1]	340 (148)	5.48 (2.38)	39.0	17.1
Of the above, space heating is[2]	288 (125)	2.88 (1.25)	33.0	9.0

Note: [1] Buildings total energy use values ranged from 300 (130) to 550 (239) kWh/m^2.

[2] Because of heat emitted by the machines, most moulding process areas have no need for space heating.

5. PRACTICAL MEASURES - MACHINES

5.1 Introduction

This section is devoted to the prime movers and other equipment that directly consume electrical energy and are typically found in plastics processing sites. Although there are ongoing technical measures to improve both functionality and efficiency, they rarely justify the immediate replacement of existing plant and equipment. However, ongoing technical improvements highlight the importance of including energy efficiency as a key criterion when the time comes for major repairs or replacement.

System Controls

Hydraulic, electrical and pneumatic control systems have all been enhanced by the introduction of the microprocessor, which enables complex functions to be controlled automatically. However, even such advanced control systems have limitations, and it is essential that, when searching for energy savings, the difference in response speed between sensor and actuator is not overlooked. This is particularly the case with pneumatic and, to a lesser degree, hydraulic systems.

It is important to remember that the response time of a physical condition does not alter just because a new control system is fitted. For example, the speed of heat transfer from barrel to polymer is governed by the quantity of heat applied and the material through which it is passing, not by the speed of the microprocessor. If a control system reacts too fast, there is a distinct possibility of ‘hunting’ occurring. Similarly, if reaction times are too long, ‘overshoot’ can occur, temperatures can increase to out of control levels and elements or products may burn out. Where changes in the settings of control systems are contemplated to save energy, a degree of caution is necessary and only small changes should be made to ensure that controls always remain in charge. It is always sensible to have a standby instrument, such as an independent or stand-alone pressure gauge or a thermometer, to observe the results of any changes.

Setting-up Documentation

Energy savings that are achieved through changes to technology will only be retained so long as care is taken with machine settings. Despite the presence of quality control/audit systems (QA) in many factories, control of setting conditions is often inefficient, with documentation poorly controlled and frequently difficult to locate. The prevailing culture is of in-house departments that are so familiar with products that they do not need to refer to setting data. The consequence of this is that, when changes are made, the new settings are quite likely to be ignored.

In fact, product quality will always be affected by changes to cycle conditions, and any increase in cycle time will usually mean that more energy is used.

Many modern microprocessors have a data recording facility that will record setting conditions to assist re-setting the machine. Some systems also have in-built protection against unwarranted changes – an important asset, as divergence from set standards can lead to a loss in all hard-won energy savings.

5.2 Motors and Drives

As a result of their reliability and efficiency, electric motors often tend to be forgotten when companies are thinking about energy efficiency. However, although motors and associated drives are available in a range of sizes, it is often difficult to match their output precisely to the needs of the equipment to be driven, and this leads to energy losses. In addition, the loads posed by the equipment are rarely constant, and this fluctuation leads to further inefficiencies.

Motors are at their most efficient when their load equals, or is slightly greater than, their rated capacity. There is nothing wrong in expecting a motor to run for short periods at measurable amounts of overload, provided that there is a period of lesser load when the windings can cool a little. As an example, motors on ‘Banbury’ type mixers have particularly robust motors to handle the wide range of loads that are usual in this machine (often twice their rating for part of the cycle). As excess heat is dissipated during the remainder of the cycle, the machine is always ready for its next peak load.

Extruders, fans, compressors and pumps are among the applications that present motors with an almost steady load, but even they fluctuate slightly and their basic operating load rarely matches the standard motor. Simple calculations show that the power used in one month’s continuous running is as much as the cost of a standard motor. Therefore, it is inefficient to fit oversized motors, and equipment demand should be carefully matched with motor size. Devices, such as Variable Speed Drives (VSDs) and ‘soft start’ units, will allow motors to run nearer their optimum efficiency and save both energy and money.

Hydraulic systems, such as those used to operate many machines (including injection and blow moulding machines), provide loads that fluctuate over wide ranges. In trade moulders, where there is a tendency to purchase machines slightly larger than needed, motors tend to rarely reach their design load. Consequently, they never run at optimum efficiency.

Most drives in the plastics industry are powered by simple and reliable induction motors and, until recently, the options for reducing their energy consumption were fairly limited. However, new generation higher efficiency motors (HEMs), now available at the same price as the older, less efficient models, have opened a range of opportunities to reduce energy consumption and cut costs. Efficiency levels have been increased by up to 3% as a result of developments in construction materials, winding configurations, cooling circuits and bearings. HEMs have a peak efficiency at 75% of load, thus reducing the problem of oversizing.

Although 3% may not sound too much, in practice, the domination of energy cost over purchase price makes a significant difference to the way that companies need to look at electric motors. Electric motors can consume their capital cost within just 40 days of continuous operation, and with running costs exceeding initial purchase cost by a 100 times in a ten-year lifetime, it makes sense to base decisions on a ‘life cost’ basis. This should include all purchase, maintenance, repair and operating costs.

The changes brought about by the development of HEMs are so significant that, in order to reduce costs, companies operating electric motors should develop and implement a management policy for their purchase and operation. This policy should include guidelines on:

- repair and replacement based on lifetime costing; and
- the specification of HEMs for all new purchases.

When new motors are required, the benefits of opting for HEMs seem fairly obvious. However, the failure of an existing motor is a different matter and is likely to prompt the question of whether the motor should be repaired or replaced. Of course, any decision on repair or replacement may be pre-empted by the need to rapidly reinstate the drive in order to avoid additional costs occurring as a result of equipment downtime. But, if there is less urgency to replace, or if a spare motor exists, then repairing the failed unit may appear to be the most cost-effective course of action. However, think carefully before opting for a repair. As Table 4 shows, taking lifetime costs into account can shed new light on any decision (N.B. Payback is calculated on the cost difference between new purchase and repair).

Table 4 Total purchase and energy costs of repairing and replacing a failed 30 kW motor

	Standard motor	**After rewind**	**HEM**	**Typical difference**	**Simple payback**
Efficiency	90.5%	90.0%	92.5%	2.5%	
Input power	33.15 kW	33.33 kW	32.43 kW	0.90 kW	
Cost of repair/purchase		£850	£1,100	£250	
Case 1: 8,000 hr/year @ 100% load					
Annual energy use	265.1 MWh	266.6 MWh	259.5 MWh	7,100 kWh	
Annual energy cost (estimated at 5p/kWh)	£13,255	£13,330	£12,975	£355	<1 year
Case 2: 4,000 hr/year @ 75% load					
Annual energy cost (estimated at 5p/kWh)	£4,970	£4,999	£4,865	£134	2 years

Table 4 clearly illustrates the relationship between long-term running costs and initial purchase price, and shows how replacing a non-working standard motor with an HEM can result in a significant cost benefit for the operator. In these calculations, a fairly conservative 3% is allowed for efficiency gains. However, in practice, this may be nearer 4%, as a repaired motor is likely to be up to 1% less efficient than before repair, and up to 3% can be gained from the extra efficiency of an HEM.

Matching Electric Motors to Demand Cycles

Fig 10 shows the instantaneous energy demand from an injection moulding machine and illustrates the peaks and troughs of demand. The cycle of activities can be clearly seen from the energy demand curve. This graph highlights the need for motors to be sized according to their application. It is strongly recommended that expert advice on motor sizing is sought.

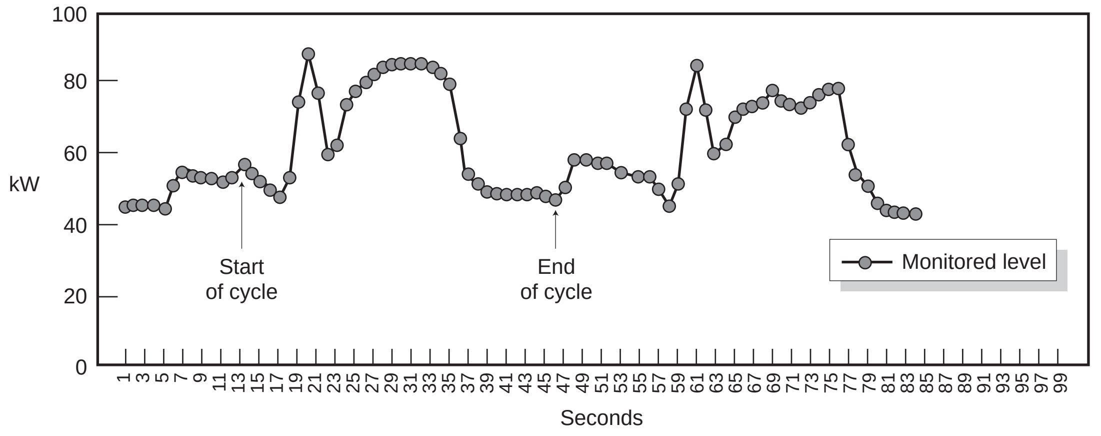

Fig 10 Instantaneous energy measurements on an injection moulding machine

One fairly simple no-cost method of improving efficiency is to reconfigure motors from Delta to Star connection. Changing to Star connection cuts energy consumption by reducing the voltage across the motor windings. Although this procedure is only possible where motors can be accurately predicted to always run at less than 45% of their rated motor output, it is worth serious consideration as savings of up to 10% can be made with no additional investment.

Variable Speed Drives (VSDs)
As the speed of an electric motor is dependent on the number of poles and the supply frequency, it is a fixed speed machine. Because of this limitation, many moulding machines using hydraulic systems are driven at a constant speed, even though the demand varies considerably over the process. Typically, flow from the hydraulic pump is controlled in a very inefficient way by a relief valve and re-circulation of the hydraulic fluid.

One way of varying the speed of the motor to meet the demand of the process is to fit a variable speed drive (VSD). A variable speed drive uses power electronics to convert the fixed mains frequency to a variable frequency supply, and this enables the speed of the motor to be varied. The hydraulic pump can then be driven at a speed and flow that exactly matches the variable demand. By eliminating inefficient mechanical controls and matching power demand precisely to the requirements of the machine, considerable energy can be saved.

There are a number of other benefits that can be gained from fitting VSDs:

- Reduced demand on the hydraulic system means that the hydraulic oil runs at a lower temperature and thus requires less cooling - an additional energy saving measure.
- Reduced noise.
- Lower maintenance costs.
- Better all-round performance.

VSDs can also be applied to fans, water pumps and air compressors.

5.3 Heat Transfer

Heat that does not reach the intended target accounts for a very large percentage of the energy cost of plastics processing. Reducing the level of ineffective heat transfer provides significant energy saving opportunitites.

Around 95% of the energy required to process the polymer escapes during the process as heat through radiation, convection or conduction. The remaining portion eventually escapes as heat as the product cools to ambient temperature. Heat transfer between heater and polymer is only one of a number of changes that take place during the making of a plastic product. However, not all of these changes are planned and some heat losses are caused by inefficient or badly designed processes. Savings can be made by controlling the unplanned losses.

Screw Barrels
Heat is generated by both the mechanical action of the screw and by external heater bands. The heater bands apply heat preferentially by contact with the exterior of the barrel. Most heater bands have sheet metal cases and, when first fitted, do not make contact with the machined barrel across the entire area. The contact area increases as the heaters are clamped in place but, generally, without reaching 100%. Poor contact means that the amount of heat passing to the barrel is reduced, with some escaping to the atmosphere. New heaters should be successively clamped and released to bed them in place. Contact levels can be further improved by smearing the mating surface with a copper-based paste, such as that used for electronic heat sinks.

Heat losses can be further reduced by fitting insulation muffs to the outer surfaces. This also improves the safety of the operation, as machines with older-type controllers may not respond quickly enough to avoid overshoot when started from cold. If there are doubts about safety levels, always take suitable precautions. Appropriate insulation materials may also be used as a barrier between metal surfaces, such as between moulds and platens, to prevent heat escaping into the body of the machine. This is frequently done on thermoset and rubber moulding presses.

Action Point: Barrel insulation

- Barrel insulation has exceptional financial effectiveness with rapid payback times, and should be a top priority for action.

Heat from Electric Motors

Loss of efficiency in motors appears as excess heat in the windings, which is then dissipated by fans on the motor shaft. On small motors, the small quantity of heat is generally ignored, but on larger motors, it is worth considering ducting the air supply to the outside of the building. Alternatively, this low grade heat could be used as space heating in the winter months for areas outside the production zone. Using this waste heat to raise temperatures in the polymer stores would reduce the processing load.

Heat from Hydraulics

Hot hydraulic oil provides another source of low grade heat. Its usefulness is generally limited to warming the surrounding air or, where heat exchangers are fitted, to warming water. However, it is important that oil is never allowed to overheat as this causes rapid degeneration of both the oil and the plant.

Heat from Spread Fabrics and from Forming Machines

The fumes given off by these processes, and collected by ventilation systems, are usually contaminated by polymeric substances. As these substances condense on cold surfaces, they are difficult to pass through any form of heat exchanger and are, generally, not suitable for re-use.

Heat from Moulds

Similar techniques may be used for moulds as those used for screw barrels. External surfaces may be insulated, as the heat transfer through the body of the press is quite substantial. Although a relatively thin sheet of hard insulation material is often placed between mould and platen, tests have shown that doubling the thickness is cost effective. Tests on a compression press have shown that protecting machinery from draughts by placing polycarbonate sheet inside the normal machine guards was cost effective.

6. ENERGY PURCHASING

The introduction of competition into the energy market has made a major impact to the way that electricity, gas and other fossil fuels are purchased. There are now a number of suppliers available, with significant variations in tariffs. Some care in selecting suppliers is necessary, and outside energy consultants can provide invaluable assistance, particularly to smaller companies lacking either time or expertise. Consultants will undertake contract negotiations with energy suppliers on behalf of clients, with fees often based on accrued savings. However, in the long-term, companies will not achieve their maximum energy savings potential until the management of energy becomes a totally integrated in-house activity.

6.1 Electricity

Considerable changes have taken place in the purchasing of both electricity and gas since privatisation. As we said in Section 2.5, customers now have a considerable choice of different suppliers and tariffs from which to choose..

Contracts usually centre around variables such as Power Factor, Maximum Demand, and Maximum Power Requirement. This makes it doubly important for a company to know exactly how their electricity supply is measured and billed. Most companies now have installed Power Factor Correction equipment and, even if this does not affect costs, a corrected Power Factor will increase the safe load from the transformer, thus avoiding the necessity to rapidly increase capacity over a short period of time.

Maximum Demand still plays a large part in penalty clauses and can be avoided in various ways. At the simplest level, avoiding starting a number of machines at the same time (usually in the same 30-minute period) can reduce maximum demand levels. Alternatively, supplementary on-site diesel generators can also avoid the Allowed Maximum Demand being reached.

6.2 Fossil Fuels

As with the purchase of electricity, consumers now have a wide range of potential suppliers for fossil fuels, coal, oil and natural gas. Purchases should be undertaken on a competitive basis, with suppliers tendering for the supply of fuel at the best price for the supply location.

Natural Gas
Gas can be purchased on two types of contract:

- Firm supply contract.
- Interruptible supply contract.

Firm supply contracts cover the smaller end of the market, including the domestic market, with supply contracts usually extending over a 12-month period. However, if it is felt that market gas prices are likely to rise during the contract period, it may be worth considering a longer period. When entering into a long-term contract, it is essential to include a clause for early termination in order to cater for major fluctuations in market prices. This will enable a long-term contract to be terminated and re-negotiated.

The cost of gas can be reduced through an interruptible supply contract. Interruptible supplies are normally for larger gas consumers with annual consumptions in excess of 200,000 therms, or 5.86m kWh. Interruptible contracts enable suppliers to interrupt supplies over a contracted period ranging from a number of hours to several weeks. In order to cope with this interruption, it is necessary to have a stand-by fuel and a dual-fuel firing capability.

7. THE ENVIRONMENT AND ENERGY HELPLINE

Don’t forget that help is only a phone call away for companies needing free, expert, up-to-date advice and information on environmental and energy issues. The Environment and Energy Helpline on freephone 0800 585794 can provide answers to the most pressing queries - plus plenty of practical tips on how to increase profits by reducing energy use.

The Helpline is operated by the Energy Efficiency Best Practice Programme, which aims to help UK businesses save money. Advice, publications, seminars and workshops are all offered FREE to UK businesses.

Environment and
Energy Helpline
0800 585794

To benefit from any of the free services described above, or for further information, call the Environment and Energy Helpline on 0800 585794. The following web site also contains useful information:

www.energy_efficiency.gov.uk

APPENDIX 1

ENERGY AWARENESS IN THE ORGANISATION -
A SELF-ASSESSMENT QUESTIONNAIRE

Please tick one answer in all 6 sections

	Level	Score	Accum.
Energy policy			
Full action plan as part of environmental strategy	4		
Formal policy but no top commitment	3		
Unadopted energy policy set by energy manager	2		
An unwritten set of guidelines	1		
No explicit policy	0		
Organising			
Energy management fully integrated, clear responsibility	4		
Energy manager responsible to Energy Committee	3		
Energy manager in post but authority unclear	2		
Part time energy manager	1		
No energy management	0		
Motivation			
Regular formal and informal channels of communication	4		
Energy committee and direct contact with major users	3		
Contact with users through ad hoc committee	2		
Informal contact with engineer and a few users	1		
No contact with users	0		
Information systems			
Set targets, monitored consumptions and quantified savings	4		
M&T reports but savings not quantified	3		
M&T reports on supply meter data	2		
Cost reporting on utility invoice data	1		
No energy accounting	0		
Marketing			
Value of energy management marketed within company	4		
Programme for staff awareness with regular publicity	3		
Some ad hoc staff awareness training	2		
Informal contacts to promote efficiency	1		
No promotion of energy efficiency	0		
Investment			
Positive favouring of ‘green schemes’ in Projects	4		
Energy Projects treated as any other project	3		
Short term investment criteria only	2		
Only low cost measures undertaken	1		
No investment to increase energy efficiency	0		

Score	Assessment	Comments and Action
16 - 24	Very Good	Energy management has the highest priority in your company. But don’t forget that maintaining awareness can be difficult - it is easy to become complacent. **Action:** Use the guide as a reference aid in maintaining high standards.
12 - 15	Good	Energy management is the concern of the whole company, although some managers consider it to be technical rather than part of their responsibility. **Action:** Review the basic organisational aspects discussed in Section 2.1 and improve the deficient areas, formalising where possible. Use this guide as a reference.
8 – 11	Medium	Energy management is carried out on an almost casual basis with non-technical managers leaving it to technical staff. **Action:** Section 1.1 is the starting point to formalise energy management by integrating it into the company’s management structure and producing a positive energy programme.
4 – 7	Fair	Only a few members of staff realise the value of energy management and there is little or no corporate policy. Great potential to save. **Action:** Use this guide to assist in setting up a fully integrated energy management system within your company.
0 – 3	Poor	Energy management is non-existent, so there is great potential to reduce energy consumption, probably by 20% or more. **Action:** Use this guide to assist in setting up a fully integrated energy management system within your company.

APPENDIX 2

CHECKLIST FOR AN INITIAL SITE SURVEY

Who should get the results?

The results of the survey should go right to the top - the Chief Executive.

What are the objectives of the survey?

The objective of the initial survey is to familiarise yourself with general site energy use – ask the following questions:

- Which areas have the largest electrical load? (look for the largest machines; they will most likely also have the largest motors and create the largest load, when used).
- If present, is the insulation on machines in good condition?
- Which motors are left running?
- Does the compressed air pressure need to be so high, or the vacuum so low?
- Which lights and machine heaters are still on?
- Where can you hear steam and compressed air leaks?
- Which cooling water pumps (and chillers) and vacuum pumps are still running?
- Is the lighting dirty or broken?
- Why are the motors that size and would a smaller motor be more efficient?
- Are there any good reasons why machines need to be kept idling to be ready for the next production run?
- Are there good, simple maintenance measures?
- Are ‘accepted’ practices wasting energy?
- During lunch breaks and after normal working has ceased, are machines still running and lights left on continuously.

When?

Carry out this survey immediately - if energy is being wasted, it is costing money.

How?

- Take an unannounced walk around the site at about mid-shift.
- Look for signs of machines that are not in production but appear to have motors or other equipment (e.g. conveyors, pumps, granulators).
- Look out for running water and air or steam leaks.
- Make a note of any instances of energy use where no productive work is being carried out.
- Look for fans running and lights left on when not needed.
- Arrange for an engineer to measure the factory electrical load and calculate the cost.

APPENDIX 3

CHECKLIST FOR BUILDINGS ENERGY USE

Activity	Checked	Date
Carry out energy audit of buildings.		
Carry out infrared thermography survey of the outside of buildings to pinpoint heat losses.		
Look at replacing normal tungsten bulbs with compact fluorescent (CF) lighting.		
Install high frequency tri-phosphor fluorescent lighting tubes when replacing or refurbishing existing older systems.		
Look at high and low pressure sodium lighting as an option for large areas where lighting colour is not critical.		
Look at automatic lighting controls that sense ambient light levels and building occupancy.		
When adding new buildings, consider energy efficient designs with passive solar heating, passive ventilation, added thermal mass, and natural lighting systems.		
Review building insulation thickness.		
Consider installing an automatic Building Energy Management System (BEMS) – these control energy cost without relying on staff to set controls correctly.		
Check whether tamperproof thermostat and control settings have been fitted to radiators.		
Investigate cost-effectiveness of draught proofing doors and windows.		
Consider installing condensing boilers as either new-fit or replacement for small hot water systems.		
Look at whether automatic fast-acting roller shutters will save energy on external access doors.		
Check insulation on supply pipes to radiators.		
Look at installing false ceilings on high ceilings or using destratification fans to blow hot air from the roof space back down into the working space.		
Check whether partitions or local systems for key areas could reduce bills for ventilating and heating large building spaces.		
Check whether it is necessary to heat lightly occupied warehouses.		

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FEB 012	Lighting
FEB 013	Avoiding energy waste
FEB 015	Gas fired boilers
FEB 016	Building insulation
FEB 019	Process insulation
GPCS 032	All electric injection moulding
GPCS 088	VSDs on water pumps
GPCS 102	Lighting controls in stores
GPCS 143	An improved infra-red camera for trouble-shooting on a paper machine
GPCS 152	Advanced factory units
GPCS 157	Lighting in warehouses
GPCS 158	Lighting in factories
GPCS 170	VSDs in a chemical plant
GPCS 214	Energy saved by raising employee awareness
GPCS 222	Purchasing policy for higher efficiency motors
GPCS 232	VSDs for wood dust extract fans
GPCS 252	Energy management in a small plastics injection moulding plant
GPCS 253	Energy management at a large plastics injection moulding plant
GPCS 270	VSDs on cooling tower induced draught fan
GPCS 272	Refurbishing buildings
GPCS 274	Insulation of pipe fittings
GPCS 276	Energy management in a manufacturing company
GPCS 354	An energy management and monitoring system
GPG 002	Energy saving with electric motors and drives
GPG 048	Reducing energy use in injection moulding
GPG 084	Managing and motivating staff to save energy
GPG 085	Energy efficiency training and development
GPG 092	Reducing electricity use in extrusion blow moulding of thermoplastic
GPG 112	M&T for large companies
GPG 125	M&T in small and medium-sized companies
GPG 126	Compressing air costs
GPG 158	Industrial lighting
GPG 169	Putting energy into total quality – a guide for energy managers
GPG 172	Marketing energy efficiency – raising staff awareness
GPG 186	Developing an effective energy policy
GPG 187	Space heating
GPG 200	A strategic approach to energy and environmental management
GPG 217	Cutting energy losses through effective maintenance
GPG 251	Maintaining the momentum – sustaining energy management

For details of the latest publications and help with specific questions, please call:

Environment and Energy Helpline 0800 585794

The Government's Energy Efficiency Best Practice Programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry, transport and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice Programme are shown opposite.

Further information

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Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R & D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Energy Efficiency in Buildings: helps new energy managers understand the use and costs of heating, lighting etc.