Energy efficiency in plastics processing

Practical worksheets for industry

Energy worksheets 1 - 12

TANGRAM TECHNOLOGY

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Energy worksheets

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Reducing energy costs - the first steps

The "Climate Change Levy" will increase the cost of electricity by 0.43p/kWh and the base energy generation costs are rising throughout the world. Energy costs are always somebody else's problem and the plastics processing industry generally regards the energy as an overhead and as a fixed cost. This is untrue and energy is both a variable and a controllable cost. Most processors could easily reduce energy costs (without large investments) and increase profits through simple good energy management practice. This series aims to show you how to reduce energy usage and increase your profits.

Energy is a variable and a controllable cost

The vital questions

Before you can start to reduce your energy costs you need to understand where, when why and how much energy you are using. This information provides the benchmarks and signposts for improvement.

Where are you using energy?

The main electrical energy users are motors and drives, heaters, cooling systems and lighting systems. A simple site energy distribution map will show where energy is being used. If you are using a single meter it may be cost effective to use sub-meters to get further information on the areas of high energy use. Sub metering allows you to start to calculate the cost of energy for each operation and to identify areas of high energy usage - a key factor in reducing energy costs. A first step is to produce an energy map of your site to locate areas for monitoring and improvement.

When are you using energy?

The time at which you are using energy is important and demand plotted versus time will give invaluable information on how to reduce the energy costs (see below). Data for such plots should be available from your supply company. Look for unusual peak variations from day to day and energy use when there is no production. A demand graph also helps you to find the 'base load'. This is the load used for heating, lighting, compressors and pumps when you have no production at all.
Another way to find the base load is to record the meter readings (in kWh) and production volumes (in kg) at the end of each shift. Plot the amount of polymer processed against the energy consumption. From the graph, the energy use at zero production gives an idea of the 'base load'. Reducing the base load is a sure way to make savings.

Why are you using energy?

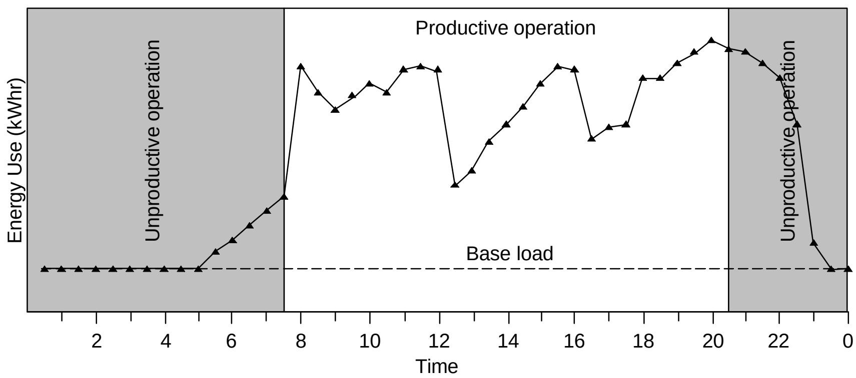
Ideally energy should be used only to produce good product and the most important energy benchmark is the energy used to produce good product (in kWh/kg). This is called the specific energy consumption (SEC) and can be found from the slope of the graph produced to find the base load. It can be compared to the industry averages to provide targets for energy reduction. Is energy being used to keep machines idling when they could be turned off? Are heaters running that are not being used? Are compressors running just to pump air out of leaks? Finding out why you are using energy will reveal a wide range of possible steps for reducing energy use.

How much energy are you using?

Electricity charges are based on a combination of factors (see right) and an initial survey will reveal areas for potential savings, sometimes actions as simple as changing the tariff can reduce costs at no cost! 'Peak demand lopping' can be very effective to reduce short peaks in the maximum demand.

Get free advice and help

Energy management will save money and make you more competitive. Start your energy management programme today and reap the benefits of improved profits by cost effective investment and management.
Action Energy provides free resources for energy management and cost reduction in plastics processing. An initial handbook "Energy in Plastics Processing - a practical guide" (GPG292) gives essential information on how to start reducing your energy costs and signposts further free information.
Get the information, save the money and become more competitive!



Typical Site Energy Usage over Time

Key tips for reducing the cost of electricity

Maximum Power Requirement is the maximum current a site can draw at the supply voltage. Reduce the cost by:

- •Staggering start-ups.
- •Matching the MPR to the requirements.
- •Getting the MPR right for new premises to avoid costly charges.
- •Negotiating an annually based MD instead of an MPR charge.

Maximum Demand is the current drawn at the supply voltage averaged over half an hour. Reduce the cost by:

- •Staggering start-ups.
- •Giving machinery time to stabilise before starting up new processes.

Power Factor is a measure of the phase shift created by machinery. Lightly loaded machinery tends to have a high phase shift, and a low power factor. Improve the power factor by running electric motors efficiently to get power factors close to 1.

Load Factor is a measure of the hours per day that the user draws from the supply. Reduce the cost by:

- •Running for greater than a single shift.
- •Carrying out some operations outside the main shift pattern e.g. regrinding.

The rewards

Energy efficiency measures can improve your profits significantly for minimum effort and costs. For a plastics company with a turnover of £10 million per year and a net profit of 10% then the profit will be £1 million. The average electricity bill will be approximately £200,000 (between 1 and 3% of turnover). Simple no-cost or low-cost energy reduction practices can reduce this by a minimum of 10% (and up to 20%) and increase profits by at least 2%. This is the equivalent of adding sales of £200,000 to turnover and is a worthwhile investment by any standards.

Low cost energy efficiency measures can improve profits significantly

The initial site energy survey

The objective of an energy survey is to gain an overview of the general site energy use. It is a walk around the site with an energy manager's hat on. This will identify some rapid no-cost or low-cost improvements that can be made to save money.
The survey should be carried out as soon as possible - if energy is being wasted now, it is costing money now.
The diagram shows the main areas of energy use in plastics processing. Use this as a guide during your walk-around to look for areas of high or unnecessary energy usage.

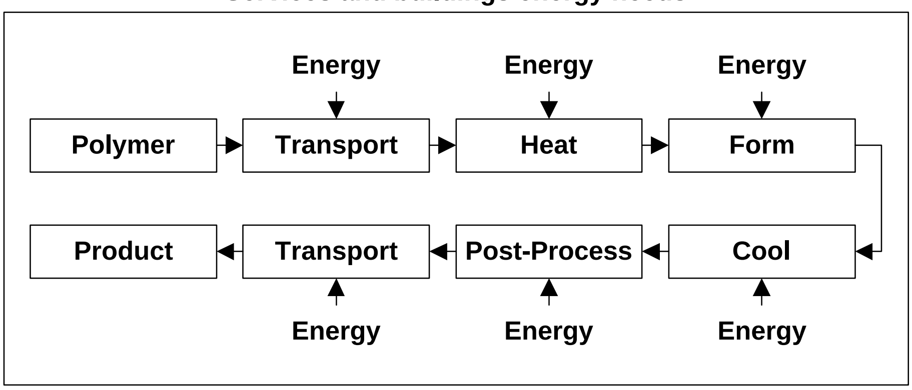
•How do you do a site survey?

•Take an unannounced walk around the site at around mid-shift. If there is no night shift it can also be profitable to take a walk around the factory when there is no production being carried out.

The questions to ask (and answer)

•Which areas have the largest electrical load? (look for the largest machines, they will most likely also have the largest motors and create the largest load, when they are used).
•Is the thermal insulation, if present, on all the machines in good condition? If there is no insulation then why not?
•Look for signs of machines that are not in production but have motors or ancillary equipment running (e.g. conveyors, pumps, granulators, fans, machine heaters).
•Are there any good reasons why machines need to be kept idling to be ready for the next production run?
•Which motors are left running when not doing productive work?
•Why are the motors the size they are and would a smaller motor be more efficient?
•Which cooling water pumps (and chillers) and vacuum pumps are still running?
•Is the airflow from fans being throttled back with dampers and could variable speed drives be used instead?
•Look for areas of energy use where no productive work is being carried out and yet machines are running and using energy.
•Look for water, air or steam leaks.
•Where can you hear steam and compressed air leaks? The hissing noise you hear from leaks is costing real money. If there is no production being carried out then why is the compressed air system still running?
•Is compressed air being used for expensive applications where other cheaper methods can be used? e.g. cleaning or drying.
•Does the compressed air pressure need to be so high, or the vacuum so low?

Services and buildings energy needs



Energy uses in plastics processing

•Is the lighting dirty, broken?
•What are the good, simple maintenance measures that can be adopted to reduce energy use?
•Are 'accepted' practices wasting energy? Can they be modified at no cost at all?
•Are there clear setting instructions for all machines and products and are they implemented when setting up?

Turning the survey into energy savings

An initial site survey is a key starting point for energy saving

A site energy survey is useless unless action is taken as a result of the findings. Use the survey to estimate the excess energy usage of the site and arrange for an electrician to measure the factory electrical load and calculate the costs involved. Use the survey to identify operating practices that cost money and need to be changed. The results of the survey should be sent to the Managing Director and Production Director with full recommendations and costs for carrying them out.

Raising energy awareness

The cost savings possible from energy efficiency will only be achieved if there is a management commitment to actually carry out the work necessary and save the money. This is best ensured by having an energy policy that is as much a part of the overall company operations as the quality policy. The energy policy should ideally be part of a broader company environmental policy and, at the very least, should be formally adopted with top-level management commitment.
The policy should be the responsibility of a designated Energy Manager who has clear responsibility for energy matters. There needs to be regular formal and informal communication with major users who are held accountable for their energy usage which should be monitored and targeted. The quantified savings from the implemented energy policy should be promoted within the company and used to create a favourable climate for investment treatment of other energy saving programmes.
Energy efficiency is a competitive advantage in any market and an initial site survey is the start of gaining the advantage for your company.

Capital equipment selection: changing the rules

Many people think that energy efficiency is simply about turning out lights and turning down the heating. Though partially true, it is not the whole story. Energy efficiency is also about using cost-effective technology to permanently reduce a company's energy consumption. For example, changing the behaviour of people to turn out lights requires them to be motivated and constantly encouraged. Changing the light switch for a passive infrared (PIR) detector is quick, low cost and effectively permanent. In many cases, it is easier to change the rules than to change the people.
This is even more critical when selecting capital equipment for plastics processing. It is easier and cheaper to specify and purchase energy efficient equipment at the start than to pay continuously for the energy it uses and to then try to upgrade the equipment later. Purchasing energy efficient capital equipment is the simplest and easiest way to permanently improve a company's overall energy efficiency and reduce its energy costs.

Purchasing energy efficient capital equipment will permanently change the energy efficiency of a company

The cost of the energy used during its lifetime will be more than the initial cost of virtually any capital equipment. It will be even more for machines that are not energy efficient. Energy efficient machines save money in the long term - an important factor when customers are beginning to expect price decreases through the lifetime of a product.
As with any capital equipment, the initial purchase cost should not dominate the decision-making process. The 'whole life' cost of the equipment (initial cost + operating costs) is the important cost for any plastics processor who wants to continue operating in the long term.

- **Tip:** Make an 'energy efficiency assessment' part of the capital expenditure approval process. If there is no assessment of energy use as part of the operational costs, then the capital expenditure should not be approved.
- **Tip:** Use the Energy Technology List (www.eca.gov.uk) to identify energy efficient plant and machinery for technologies such as motors, compressed air, refrigeration, boilers and lighting.
- **Tip:** Ask suppliers for proof of the energy efficiency of their products and check that it is applicable to the project.
- **Tip:** Be prepared to pay slightly more in initial purchase cost for energy efficiency.
- **Tip:** Electric motors are often hidden and use large amounts of energy. Specify energy efficient motors for all purchases.
- **Tip:** Set up a simple 'motor management policy' so that everybody knows the rules for purchasing, replacing and rewinding of electric motors for energy efficiency.
- **Tip:** Look for projects where the rules can be changed to the company's advantage and make energy saving automatic.

Typical projects

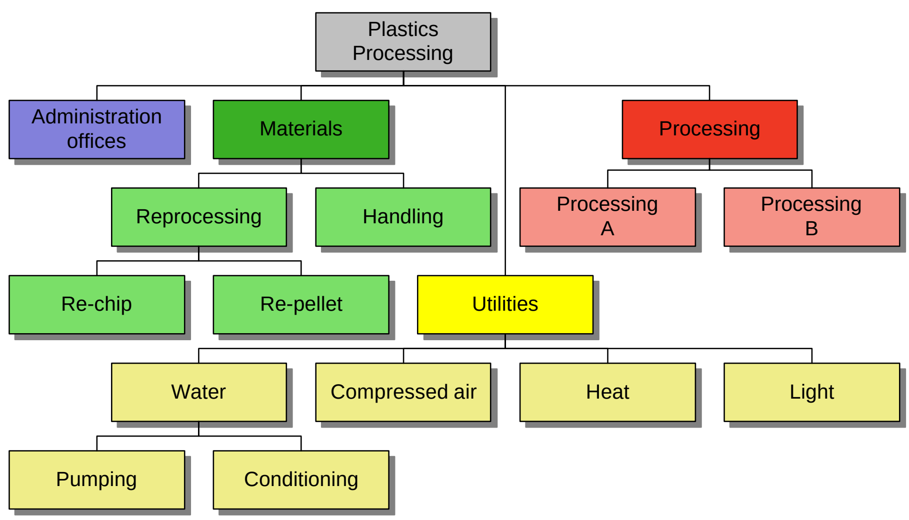
Plastics processors can save money in all areas of their operations by investing in energy efficiency. The diagram below shows where energy is used in plastics processing.
Opportunities for energy savings through investment are everywhere. Technology makes it possible to re-equip a factory for lower operating costs.
Potential areas for investment to reduce energy use and costs include:

- All-electric injection moulding machines
- Cooling water treatment
- Polymer drying
- Polymer transport and conveying

The cost of energy used during a machine's life will often exceed its initial purchase cost. Energy efficient machines and controls may cost more at the start, but they cost less in the long term.

- Lighting schemes and controls
- Compressors and controls.

These are all projects where current technology has proven energy saving benefits. Typical projects have paybacks ranging from under 4 years and often as low as 9 months.



Opportunities for energy savings through investment are everywhere. Technology makes it possible to re-equip a factory for lower operating costs.

Injection moulding

Over 90% of the energy costs in injection moulding are accounted for by electricity. This makes electricity purchasing very important for moulders and costs can be significantly reduced by good purchasing and operational controls. Only 5 to 10% of the total energy used in the process is actually input to the polymer, the other 90 to 95% is used to operate the machine and large savings can be made.

Good practice is inexpensive and reduces all costs - not just energy costs

Moulding machines

As with most machines, the initial cost of a moulder will be less than the cost of energy used during its lifetime. The energy cost will be even more for machines that are not energy efficient. Although it may cost more initially, energy efficiency will save money in the long term, a factor that is becoming more important in markets where customers expect decreasing prices through the lifetime of a product.

•**Tip:** Use 'whole life costing' for new machines and include energy costs.

•**Tip:** Contact machinery suppliers for information on additional equipment to reduce energy consumption.

•**Tip:** New generation machines often have improved energy efficiency and can reduce product costs by over 3%.

Getting the right machine for the job is vital and the machine should be closely matched to the product.

•**Tip:** Using large machines for small products is inherently wasteful. Are all jobs on the appropriate machines?

•**Tip:** Total efficiency decreases as the operating conditions move further away from the design conditions.

Electric motors account for 60% of the electricity used in moulders and the moulding cycle causes intermittent, variable loads with Power Factor values in the region of 0.7. PF correction equipment can increase the PF to greater than 0.95 with a payback of less than one year.

•**Tip:** Improving the PF is cost effective and simple with excellent payback.

•**Tip:** Motors are most efficient near the design load. Oversized motors at part load are less efficient than small motors at full load. Check all motor sizes.

Controlling the start-up sequence of machines can reduce energy costs with no other effect. Starting multiple machines at the same time will increase the Maximum Demand and the energy cost.

•**Tip:** Fit a warning device to the MD meter to sound when the load approaches the allowable limit.

•**Tip:** Plan and control the start-up sequence

Machines use energy even when idling, the amount varies with the machine to but can range from 52% up to 97.5% of the full moulding consumption. An idling machine is not 'free'.

•**Tip:** Idle periods of between 20 to 45 minutes may make it cheaper to switch off and restart.

•**Tip:** Are barrel heaters and cooling fans left on between runs?

•**Tip:** Is cooling water circulating through idle tooling?

•**Tip:** Is compressed air supplied to idle machines?

'All-electric' machines are an energy efficient solution and can both reduce energy use and make computer control easier and more direct. On conventional machines the hydraulic systems provide peak power for a very short time and the hydraulic system is overrated for most of the time.

•**Tip:** The use of accumulators for rapid hydraulic energy release can significantly reduce the hydraulic system size.

Heat transfer to the barrel is improved by pre-seating the heating element to the barrel and by using flexible metal bearing compounds.

•**Tip:** Thermal efficiency can also be improved by barrel insulation. This has a rapid payback (generally under one year) and improves other areas such as Health and Safety and fluctuations due to air currents.

Preventative maintenance such as de-aeration of the oil system and maintenance of the controls will reduce energy costs.

•**Tip:** Monitor the energy use to identify deterioration of the machine.

•**Tip:** Increased maintenance can lead to significant energy savings.

Moulds

Product cooling time is generally more than 50% of the cycle time. Efficient cooling can greatly reduce cycle times and energy usage - a double benefit.

•**Tip:** Is cooling water at the maximum temperature and minimum quality, how efficiently is it treated and distributed?

•**Tip:** Air in the cooling system reduces the cooling effectiveness. Degassed and pressurised systems can reduce cycle times and energy usage.

Excessive tool change times will waste energy if the machine is idling. Rapid set up of tooling reduces energy and improves overall factory effectiveness.

•**Tip:** Are tool changes planned into production schedules? Are they quick?

Ancillaries and services

Ancillaries use energy in electric motors and consumption of utilities. For highly automated production the total ancillary energy demand can be comparable to the machine energy demand. The main opportunities are minimising the demand for utilities. Motors are generally small and run intermittently and it is often not cost effective to retrofit more efficient motors or controls.

•**Tip:** Specifying energy efficiency during design of handling and ancillaries will give rapid payback on any additional costs involved.

•**Tip:** Check that handling systems can be set to operate 'on-demand' only.

•**Tip:** Match utilities to the demand.

Granulation and scrap recovery uses large amounts of energy and can will raise energy bills considerably.

•**Tip:** Carry out granulation at night.

Heat recovered from hydraulic systems and chiller units through heat exchangers can be used to provide space heating for offices and other areas with pay back times of 6 months.

•**Tip:** Look for opportunities to recover heat and reuse energy.

Management controls

Tweaking of machines by operators causes more lost time and energy than almost any other cause.

•**Tip:** Optimising the machine settings reduces the electrical energy needed. Get machines set right, record the settings and do not change them unless absolutely necessary.

•**Tip:** Use Statistical Process Control to control machine settings and performance.

The goal

Management is really at the heart of energy efficiency, without good management, neither energy efficiency nor any other change in operating practices will be effective. Energy efficient injection moulding is simply good moulding practice. It is inexpensive and reduces all costs – not just energy costs. Start working on energy efficiency today and reduce your costs to become a world class energy efficient moulder.

All-electric moulding

The cost of energy has traditionally been between 4 and 5% of the cost of a moulding, but this is increasing rapidly with rising energy prices. Energy efficiency is not a secondary issue - it can easily be the difference between profit and loss for a company. Despite proven energy efficient performance and many other benefits, all-electric injection moulding machines have been slow to penetrate the UK market. Early all-electric machines were more expensive than hydraulic ones, but this differential is decreasing rapidly. The important cost is the 'whole life' cost (initial cost + operating costs) and all-electric moulding machines offer real and significant savings in total costs compared with conventional machines.

Energy efficiency can be the difference between profit and loss for a company.

Energy savings

All-electric injection moulding machines have the potential to reduce the energy costs for a moulding by between 30 and 60%, depending on the moulding and the machine. Similar savings are possible across a broad range of materials and material grades, and can be achieved even if the cycle time is kept at that required for conventional machines. However, in many cases, shorter cycle times are also possible by using parallel operations (e.g. opening and ejection at the same time) to further reduce energy consumption and increase productivity.
All-electric machines also eliminate the need for cooling the hydraulic system, together with the associated equipment requirements and energy use.

Operational benefits

Removing the hydraulic system is one of the major benefits with all-electric machines. It brings many benefits, including:

- There is no hydraulic oil to be stocked, provided, filtered, changed or disposed of
- There is no hydraulic oil to contaminate the product, the operations area or the general environment
- There is no start-up time delay while waiting for the temperature of the hydraulic oil to stabilise
- There are no production effects due to temperature changes in the oil.

More accurate
All-electric machines allow machine movements to be integrated directly with the control system. This greatly improves machine set-up, adjustment and process control.
Improved control means that process movement and shot weights are often ten times more accurate than conventional machines, i.e. shots weights can be controlled to within 0.001 grams (1mg). This increased precision improves product quality and reproducibility. It also allows easy monitoring of process parameters and can be used to improve mould protection.
Faster
The direct drive from motor to machine movement reduces the system inertia (there are no valves to open or close) and makes the process quicker, more direct and more controllable. This can lead to significant cycle time reductions (up to 30%) without any loss of product quality.

Maintenance

All-electric machines generally require much less maintenance; hydraulic systems account for a high proportion of the maintenance needs of conventional machines. Removing the hydraulic system means:

- There are no consumables such as oil and filters to carry
- There is no need for cleaning and servicing, or fixing oil leaks
- The smaller number of parts means fewer to service and replace
- Servicing is less complex, faster and cheaper.

Overall, all-electric machines have a much lower risk of failure and are generally easier and cheaper to maintain and repair than conventional machines.

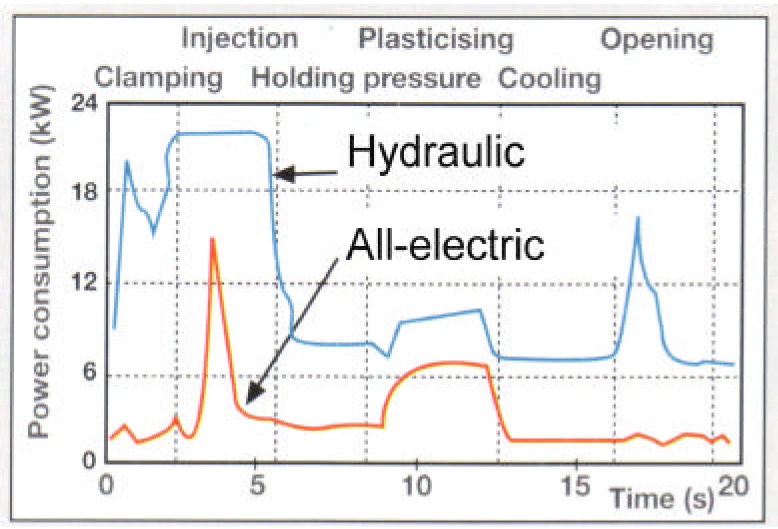
All-electric machines can significantly reduce the energy consumption and production cost for many mouldings.

Secondary Operations

Hydraulic control of cores on existing moulds that is currently powered by the machine hydraulic system is possible using an accessory hydraulic power pack.

Costs

All-electric machines bring significant energy and cost benefits. Energy savings of 30% are typical, but can rise to 60% if cycle time reductions are considered.
All-electric machines use less water; depending on the product, water consumption can be reduced by up to 65%.
Improved cycle times and increased precision gives improved productivity, while the reduced need for production capacity can lead to significant cost reductions overall.
All-electric machines offer a chance for the UK moulding industry to save energy and carbon, while also reducing costs. Overseas competitors are already doing it.



Opportunities for energy savings through investment are everywhere. Technology makes it possible to re-equip a factory for lower operating costs.

Extrusion

Extrusion is not only a final forming process but is also an intermediate process for other processing techniques such as injection moulding, blow moulding and film blowing. The efficient operation of extrusion screws is therefore essential to much of the plastics processing industry. The process is highly dependent on electricity and most of the energy used is directly related to machine operation. For profile extrusion the energy used to drive the extruder itself is 50% of the total and the remaining energy is used for items such as ancillaries and utilities.

Surveys show that a typical company should be able to reduce energy usage by 10% without major capital outlay.

Extrusion is a key forming process and is integral to many other processes

The extruder

The initial cost of energy efficient extruders may be higher but they will give rapid returns on the extra investment. Options such as high efficiency AC motors and Variable Speed Drives have good payback for both new purchases and when replacing motors and drives.

Whatever the age of the machine, it is essential to get the right extruder for the job and the screw diameter and design should be checked to make sure they are right for the polymer and product.

•**Tip:** Using large extruders for small profiles is wasteful.

•**Tip:** Total efficiency (including energy efficiency) is best operating at the design conditions.

•**Tip:** Set the extruder to run at its most efficient speed (usually maximum design speed) and control the screw speed to give an extrusion rate as close to the maximum as possible and still produce good product.

Motors run most efficiently close to their design output - a large motor at part load is less efficient than a small one at full load.

•**Tip:** Size and control the electric motor to match the torque needed by the screw.

Optimising the extruder speed maximises the heat from mechanical work and minimises the amount of electrical energy needed. Provided the downstream equipment does not limit the output, the energy consumption can decrease by nearly 50% by doubling the rotational speed of the extruder.

Accurate temperature control is needed for good extrusion - excess temperatures are wasted energy. The polymer needs to be kept close to the optimum processing temperature.

•**Tip:** Barrel insulation has a payback of under 1 year and also reduces Health and Safety issues and air current fluctuations.

•**Tip:** Check the controls to make sure that the heating and cooling are working efficiently together.

'Standby' operation can use significant energy from barrel heaters, cooling water, calibration vacuum and lights.

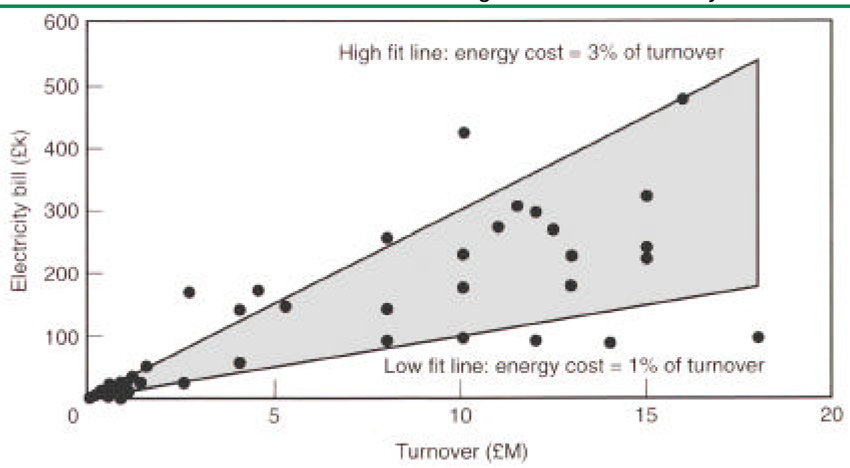
•**Tip:** Find the minimum 'standby' settings and set a routine to always leave machines in this condition.

•**Tip:** Turn off barrel heaters and cooling fans between runs.

•**Tip:** Turn off cooling water on idle machines.

Energy use can be used as a diagnostic tool to identify deterioration of the machine condition and the need for maintenance

•**Tip:** Increasing the frequency of maintenance costs time and money but can lead to significant energy savings.



The cost of energy to extrusion companies

The ancillaries

The main opportunities for energy saving in ancillaries are in minimising the demand for utilities, such as vacuum and compressed air. The electric motor drives are generally small so replacement with efficient motors is only likely to be cost effective when motors fail. Specifying energy efficient features at the design stage will give rapid paybacks on any additional costs.

The first step is to get the extruder right - if the extruder is at the optimum conditions the need for downstream cooling and calibration will be minimised. For utilities the approach should be to 'minimise the demand and then optimise the supply'.

•**Tip:** Find the maximum acceptable extrudate temperature after cooling and set the maximum cooling water temperature to achieve this.

•**Tip:** Check that cooling water is not circulating through idle calibrators.

•**Tip:** Check that cooling water is treated, chilled and distributed efficiently.

•**Tip:** Check that compressed air is not supplied to idle machines.

•**Tip:** Check that compressed air is generated and distributed efficiently at the minimum pressure needed by the process.

•**Tip:** Check that the vacuum supply is the minimum needed and that it is generated and distributed efficiently.

•**Tip:** Check that the vacuum supply is switched off when it is not needed.

•**Tip:** If replacing electrical motors then match the size to the actual demand and fit energy efficient motors.

Management

'Tweaking' of machines by setters and operators causes more lost time and energy than any other cause.

•**Tip:** Get the machines set right, record the settings and do not change them unless absolutely necessary.

Increased maintenance involves additional effort and costs but can lead to significant energy savings.

•**Tip:** Set up a total productive maintenance (TPM) programme to keep all machines and systems in top condition.

Energy efficiency will save money - start an energy management programme today and improve profits.

Extrusion blow moulding

For blow moulding, the Specific Energy Consumption (the energy used to process a kg of polymer) varies from 'typical' values of 1.5 - 2.0 kWh/kg up to 'high' values of greater than 3.0 kWh/kg. If your factory SEC is greater than 2.0 kWh/kg there are some real savings to be made from energy efficiency and experience shows that energy savings of 5 to 10% can be made through simple low cost measures. For a company with a turnover of £5 million this means saving £10,000 to £20,000 per year for minimal expense. With rising energy prices and the Climate Change Levy, energy inefficient firms will be at a considerable commercial disadvantage.

Machine

The major component of energy use is the extruder area which typically uses 40% of the total energy (see previous Worksheet on extrusion). As with other processes, energy efficient machines have lower long-term operating costs than standard machines will pay back any extra investment.

The use of all-electric machines is an energy efficient option for blow moulding because these machines remove the energy losses at the electro-hydraulic interface and can reduce energy costs.

Whatever type of machine is used, good process parameter control gives efficient operation and can give huge savings.

•**Tip:** Use just enough energy to complete each process stage. Look for opportunities to reduce heating time, cooling time and other cycle stages to save energy.

•**Tip:** Process controller improvements make it worthwhile investigating upgrades. Controlled, accurate and minimised wall thickness and parison length, will improve energy efficiency and materials usage.

Blow moulding machines use only small amounts of externally applied heat (most is generated mechanically) but heat transfer from barrel heaters can be maximised and evenly distributed by good seating to the barrel and the use of a conductive metal compounds. The energy used will be reduced and controlled by barrel insulation jackets - these also improve Health and Safety, reduce start-up times and generally have a pay-back of less than 1 year.

•**Tip:** Set the polymer at the minimum temperature it actually needs.

•**Tip:** Turn off barrel heaters and cooling fans between runs.

Parison weights are often up to 40% more than the weight of the final product. Any trimmed materials (tops and tails) can be recycled and recovered but the energy used is lost forever. Large tops and tails cost real money even if the material is recycled.

•**Tip:** Improved control of the parison and final product size will improve energy and process efficiency.

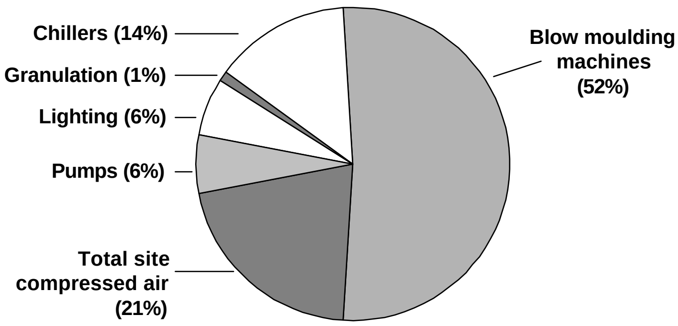
•**Tip:** The amount regranulated varies from under 10% to nearly 80%. You can improve in this area.

Regranulation should be done off-line (at night) to minimise energy costs, but first minimise tops and tail production - reduce and then recycle.

When a machine is not producing for a short time it is not practical to shut down the extruder but shutting down the hydraulic systems can give considerable energy savings.

Start-up procedures can be set to bring the energy demands online at the best possible time, i.e. heaters until stabilised, hydraulics and finally the extruder drive. Similarly shutdown procedures can be developed to switch off the energy intensive areas of the machine.

•**Tip:** Develop start-up and shut-down procedures to save energy and time.



Electricity use in a typical blow moulding factory

Ancillaries

Parison forming must be complete before the outside surface chills and stops surface texture formation. The compressed air pressure for blowing should be just sufficient to form the parison before chilling but it can then be reduced to hold the parison against the mould surface.

•**Tip:** Excessive air pressures for blowing or holding wastes energy.

•Most of the heat put in during the melting stage must be removed before the product is released from the die. Product cooling time is about 50% of the cycle time and minimisation of the melt temperature will save energy in heating and cooling as well as reducing the cycle time.

•**Tip:** Setters may raise temperatures or increase cooling times to get a job running - Check the settings.

The chiller system uses large amounts of energy and the process efficiency affects both time taken and energy used. Water has a better cooling efficiency than air and bubbles in the cooling water will decrease the efficiency of the cooling.

•**Tip:** Seal, degas and pressurise the water cooling system.

Cooling is most efficient with good contact between the parison and mould and this should be kept by the air feed during cooling.

Hydraulic systems for mould closing should be matched to the demand (blowing pressure x projected area) to reduce the energy needed and the hydraulic oil should be de-aerated on a regular basis to improve the efficiency of the hydraulic system. The hydraulic fluid should also be kept at a steady temperature to improve the process control and prolong the life of the oil.

•**Tip:** Some companies use chilled water from mould cooling to cool the hydraulic oil. This may make the hydraulic oil too cool and give rapid viscosity changes and control and quality problems. Check the temperature.

General Tip

The real secret to reducing energy consumption and costs is not in the technical aspects of any process - it is in the management attitude.

A desire to reduce costs through energy management and an effective implementation, monitoring and targeting programme will produce the results and the commercial benefits.

Cooling process water

A reliable and consistent source of cooling water is essential for fast and repeatable plastics processing. Cooling process water and refrigeration plant use approximately 11% of all the energy consumed in manufacturing in the UK. However, energy and carbon savings of up to 25% are easily achievable without any technical risk, simply by implementing good practice and proven technology.

•**Tip:** Cooling plant is generally reliable and is ignored unless there is a problem. Regular analysis of performance data will quickly detect any losses in efficiency.

Savings of up to 25% are possible with little technical risk.

Air blast cooling

Low ambient temperatures in the UK and the flow temperatures used in plastics processing mean that use of air blast cooling can reduce energy costs considerably. Air blast cooling pre-cools the return water from the process and significantly reduces both chiller loads and energy use. This can produce significant energy and carbon savings for low additional costs.

If the ambient temperature falls to 1ºC or more below the return water temperature, then the return water is diverted through the air blast cooler. The more the ambient temperature is below the return water temperature, the greater the air blast cooling effect. It is possible to switch off the main chiller when the ambient temperature is 3ºC below the return water temperature.

The cost savings generated by using air blast cooling give a typical payback period on the investment of less than 2 years and often as little as 12 months.

•**Tip:** Chillers with new or retrofitted air blast cooling circuits can show large reductions in operating costs.

•**Tip:** Chillers with air blast cooling circuits have shorter compressor running times, lower maintenance costs and extended chiller life.

Air blast coolers are available for capacities as low as 5 kW with no effective upper limit as units can be linked together to provide greater cooling capacity.

Chillers

Every conventional chiller is a compressor that pumps refrigerant; for every 100 kW of cooling capacity, it will use about 30 kWh of electricity. Even a small plastics processing site can need a 200 kW chiller, with an operating cost of over £16,000/year. However, simple measures can often improve the energy efficiency of chillers significantly.

Cooling load

Eliminating or reducing cooling loads will reduce running costs and improve efficiency.

•**Tip:** Only supply cooling where needed.

•**Tip:** Use the maximum possible water temperature; a 1ºC rise in the supply temperature reduces the energy required by about 3%.

•**Tip:** Fit adequate insulation to minimise unnecessary loads on the chiller.

Systems

Minimising the load allows a better assessment of the system design and particularly how it responds to part loads.

•**Tip:** Optimise existing systems. Use the most suitable refrigerant and optimise the system for high part-load and winter efficiency. This is particularly important when additional chillers have been added to the system.

•**Tip:** Balance pumps and chillers and match them to the normal load (with controls to match a variable load).

•**Tip:** Check that pipework and pumps are sized correctly for current demands.

•**Tip:** Keep chillers well ventilated to provide good airflow over the condensers.

•**Tip:** Use heat recovery to provide energy for space heating and hot water.

Components

Component selection is another important factor in energy efficient operation.

•**Tip:** Scroll and screw compressors are more efficient and can replace existing chillers.

•**Tip:** Avoid running chillers at low loads.

•**Tip:** Use large evaporators and condensers and avoid direct expansion evaporators if possible.

•**Tip:** Use variable speed drives (VSDs) for pumps and fans to match the output to process demands.

Operation and maintenance

Cooling systems often operate at low efficiency due to a lack of routine maintenance.

•**Tip:** Service chillers regularly and keep records of plant conditions.

•**Tip:** Clean evaporators, air blast coolers and heat exchanger surfaces regularly.

•**Tip:** Check flow/return temperatures and system flow rates to verify these are correct and optimised.

•**Tip:** It is a legal requirement to keep systems gas tight and to repair gas leaks.

•**Tip:** Design moulds and cooling baths or spray tanks to provide good heat transfer from the plastic to the cooling water.

•**Tip:** Set all systems components to turn off automatically when not in use.

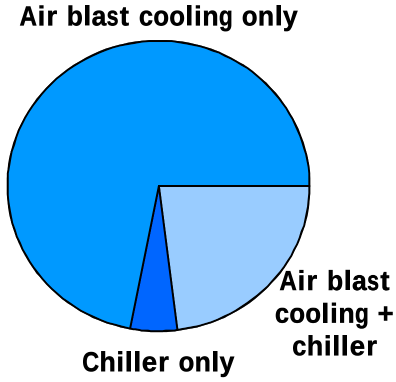
Measures of performance: energy efficiency ratios (EERs)

Coefficient of performance (COP) is the ratio of the cooling capacity to the absorbed power of a compressor.

Coefficient of system performance (COSP) is the ratio of the cooling capacity to the absorbed power of the complete system. This includes the effect of the power consumption of fans and pumps as well as the compressor.

COP and COSP can be used to indicate the relative energy efficiency of the chiller or the system and to compare systems with one another.

The measurement of COP and COSP depend on the conditions used to asses them and should only be used for comparison when identical conditions are used.



Air blast cooling is possible for most of the year in the UK.

Drying

Drying uses large amounts of energy but is necessary for processing hygroscopic polymers (i.e. those that absorb water) and for repeatable processing of non-hygroscopic polymers. If a polymer is not dried, any moisture present will be converted to steam during processing and create surface marks or even weaken the moulding. However, simple measures can achieve significant energy and carbon savings during drying.

•**Tip:** Drying is a hidden cost. Find out the time taken, the optimum temperature required and the energy used.

•**Tip:** Good storage of materials will reduce their moisture content before drying.

•**Tip:** Reducing cycle times in warm dry weather will reduce energy use.

Drying is a hidden cost and new technologies offer improved energy performance and reduced costs

Desiccant drying

Desiccant dryers pass moisture-laden air through a desiccant (a moisture-removing material) to produce warm dry air, which is then passed through the polymer. The air then removes moisture from the granules and is recycled back to the dryer for further drying and use.

The desiccant has to be regenerated using a high heat cycle to remove the moisture that it has adsorbed. A typical dryer uses continuously rotating desiccant canisters or valve arrangements to cycle the desiccant through the drying and regeneration stages. The typical time for drying using a desiccant is 4-6 hours.

Heat exchangers

Conventional desiccant machines do not recover the heat lost from the dryer during the process and often incur cooling costs. The latest machines use integral heat exchangers to recover heat from the exhaust air and recycle this back to pre-heat the cooler dried air from the desiccant dryer. This process can improve the heat balance such that up to 56% of the input energy is used to actually dry the polymer. This almost doubles the efficiency of the system and significantly reduces energy use and costs.

•**Tip:** Units that have automatic desiccant regeneration controlled by dew point sensors or by material moisture content are more consistent.

•**Tip:** The lower the dew point of the air supplied, the quicker the drying time - but this needs to be balanced against the frequency of regeneration and the energy used for this.

•**Tip:** Small spherical desiccant sieves give faster drying, better reactivation and greater adsorption.

•**Tip:** High reactivation temperatures improve reactivation and give greater adsorption in use.

•**Tip:** Optimise cycle times for the desiccant during drying to avoid overloading the desiccant and thus reducing process efficiency.

•**Tip:** Design desiccant drying systems to be 'closed loop' to exclude ambient air and obtain the lowest dew point.

New technologies

Carousel drying

This uses a rotating wheel that is impregnated with desiccant crystals. The wheel continuously rotates and passes the desiccant through the adsorption, regeneration and cooling cycles every 4.5 minutes. Control of the drying process is by adjusting the dryer speed and other variables.

The wheel has a low thermal mass that allows the use of lower regeneration temperatures than conventional systems whilst still achieving the necessary overall temperature for regeneration. The wheel produces a lower pressure drop and allows the use of smaller, energy efficient blowers.

Low pressure drying

Low pressure drying (LPD) uses a vacuum applied to the dryer cabinet to accelerate drying. The vacuum reduces the boiling point of water from 100°C to around 56°C, and water vapour is driven out of the granules even at low temperatures. LPD reduces drying times by up to 85%, reducing energy use by 50-80%. It also simplifies the process plant needed for effective drying, as desiccants are eliminated and no longer need to be regenerated and replaced. This provides a further opportunity to save money and energy.

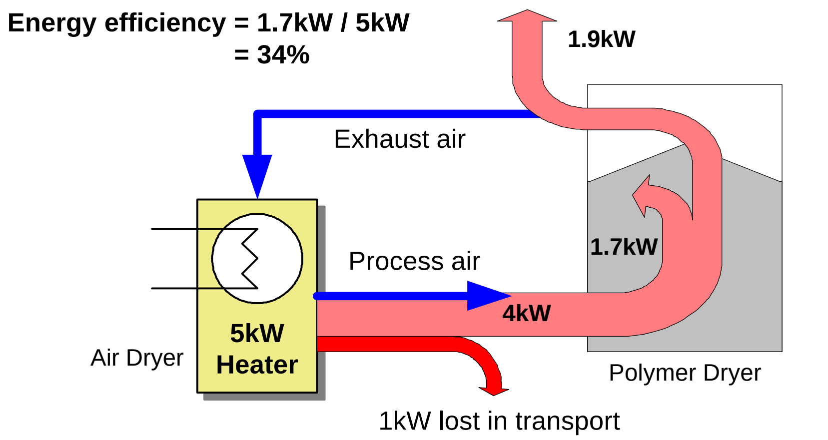
The system is suited to machine-side drying of materials and rapid material changes. The short drying time gives a rapid start-up and the smaller batches of material reduce the cleandown and changeover times. LPD also reduces the risk of thermal degradation of the polymer by reducing both the heating cycle and the temperatures used.

Infrared rapid drying

Infrared drying uses infrared radiation to heat the polymer granules directly. The energy applied to the granules creates internal heating though molecular oscillation. This internal heat drives moisture out of the material into a stream of cool ambient air that removes it from the process.

The system uses a drum with an internal spiral feed to transport and agitate the material as it is carried along underneath the infrared heaters. The final moisture content of the polymer is controlled by a combination of the power of the infrared heaters and its residence time in the system.

Infrared drying is particularly suitable for drying reprocessed PET material because it can combine the processes of recrystallisation and drying in a single pass. Drying and recrystallisation times for PET can be reduced to less than 10 minutes, with an energy consumption as low as 120 watts/kg/hour for drying to a final moisture content of less than 0.005%.



Energy flow in a conventional drying system - only 34% of the total input energy is used to heat and dry the polymer. The rest of the input energy is lost before or after drying.

Motors and drives

Approximately two-thirds of the energy costs in plastics processing are the result of electric motor usage. Yet motors are often overlooked when considering energy usage. The motors in the main processing equipment such as compounders, moulders and extruders are obvious but the majority of motors are 'hidden' in other equipment such as compressors, pumps and fans. When the energy cost of running a motor for 1000 hours can exceed the purchase cost and when the 'whole life' costs are often over 100 times the purchase cost then failing to take action with all the motors in a factory is expensive!

The energy cost of a motor can exceed the purchase cost in just 1000 hours of use

The motor management policy

The greater importance of running costs over the initial purchase price means that companies need to change the way they look at motors. Decisions need to be made on the 'whole life' cost where all purchase, maintenance, repair and operating costs are considered. The energy efficiency improvements available with the development of VSD and high efficiency motors (HEM) mean that, in order to reduce costs, companies must develop and implement a motor management policy for the purchase and operation of motors. This policy should include guidelines on:

- repair and replacement based on lifetime costing
- the specification of HEM for all new purchases

When new motors are required, the benefits of opting for HEM are obvious. However, the failure of an existing motor needs a decision on whether the motor should be repaired or replaced. Repairing a failed motor may appear to be a cost-effective action but repair can reduce energy efficiency by up to 1% and may not be the most economical long-term action. A motor management policy can provide the rules for making the best financial decision.

Motor sizing

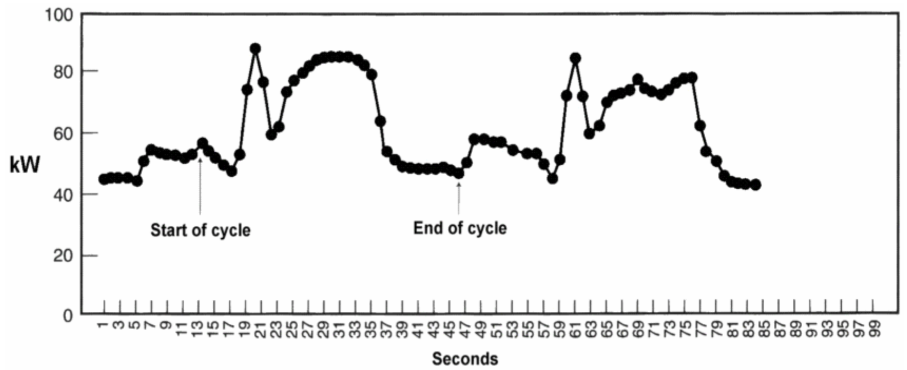
Motors are most efficient when their load equals, or is slightly greater than, the rated capacity. Motors can be overloaded for short periods provided that there is a later lower load to allow cooling. If machines larger than needed are purchased or used then the motor will not reach the design load and will never run at optimum efficiency. Oversized motors are inefficient and equipment needs to be carefully matched with demand. Even 'steady' loads from extruders, fans, compressors and pumps will fluctuate slightly and the basic operating load rarely matches a standard motor.

The demand graph (below) shows the instantaneous energy demand during a typical moulding cycle and illustrates the wide variations in load demand from a typical moulding machine.

- **Tip:** It is strongly recommended that expert advice on motor sizing is sought to reduce costs.
- **Tip:** Where motors can be accurately predicted to run at less than 33% of the rated output it is possible to reconfigure the motor from Delta to Star connection. This simple low-cost action can produce savings of up to 10%.
- **Tip:** VSD will allow motors to run at the required speed to save energy.

High efficiency motors

The cost premium for HEM is now very small and easily offset by the energy cost savings that result from their use. HEM achieve efficiency levels of up to 3% more than conventional motors and have a peak efficiency at 75% of load, thus reducing both energy costs and oversizing problems. A 3% efficiency gain may not sound much, but a £500 motor uses approximately £50,000 in energy over a ten year life and a 3% saving is £1500 - this is equivalent to three free motors.



Instantaneous energy use of a moulding machine

The life cost of a motor is often over 100 times the purchase cost

Variable speed drives (VSD)

The speed of an AC motor is fixed by the number of poles and the supply frequency. As a result, the hydraulic pumps in many processing machines are driven at a constant speed, even though the demand varies considerably during the cycle. The flow demand changes from the hydraulic pump are controlled by a relief valve and recirculation of the hydraulic fluid. Another way of meeting the varying demands is to fit a VSD to the motor. A VSD allows the speed of an ac motor to be varied and the pump output can be matched to the variable demand. The energy demand graph shown would have considerably fewer peaks and troughs if a VSD were to be used on the machine. The application of VSD can significantly reduce energy costs. Other VSD benefits are:

- reduced demand on the hydraulic system means that the hydraulic oil runs at a lower temperature and requires less cooling - an additional cost saving measure
- reduced noise
- lower maintenance costs
- better all-round performance.

VSD can also be applied to fans, water pumps and air compressors where the load varies considerably. For constant loads, the use of a correctly sized motor is the best option.

Despite this, the varying loads and the difficulty of matching the output to the need will inevitably lead to some energy losses.

Next steps

- Contact Action Energy for information on motors (GPG002), motor management policies (GIL056) and case studies on the savings possible with HEMs and VSDs.
- Start to save real money by choosing the best motors and systems.

Compressed air

Compressed air is a convenient and often essential utility, but it is very expensive to produce. In fact, most of the energy used to compress air is turned into heat and then lost. At the point of use, compressed air costs more than ten times the equivalent quantity of electrical power, ie an equivalent cost of around 50p/kWh. At this price, it should never be wasted and only be used when necessary.

Compressed air is an expensive resource. Minimise the demand and then optimise the supply.

Air also needs to be treated to remove moisture, oil and dirt and the higher the quality required, the greater the energy consumed by the treatment system. The chart below shows the cost of compressor ownership over ten years. In a typical 24-hour day, five and a half-day week, a 100 kW motor will use energy worth around £30,000 per year, assuming the cost of electricity to be 45p/unit. At these cost levels, an energy-efficient system is highly cost-effective, even if it costs slightly more to install.

The cost of compressed air makes it an expensive resource and the way to achieve the best savings is to minimise the demand and then to optimise the supply. Savings up to 30% can be made by inexpensive good housekeeping measures such as making end-users aware of the cost of generating compressed air and enlisting their help in reporting leaks.

Minimise demand

Reduce leakage

A significant amount of energy is wasted through leakage. Typically, leak rates are up to 40% (ie 40% of the generating power is wasted in feeding leaks). A 3 mm diameter hole in a system at 7 bar will leak about 11 litres/sec and cost around £1,000 per year. In a system with numerous leaks, this cost will multiply rapidly!

Simple leak surveys and maintenance can produce dramatic cost reductions, and in some cases, leak reporting and repair have enabled companies to shut down some compressors for all or most of their operating time.

- **Tip:** Simple and repeated walk-around surveys, with leaks tagged and repaired as soon as possible, will significantly reduce leakage rates.
- **Tip:** Isolate redundant pipework, this is often a source of leakage.
- **Tip:** Measure losses due to leakage and target reductions.

Reduce usage

Compressed air is often misused because everyone assumes it's cheap. Check every application to see whether it is essential or simply convenient.

- **Tip:** Stop the use of compressed air for ventilation or cooling - fans are cheaper and more effective.
- **Tip:** Fit high efficiency air nozzles - payback can be as short as four months.
- **Tip:** Consider the use of electric tools instead of compressed air tools.
- **Tip:** Do not use compressed air for conveying granules or products.

Optimise the supply

Reduce generation costs

The higher the compressed air pressure, the more expensive it is to provide the air. Twice the pressure means four times the energy cost. The real needs may be lower than you are supplying. In some cases, the machine rating is for a 7 bar supply but pressure reducers are fitted inside the machine. What are your real needs?

- **Tip:** Check that compressed air is not being generated at a higher pressure than required.
- **Tip:** Switch off compressors during non-productive hours. They are often only feeding leaks or creating them.
- **Tip:** Check that compressors are not idling when not needed - they can draw up to 40% of full power when idling.
- **Tip:** Position air inlets outside if possible - it is easier to compress cold air.
- **Tip:** If there is a machine or area that requires compressed air longer than the rest, consider zoning or a dedicated compressor so that others can be switched off.
- **Tip:** Investigate electronic sequencing to minimise compressors going on and off-load.
- **Tip:** Maintain the system - missing a maintenance check increases costs.

Improve distribution

The longer the compressed air pipeline, the higher the pressure loss over the pipeline and the greater the cost of the system.

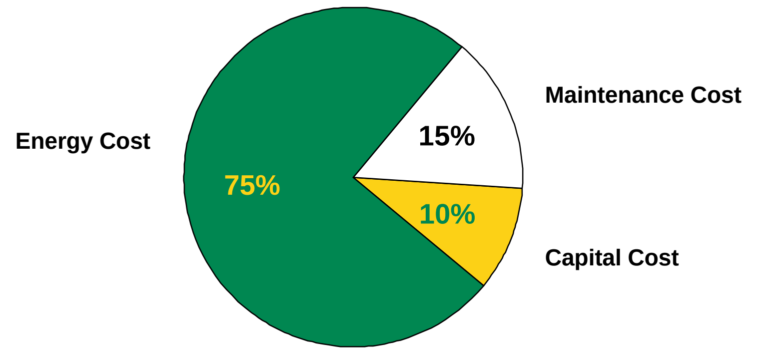
- **Tip:** Make sure that pipework is not undersized, this causes resistance to airflow and pressure drops.
- **Tip:** Use a ring main arrangement in each building - air can converge from two directions. This reduces the pressure drop and makes changes to the system easier.
- **Tip:** Avoid sharp corners and elbows in pipework as these cause turbulence and hence pressure drops.

- **Reduce treatment costs**

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

Next steps

Compressed air is not free and you can save at least 30% of the costs of compressed air by simple management systems and maintenance. Start now by contacting the Action Energy Helpline for full information on how to reduce your costs.



Whole life costs for compressors (10 year life cycle)

Buildings

Buildings-related energy use is often seen as secondary but it actually represents an average of 17% of the total energy costs. Buildings-related energy is an easy area in which to make energy savings because any changes do not impact on production. In most, cases a simple site survey can reduce costs considerably.

Building energy costs are a significant percentage of the total energy costs.

For the plastics processing industry, recent years have seen vast improvements in factory buildings and working conditions. This upgrading of conditions has produced significant improvements in all-round site efficiency, and has resulted in a general reduction in the usage of energy. However, large opportunities still remain for energy savings in areas such as lighting, space heating and general hot water supplies.
Many processes generate excess heat and it is worth investigating if this can be used for other purposes, such as space heating on colder days.
•**Tip:** Processes that involve any vaporising solvents will require 'local exhaust ventilation'. Processes that only generate heat have options for general or local ventilation or preferably energy recycling through a heat exchanger.

Building audit tips

The starting point to reduce building energy use is an audit of the buildings and systems. The following tips can serve as a basis for the initial audit.

Existing buildings

Improving the energy efficiency of existing buildings can be very cost-effective and easy to do.
•**Tip:** Reducing heating load is the top priority, so prevent unnecessary heat loss by making buildings as airtight as possible. Draught-proofing doors and windows is cheap but effective.
•**Tip:** Automatic fast-acting roller shutters save energy on external access doors used for forklifts and other mechanised access.
•**Tip:** High ceilings increase your heating costs. Investigate the use of false ceilings, or destratification fans to blow hot air from the roof space down to the working area.
•**Tip:** Restrict the areas to be heated by using partitions or local systems to control the key areas. Don't ventilate or heat the whole building space for a few small areas.
•**Tip:** Do not heat areas where you have windows or outside doors open.
•**Tip:** Do not heat lightly occupied stores or warehouses when you are only trying to prevent excessive dampness.
•**Tip:** Insulate supply pipes to radiators.
•**Tip:** Install tamper-proof thermostats and controllers to stop staff changing them. For larger sites, Building Energy Management Systems control energy costs without relying on staff.
Improving building energy efficiency also improves staff comfort and work output

New buildings/refurbishment

New or refurbished buildings are an ideal opportunity to reduce long-term costs. Low energy buildings are not only cheaper to operate but are more comfortable for staff.
•**Tip:** Get a copy of GPG304 - *The Purchaser's Guide to Energy-Efficient Buildings for Industry* from the Action Energy helpline and look for energy-efficient designs with passive solar heating, passive ventilation, added thermal mass, and natural lighting systems.
•**Tip:** Ensure building insulation and fabric meet the current best practice.
Tip - Double glazing can both reduce heat loss and improve comfort. Modern low-e glass and systems are even more effective than standard double glazing.
•**Tip:** Condensing boilers are the best option for new or replacement small hot water systems.

Lighting

Although they may only be a relatively small part of the overall energy usage, lighting systems offer easily demonstrable opportunities to save energy. Pay attention to areas with:
•High or continuous lighting levels and no or low occupancy. Use occupancy sensors or time switches.
•Fluorescent tubes at high levels without reflectors. The use of reflectors increases light levels and the number of fittings can often be reduced.
In lighting, simple measures can save money easily and a well-designed lighting system can be a permanent energy-saving feature. Examples and information on improved lighting methods are available in Good Practice Guides from the Action Energy helpline.
•**Tip:** Many major lamp manufacturers also offer advice and contract consultancy on lighting. Use any free help to save energy.
•**Tip:** Replacing normal tungsten bulbs with compact fluorescent (CF) lighting saves money in the long-term. Although they cost more, CF bulbs use only 25% of the energy of tungsten bulbs and last about ten times longer. The reduced maintenance costs, especially for lights in high fitments, can easily fund the extra purchase costs.
•**Tip:** High frequency tri-phosphor T8 tubes should always be installed when replacing or refurbishing existing older systems where good colour is needed. For areas where colour is not critical, high pressure sodium lighting is an option.
•**Tip:** Use natural daylight where possible and keep skylights clean to reduce the amount of artificial lighting needed.
•**Tip:** Research shows that lighting switched on in the morning will rarely be switched off until the evening - whatever the changes in daylight levels in the intervening period. Carry out a lighting audit to determine if lighting demands can be reduced.

ECG018 - *Energy Efficiency in Industrial Buildings*. The figures below give the **average** annual delivered energy use and cost. The main figures represent an average working day of 2.3 eight-hour shifts and the figures in brackets give the values per eight hour shift worked.

	kWh/m^2	£/m^2	% total	kWh	% total cost
Process	532 (231)	26.60 (11.56)		61.0	82.9
Buildings	340 (148)	5.48 (2.38)		39.0	17.1
Of the buildings energy use, the space heating element was over 50%:					
Space heating	288 (125)	2.88 (1.25)		33.0	9.0

The buildings energy use values from the sample ranged from 300 (130) to 550 (239) kWh/m^2. Calculate your annual buildings energy use per m^2 per shift, and compare it to the sample range above

Action Energy Publications for the Plastics Sector

For full details of publications get a copy of the Plastics 'Essentials' Pack.

Plastics specific information

Energy in Plastics Processing - A Practical Guide, GPG292
Extrusion of thermoplastic pipes and profiles, ECG 055
Energy efficient thermoplastics extrusion, GPG 239
Reducing electricity use in extrusion-blow moulding of thermoplastics, GPG092
Reducing electricity use in injection moulding, GPG048
Energy management in a small plastics injection moulding site, GPCS252
Energy management in a large plastics injection moulding site, GPCS253

General

Energy Management Pathfinder, GIR063
EMMA - The *E*nergy *M*anage*M*ent *A*dvisor, EMMA98
Focus - The managers guide to reducing energy bills

Motors and drives

Reducing Energy Consumption of Electric Motors and Drives, GPG002
Energy Savings from Motor Management Policies, GIL056
Quick Start - Your Fast Track to Energy Savings in Electric Motor Systems, GIR079
Retrofitting AC Variable Speed Drives, GPG014
Energy savings in industrial water pumping systems, GPG249
Variable Speed Drives on Water Pumps, GPCS088
Variable Speed Drives on process plant, GPCS170
Purchasing Policy for Higher Efficiency Motors, GPCS222
Variable Speed Drives on fans, GPCS232
Variable Speed Drives on a Cooling Tower Induced Draught Fan, GPCS270

Compressed air

Compressing Air Costs, GPG126
Energy Saving in the Filtration and Drying of Compressed Air, GPG216
Heat Recovery from Air Compressors, GPG238
Energy Savings in the Selection, Control and Maintenance of Air Compressors, GPG241
Compressing Air Costs - Generation, ECG040
Compressing Air Costs - Leakage, ECG041
Compressing Air Costs - Treatment, ECG042
Cost and Energy Savings Achieved by Improvements to a Compressed Air System, GPCS136
Compressed Air Costs Reduced Automatic Control, GPCS137
Compressed Air Savings Through Leakage Reduction and the Use of High Efficiency Air Nozzles, GPCS346
Compressed Air Leakage Reduction Through the Use of Electric Condensate Drain Traps, GPCS369

Buildings

Energy Efficiency in Lighting for Industrial Buildings - A Guide for Building Managers, GPG158
Electric Lighting Controls, GPG160
Heating System Option Appraisal - A Manager's Guide, GPG182
Energy Efficiency in Refurbishment of Industrial Buildings, GPG295
The Purchaser's Guide to Energy-Efficient Buildings for Industry, GPG304
Energy Efficiency in Industrial Buildings, ECG018
Energy Use in Offices, ECG019
Lighting in warehouses, GPCS157
Lighting in factories, GPCS158
Energy Efficiency in Refurbishment of Industrial Buildings, GPCS192
Energy Efficient Lighting in a High Precision Components Factory, GPCS307
Energy Efficient Lighting in Industrial Buildings, GPCS309
Controlling energy use in buildings, GIR047

Policy and management

Energy Champions, GPG067
Managing and Motivating Staff to Save Energy, GPG084
Energy Efficiency Training & Development, GPG085
Energy Efficiency in the Workplace - A Guide for Managers and Staff, GPG133
Marketing Energy Efficiency - Raising Staff Awareness, GPG172
Developing an effective energy policy, GPG186
Managing People, Managing Energy, GPG235
Maintaining the Momentum - Sustaining Energy Management, GPG251
Team building and energy saving, GPCS289
Running an Awareness Campaign, RAC PACK
Energy Saved by Raising Employees' Awareness, GPCS214
Investment Appraisal for Industrial Energy Efficiency, GPG069
Financial Aspects of Energy Management in Buildings - A Summary, GPG075