GOOD PRACTICE GUIDE 209

Reducing energy costs in dairies

A guide to improved profitability

GOOD PRACTICE GUIDE 209

BEST PRACTICE PROGRAMME

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

REDUCING ENERGY COSTS IN DAIRIES

This Guide is No. 209 in the Good Practice Guide Series and it provides advice on practical ways of improving energy efficiency in liquid milk dairies and creameries. The Guide examines how energy is used within the dairy industry and assesses the potential for energy savings. It presents a range of energy saving measures, including better energy management techniques, adaptations to process and cleaning equipment, and improvements in the support services that the industry depends on. Both no- and low-cost measures are discussed as well as those involving a greater level of capital expenditure.

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Cover photographs: longlife milk packaging plant courtesy of Tetra Pak Ltd; bottling plant courtesy of Chris Pearsall/ National Dairy Council; heat exchanger courtesy of National Dairy Council; cheese packaging courtesy of Taw Valley Creamery

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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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REDUCING ENERGY COSTS IN DAIRIES

1. SUMMARY

1.1 Energy is a Controllable Resource

Using energy efficiently helps to maximise profits by reducing energy costs. It is also kinder to the environment, contributing to the ‘green’ image of your company and industry sector. Energy is used for heating and cooling and to power equipment, and the cost to the dairy industry exceeds £70 million per year. The potential for energy saving is significant. It ranges from 5% of present consumption in the case of washdown and cleaning-in-place procedures to as much as 30% of the energy used for compressing air.

This Good Practice Guide shows how to cut your energy costs. It provides simple guidelines on the most effective ways of determining where energy and cost savings can be made. Every £1 saved at 5% profit is equivalent to £20 from sales. Savings on energy use go straight onto the bottom line.

A number of check-lists are provided. The actions are practical to implement and, in many cases, require minimal capital investment.

For example, one dairy made an annual energy saving worth £14,230 and savings on water worth a further £17,750 by monitoring its energy consumption and putting in place a number of good housekeeping measures. The initial capital outlay amounted to only £5,940. Another company is saving £12,000 a year by simply putting in place a system to identify and repair leaks in its compressed air system. These case studies demonstrate that more energy-efficient practices can effectively and permanently reduce operating costs for a relatively small investment.

References are given to other useful documents published by the Department of the Environment, Transport and the Regions and available from ETSU or BRECSU. These provide more detailed information on some of the subjects discussed. A full list of relevant publications is provided in Appendix 1.

FINDING YOUR WAY AROUND THIS GUIDE

2. THE DAIRY INDUSTRY: ENERGY CONSUMPTION AND COSTS

2.1 Summary

This Guide is aimed at all those companies that take in raw milk and treat it to produce a final liquid or manufactured product.

The UK dairy industry has an estimated annual turnover of £15 billion of which *£73 million is spent on energy.*

Overall, the largest single users of electrical energy are refrigeration units and cold stores, air compressors and pumps, packaging processes and lighting. In the case of creameries, substantial amounts of electricity are also used for dryers, effluent plant, and evaporators and separators.

Process heat, usually generated in oil- or gas-fired boilers producing steam, is used primarily in pasteurisers, evaporators and dryers and in the provision of hot water for cleaning or cleaning in place (CIP).

2.2 Energy Consumption and Costs

Energy Consumption

Creameries use substantial amounts of energy, although the energy performance indicator varies with the product manufactured (Table 1). Butter and cheese production involves cooling and churning or pressing processes prior to packaging. The production of powdered milk and whey is very energy intensive in the evaporation and drying stages, and evaporators and dryers account for more than half of total energy use in creameries.

Table 1 Creameries: Mean energy performance indicators

Creamery products	**Mean energy performance indicator kWh/000 litres raw milk input**
Mainly yoghurt and milk powder	607.5
Hard cheeses	446.5
Soft cheese and butter	345.1
Liquid milk products	227.1

Of almost 1.5 billion kWh of delivered energy consumed by the liquid milk sector, 24% is in the form of electricity and 76% in the form of fossil fuel. In the creameries sector, that proportion of the 3.7 billion kWh of delivered energy supplied as electricity falls to 17%, with 83% coming from fossil fuel. Variations do occur, depending on the products manufactured (Table 2).

Table 2 Creameries: Electricity as a percentage of the total energy bill

Creamery products	Electricity as % of total energy bill
Mainly yoghurt and milk powder	15%
Hard cheeses	18%
Soft cheese and butter	60%
Liquid milk products	19%

Energy Costs

Table 3 shows the cost of energy in the dairy industry. A more detailed breakdown of energy costs for the two sectors of the industry is shown in Figs 1 and 2.

Table 3 Energy costs in the dairy industry

	Electricity cost £M/year	Fuel cost £M/year	Total cost £M/year
Liquid milk sector	15.8	8.3	24.1
Creameries sector	24.8	23.8	48.6
Total	**40.6**	**32.1**	**72.7**

Source:[1]

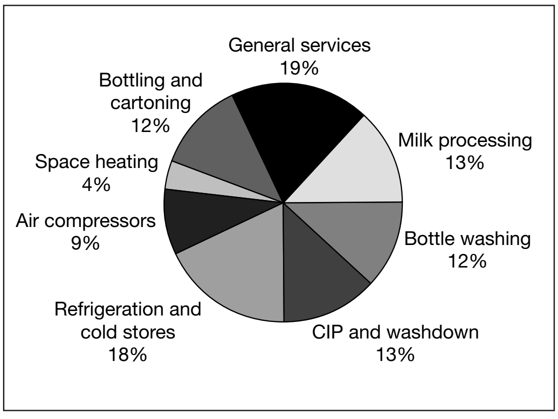

Fig 1 Energy cost breakdown in liquid milk dairies

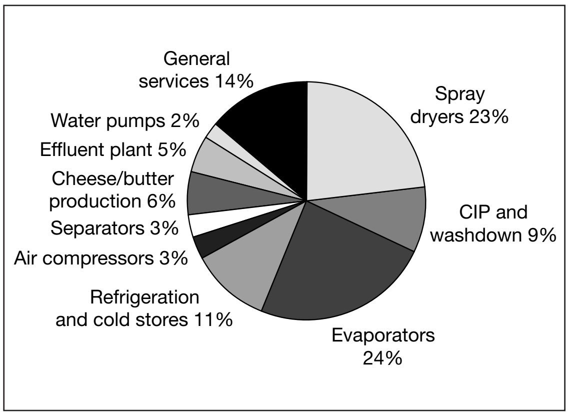

Fig 2 Energy cost breakdown in creameries

[1] Data derived from information contained in the following Energy Consumption Guides, copies of which are available from ETSU:
ECG 26, *The liquid milk sector of the dairy industry*
ECG 50, *The creameries sector*

2.3 The Potential for Energy Savings

Significant potential exists for energy savings in both liquid milk dairies and creameries (Figs 3 and 4). Furthermore, experience in a number of dairies has shown that energy savings of 10 - 20% can be achieved, particularly in the smaller concerns, by improving energy management techniques and without major capital investment.

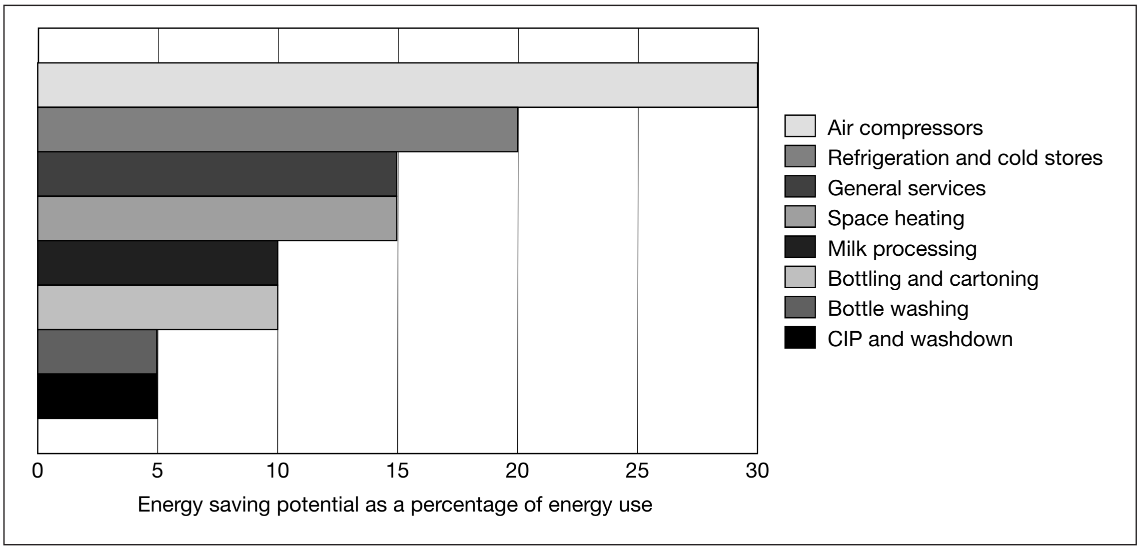

Fig 3 The energy saving potential of cost-effective measures in liquid milk dairies

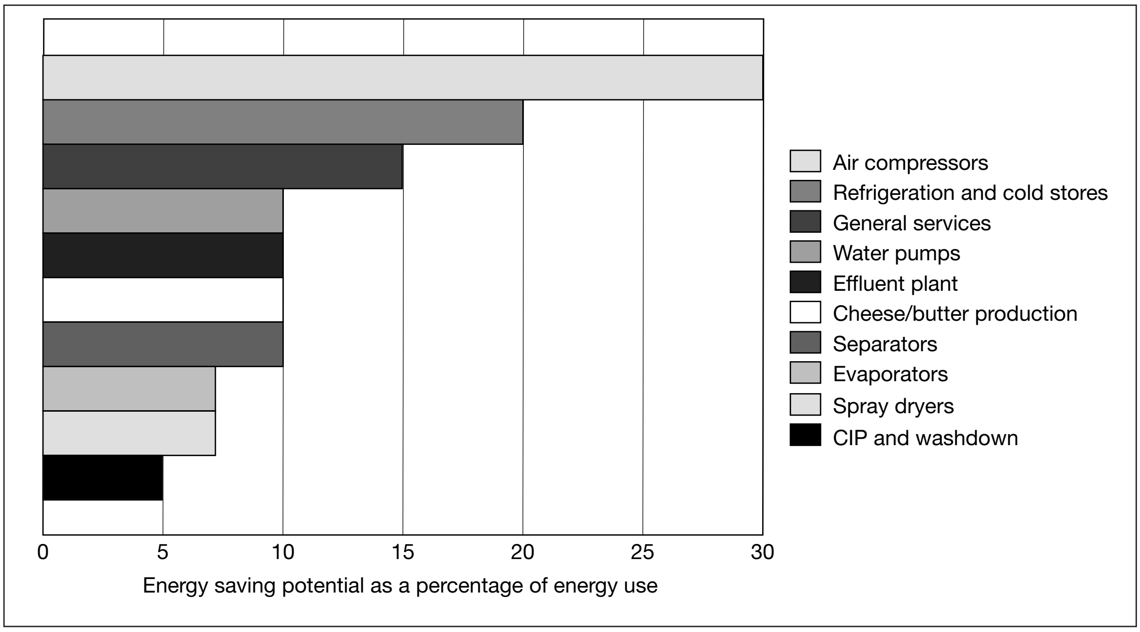

Fig 4 The energy saving potential of cost-effective measures in creameries

It is clear from the figures in Table 3 that a 10% improvement in energy efficiency would have a considerable impact on both energy consumption and profitability. Energy savings would total approximately 0.5 billion kWh (1.8 PJ), and there would be substantial cost and environmental benefits.

Closer examination of these energy cost breakdowns and savings potential reveals that both creameries and dairies could save around 13% of their energy costs by implementing cost-effective technical measures. For a dairy with a turnover of £30 million, this could represent up to £20,000 savings per year. Savings from energy management techniques would be in addition to this.

3. MONITORING ENERGY CONSUMPTION AND SETTING TARGETS

Associated Dairies - MD Foods made energy and utility savings worth £44,000 over 15 months when they installed a computer-based Monitoring and Targeting system. They invested £5,940 (1990 prices) and the system produces data that enables the dairy management to pinpoint areas of waste and take corrective action. You could do this too by following the advice below.

Better control of energy costs, whether associated with electricity or primary fuels, is only possible if decisions are based on accurate information. Your savings campaign must begin with the basic facts - which forms of energy you are using, how much you are consuming in each case, and how much this consumption costs. Some form of monitoring is therefore essential.

> Without routine monitoring of electricity and fuel consumption, it is difficult to make effective and long-term energy savings.

Monitoring and Targeting (M&T) is a disciplined and systematic approach to the control of energy consumption and costs. Initially, you monitor your energy use on a weekly or monthly basis, make comparisons with previous figures to see whether consumption has varied, analyse the variations, communicate your findings to the appropriate energy users, and set targets for a reduction in consumption. Thereafter, the monitored consumption is compared with the targets set. The use of computers speeds up and aids both data handling and the presentation of results.

Monitoring and Targeting helps to provide answers to a number of important questions:

? *How does energy performance this week (month) compare with that for last week (month)?*

? *If the energy performance has changed (for better or for worse), can the reasons for that change be identified?*

? *What areas for improvement can be identified?*

? *How much energy has been saved or wasted?*

The four steps below should help you to monitor your energy consumption effectively, allowing you to reach the right decisions about implementing future energy efficiency measures.

Step 1 Make a note of your monthly energy consumption.

There are several possible sources for the data that you need:

- electricity and fuel invoices;
- meter readings;
- a computer-based recording system.

However, you should remember that energy invoices often estimate consumption and, even if meters are read by the supplier, it is rarely on the same day of each month. Artificial variations will therefore occur from month to month and it is recommended that you take your own readings on a regular date.

Use the conversion table in Appendix 2 to convert each type of energy into a common unit such as kilowatt hours (kWh).

> ***Example:***
>
> | | |
> |---|---|
> | Metered electricity consumption for January: | 100,000 kWh |
> | Metered gas oil consumption for January: | 30,189 litres |
> | 30,189 x 10.6 = | 320,000 kWh |

Step 2 Decide on the best unit of measurement for your monthly production.

This might be the total volume of milk processed in litres, or any output measure you consider appropriate - tonnes of butter or cheese, thousand cartons of milk, etc.

> A typical volume of milk processed in January might be 2.5 million litres.

Step 3 Use the values obtained to calculate your Specific Energy Consumption (SEC)

Specific Energy Consumption (SEC) is a useful means of relating your electricity and fuel consumption to your production - whether volume of milk processed or a specific output measure.

For dairies and creameries the most useful SEC figures are calculated as follows:

$$\frac{\text{Total electricity used in kWh}}{\text{Total volume of milk input}}$$

and

$$\frac{\text{Total fuel used in kWh}}{\text{Total volume of milk input}}$$

> ***Example:***
>
> Fuel SEC for January: $\frac{320{,}000\ \text{kWh}}{2.5\ \text{million litres}} = 0.13$ kWh/litre
>
> Electricity SEC for January: $\frac{100{,}000\ \text{kWh}}{2.5\ \text{million litres}} = 0.04$ kWh/litre

These values can be used as the performance indicator or yardstick against which subsequent values can be measured.

NB: To determine how your SECs have changed over the past few months/years, you can extract the relevant data from past invoices and production data.

Step 4   Repeat steps 1-3 on a regular (weekly or monthly) basis

It is essential to continue monitoring energy consumption and to analyse that consumption in relation to production. The SEC values obtained each week or month can easily be plotted in the form of an energy histogram and this will highlight any trends and variations. The differences between successive values indicates that there has been a change in energy efficiency. Any deterioration in energy efficiency should immediately be investigated. Any energy efficiency measures that you implement as a result of reading this Guide should be reflected as improvements in SEC. The degree of improvement will vary with the measures taken.

Example:

If refrigeration plant defrosting systems are not optimised, or if hot water is running to waste, and you remedy the situation, there will be a reduction in the kWh/litre measurement currently being used as a yardstick.

Once energy consumption is being properly monitored, an improvement in energy efficiency can be encouraged by setting a **target** SEC value that is lower than the current yardstick. This target can be set for the whole organisation, for a production process or for a particular machine as long as the energy consumption for the process or unit chosen can be properly measured.

One method of determining an appropriate target is to use a scatter graph to plot energy use against the production parameter used and then carry out a regression analysis of the scatter. The target can be set either at the 'average' level determined by the regression analysis, or at a level below this that is determined by the potential savings planned over a given period (e.g. 5%, 7%, etc.). Agreeing targets is always the preferred option so that the appropriate degree of motivation is maintained.

Most modern PC spreadsheet packages contain an analysis facility of this type. The calculated correlation coefficient should be studied to assess the strength of the relationship between the variables.

Monitoring and Targeting is a continuous process. Once a target has been met, there should be a reappraisal of the opportunities for making further improvements in energy efficiency and, if appropriate, a new target should be set.

A blank outline chart for energy monitoring is provided in Appendix 3 for you to photocopy and use.

Further information about M&T can be found in three Good Practice Guides available from ETSU:

GPG 31	*Computer-aided Monitoring and Targeting for industry*
GPG 112	*Monitoring and Targeting in large companies*
GPG 125	*Monitoring and Targeting in small and medium-sized companies*

Information on the application of M&T to all aspects of waste recovery/recycling can be found in:
Fuel Efficiency Booklet 13 *Waste avoidance methods*

GOOD PRACTICE CASE STUDY 138:
ENERGY MONITORING AND TARGET SETTING

One dairy, although recording its energy and water consumption, was making little use of the information obtained in terms of setting targets for reduced consumption and cost. A new Monitoring and Targeting (M&T) system was therefore proposed and agreed. New electricity and water meters were installed and a computerised M&T package ensured that meters were read weekly and that the relevant reports were produced.

The dairy achieved significant savings by implementing a number of good housekeeping measures aimed primarily at reducing water consumption. As a direct result of these measures, energy consumption was also reduced. Savings were achieved by:

- Rescheduling working practices

  The steriliser plant was being under-used, and rescheduling of the production pattern allowed it to be operated at full capacity for four days per week rather than at partial capacity for five days per week.

- Water and condensate reclamation

  The water and condensate used in the bottle washing plant was being dumped to drain. Small pipework modifications allowed this water to be re-used in the crate washers.

- Washdown hoses

  Monitoring identified the hoses as large consumers of water and steam. Each hose was fitted with a trigger spray gun to minimise consumption.

- Cleaning-in-place (CIP)

  The cleaning systems were also identified as large water and steam consumers. Small adjustments to the automatic timers resulted in considerable savings.

The initial capital outlay amounted to £5,940, including the purchase and installation of meters and computer software. In the first year of operation, energy savings of 5,295 GJ, worth £14,230, were achieved, together with water savings worth a further £17,750 (1991 prices).

This gives a payback period on the investment of just over two months.

Full details of this case study are given in GPCS 138, *Energy monitoring and target setting at a dairy*, available from ETSU.

4. OPTIMISING ENERGY TARIFFS

As well as monitoring energy consumption, dairies and creameries must ensure that correct and optimum electricity and gas tariffs are being applied to the energy consumed. You should discuss your plant requirements and tariffs with your electricity and gas supply companies.

Electricity Tariffs

Most electricity companies use a tariff for their industrial consumers that is dependent on the maximum demand charge. This means that all but the smallest consumers in this category are charged according to their peak power consumption each month as well as their total energy consumption. The maximum demand charge is measured in terms of the highest number of kW consumed during any half-hour period in the month. The charge is usually highest in December and January, a little lower in October, November, February and March and very low or zero for the rest of the year. It encourages companies to spread their power consumption evenly, thereby helping the electricity supply industry to meet demand with a minimum of generating capacity.

> In the months of December and January, a single 30-minute period of high consumption can have a dramatic effect on your invoice.

If a maximum demand tariff is in operation, you can reduce its effect by taking appropriate measures to 'smooth' the electrical demand.

- **Stagger your plant start-up times**
  Motors draw maximum power during start-up, so it is advisable to stagger machine start-up times (within the constraints of production requirements) rather than to switch everything on together at the start of a shift.

- **Turn off equipment that is not in use**
  Soft-starters can be employed if you are concerned about the potential mechanical wear and tear caused by repeated starting and stopping. Items of equipment that draw a great deal of power for short periods, such as large, intermittently-used pumps, can be interlocked to prevent more than a set number being in use at any one time.

- **Optimise the power factor**
  Power factor can be regarded as a measure of the efficiency with which machines use power, and a low power factor can be the cause of a high maximum demand. Under normal circumstances, a site's power factor should be between 0.95 and 0.99. However, electric motors have a poor power factor and this reduces the factor for the site as a whole. You can use power factor correction capacitors to resolve this problem, but these tend to lose efficiency over time and, if maximum demand is rising, then capacitor failure may be the cause.

- **Consider using steam or gas as a viable alternative to electric heaters**
  If steam is available at your site and there is sufficient boiler capacity, you may find it cost-effective to replace any electric heaters with steam heaters. Gas-fired radiant heaters may also be used to cut maximum demand charges.

> A detailed guide to optimising your use of electricity can be found in Fuel Efficiency Booklet 9A, *Economic use of electricity in industry*, available from ETSU.

5. MOTIVATING STAFF TO SAVE ENERGY

A large manufacturing site made savings through an employee motivation programme. It encouraged people to identify energy wastage in their work and devise appropriate improvements. You too could save money by following the advice below.

People are a very important component of energy efficiency programmes. Equipment and energy management systems can provide the technology for saving energy but if staff, and indeed management, become personally involved, further savings can be made. The check-list and subsequent text are designed to help you assess your level of energy management and ensure that both staff and management are motivated to save energy.

Motivating staff to save energy

1.	Do your staff know why you are introducing energy saving measures?	✓ *Provide them with information about energy consumption and costs.* ✓ *Show how energy saving measures can reduce consumption and costs.* ✓ *Use graphs and diagrams to get the message across.*
2.	Do your staff understand the business consequences of the failure to save energy?	✓ *Explain how costs affect profitability and how this, in turn, has an effect on business success and job security.* ✓ *Use examples and diagrams to get the message across.*
3.	To what extent are staff allowed to take energy efficiency initiatives?	✓ *Give your process operators the authority to decide on the most effective, energy-efficient way in which to carry out their work.*
4.	Do you operate a management system that makes it easy for staff to report wastage of energy or other resources?	✓ *Encourage staff to report wastage of all kinds.* ✓ *Make sure they know who to report to in each case.*
5.	Are you motivating your staff effectively?	✓ *Make use of existing channels of information such as notice boards, newsletters and regular meetings.* ✓ *Give staff the opportunity to become personally involved in making decisions about energy saving actions that will affect them.* ✓ *Introduce an incentive scheme to reward new and successful energy saving ideas.*
6.	Do your staff believe that you, as their manager, are genuinely interested in their individual contribution to energy savings?	✓ *Make sure that people are given appropriate credit for their personal contribution to saving energy.*

Saving energy is not a particularly exciting or interesting cause for most people, but energy saving measures require the continued vigilance, on a daily basis, of all employees, especially those responsible for operating machinery. To achieve and maintain savings it is essential for your staff to be well motivated - not just at the start of an energy saving campaign but continually.

The cost of resources, including energy, may be at the forefront of your mind, but this is not the case for most staff. The three main reasons for this are:

- most people concentrate on the job in hand rather than on the facilities used;
- most people use energy repetitively and subconsciously - it is a background resource;
- most people view energy costs as unimportant.

Energy users must share in the ownership of energy waste problems.

To ensure that the energy saving measures identified in this Guide are implemented, you must establish a formal energy management structure. One person should be in charge of meter reading and recording data. A senior manager should check the weekly summaries of consumption and change and initiate action. Production managers should ensure that the required actions are carried out effectively. All staff should be made aware of the cost benefits of saving energy.

You are more likely to get the commitment of staff if you:

- ensure that staff are kept fully informed about the measures being initiated and the reasons for their implementation;
- give staff a reason for saving energy;
- provide regular feedback on the progress that has been made to date.

Further information on how to motivate your staff can be found in Good Practice Guide 172, *Marketing energy efficiency - raising staff awareness*, available from BRECSU, and Good Practice Guide 84, *Managing and motivating staff to save energy*, available from ETSU.

CASE STUDY: UNDERTAKING A MOTIVATIONAL PROGRAMME

A large manufacturing site operating a highly automated process undertook an employee motivation campaign to increase awareness of and accountability for energy use, thereby reducing energy consumption and cost. The approach used involved motivating people to identify energy wastage in their work and to devise appropriate improvements.

The project aims were as follows:

- to make each profit centre accountable for its own energy usage, thus extending ‘ownership’ of energy to the end users;
- to extend the Total Quality Management (TQM) and Activity Based Costing (ABC) principles already in place to include energy management;
- to improve profitability by using energy saving ideas from employees closest to the operations.

Teams of 4 - 6 members representing all levels, including management, production operators and maintenance staff, were set up in each profit centre. Members met regularly to generate and progress ideas for energy and utility savings. People are motivated by different things and many were motivated simply by the responsibility, the problem-solving and by seeing the results of their efforts. An additional incentive was provided by the allocation of 10% of the cost savings generated by reduced energy usage to charities proposed by the team members.

The potential for energy savings during the weekend shutdown and restart periods were subject to particular scrutiny. Unnecessary lighting, ventilation, heating, compressed air, steam and equipment operation were eliminated. Opportunities were identified to modify controls, allowing critical equipment to be operated while other machinery was shut down. In addition to direct savings in energy, the teams identified some activities and processes that were no longer required. Waste occurring at product change-over was investigated and significant savings were made in both material and water costs. Further opportunities requiring capital outlay were identified, obsolete processes were removed and process changes instigated.

6. ENERGY AUDITS AND SURVEYS

Energy audits and surveys are investigations of site energy use that are designed to identify energy and cost saving measures. They can be performed by your own staff if the expertise, time and instrumentation are available. Alternatively, you can employ external specialist consultants.

An energy audit is a study that establishes the quantity and cost of each type of energy input into a building, site or process over a given period. This could include evaluation of the end use and would include any on-site generation. An energy audit also assesses how energy consumption is managed.

A simple preliminary audit, which can be performed by someone with little specialist knowledge about energy, will deal primarily with readily available information such as management structures and energy bills. It does not involve a detailed site investigation.

A full audit requires specialist expertise as it involves assessing energy use on a service-by-service basis. An energy audit, like a financial audit, provides information to management that will help in decision-making and will typically be based on the most recent financial year.

An energy survey is a technical investigation into the control of energy flows in a building, site or process. Its aim should be to identify cost-effective energy saving measures, and technical and financial appraisal of the options identified should result in a series of recommendations. A survey should, typically, be carried out every few years, the actual frequency depending partly on the rate at which the site is changing, and partly on the degree to which circumstances have altered. It may also be appropriate to carry out a survey before a major redevelopment to provide up-to-date information.

Further information on energy audits can be found in two Fuel Efficiency Booklets, available from ETSU:
FEB 1A, *Energy audits for industry*
FEB 1B, *Energy audits for buildings*

7. IMPROVING THE EFFICIENCY OF PASTEURISERS AND STERILISERS

7.1 Pasteurisers

The pasteurisation process often uses a plate heat exchanger or regenerative pasteuriser.

A key design element is the regeneration ratio which defines the efficiency of the unit (commonly 85 - 90%). The regeneration ratio of a pasteuriser is calculated as follows:

$$\frac{\text{Temperature of heated milk - temperature of regeneratively cooled milk}}{\text{Temperature of heated milk - temperature of chilled milk}}$$

Take as an example a pasteuriser where the chilled milk enters the unit at 4°C and is heated to 72°C for several seconds before being cooled back to 14°C by the incoming cold milk and then to 4°C by chilled water. The regeneration ratio is:

$$\frac{72 - 14}{72 - 4} = 0.85$$

Because a heat recovery efficiency of 90% is achievable in liquid milk dairies, pasteurisation consumes only small amounts of energy. However, this level of efficiency should be regarded as the optimum as higher levels would require larger heat exchangers, thereby increasing the energy requirement for pumping.

CASE STUDY: IMPROVING THE PASTEURISER REGENERATION RATIO

A dairy experienced a shortage of chilled water capacity following expansion of its production. A refrigeration contractor quoted £150,000 for the required new plant.

Before going ahead with the purchase of this equipment, the dairy commissioned an analysis of the existing pasteuriser's regeneration ratio. This was found to be well below the industry average. The decision was taken to overcome the shortfall in cooling capacity by improving the heat exchanger in the pasteuriser at a capital cost of just £25,000.

This solution was not only £125,000 cheaper but it also resulted in electricity savings worth £10,000/year.

7.2 Sterilisers

Sterilisation consumes more energy as the temperatures involved are higher. There are three different types of sterilisation process. These vary greatly in energy efficiency.

- For sterilisation in bottles where the bottles are cooled in a water bath using cold water, heat recovery is poor and additional energy is required for bottle washing.
- For direct ultra-heat treatment (UHT), part of the heat of condensation can be re-used if vapour compression is employed.
- Indirect UHT treatment is by far the most energy-efficient method of sterilisation since internal heat recovery is possible throughout the temperature interval.

7.3 Effective Energy Management of Pasteurisers and Sterilisers

The effective energy management of pasteurisation and sterilisation equipment involves:

- taking advantage of the most energy-efficient heat exchangers available;
- ensuring that your equipment is routinely checked and maintained, in particular that the heat exchange surfaces are regularly descaled;
- ensuring that your circulating hot and cold water streams are efficiently laid out and well lagged;
- converting to indirect UHT methods for sterilisation whenever possible.

Further information on a broad range of heat exchangers, including those used in pasteurisation processes, can be found in Good Practice Guide 89, *Guide to compact heat exchangers*, available from ETSU. More general issues of heat recovery are covered in Good Practice Guide 141, *Waste heat recovery in the process industries*, also available from ETSU.

8. IMPROVING THE EFFICIENCY OF EVAPORATORS AND DRYERS

A dairy producing milk powders has reduced its energy consumption to 50% of 1973 levels by improving the effectiveness of its spray dryers. You could do the same by following the advice below.

The processes that are used to produce condensed, evaporated, and powdered milk and whey are very energy intensive. Nevertheless, there are a number of techniques that can be adopted to reduce your energy consumption and costs in this area, and these are summarised in the check-list below.

Minimising energy use in evaporation and drying processes

Evaporation		
1	Do you use an older-style TVR evaporation plant with three or four evaporation effects?	✓ *Consider increasing the number of evaporation effects to closer to the maximum of seven.*
2	Do you need to increase the capacity of your existing evaporation plant?	✓ *Consider installing a membrane separation unit upstream of your existing evaporator.* ✓ *Make sure that you install the right type of membrane for your process, as efficiency varies with the salt and protein content of the source stream.*
3	Does your existing evaporation plant need to be replaced?	✓ *Consider MVR as well as TVR plants.* ✓ *Remember that MVR uses electricity, whereas TVR uses steam. Complete a full cost analysis for your particular situation before making your decision.*
Spray Drying		
1	Is the solids concentration of the feed entering your spray dryer as high as possible?	✓ *Make sure that the feed first passes through an evaporator. This will increase the solids content up to a maximum of about 50% - ideal for spray dryer operation.*
2	Is your spray dryer energy efficient?	✓ *If your dryer is a single-stage unit, consider adding a fluidised bed at the bottom of the chamber.* ✓ *If your inlet air is steam-heated, compare the economics of steam heating and a decentralised gas-fired air heating unit. The latter may be a more cost-effective option.*
3	Are you making full use of every heat-recovery opportunity?	✓ *Install a recuperator to recover heat from the exhaust air for pre-heating the inlet air.* ✓ *Consider the possibility of using residual heat from your evaporator in your spray dryers.*

8.1 Evaporators

An evaporator typically concentrates heat-treated whey or milk from around 6 - 12.5% dry matter to around 50% dry matter. Older evaporation plants are multi-stage units that incorporate three or four evaporation effects and thermal vapour recompression (TVR). Thermal vapour recompression uses high pressure steam to increase the pressure of the vapour which is then used to drive the evaporation process.

An evaporation process that combines several stages with vapour recompression uses significantly less energy than the evaporation of water without any heat recovery. A typical three-stage evaporation plant with TVR has an energy consumption of approximately 0.12-0.15 kWh per kg of water removed. You can reduce your energy consumption still further by increasing the number of evaporation effects, up to a maximum of seven.

In modern mechanical vapour recompression (MVR) evaporation plants, the vapour is recompressed using a turbo compressor or a high pressure fan, and energy consumption is much lower than with TVR (approximately 0.01 - 0.02 kWh per kg of water removed). However, MVR uses electricity while TVR uses steam, so the choice of vapour recompression technology also depends on the relative costs of electricity and fuel.

> Have you considered the energy efficiency of your evaporation plant? If new plant is required have you thought about upgrading to multi-stage TVR or MVR?

8.2 Membrane Concentration

Membrane separation processes are widely used within the dairy industry. Their benefits include selectivity, product consistency, the ability to deliver special product characteristics (a smoother fromage frais, for example), lower-temperature processing for improved product quality, and increased plant capacity. In order of decreasing pore size - and hence increasing energy (electricity) consumption - the most important of these membrane separation processes are ultrafiltration (UF), nanofiltration (NF - sometimes referred to as ultra osmosis) and reverse osmosis or RO (hyperfiltration).

Ultrafiltration separates proteins from milk and whey and is widely used to make some soft cheeses. The system operates at around 50°C producing a ‘retentate’, which contains the fat and protein used for cheese-making, and a ‘permeate’, which is a solution of lactose and salts. Although UF is sometimes used as an alternative to centrifugation, the energy consumption of both techniques is similar.

The permeate produced by UF can be further separated using either evaporation or RO. Reverse osmosis removes nearly all non-water components in the whey. The feed is passed through a membrane at a temperature of 30 - 50°C and at a pressure of 30 - 50 bar to counteract the osmotic effect.

Nanofiltration involves the use of ion-selective membranes and results in selective demineralisation as well as dewatering. The pressures required are only about half those applied in RO because of the reduction in osmotic pressures. Nanofiltration is therefore the more energy efficient process of the two.

Compared with direct evaporation, membrane processes are energy-efficient techniques, with an energy consumption of 0.004-0.01 kWh per kg of water removed. However, their adoption within the dairy industry is limited by the maximum osmotic pressure of about 40 bar that can economically be achieved. This, in turn, limits the concentration of solids to a maximum dry weight of 12 - 20%, depending on the salt and protein composition of the source stream.

From an energy efficiency point of view, the most likely role for membranes is for pre-concentration prior to an existing evaporator. Reverse osmosis could, for instance, achieve concentrations of 6 - 12% for whey and 15 - 20% for partially desalted whey. Using membrane separation in this way will increase the capacity of existing evaporator plant and is usually more economic than adding another evaporator. Membranes alone are much less likely to be used for separation prior to a spray dryer as evaporators can achieve much higher and more appropriate concentrations (about 50% solids).

If you are using evaporators without pre-concentrating the feed, it is worth evaluating the cost-effectiveness of installing UF, NF or RO equipment - to increase the energy efficiency of the plant and, perhaps more importantly, to increase the product capacity of the evaporator and even improve product quality and evaporator life by salt and chloride removal.

8.3 Spray Dryers

Spray drying in the dairy industry is used to convert viscous liquids into a highly soluble, dry, free-flowing powder. Unlike the evaporator, the spray dryer has no means of recovering the latent heat in the vapour. It is therefore a high energy consumer, losing heat with the exhaust air and in the powder as well as in the vapour. The energy consumed in spray drying is five to ten times greater than in evaporation (0.05 - 0.1 kWh per kg of water removed).

The higher the outlet temperature of the spray dryer, the lower the residual moisture content of the resulting powder. However, for energy efficiency, it is important to ensure that the inlet temperatures of the drying air are as high as possible and the outlet temperatures as low as possible. Multi-stage spray dryers incorporate fluidised bed dryers in the bottom of the spray drying chamber and also, sometimes, as a separate subsequent process to remove the last of the residual moisture. The outlet air can therefore be at a lower temperature and a higher saturation level.

Measures for improving the energy efficiency of spray dryers include:

- maximising the concentration of the initial fluid using an evaporator, thereby reducing the degree of spray drying required;
- converting a single-stage spray dryer to a two-stage system by adding a fluidised bed at the bottom of the chamber;
- recovering as much of the waste heat as possible by installing a recuperator that uses exhaust air heat to pre-heat the inlet air;
- using the residual heat from the evaporators to pre-heat the inlet air;
- using a thermal transfer fluid to heat the inlet air, thereby avoiding contamination and introduction of steam or water vapour into the product flow;
- ensuring maximum operation at the full design rating.

Further information on spray drying can be found in Good Practice Guide 185, *Spray drying*, and Good Practice Case Study 323, *Adopting a practical, low-cost approach to energy efficiency in drying plant*. Both are available from ETSU.

CASE STUDY: IMPROVEMENTS TO A SINGLE-STAGE SPRAY DRYER

A dairy producing milk powders has three spray dryers, two of which were single-stage units until a vibrating fluidised bed was retrofitted, turning them into two-stage units. The hot inlet air for the drying chambers was heated in an oil-fired boiler, but efficiency was poor, with elevated flue gas temperatures as a result of dirt forming on the interior surfaces.

The boiler was subsequently converted to gas and an economiser was fitted, considerably reducing the flue gas temperature and improving boiler efficiency. In 1988 a new efficient spray dryer with a separate air heater and extensive heat recovery was installed. This dryer is a multi-stage unit with an interior static fluidised bed and an external vibrating fluidised bed. When droplets reach the lower end of the drying chamber, the moisture content is 10 - 15%. At this level it is still possible to obtain some agglomeration of the droplets, thereby improving product quality and allowing a reduction in the outlet temperature to 80°C. The inlet temperature can be as high as 270°C.

The air is pre-heated using the heat in the condensate from the evaporator and from the outlet air. The inlet air thus reaches a temperature of 55°C before entering a thermal fluid gas-fired heater, chosen for reasons of flexibility. The static fluidised bed dryer is supplied with steam-heated air at 90°C.

These improvements have reduced energy consumption in the dairy to 50% of 1973 levels.

9. ENERGY-EFFICIENT CLEANING

Cleaning uses significant quantities of energy in both dairies and creameries. Cleaning is also a process that results in excessive heat losses, most of which go undetected unless the energy and water consumption of each cleaning activity is accurately measured. This section outlines the main techniques by which you can reduce heat losses during cleaning. The check-list opposite provides a summary.

> There is a correlation between specific energy consumption and water use, so adopting wastewater management principles will help you to improve your energy efficiency.

9.1 Cleaning-in-Place (CIP)

The energy efficiency of the internal cleaning of pipes, tanks and heat exchangers has been improved by the introduction of cleaning-in-place (CIP) systems. A CIP system is an automatic cleaning system involving a pre-rinse with cold water (to displace any remaining product), and alkaline and acid rinses. The duration of the cleaning process depends on the equipment being cleaned: cleaning tanks may take approximately 30 minutes but cleaning evaporators may take up to five hours.

Heat losses occur throughout the CIP process as a result of the heating and cooling of pipes and the loss of hot alkaline and acid water between rinses. You can control these losses by keeping temperatures and chemical concentrations as low as is consistent with effective cleaning, minimising cleaning times and splitting the CIP system into smaller subsystems to reduce cold water mixing.

9.2 Washdown

Floors and the external surfaces of equipment in dairies are hot-washed using hoses, which consume considerably more energy than CIP systems.

Your first step in improving the efficiency of energy and water use for washdown should be to monitor wastewater production and apply targets for its control. Significant energy savings can be achieved if some of the waste water can be re-used, if trigger action guns are fitted to prevent accidental running of hoses, and easy-to-use single 90° action ball valves are installed, to encourage operators to turn off the water flow. Further guidance on how to save hot water is given in Section 17.

9.3 Bottle Washers

Bottle washing is also an energy-intensive process. Bottle cleaning machines consist of a series of rinsing and chemical baths. The chemical bath is held at a specific temperature (around 80°C) but the rinsing baths achieve a temperature equilibrium since the rinse water flows at a manually adjusted rate counter to the chain that carries the bottles in their baskets.

You can improve the energy efficiency of bottle washing by careful process control. Specific measures include:

- optimising line speeds;
- minimising bottle and product changes;
- minimising vapour escape and internal vapour transport (from hot to cold baths);
- re-using final rinse water for pre-rinsing.

> **The requirements of food hygiene and safety should, of course, override any economic considerations.**

Reducing heat losses during cleaning

General		
1.	Do you know how much water and energy you use for cleaning?	✓ *Install a separate water meter for each of your main cleaning processes.* ✓ *Monitor the water consumption of each process and set targets to encourage a reduction.* ✓ *Repeat these procedures for the energy used to heat your cleaning water.* ✓ *Make sure your staff know that there is a clear relationship between cleaning water consumption and energy consumption. Encourage them to save both.*
2.	To what extent is your cleaning water recycled?	✓ *Consider installing a biological clarification system for your wastewater. This will allow you to recycle a proportion of the water used.*
Cleaning-in-Place		
1.	Have you installed an automatic CIP system?	✓ *Consider installing such a system as a means of reducing water consumption.* ✓ *Make sure that the system you install measures your energy and chemicals consumption. This will allow you to monitor both and, possibly, initiate savings.*
2.	Is your CIP plant operating at maximum efficiency?	✓ *Divide your CIP plant into small sub-systems. This will help minimise heat losses by reducing cold water mixing.* ✓ *Make sure operating temperatures and cleaning times are kept as low as is consistent with achieving acceptable cleaning rates and performance.*
Washdown		
1.	Are your washdown procedures designed to minimise water consumption?	✓ *Consider re-using washdown water wherever possible.* ✓ *Install automatic trigger mechanisms on all your hoses.*
Bottle Washing		
1.	Is your bottle washing plant controlled to minimise energy and water use?	✓ *Careful control can minimise waste. Ensure that bottle, product and line-speed changes are minimised.* ✓ *Take steps to reduce internal vapour transport and external vapour loss.*

10. ENERGY-EFFICIENT PACKAGING

The main savings that can be made in packaging machine operation involve minimising product waste by regular maintenance and siting the machines in an area convenient for rapid loading into cold stores. Compressed air and electric motors are discussed in Sections 12 and 13.

The choice of packaging will also affect the environmental and energy impacts of the product. These issues should be given due consideration when you select specific packaging materials.

The following check-list provides guidance on how to minimise energy use in your packaging processes.

Minimising energy use in packaging

1.	Are your packaging machines and conveyors properly maintained?	✓ *Regular maintenance can significantly reduce down-time and help to minimise energy consumption. Ensure that you implement a regular and routine maintenance schedule for all your packaging equipment.* ✓ *Check regularly for compressed air leaks when equipment is not operational.*
2.	Is your packaging system designed to minimise waste - of product, packaging materials and energy?	✓ *Make sure that your packaging machines are constantly monitored during operation. This will ensure that packaging faults are quickly spotted.* ✓ *Plan your packaging processes to minimise product changes and washdown requirements.* ✓ *Turn off conveyors when not in use.*
3.	Is your packaging area located for maximum energy efficiency?	✓ *Choose a location that will:* • *minimise pipe and product runs to the packaging machines;* • *allow rapid loading of the packaged products into cold stores.*
4.	Is your packaging hall efficiently heated and ventilated? (See also Section 16).	✓ *Consider using waste process heat for space heating.*

11. IMPROVING THE EFFICIENCY OF BOILERS AND STEAM DISTRIBUTION SYSTEMS

One company saved £13,000 on fuel annually after investing £28,000 in a system that recovered heat from boiler flue gases. A creamery invested £9,660 on a heat recovery system which saved energy worth £5,740/year, giving a payback period of just 1.7 years. Following the advice below could enable you to make similar savings.

A well-operated shell boiler of modern design can be expected to have a thermal efficiency of 75 - 80% at its design output. Many boilers, however, do not attain this level of performance because of poor maintenance.

The following check-list and text are designed to help you assess the current efficiency of your boilers and steam system, and provide guidance on improvements that can be made.

There are three main areas of heat loss. Heat lost in the flue gases accounts for about 75% of total heat loss, with the remainder split about equally between radiation losses from exposed boiler surfaces and blowdown losses. Minimising heat loss can significantly improve thermal efficiency, and further efficiency improvements can often be achieved by installing a heat recovery system.

The combustion efficiency of the system can be assessed by measuring the exit temperature of the flue gases and their oxygen and carbon dioxide content.

11.1 Minimising Flue Gas Heat Losses

You can minimise your flue gas heat losses by:

- ensuring an appropriate fuel:air ratio;
- preventing fouling of tubes and surfaces.

Heat is transported from the boiler to the flue by the combustion gases and by any excess air present that has not been required for the combustion process. If too much air is supplied with the fuel to the burner, there will be excess air in the flue gas stream and excessive heat loss. If too little air is supplied for combustion, some of the fuel will remain unburnt, and smoke will be produced. You can use the burner controls to give the correct fuel:air ratio. You should consult your supplier to establish the correct settings.

You should also check regularly that the fuel:air ratio is correct. The usual method is to analyse the flue gases leaving the boiler, and portable test equipment is available for this. This automatically computes boiler efficiency and is adequate for regular checking purposes.

If boiler tubes and surfaces become fouled because of poor combustion, flue gas heat losses will increase and specific fuel consumption will rise. The costs of cleaning will be repaid quickly in fuel cost savings, and you should seek your manufacturer’s advice on the frequency of cleaning required.

Optimising boiler energy use

Boilers			
1.	Are your boilers used in a way that will minimise energy consumption?	✓ ✓ ✓	*Make sure that boilers are fired up as late as possible and switched off as early as possible.* *Always meet the demand using the minimum number of boilers.* *Ensure boilers are operating at optimum pressures. You may consider de-rating the boiler if the steam system requires a lower pressure than the minimum recommended by the boiler manufacturer.*
2.	Are you certain that each boiler is operating at maximum efficiency?	✓	*Log boiler performance continually. This will quickly highlight any deterioration. The ratio of steam to fuel is the main measure of efficiency. It should be regularly monitored and maintained at a high level. You should therefore:* • *install individual fuel meters so you can monitor changes in each boiler's energy consumption;* • *install individual boiler feedwater meters so that you can monitor feedwater consumption and estimate blowdown.*
3.	Do your boilers suffer from excessive heat loss?	✓ ✓ ✓ ✓	*Check the fuel:air ratio to ensure it is correctly set.* *Implement a regular cleaning programme to prevent tubes and heat transfer surfaces becoming fouled.* *Check your boilers regularly for damage to insulation. This will minimise radiation heat losses.* *Reduce your blowdown losses by treating boiler feedwater or by recovering and re-using some of the heat lost during blowdown.*
4.	Have you considered a flue gas heat recovery system?	✓	*Recover some of the heat in your flue gases by installing an appropriately-sized economiser to pre-heat boiler feedwater or combustion air.*
Steam System			
1.	Can you be certain that you are not wasting steam?	✓ ✓ ✓ ✓	*Check that redundant pipes are disconnected.* *Install valves for isolating pipework that is temporarily not in use.* *Regularly check the system for leaks and ensure all leaks are immediately repaired. Steam leaks not only waste energy, they are a safety hazard.* *Make sure that all pipework, valves and flanges are properly insulated. Check insulation regularly.*

11.2 Minimising Radiation Losses

Radiation losses on modern boilers are usually 1% or less of the heat input at maximum rating. However, they can be as high as 10% where insulation is damaged or inadequate. You should check your boiler regularly to ensure that this is not the case.

11.3 Minimising Blowdown Losses

Regular boiler blowdown is necessary to remove sludge and total dissolved solids and to prevent scaling. High blowdown losses can be reduced, either by improving the treatment of the boiler feedwater to minimise the formation of sludge and scale, or by investing in heat recovery equipment. An appropriately-located heat exchanger can, for instance, recover some of the heat lost during blowdown and use it to pre-heat the boiler feedwater.

11.4 Flue Gas Heat Recovery

The flue gases leaving a boiler are at a higher temperature than the steam produced. Part of this heat may be recoverable by using economisers to pre-heat boiler feedwater or by pre-heating the boiler combustion air.

11.5 Minimising Steam System Losses

Heat is wasted in the generation of steam if the number of boilers in operation is above the minimum needed to satisfy demand. You can minimise this waste in two ways:

- Provided adequate reserves of steam are available to maintain production to the required product safety and quality standards, it may be worth risking the temporary reduction or loss of steam associated with possible boiler failure in order to operate the minimum number of boilers at their optimum efficiency.
- If the steam-using system requires a lower pressure than the minimum recommended by the boiler manufacturer, you should consider derating the boiler.

To minimise heat loss in the steam distribution system you should carry out the following:

- Ensure that all pipework and valves conveying steam and condensate are properly insulated and weatherproofed.
- Turn off the supply when there is no heating requirement.

CASE STUDY: HEAT RECOVERY FROM BOILER FLUE GASES

This case study focuses on an enterprise that uses steam for both process and space heating. The original central boiler plant consisted of four dual-fuel shell boilers, each rated at 3.5 MW, with flue gases passing into a common duct. Normal operation had three boilers on-line with the fourth acting as a stand-by.

An economiser was installed in a by-pass duct parallel to the common flue duct and adjacent to the chimney. This was sized to match the combined output of two boilers, which represented average operating conditions. It was not considered economic to incur the additional capital cost of a larger economiser to meet the occasional peak loads when all three boilers would be operating.

The feedwater system was modified by replacing the existing individual boiler feed pumps with a single unit, feeding continuously through the economiser. Dampers were provided to isolate the economiser when the boilers were oil-fired.

The modified system raises the temperature of the feedwater from 85°C to 111°C, giving a heat recovery under maximum design conditions of 300 kW. The final flue gas exit temperature of 130°C provides a safe margin above the acid dewpoint temperature, even for natural gas. The economiser is protected against overheating by a thermostatically operated water dump valve.

The investment cost was £28,000, and annual fuel savings of 8,000 GJ were achieved, worth £13,000. This gave a payback period of just over two years.

For multi-boiler sites of this type, a common economiser is more cost-effective than individual units as it operates closer to its design rating.

Further information on boilers can be found in various publications available from ETSU.

Fuel Efficiency Booklet 14, *Economic use of oil-fired boiler plant*
Fuel Efficiency Booklet 15, *Economic use of gas-fired boiler plant*
Fuel Efficiency Booklet 17, *Economic use of coal-fired boiler plant*
Good Practice Guide 30, *Energy efficient operation of industrial boiler plant*
Good Practice Case Study 339, *Heat recovery from boiler blowdown*
Energy Consumption Guide 66, *Steam generation costs*
Energy Consumption Guide 67, *Steam distribution costs*

12. THE EFFICIENT GENERATION AND MANAGEMENT OF COMPRESSED AIR

Compressed air is very expensive to generate. Estimates suggest that, over a ten-year period, 75% of the total cost of compressed air is for energy, 15% for capital and 10% for maintenance. Furthermore, compressed air represents an inefficient use of energy. It accounts for up to 20% of the electricity consumed in dairies and creameries, but less than 10% of the electricity input to the compressor motor is converted into mechanical energy, the rest being dissipated as waste heat.

You should therefore make sure that your compressed air system is as energy efficient as possible. Furthermore, compressed air control is an essential component in any wider programme designed to minimise energy consumption and costs.

The check-list and subsequent text outlines procedures to help you minimise the energy consumption of your compressed air systems.

Reducing the energy consumption of compressed air systems

Leakage Reduction		
1.	Do you know whether your compressed air system leaks?	✓ *Assess your air leakage rate.* ✓ *Repair any leaks identified.*
2.	Are you actively working to minimise system leakage?	✓ *Set targets for leakage reduction over a period of time.* ✓ *Remove redundant pipework.* ✓ *Isolate sections of the distribution system when not in use.* ✓ *Initiate a system of regular surveys and repair immediately any leaks that are found.*
Compressed Air Use		
1.	Is your organisation using compressed air unnecessarily?	✓ *Check all the uses to which compressed air is put and make sure that they are appropriate.* ✓ *Consider more cost-effective alternatives to compressed air where these exist.* ✓ *Consider installing or upgrading load control management systems.*

System Efficiency		
1.	Is your distribution system properly designed and maintained?	✓ *Consider installing a ring main or grid system to improve the pressure balance in the system.* ✓ *Check that pipes are correctly sized and that air velocities and pressure drops are appropriate.* ✓ *Initiate a regular maintenance programme to check for leaks and to check and clear drains.* ✓ *Consider installing an automated control system that will isolate sections of the distribution system whenever they are not in use.*
2.	Are you considering the installation of new treatment equipment?	✓ *Make sure that the equipment is appropriate for the required duty and that it minimises energy consumption.*
3.	Have you optimised the efficiency of your existing treatment equipment?	✓ *Check level of treatment (air dryness levels etc.).* ✓ *Check pressure drops across treatment plant.* ✓ *Check temperatures at dryer inlet and in dryer room.* ✓ *Consider treating the bulk of the air supply to a minimum acceptable level and then upgrading the quality, if necessary, at the point of use.*
4.	Have you optimised the efficiency of your generation system?	✓ *Reduce system operating pressure if possible.* ✓ *Optimise compressor control. Install automatic control systems where appropriate.* ✓ *Recover waste heat from the compressor for other uses.* ✓ *Reduce the number of compressors used. Consider uprating an existing compressor to meet increasing demand.*

12.1 Assessing Your Compressed Air Costs

Table 4 will help you to estimate your annual costs for compressing air. You will need to know the rating of the compressors (kW) or their rated output (l/sec). You will also need to estimate levels of machine utilisation by noting the average on-load and off-load operating periods. The annual costs shown in Table 4 are based on an electricity cost of 4.5 p/kWh.

Table 4 Annual cost of operating air compressors

Compressor capacity			Annual costs (£) 48 h/week utilisation		Annual costs (£) 120 h/week utilisation	
kW	**l/sec**	**cfm**	**75%**	**50%**	**75%**	**50%**
18	55	110	1,700	1,100	4,200	2,800
25	75	150	2,300	1,600	5,900	3,900
37.5	110	220	3,500	2,300	8,700	5,800
55	165	330	5,100	3,400	12,700	8,500
85	250	500	7,800	5,200	19,500	13,000
165	500	1,000	14,900	10,000	37,400	24,900
250	750	1,500	22,400	14,900	56,000	37,300
320	1,000	2,000	28,400	18,900	70,900	47,300

12.2 Estimating the Potential Savings

Recent studies of industrial compressed air systems reported in Good Practice Case Studies have shown that about 30% of the total annual operating cost of compressing air could be saved by introducing simple cost-effective energy efficiency measures. Table 5 shows the potential cost savings in relation to installed capacity.

Table 5 Potential cost savings from compressed air systems (30% saving)

Compressor capacity			Potential annual savings (£) @ 4.5 p/kWh	
kW	**l/sec**	**cfm**	**48 h/week**	**120 h/week**
18	55	110	700	1,700
85	250	500	3,100	7,800
165	500	1,000	6,000	14,900
320	1,000	2,000	11,400	28,400

12.3 Reducing Costs

In order to maximise cost savings you should consider every aspect of the design, operation and use of your compressed air system. The following sub-sections offer some important pointers.

Leakage

One of the simplest ways of reducing costs is to minimise air leakage from the system. A 3 mm hole discharging from a pressure of 7 bar will waste about 11 litres/second of air. This corresponds to an annual cost of £1,050 if the system is on-line for 120 hours/week over 48 weeks per year.

The first step in reducing leaks is to assess the leakage rate. There are three possible techniques that can be used to achieve this.

Assessing Compressed Air Leakage Rates: Method 1

1. Install a flow meter and pressure transducer in the main supplying the distribution system.
2. Monitor the output from the flow meter during a representative period to establish the leakage rate.

Assessing Compressed Air Leakage Rates: Method 2

This no-load test applies where compressors are operated in on/off mode, i.e. when the compressor is on-load it produces a known amount of air.

1. Close down all air-operated equipment.
2. Start the compressor and operate it to full line pressure, when it will off-load. Any air leaks will subsequently cause the pressure to fall and the compressor will come on-load again.
3. Calculate, over a number of cycles, the average time the compressor is on-load (T) and off-load (t).
4. Calculate total leakage using the following equation:

$$\text{Leakage (l/s)} = Q \text{ x } \frac{T}{T+t}$$

where Q = air capacity of the compressor (l/sec)

Assessing Compressed Air Leakage Rates: Method 3

Method 3 is a no-load test for modulating compressors. This test is more difficult as compressor output is unknown. However, the following procedure is valid if you have a pressure gauge downstream of the receiver.

1. Calculate the volume (V) of air mains downstream of the receiver isolating valve, including all the pipework (25 mm and above) and the receivers.
2. Pump up the system to operating pressure (P_1), and then close the isolating valve.
3. Record the time (T) for the pressure to drop to P_2.
4. Calculate leakage using the following equation:

$$\text{Leakage (l/s)} = \text{V(litres) x } \frac{P_1 - P_2\text{(barg)}}{\text{T(sec)}}$$

The results of the leakage test will allow you to **set targets** for reducing leaks.

You should then carry out **regular surveys** of the system to identify leakages and instigate repair. Ultrasonic leak detectors can be used to identify leaks when there is significant background noise from other machinery.

Removing redundant pipework will reduce the potential for leakage.

You should **retest** the system for leakage **at frequent intervals -** for example, once every two to three months.

CASE STUDY: REDUCING COMPRESSED AIR LEAKAGE

A leakage survey carried out at a major industrial manufacturing site estimated that leakage accounted for 60% of compressor output.

The survey was carried out by measuring compressed air flow rates to the main factory areas using a turbine flow meter, identifying where leakage was occurring and calculating the amount of air lost.

Following the survey, a system for regularly identifying and repairing leaks was put in place, resulting in annual cost savings of £12,000.

Use

Compressed air is often used for applications for which it is inappropriate and costly. It can also be used incorrectly at the point of use. Consider the ways in which you use compressed air and see whether more cost-effective alternatives are available.

Distribution

Significant energy can be wasted if the distribution system has been incorrectly designed and is not maintained properly.

Configuration
You can improve the pressure balance in the system by installing a ring main or grid system in place of individual branches.

Pipe sizing
The Guides referred to at the end of this Section contain useful charts and tables for pipe sizing.

The system should be designed so that air velocities do not exceed 6 m/s in the main sections.

At full demand the pressure drop between the main and the point of use should be about 0.1 - 0.2 bar. You should also carry out regular checks on valves and fittings to ensure that pressure drops are not excessive.

Regular maintenance
Regular maintenance of the distribution system is essential for efficient operation. You should carry out regular checks for leaks. You should also check the drains and clear any contamination from the system.

Isolation
Compressed air may be used in a number of different processing areas within the dairy. Not all these areas are necessarily operational at the same time and it may therefore be possible to isolate sections of the distribution system during non-operational periods to minimise the waste associated with leakage. The isolation process can be automated by linking a control valve to a Programmable Logic Control (PLC) system.

Treatment Systems

Several different types of treatment system are available for air compressor units. If you are installing new equipment, it is important that you select the right equipment both for the required duty and to minimise energy consumption. Details of how to select appropriate equipment can be found in the various Guides that are available from ETSU and BRECSU.

You may also be able to improve the efficiency of your existing equipment by following the steps outlined below.

- Check the air dryness (dewpoint) against the specification.
- Check the pressure drop across the pre- and after-filters. This should not exceed 0.4 bar with the system on full demand.
- Measure the dryer pressure drop. This should not exceed 0.3 bar with the system on full demand.
- Measure the dryer inlet temperature. This should not exceed 35°C with the compressors on full load.
- Measure the temperature of the dryer room. This should be within 5°C of the outside ambient temperature.
- Check that the condensate collection system is working properly and that there is no constant bleed of air.
- Consider treating the bulk air supply to the minimum acceptable level and upgrading the quality, if necessary, at the point of use.

Generation System

A study of several air compression units during the preparation of an Energy Consumption Guide showed that, on average, energy savings of 10.4% could be made by improving compressor efficiency alone. The improvements that can be made will depend on the type of compressor in use. Factors to be considered include:

Generation pressure
The compressed air system should be reviewed to determine whether the system is operating at pressure levels above those required at the point of use.

For example, a 6 mm nozzle consumes compressed air at the rate of 38 litres per second at 6 bar and 43 litres per second at 7 bar. Reducing the system pressure to 6 bar would save £260 per year for this item alone. The same reduction throughout a dairy using 500 litres per second of compressed air over 48 weeks of the year would, assuming power costs of 4.5 p/kWh, achieve annual savings of £3,500.

It may also be possible to reduce pressures during periods of non-production if other users require air at a lower pressure than production equipment.

Control
Various control systems are available for optimising compressor use. The type of control system that is appropriate will depend on the compressors in use and on the pattern of compressed air generation. Modern control systems can automatically sequence compressors, shutting down machines that are off-load. With these systems it should be possible to reduce total generation costs by 5 - 20% for a relatively small capital investment.

Heat Recovery

More than 90% of the energy consumed by a compressor is rejected in the form of low grade heat. You may be able to install heat recovery systems that can make use of hot water or air from the compressor house, perhaps for space heating. The cost of installing such a system will vary with the application, but payback periods of between one and three years are typical.

Quality and Temperature of Inlet Air

The condition of the air entering the compressor is extremely important. A 4°C drop in the intake temperature can, for instance, increase compressor efficiency by 1%. The associated saving for the dairy example defined earlier would be £200 per year. Conversely, for every 25 mb of pressure lost at the inlet because of clogged filters, compressor efficiency falls by 2%; the cost to the dairy would be about £400 per year.

Maintenance

If the same dairy were to be served by a poorly maintained, oil-free piston compressor, compressor efficiency would deteriorate by 12.5% over a 12-month period, adding more than £2,000 to the annual operating costs.

Other Factors

Other factors to be considered include:

- number of compressors used;
- location;
- quality of cooling services.

Further information on reducing compressed air costs can be found in various publications available from ETSU:
Energy Consumption Guide 40, *Compressing air costs - generation*
Energy Consumption Guide 41, *Compressing air costs - leakage*
Energy Consumption Guide 42, *Compressing air costs - treatment*
Good Practice Guide 126, *Compressing air costs*
Fuel Efficiency Booklet 4, *Compressed air and energy use*

13. MORE EFFICIENT MOTORS AND DRIVES

Much of the equipment used in the dairy industry, pumps and conveyors in particular, depends on effective and efficient electric motor and drive systems. These systems, excluding those used in compressors and refrigeration equipment, account for about 10% of electricity consumption in a dairy or creamery, and there are several possible ways in which you can reduce the associated operating costs. The paragraphs below provide a structured approach to cost reduction, and the various options are summarised in the following check-list.

Reducing the energy consumption of motors and drives

Wasteful loads mean wasted cash	
Have you reduced the external load on your motor and drive system to the minimum?	✓ *Reduce leakage and pressure drops in your compressed air system.* ✓ *Make sure machinery operates at its optimum efficiency level whenever possible.* ✓ *When new equipment is required, consider installing more energy-efficient models.* ✓ *Improve maintenance schedules to ensure that equipment is operating reliably and efficiently.* ✓ *Make sure that transmission systems operate efficiently and are well maintained.*
More hours means more cost - even when idling	
Do you minimise the hours of use of your motor and drive systems?	✓ *Switch off machinery that is not in use.* ✓ *Consider automatic switch-off where controls permit.* ✓ *Install soft starters for more frequent on-off cycles.*
Running cost can be 100 times purchase cost over a motor's life	
Do your motors match the duty required of them?	✓ *Consider replacing an oversized motor with one of a more appropriate rating.*
How efficient are your motors?	✓ *When a motor ultimately fails, assess whether rewinding or replacement is the more cost-effective option.* ✓ *When replacing a motor, consider purchasing a high efficiency unit.*
Lower speed means lower cost	
Can you adjust your motors to match changes in system duty?	✓ *Consider installing two-speed or multi-speed motors.* ✓ *Consider installing variable speed drives.*

The various options for cost reduction can be summarised in order of priority:

1. Reduce the external load on the motor and drive.
2. Ensure that motors and drives are switched off when not in use.
3. Improve the efficiency of the motors used.
4. Reduce motor speed.

Load Reduction

Reduce system load
Your first step in minimising energy consumption is to reduce the external load on the motor and drive system as much as possible. Examples of load reduction include reducing both leakage and the pressure drops in a compressed air system (see Section 12).

Use efficient equipment
Assess the machinery that is in use to determine whether it is operating at its optimum duty or at part-load. It may be possible to minimise the degree of part-load operation by altering your operating procedures. If you are about to install new machinery, for example a fan, you should take into consideration the efficiency of the equipment as well as its cost and other issues. As most equipment is in service for several years before replacement, significant savings can be made by choosing items that have been demonstrated by the supplier to be more efficient than other products.

Maintain motor, drive and equipment efficiency
Maintenance is essential if motors, drives and machinery are to operate efficiently and reliably. General vibration checks, e.g. using a shock pulse method, can indicate whether the shaft alignment is correct or if there is an electrical fault. Motor maintenance is relatively straightforward and should cover the following areas:

Bearing condition
You should make regular checks on the bearings of all large motors. Standard vibration techniques, such as the shock pulse method, can be used to monitor bearing condition, and this will indicate whether bearing races are deteriorating. Your monitoring results will need careful interpretation as spurious readings can be obtained, for example if greasing has recently been carried out. Monitoring the temperature of bearings is not as sensitive as the use of vibration techniques. It may be more appropriate to use external resources for this work rather than maintaining in-house expertise and equipment.

Bearing lubrication
A schedule for lubricating bearings and gearboxes should be in place which covers the frequency, quantity and type of lubricant used in each case. This should be in accordance with the equipment suppliers' recommendations. You should always apply the correct quantity of lubricant as using an excessive amount can cause premature equipment failure. Lubricants are available which their suppliers claim will reduce energy consumption. These lubricants usually contain an additive, for example micro spheres, which reduce friction losses. These products should be treated with some caution and tested first on equipment that is not critical for production purposes. It is also prudent to consider whether long-term degradation of materials is likely to occur. For example, oils containing chlorine will damage bronze.

Other aspects that should be considered include:

- mechanical alignment;
- electrical integrity of insulation;
- condition of commutator, slip rings and brushes;
- general cleanliness of motor.

Optimise transmission arrangements

Direct drive methods are more efficient as there is no intermediate link to increase friction losses.

Most system transmission systems operate with reasonable efficiencies. For example, about 80% of the input power required for bucket elevators is directly related to the weight of material being conveyed. The remainder is required to meet friction losses and loading and discharge losses.

The selection of an appropriate drive arrangement is usually made in relation to cost, operation and maintenance issues. For example, some sites may prefer not to use gearboxes because of the potential for leakage.

Nevertheless, you should ensure that all systems are well maintained. For systems using chains this means regular greasing. For belt systems, regular checks on belt condition, tension and alignment will identify whether a belt is worn or slipping, which can waste energy between the motor and impeller shafts. As well as minimising energy wastage, replacing worn belts will also help to prevent failure during operation.

Although some equipment suppliers use toothed or notched timing belts to maintain accurate speed or differential conditions, the ‘V’ and wedge types of belt are those most commonly used. They take up less space than flat belts, and the number of belts required can sometimes be reduced. Important aspects when fitting these belts are as follows:

- The size of belt must be correct in relation to the pulley groove.
- Where multiple belts are used they should be from matched sets and should be changed at the same time.
- Belts on the same drive should be from one manufacturer.
- Pulleys should be aligned correctly, i.e. parallel and in the same plane with no offset.
- A belt tension indicator should be used during fitting to ensure that the correct tension is applied.

Fitting clear polycarbonate guards to drive arrangements can be advantageous. This allows easy viewing of the belt so that visual alignment and tension checks can be carried out while the equipment is on-line. However, you must comply with all safety regulations when altering drive guards.

Switch Machinery Off When Not Required

You should ensure that machinery not in use is switched off and not left running. In some cases it may be possible to automate this procedure by configuring control systems appropriately.

Soft starters
Soft starters are electrical devices that allow a rapid but gradual build up of electrical power rather than a sudden surge. They are used mainly to avoid wear on the transmission, problems associated with mechanical shocks and to restrict in-rush current and so reduce the peak load on the electrical supply.

Since risk of damage to motor and drive chain is lessened, they can make it feasible to turn plant on and off more readily to save energy.

Some soft starters also incorporate an energy optimiser which can limit efficiency losses when motors are operated at part-load. The savings from this feature depend on the motor loading; savings are marginal at loadings above 50%. Savings from energy optimisation are unlikely to justify the capital cost of a soft starter, but are worth having if a unit is needed for other reasons.

Reduce Motor Losses

Use the correct size motor
One of the simplest ways of reducing motor losses is to optimise the size of motor being used in relation to the duty.

Equipment suppliers often allow an excessive margin when selecting motors for their equipment. It is therefore worthwhile comparing the motor rating with the equipment duty, especially when replacing motors.

Down-size the motor where possible. It is more efficient to use a smaller motor at its full design load than to use a larger motor at part-load.

If replacing a motor, always consider using a high efficiency version.

Use high efficiency motors
The purchase cost of an electric motor is usually minimal compared to its annual running costs, e.g. an 11 kW motor can cost less than £500, but its running costs over a ten-year life are likely to exceed £50,000.

Modern induction motors have efficiencies of 80 - 90%. However, high efficiency motors (HEMs) have been available for at least ten years with efficiency improvements of 2 - 3% over the standard models. This improvement has been independently verified.

Efficiencies have been increased by a combination of design improvements, e g:

- reducing resistance by increasing the amount of copper conductor used;
- using higher quality stator laminations;
- these improvements in turn allowed reductions in the size of cooling fans.

The cost of purchasing energy-efficient motors is now considerably less and, in some cases, similar to standard models. Information about the efficiency improvement and cost of HEMs should be obtained directly from the suppliers of the different models. Suppliers should also be asked to verify their claims of higher efficiencies.

Obtain quotes for HEMs and compare with standard models - there is often no price premium, but the savings can be considerable over the life of the motor. As an example, Table 6 shows the typical savings that can be obtained from a high efficiency 7.5 kW motor compared to standard models at full load. Overall, higher annual running hours and higher loading means more savings.

It can also be cost-effective to replace large motors (say 70 kW and over) with high efficiency versions before they fail, when their running hours are high.

Table 6 Typical savings with a 7.5 kW high efficiency motor at full load

Annual use (hours)	Annual savings
2,000	£45
4,000	£90
6,000	£135
8,000	£180

High efficiency motors have:

- the same maintenance requirements as standard motors;
- at least equal reliability;
- possibly a longer operating life due to lower operating temperatures.

The cost benefit of using high efficiency motors is just as great at part-load operation; the increase in efficiency can be as high as 6.5% at 50% loading.

All *new* motors, including high efficiency motors, are available only in metric sizes, so if replacement of an imperial size motor is being considered, then the cost of altering the frame/bed-plate should also be taken into account.

Replace or rewind?
Often, the only aim is to get the plant operating again - so the quickest route wins.

However, motors that are rewound show a typical drop in efficiency of 0.5 - 2.0%. When sending motors for rewinding, it is worth checking that the repairer can demonstrate high standards of repair. The drop in efficiency can be 0.5% or less with high quality rewinds.

The choice between motor replacement and rewinding is site-dependent. Good Practice Guide 2, *Guidance Notes for Reducing Energy Consumption Costs of Electric Motor and Drive Systems,* describes a method of calculating the breakpoint in terms of annual running hours by motor size. This calculation is based on the total costs for a new motor and repair of an old one, and also the energy costs due to different efficiencies.

Other factors that should be taken into account include whether the motor:

- is imperial or metric;
- is already a high efficiency motor;
- has been rewound before.

For motors below typically 12 kW, it is usual to replace rather than rewind.

Reduce Motor Speed

Reducing the speed of motors can cut energy costs significantly. For example, a 20% cut in speed on a fan or pump can reduce the energy cost by 50%, since the power drawn is proportional to the speed cubed. Speed should be cut to match the actual load requirements.

There are several ways to achieve this, including use of Multi-Speed Motors, change of pulley size, and eddy current couplings. However, the most versatile is the electronic variable speed drive. Careful consideration is required, and full details are given in Good Practice Guide 14, *Retrofitting AC Variable Speed Drives*, see box opposite.

Variable speed drives
Electronic variable speed drive (VSD) systems allow equipment to run at its optimum speed across a range of operating loads. They are available in several categories, including modern electronic systems which allow almost infinitely variable and constantly changing speed at relatively low cost. Such systems normally use an inverter.

Variable speed drives, sometimes known as inverters, have traditionally been used for process control applications but are now increasingly used to improve energy efficiency. Several Best Practice Programme Case Studies have shown the very high level of savings achievable.

VSDs can be automatically or manually controlled, are very versatile and nowadays extremely reliable. An additional benefit is that most also include a soft start feature which can reduce machinery wear (see Section above).

Further information on energy efficient motor and drive systems can be found in two publications available from ETSU:
Good Practice Guide 2, *Guidance notes for reducing energy consumption costs of electric motor and drive systems*
Good Practice Guide 14, *Retrofitting AC variable speed drives*

14. ENERGY-EFFICIENT REFRIGERATION AND COLD STORES

Typically, at least one quarter of the electricity consumption in a dairy or creamery is for refrigeration. Furthermore, systems commonly use 20% more electricity than necessary. There are therefore enormous opportunities for improving the efficiency of most refrigeration plant and, surprisingly, most improvements involve very low cost and therefore have short payback periods.

Most of the refrigeration plant in a dairy or creamery falls into one of two categories:

- plant generating chilled water for processing;
- storage plant for milk and milk products.

Water is usually cooled in a central chiller, frequently using refrigerants R22 or ammonia. The chilled water is circulated around the dairy to provide cooling for various processes. Cold stores, on the other hand, are cooled using direct expansion systems, often using R22. In addition, there may be some smaller units, for example for making ice cream.

The following check-list indicates three types of improvement that can be made in the provision of either chilled water or storage:

- improvements that involve no cost and are usually simply changes to 'housekeeping';
- low-cost improvements that usually require an input from a qualified refrigeration service engineer;
- investment opportunities that require a more substantial capital input but usually have an acceptable payback period.

Reducing energy consumption in refrigeration

Load		
Is the product warmer than necessary when it enters the cooled space?	✓	*Good management/housekeeping, for example moving the product directly from a vehicle into storage rather than leaving it where its temperature can rise, should prevent this.*
Is heat allowed to enter the cooled space unnecessarily?	✓	*Don't leave doors open for longer than necessary.*
Is the cooled space occupied by staff unnecessarily?	✓	*Ensure that loading/unloading takes place as quickly as possible.*
Do chilled water pipes pick up heat unnecessarily?	✓	*Ensure that the chilled water pipework is insulated.*

Temperature Lift (Temperature lift is the difference between the evaporating and condensing temperatures and should be as small as possible.)	
Is the evaporating temperature as high as possible?	✓ *The temperature of the cooled space or chilled water should not be lower than necessary. If this is the case, reset the thermostat - a 1°C increase in temperature will reduce your energy consumption by 2%.* ✓ *The evaporator/chiller should not be dirty or scaled up. If necessary, clean it.*
Is the condensing temperature higher than necessary?	✓ *Clean blocked or scaled-up condensers.* ✓ *Locate air-cooled condensers out of direct sunlight (or shade them) and ensure that they have an unrestricted air flow.* ✓ *If the condensing temperature is held artificially high regardless of the ambient temperature, i.e. if head pressure control is used, you may be able to reduce the pressure maintained by the control, or to eliminate the control altogether.*
Need	
Do you need refrigeration?	✓ *Some products can be partially or totally cooled using ambient air or water.*
Defrosting (Ice on an evaporator reduces heat transfer, thereby reducing system capacity but increasing power consumption.)	
Is the evaporator usually iced up?	✓ *The defrost timing may need to be adjusted.* ✓ *The termination thermostat may need to be repositioned.*
Is the evaporator partially iced up; is the drain pan and/or line iced up; or is there ice on the walls, ceiling and/or floor around the evaporator?	✓ *Defrost heaters. Drain pan heaters and/or drain line heaters may need replacing.*
System Control	
Does the system control ensure that: • the evaporating pressure is as high as possible; • the condensing pressure is as low as possible; • compressors operate on in-built capacity control (which is usually inefficient) as little as possible?	✓ *You can usually adjust control settings to achieve these states without reducing reliability.*

Refrigerant		
Does the system leak refrigerant? NB: Bubbles in the liquid line sight glass usually indicate that the system is undercharged and therefore possibly leaking.	✓	*An undercharged plant consumes more energy. The leaks should be found and repaired.*
INVESTMENT OPPORTUNITIES		
Load		
Is heat allowed to enter the cooled space unnecessarily?	✓ ✓ ✓	*Repair/replace thin or damaged insulation.* *Fit door strip curtains or automatic doors to reduce warm air ingress.* *Replace damaged door seals.*
Compressor		
Is the compressor inefficient because of its age and/or poor condition?	✓	*Replace compressors that have valves in poor condition and/or badly worn bearings.*

Further information on energy efficiency in refrigeration and cold stores can be found in a number of publications available from ETSU:
Save energy, save money - an opportunity checklist for refrigeration systems (ref. FL95011)
Fuel Efficiency Booklet 11, *The economic use of refrigeration plant*
Good Practice Guide 42, *Industrial refrigeration plant: energy efficient operation and maintenance*
Good Practice Guide 44, *Industrial refrigeration plant: energy efficient design*
Good Practice Guide 59, *Energy efficient design and operation of refrigeration compressors*
Good Practice Guide 236, *Refrigeration efficiency investment: putting together a persuasive case*

15. ENERGY-EFFICIENT LIGHTING

The relatively high cost of electricity when compared with that of fossil fuels means that, although light bulbs and fluorescent tubes do not consume vast quantities of electricity, lighting can be a significant component of total energy costs. An evaluation of lighting use can therefore be regarded as an important step in the pursuit of energy efficiency. The check-list below will help you to ensure that your lighting system is both efficient and suited to the task for which it is required.

Minimising energy use in lighting

No-Cost Improvements			
1.	Do you have a regular cleaning programme for your lighting system?	✓	*Dirty lights result in light loss and may increase the use of the lighting system. Clean lamps, reflectors and glass panels at regular intervals.*
2.	Do staff switch off lights when leaving an area or when natural daylight is adequate?	✓ ✓	*Motivate your staff to save energy by switching off.* *Ensure that switch banks are labelled.*
3.	Is your lighting at the optimum level for the tasks being undertaken?	✓	*Optimum lighting levels for different tasks are listed in Fuel Efficiency Booklet 12. Use a light meter to check whether lighting levels in your premises are appropriate for the tasks being undertaken.*
Investment Opportunities			
1.	Do staff switch off lights when leaving an area or when natural daylight is adequate?	✓	*Ensure that switches are located where they are most likely to be used, e.g. at exits.*
2.	Can you adjust the lighting in a large area when only part of that area is in use?	✓	*Install a zoned switching system.*
3.	Is the lighting in your premises switched to reflect occupancy, task need and natural daylight levels?	✓ ✓ ✓	*Install controls that switch off most of the lighting after the end of normal working.* *Install occupancy sensors, particularly in stores and other areas that are not continually occupied during working hours.* *Install daylight sensors that switch off lights near windows when natural daylight is adequate.*
4.	Does your lighting system use the most efficient fittings?	✓ ✓ ✓	*Replace tungsten filament bulbs with compact fluorescent tubes.* *Replace standard fluorescent tubes with high efficiency tubes.* *Improve the efficiency of standard fluorescent tubes by installing high frequency ballasts.*

Savings on lighting can often be made at little or no cost, although more substantial savings can be achieved with some degree of investment. Significant improvements can be achieved by replacing existing fittings with more efficient lamps and lighting controls, and by making better use of daylight.

Where tungsten filament lighting is installed and is in use for all or most of the time, considerable savings can be made by changing to fluorescent lighting. Modern compact fluorescent tubes are now available that fit into existing tungsten filament bulb fittings, and these should be installed whenever an existing bulb fails. The alternative option is to install tubular fluorescent fittings, preferably with high-frequency control gear. As well as being more efficient, both compact and tubular fluorescent fittings offer a longer life. The saving that can be achieved by changing to fluorescent lighting varies from 50% to 70%, depending on the option chosen.

Savings can also be made where fluorescent tubes are already installed. It may, for instance, be possible to replace 38 mm diameter tubes with more efficient 26 mm diameter tubes and achieve an energy saving of about 8%. Savings of 8 - 30% can be achieved with existing fluorescent lighting by replacing quick-start or instant-start control gear with switch-start or, preferably, high-frequency control gear.

Further information on energy-efficient lighting can be found in three publications, available from BRECSU:
Good Practice Guide 158, *Energy efficiency in lighting for industrial buildings - a guide for building managers*
Good Practice Guide 159, *Converting to compact fluorescent lighting - a refurbishment guide*
Fuel Efficiency Booklet 12, *Energy management and good lighting practice*

16. IMPROVING THE EFFICIENCY OF SPACE HEATING AND VENTILATION

Space heating is required in winter in office and retail areas and in those parts of a dairy or creamery that are divorced from sources of process heat, for example packaging areas. The check-list below will help you to ensure that your heating and ventilation system is both efficient and suited to the special circumstances of the particular task it is designed for.

Minimising energy use for space heating and ventilation

Heating	
Is your space heating thermostatically controlled to an appropriate level?	✓ *Set thermostats to the minimum required for staff comfort. A temperature that is 1°C too high can increase your heating bill by 10%.* ✓ *Check regularly that thermostats are operating correctly and effectively.*
Is your space heating switched on and off to reflect occupancy and external temperatures?	✓ *Make sure that heating is switched off during shut-down periods.* ✓ *Avoid heating areas unnecessarily, for example areas where personnel are not normally working.* ✓ *Use optimum start controls to match heating start-up times to external weather conditions.* ✓ *Use a frost thermostat to provide winter protection for buildings outside normal operating hours.*
Do you need to improve the efficiency of heat distribution within working areas?	✓ *Use ceiling fans to ensure that warm air is not trapped at high levels in high-roofed areas.* ✓ *Consider replacing a centralised heating system with local infra-red heaters or, if appropriate, locally-fired warm-air heaters.*
Can you make use of waste heat from processes?	✓ *Consider recovering waste heat and using it to provide space heating in other parts of the building.*
Are your offices and other staff accommodation appropriately located?	✓ *Try to ensure that these areas are separated from sources of unwanted process heat or from locations that are particularly cold or draughty.*
Is heat being lost unnecessarily through the building fabric?	✓ *Consider insulating the walls and roof of the building.* ✓ *Draughtproof doors and windows.* ✓ *Consider installing automatic closing for doors, especially loading doors.*
Ventilation	
How effective and efficient is your ventilation system?	✓ *Make sure that all ducts, filters, grills and fans are regularly cleaned.* ✓ *Ensure that the ventilation system is balanced, with the inlet and extractor fans working together.*

The first and most essential task is to make sure that your heating systems are properly controlled. Raising the temperature only 1°C beyond what is needed can increase your heating bills by up to 10%.

If you use radiators for space heating, make sure that the heating is as efficient as possible by:

- using suitable time switches to ensure that the heating is switched off during shut-down periods;
- using an optimum start controller; this ensures that the heated area is at the required temperature by a given time but minimises the pre-heat period by relating the start-up time to the outside temperature.

Another option is to consider the use of infra-red heaters, which warm people rather than large quantities of air. This method of heating is particularly appropriate in work areas that are subject to frequent air changes, for example near the loading/unloading bay or the freezer doors. Infra-red heaters are available either as gas-fired units or with electric elements. The best place to install them and how to use them will vary from dairy to dairy and should be decided after talking to the suppliers.

Energy is wasted in many industrial buildings for reasons that include poor building design in relation to energy conservation and significant heat loss and draughts through gaps and doors, particularly loading doors. Building regulations covering thermal insulation now ensure that new buildings, alterations and extensions conform to a minimum standard. It is therefore common sense to bring existing buildings into line with these standards whenever possible. Much can be achieved by sealing and draught-proofing and by installing automatic door-closing devices and fast-acting doors.

Further information on the effective control of a heating and ventilation system can be found in Fuel Efficiency Booklet 10, *Controls and energy savings*.
Further information on insulating buildings is contained in Fuel Efficiency Booklet 16, *Economic thickness of insulation for existing industrial buildings*.
An additional source of information is Energy Consumption Guide 18, *Energy efficiency in industrial buildings*.
All three publications are available from BRECSU.

17. HEATING WATER MORE EFFICIENTLY

All dairies use a lot of hot water. This is primarily to make sure that utensils and work areas are clean enough to meet strict hygiene regulations. As pointed out in Section 9, there is a correlation between specific energy consumption and water usage, and cutting down on hot water usage has three cost benefits:

- it reduces water bills;
- it reduces the fuel costs for water heating;
- it reduces the charges for effluent disposal off-site.

The check-list below will help you to ensure your hot water is produced and used in the most energy-efficient way.

Hot water can be supplied in several ways:

- by a conventional gas-fired boiler which is also used in winter for space heating;
- by a point-of-use water heater;
- from a storage tank that uses electricity to heat the water.

> Little or no space heating is required in the summer, and hot water boilers used for water heating at this time of year experience high standing losses, even when well insulated, because of the small loads involved. Can you justify using such equipment in the summer? Point-of-use water heaters may be a more economic alternative.

If your water is electrically heated, you can cut costs by making maximum use of off-peak tariffs. If your storage capacity is insufficient for a full day's production and you have to use an immersion heater to re-heat the water several times at peak rates, it may be more economical to fit a larger, well-insulated hot water tank. By fitting suitable time controls, you can then meet all your hot water requirements using off-peak tariffs.

> Effective insulation is an important means of achieving fuel cost savings because it is relatively cheap and easy to install.

Saving energy in hot water use

Water Heating		
Do you need to improve the efficiency with which your hot water is heated?	✓	*Check the level of standing losses incurred by your gas- or oil-fired boiler in summer. If these are excessive, consider installing point-of-use water heaters.*
	✓	*Where water is heated by electricity, make full use of off-peak tariffs.*
	✓	*Where off-peak tariffs are already used, but the storage capacity is inadequate, consider installing a larger storage tank.*
Can you reduce your heating requirements by reducing the water temperature?	✓	*Make sure that the water is being heated only to the required minimum temperature. Heating to a higher temperature wastes energy.*
Water Storage		
Are your water storage facilities designed to minimise heat loss?	✓	*Ensure that storage tanks are properly insulated using a well-fitted insulation jacket or sealed plastic foam.*
Water Distribution		
How much heat is being lost during water distribution?	✓	*Ensure that all hot water pipework, throughout the plant, is well insulated.*
	✓	*Regularly check all pipework for leaks.*
	✓	*Regularly check that hot water is not running directly to drain.*
	✓	*Seal off 'dead legs' in the distribution system. This will reduce the amount of hot water needed to refill the pipework after use.*
Water Use		
To what extent can you eliminate wastage at the point of use?	✓	*Fit nozzles to hoses, wash hand basins and showers to minimise water waste and ensure that it is used more effectively.*
	✓	*Consider re-using relatively clean wastewater for pre-rinse purposes rather than discharging it to drain.*
	✓	*Where re-use is inappropriate, consider installing a heat recovery system.*

Detailed information on insulation can be found in Fuel Efficiency Booklet 8, *The economic thickness of insulation for hot pipes*, available from ETSU.

18. BETTER ENERGY MANAGEMENT OF HOT AND COLD PROCESS STREAMS

The greatest energy wastage in a dairy or creamery arises not from inefficient equipment but from inefficient energy management of the hot and cold process streams. In creameries, in particular, losses often occur during the transition phases when batches are being changed. If there is no regulation of energy input then energy will be wasted unnecessarily.

When fully implemented, energy management initiatives may generate energy cost savings of 10 - 20%. Energy Monitoring and Targeting (M&T) has already been considered in Section 3, but M&T succeeds only if consumption information is the basis for subsequent action.

The energy management of process streams is the first step in achieving the targets set. The aim is to eliminate:

- unnecessary pipework;
- unnecessary lag times;
- inefficient batch changes;
- poorly insulated process streams.

Process integration is one way of managing process streams effectively. It can be applied to individual processes, sites or industrial areas, irrespective of the efficiency of the processes involved.

The first step in any process integration study is to analyse the various process streams. This makes it possible to determine how well the hot and cold utilities are actually matched to the needs of the plant. It also highlights opportunities for transferring waste heat or cooling from one process to another, thereby reducing utility heating and cooling requirements.

The next step is to calculate the minimum energy consumption for the process, site or industrial area under consideration. This assumes that all the opportunities identified are implemented, thereby fully integrating the processes involved. This minimum energy consumption is then compared with the actual energy consumption.

Finally, plant modifications can be considered. These may include a network of heat exchangers that can be installed cost-effectively to meet the process integration targets set.

Regenerative pasteurisers in which heat is transferred from the outgoing hot milk to the incoming cold milk are already widely used within the liquid milk sector of the dairy industry, and the potential exists for similar heat exchange facilities in cheese milk pasteurisers. However, the regenerative effect of a cheese milk pasteuriser is not as high as for liquid milk production since the discharge temperature is around 30°C. Nevertheless, warm whey from the cheese-making process needs to be cooled, and it may be possible to achieve this cooling by using the whey to pre-heat unpasteurised milk in a heat exchanger. Before installing such a system, you should give careful consideration to timing. Pasteurisation tends to take place early in the day and cheese-making later on. A heat exchange facility may be appropriate only if process times can be altered or if some investment is made in equipment with intermediate heated fluids.

You are most likely to benefit from a process integration study if the layout of your site has neglected to take energy efficiency into consideration. A well-planned layout can have a major influence on the efficiency and convenience of the production process. It can also increase the energy efficiency of the plant, particularly, as in the dairy industry, in areas where products are heated or chilled as part of the process.

Information on the insulation of process plant can be found in the following, both of which are available from ETSU:
Fuel Efficiency Booklet 19, *Process plant insulation and fuel efficiency*
Good Practice Case Study 355, *The use of Pinch Technology in a food processing factory*

19. CONCLUSION

Energy is used for heating and cooling and to power equipment, and the cost to the dairy industry is around £73 million per year.

The potential for energy saving is significant. It ranges from 5% of present consumption in the case of washdown and cleaning-in-place procedures to as much as 30% of the energy used for compressing air.

APPENDIX 1

FURTHER READING

The Dairy Industry	
Energy Consumption Guide 26	*The liquid milk sector of the dairy industry*
Energy Consumption Guide 50	*The creameries sector*
Monitoring and Targeting	
Good Practice Guide 31	*Computer-aided Monitoring and Targeting for industry*
Good Practice Guide 112	*Monitoring and Targeting in large companies*
Good Practice Guide 125	*Monitoring and Targeting in small and medium-sized companies*
Fuel Efficiency Booklet 13	*Waste avoidance methods*
Good Practice Case Study 138	*Energy monitoring and target setting at a dairy*
Optimising Energy Tariffs	
Fuel Efficiency Booklet 9A	*Economic use of electricity in industry*
Motivating Staff to Save Energy	
Good Practice Guide 84	*Managing and motivating staff to save energy*
Good Practice Guide 172	*Marketing energy efficiency - raising staff awareness*
Energy Audits and Surveys	
Fuel Efficiency Booklet 1A	*Energy audits for industry*
Fuel Efficiency Booklet 1B	*Energy audits for buildings*
Spray Drying	
Good Practice Guide 185	*Spray drying*
Good Practice Case Study 323	*Adopting a practical, low-cost approach to energy efficiency in drying plant*
Boilers and Steam Distribution Systems	
Good Practice Guide 30	*Energy efficient operation of industrial boiler plant*
Fuel Efficiency Booklet 8	*The economic thickness of insulation for hot pipes*
Fuel Efficiency Booklet 14	*Economic use of oil-fired boiler plant*
Fuel Efficiency Booklet 15	*Economic use of gas-fired boiler plant*
Fuel Efficiency Booklet 17	*Economic use of coal-fired boiler plant*
Energy Consumption Guide 66	*Steam generation costs*
Energy Consumption Guide 67	*Steam distribution costs*
Good Practice Case Study 339	*Heat recovery from boiler blowdown*
Compressed Air	
Energy Consumption Guide 40	*Compressing air costs - generation*
Energy Consumption Guide 41	*Compressing air costs - leakage*
Energy Consumption Guide 42	*Compressing air costs - treatment*
Good Practice Guide 126	*Compressing air costs*
Fuel Efficiency Booklet 4	*Compressed air and energy use*
Motors and Drives	
Good Practice Guide 2	*Guidance notes for reducing energy consumption costs of electric motor and drive systems*
Good Practice Guide 14	*Retrofitting AC variable speed drives*

Refrigeration and Cold Stores

Good Practice Guide 42	*Industrial refrigeration plant: energy efficient operation and maintenance*
Good Practice Guide 44	*Industrial refrigeration plant: energy efficient design*
Good Practice Guide 59	*Energy efficient design and operation of refrigeration compressors*
Good Practice Guide 236	*Refrigeration efficiency investment: putting together a persuasive case*
Fuel Efficiency Booklet 11	*The economic use of refrigeration plant*
Opportunity Checklist	*Save energy, save money*

Lighting

Good Practice Guide 158	*Energy efficiency in lighting for industrial buildings - a guide for building managers*
Good Practice Guide 189	*Energy efficiency in hotels - a guide to cost-effective lighting*
Fuel Efficiency Booklet 12	*Energy management and good lighting practice*

Space Heating and Ventilation

Fuel Efficiency Booklet 10	*Controls and energy savings*
Fuel Efficiency Booklet 16	*Economic thickness of insulation for existing industrial buildings*
Energy Consumption Guide 18	*Energy efficiency in industrial buildings*

Other

Good Practice Guide 89	*Guide to compact heat exchangers*
Fuel Efficiency Booklet 19	*Process plant insulation and fuel efficiency*
Good Practice Case Study 355	*The use of Pinch Technology in a food processing factory*
Good Practice Guide 141	*Waste heat recovery in the process industries*
A guide summarising all available EEBPP advice for food & drink processing companies	*The essentials - food & drink processing*

Literature on energy efficiency in industrial processes is available from:

Energy Efficiency Enquiries Bureau
ETSU
Harwell
Didcot
Oxfordshire
OX11 0RA
Tel 01235 436747
Fax 01235 433066
E-mail etsuenq@aeat.co.uk

Literature on energy efficiency in buildings is available from:

Enquiries Bureau
BRECSU
Building Research Establishment
Garston
Watford
WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

APPENDIX 2

CONVERSION TABLE

Fuel type	Measured units	To convert to kWh multiply by:
Electricity	kWh	1.0
Gas	Therms	29.31
	Cubic feet	0.303
Gas oil	Litres	10.6
Fuel oil	Litres	11.2
LPG	Litres	7.0
	Tonnes	13,900

Other Useful Conversions:	1 ton	=	1.016 tonnes
	1 lb.	=	0.4536 kg
	1 UK gallon	=	4.546 litres
	1 cubic foot	=	0.02832 cubic metres
	1 litre	=	1.76 UK pints
	1 kWh	=	3,412 British Thermal Units

APPENDIX 3

OUTLINE CHART FOR ENERGY MONITORING

	Gas ('00 ft^3)	Gas (kWh)	Electricity (kWh)	Total energy use (kWh)	Total milk processed (litres)	Performance indicators (kWh/litre)		
	A	B (A x 30.3)	C	D (B + C)	E	F (B ÷ E)	G (C ÷ E)	H (D ÷ E)
January								
February								
March								
April								
May								
June								
July								
August								
September								
October								
November								
December								
Yearly Total								

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

For buildings-related publications please contact:
Enquiries Bureau

BRECSU

Building Research Establishment
Garston, Watford, WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

For industrial and transport publications please contact:
Energy Efficiency Enquiries Bureau

ETSU

Harwell, Didcot, Oxfordshire,
OX11 0RA
Fax 01235 433066
Helpline Tel 0800 585794
Helpline E-mail etbppenvhelp@aeat.co.uk

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.