Low Energy Plastics Processing

Reduced Energy Consumption In Plastics Engineering European Best Practice Guide

October 2006
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Prepared by:

Rapra Technology
Shawbury
Shrewsbury
Shropshire
SY4 4NR
United Kingdom

Danish Technological Institute
Teknologiparken
Allé 29
DK-8000
Århus C
Denmark

AIMPLAS
València Parc Tecnològic
Calle Gustave Eiffel, 4
Apartado de correos 51
46980 PATERNA Valencia
Spain

British Plastics Federation
6 Bath Place
Rivington Street
London
EC2A 3JE
United Kingdom

Pôle Européen de Plasturgie
2, Rue Pierre & Marie Currie
01100 Belignat
France

Fraunhofer Institut Chemische Technologie
Joseph-von-Fraunhofer-Str. 7
D-76327 Pfinztal (Berghausen)
Germany

ASCAMM+
Campus de la UAB
P.O. Box 18
08193-Bellaterra
Barcelona
Spain

CRIF-Wallonie
Liege Science Park
Rue Bois Saint Jean 12
B-4102 Seraing
Belgium

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Supported by the European Commission under the Intelligent Energy - Europe Programme

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Reduced Energy Consumption In Plastics Engineering

The European plastics processing industry faces intense competition from lower wage economies and an alarming rise in energy prices. To remain competitive a business must have an effective energy management process, good market knowledge and an awareness of technology and support mechanisms. This industry comprises more than 27,000 companies (more than 80% SME’s), employing more than one million people, and with total sales of over 100 billion euros.

If it were possible to reduce energy consumption across the industry by 10%, this would result in an annual reduction in CO₂ emissions of more than 3 million tonnes.

RECIPE is a 3-year project to provide European plastics processors with the knowledge, justification and tools needed to reduce their energy consumption through the implementation of best practice and the introduction of new technologies.

The Objectives

• Collation of existing knowledge, material and experience from across the EU, with the intention of promoting the best of the best.

• Industry specific web-based energy saving tools.

• Look beyond current best practice to provide the industry with information on novel technologies and practices.

• Dissemination programme which will increase awareness throughout the European plastics processing industry of the most recent energy reducing technologies and materials development.

All the RECIPE publications are available to download directly from www.eurecipe.com. These include case studies, ‘How to’ fact sheets, benchmarking studies, presentations, tools for energy reduction and newsletters.
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1 Introduction

This Best Practice Guide, written for all levels of management and operational staff, provides a structured and practical approach to improving energy efficiency when plastics processing. Developed for companies that want to achieve more strategic control over rising energy costs, we hope that the opportunities outlined in this Guide will encourage processors to make energy efficiency a part of standard operating procedures. The Guide contains useful techniques, tools, tips and practical advice to get you started.

There are many reasons for wanting to improve your energy efficiency, however, the most compelling reason for the plastics processing industry is that wasting energy costs money and this is reflected in the bottom line. With rising energy costs, soaring raw material prices and the impacts of climate change, the need to monitor and reduce energy consumption is more important than ever before.

As with most industries, controlling costs is critical to sustainability and profitability. However, energy costs can be controlled and often reduced, by implementing measures that do not require significant investment. In many cases improvements can be made for low or no cost, by making slight changes to the way a process or equipment is operated to optimise its performance.

Energy efficiency offers short- and long-term benefits and by increasing the efficiency of a business the bottom line can be strengthened. It will be the ability of businesses to make rational and informed decisions about the use of energy on site that will play an increasingly important role in helping to manage the new challenges in a changing business climate.

This Guide has been written for the purpose of helping organisations plan and implement an energy efficiency programme. It has been designed for use by anyone and recognises that not everyone has time to undertake a full energy management programme. The Guide will help you undertake an energy audit and identify measures where energy and cost savings can be made most easily. Each chapter contains useful tips and actions to take, individual case studies and no-cost, low-cost and capital expenditure solutions to held reduce your energy consumption.
Before you can begin to reduce your energy costs, you first need to understand the basics of your energy usage. This section aims to help you understand:

- when you are using energy
- why you are using energy
- where you are using energy
- how much energy you are using
- benchmarking your performance

### 2.1 When Are You Using Energy?

Plastics processing involves a cycle of energy demand, however, many organisations are not fully aware of when energy is being used and the difference between productive and standby energy. Processing plastic materials at high temperatures involves a certain amount of pre-heating and, for larger systems and dies, a ‘heat soak’. This ensures that key components are at the required temperature before the process begins. This preparation period is often longer than needed in order to reduce the risk of a cold start.

#### 2.1.1 Daily Pattern and Half Hour Demand

In order to understand the pattern of energy use within an organisation, it is necessary to plot the energy usage at intervals across the whole day, or even a whole week. (See Figure 2.1 on the following page). This information should be analysed to critically assess where and when energy is being used.

#### 2.1.2 Base Load and Variable Load

Most factories and offices will have a base load, which will be present even when there is no production. This may be background heating, water pumps, security lighting and equipment that have been left on standby. This energy is an ‘overhead’ that is present irrespective of the production levels. The base load should be established, critically analysed and reduced where possible.

Look for the major energy users to see if they need to be utilised at the same time or if their use can be staggered.
2.1.3 Start-up and Shut-down

The majority of plastics processes involve a range of equipment that must be ready to operate when the production line is started. Some need to allow a long heat soak, whereas others do not require any preparation, however, it is often common practice to turn everything on early 'just to be ready'. Equally, when a production line is shut down there can be a finite period of time before the machinery is turned off. These situations mean that the equipment will be consuming power for a long period of time without producing anything. Start up and shut down procedures should be prepared to ensure that minimum energy is spent when the line is unproductive.

2.1.4 Critical Time Periods

The plot of the half-hour demand data will cover critical time periods such as the start and finish of the working day/week and routine breaks for lunch or refreshments. By analysing this data it is possible to establish the most energy efficient pattern of working. Questions that could be asked include:

- Why are all the lights left on at the end of the day for the cleaners to turn off three hours later?
- Who is responsible for turning off the air compressor?
- Why does the Managing Director need all the central heating to remain on when working late in one office?

2.2 Why Are You Using Energy?

Energy consumption is not always determined by production. Other factors, such as the weather, can cause energy use to change. For example, more energy will be needed for space heating on a cold winter day. Other factors that can cause an increase in specific energy consumption include:
• falling production levels
• an increase in scrap levels
• poor maintenance and wear
• poor quality raw materials
• the production of higher energy intensive components
• an increase in fixed energy levels

One method of ensuring that energy resources are being used to their maximum economic advantage is monitoring and targeting.

2.2.1 Monitoring and Targeting (M&T)

Energy monitoring and target setting is the collection, interpretation and reporting of information on energy use. It is based on the principle that to manage something you must first be able to measure and quantify it. The successful application of M&T leads to lower energy consumption, lower costs and a diminishing difference between actual consumption and the control standard. There are 3 stages to M&T:

1. Monitor the actual performance with half-hour readings, site surveys etc.
2. Compare performance against benchmark data.
3. Set targets for improvement which can be checked and verified.

2.3 Where Are You Using Energy?

The main users of energy in the plastics processing industry are:

2.3.1 Motors and Drives

They are used to run processing machines such as extruders and injection moulders. Melting of the plastic is primarily by transfer of energy from the drive motor, via the extruder screw to the polymer. The minimum requirement of the drive motor for any machine that melts plastic is 0.25 kW of energy for every kg/hr of polymer processed

2.3.2 Process Heating – Drying, Extruders, Injection Moulding

Many polymers require pre-drying before they can be processed and this can consume a significant amount of energy.

2.3.3 Process Cooling – Water, Air, Chillers

Once produced, all the energy that went into melting the polymer must be removed in a controlled way to avoid distortion of the final product whilst cooling. A simple calculation is to estimate 0.25 kW/kg/hr as a minimum.
2.3.4 Lighting Systems

Lighting plays a vital role in enabling people to carry out their tasks safely and efficiently and although they consume only a small percentage of the overall energy budget, it is possible to cut your lighting bills by up to 30% through a variety of energy saving measures.

2.3.5 Heating Systems

Heating can be a significant part of your energy bill; however, with better use of insulation and more efficient boilers big savings can be made. Heating bills can be reduced by up to 10 per cent simply by reducing room temperatures by one degree.

2.4 How Much Energy Are You Using?

For larger organisations it is beneficial to appoint a specific Energy Manager but even the smallest companies should have a designated person to be responsible for energy management. It is expected that businesses have a Human Resources Manager as employees are often referred to as the company’s major asset, however, with increasing energy costs it is likely that energy may constitute the biggest raw material cost and in some industries it could be more expensive than the labour costs. Being responsible for energy does not mean simply signing the invoice for payment, but should entail a critical assessment of the energy usage, tariffs and a plan for reducing energy consumption.

2.4.1 The Site Survey

The objective of the survey is to gain an overview of the site energy use. At the beginning of an energy management initiative it is important to determine the current position. Once this has been established it is then possible to set goals and priorities for future improvement. The site survey begins with a walk-round with a checklist to:

- see what is happening on the ground
- identify wasteful energy use
- identify opportunities for savings

However, as the pattern for energy use changes throughout the day it is important to conduct a series of walk-rounds, for example:

- at night
- at the weekend
- when the cleaners/security are on duty
- at lunchtime

This will provide you with a clearer picture of when and where energy may be being wasted. Involve key members of staff, both to identify problems and opportunities and to ensure they feel part of the process.
Once you have collected your information and identified the areas where savings or improvements could be made, try and prioritise which improvements will deliver the biggest savings. Only by understanding when, where, why and how you are using energy can you start to control and reduce your costs and consumption.

2.5 Benchmarking Your Performance

Energy benchmarking is the collection, analysis and reporting of data to provide industrial companies with a context for assessing comparative energy efficiencies. It is an important means of energy management, which allows companies a comparison with the ‘best of the best’. Using energy more efficiently helps your business to improve its productivity and bottom line, making it more competitive, while reducing greenhouse gases that contribute to climate change. Energy benchmarking and monitoring allows your company to identify deficiencies and adapt a better practice.

2.5.1 Specific Energy Consumption

Specific energy consumption (SEC) is a measure of the energy used for every unit throughput of polymer. This is normally expressed as the energy, in kWh, consumed whilst processing one kilogram of polymer. Hence the units are kWh/kg, or alternatively this can be expressed as kW/kg/hr.
There are two measures of SEC:

1. **Machine SEC** – recorded by noting the current, the drive details and throughput rate. We can arrive at a theoretical minimum for specific energy consumption by looking at the energy required to melt a polymer and raise its temperature to the processing temperature. For polyolefins this is approximately 0.2 kW/kg/hr and for high temperature polymers such as polyaromatics and some nylons, this rises to 0.4 kW/kg/hr. The minimum machine SEC is therefore approximately 0.4 kW/kg/hr.

2. **Site SEC** – takes an overview of a complete factory by recording energy used and the polymer processed over a set period of time. This information can usually be found in a company's records. The site SEC includes ancillary equipment, office heating and lighting as well as general site services so it is expected to be higher than machine SEC. Different types of processes will have a different SEC as they heat and cool the polymer more than once, whilst others require further operations to be carried out.

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**2005 European Benchmarking Survey of Energy Consumption and Adoption of Best Practice**

The RECIPE consortium conducted a benchmarking questionnaire based survey of the European plastics industry to assess energy usage, management and awareness. The objective was to aid plans to reduce the amount used, and cost, of energy. The survey and data analysis was carried out between April and September 2005. Highlights include:

- The average site-specific energy consumption was **2.87 kW/kg/hr**.
- This ranged from 0.63 kW/kg/hr for compounding to 6.2 kW/kg/hr for vacuum thermoforming.
- SEC was higher for small machines and lower for electric vs. hydraulic drives.
- In the UK, 80% of respondents use both gas and electricity, but Spanish respondents used mainly electricity.
- 70% of German respondents purchased energy from a local scheme and recovered energy for reuse.
- 30% had a written energy policy but only 5% employed an energy manager.
- 40% had used energy consultants and 30% monitored energy on each machine.
- An energy awareness score, with a maximum of 16, was calculated for each company – 60% scored less than the average of 4, and only 1% scored in the range 14 to 16.
- 50% of respondents felt that it was everybody's responsibility to observe the Kyoto protocol.

*To view the full report visit [www.eurecipe.com](http://www.eurecipe.com)*
2.5.2 Where Do You Fit Against the Benchmark?

In order to reduce your energy costs it is important to measure usage and compare it against a benchmark figure. If you want to control something, first you must measure it. To start the benchmarking process it is necessary to calculate the specific energy consumption (SEC) from the total energy used and tonnage processed. SEC is normally expressed as kilowatt-hours per kilogram (kWh/kg).

A simple calculation is:

\[
\begin{align*}
\text{Total energy used in (12 month) period} & = x \text{ (kWh)} \\
\text{Total tonnage produced in (12 month) period} & = y \text{ (tonnes)} \\
\text{Specific energy consumption (kWh/kg)} & = \frac{x}{1000y}
\end{align*}
\]

This figure should be compared against the figure from the benchmarking report for a similar process and situation. If you are worse than the benchmark you have work to do, but you can quantify the potential savings.

2.5.3 Can You Afford Not to Reduce Your Energy Consumption?

Between January 2004 and October 2005 energy costs have doubled. A survey carried out by the British Plastics Federation found that plastics companies face average increases of 56 and 58 per cent for electricity and gas prices respectively. Similarly, the European Plastics Converters Association (EuPC) argued in December 2005 the plastic conversion industry has been hit be escalating energy costs – for some companies over 100% for electricity and gas. The overall profitability of the industry is estimated to be 5%, the same as the amount spent on energy, therefore it is obvious that in order to survive companies must reduce their energy costs.

2.6 Purchasing Energy

Understanding your energy bill can make you a better consumer, help you become energy aware and reduce your costs. Factors that will have an impact on the cost of your energy are:

2.6.1 Maximum Power Requirement (MPR)

The maximum power requirement is the maximum current a site can draw at the supply voltage without tripping the main circuit breakers. If the MPR is exceeded the supplier will often impose a penalty charge as well a cost for upgrading the supply system to increase the MPR. Ensure that the MPR is set correctly and never exceeded.

2.6.2 Power Factor

Power factor is a measure of how efficiently electrical power is consumed, and the lower the power factor, the higher the cost. When the power factor is 1 the load consumes all the energy supplied by
the source. In comparison, when the power factor is 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. The reactive power charge on your electricity bill is targeted at companies who do not demonstrate efficient use of their energy.

Reactive power charges can be made significantly smaller by the introduction of ‘power factor correction capacitors’, a widely recognised method of reducing an electrical load and minimising wasted energy. It is not always possible or necessary to reach a power factor of 1, but a cost effective solution can be achieved by increasing your power factor to greater than 0.95.

### 2.6.3 Load Factor (LF)

Utility regulations allow energy suppliers to apply a demand charge that reflects the proportionate investment in power generation capacity needed to meet the customers maximum load requirements, or peak demand. The demand charge, unlike the energy charge, is a fixed cost that does not vary according to the number of kilowatt-hours consumed during the billing period. If you have a relatively high load factor (the load runs consistently at or near peak demand), the demand charge will represent a smaller percentage of the overall cost of energy consumed.

### 2.6.4 Maximum Demand

Maximum demand may be measured in kilowatts (kW), the power usefully used, or kilovolt-amperes (kVA), the apparent power delivered. Maximum demand is the highest average value of any thirty-minute period taken over a month, quarter or year. To avoid excessive MD charges, production procedures and schedules should be examined to ensure a smooth and constant maximum demand profile. Maximum demand controllers can be used to shed loads automatically when predetermined consumption rates are reached.

### 2.6.5 Peak Demand Lopping

This is a technique to reduce the maximum power requirement and maximum demand and therefore costs. The simple approach is to schedule the start up of major machinery to avoid cumulative loading and/or to spread the production day over a longer time period. By using an in-house generator, which only supplies power when the MPR or MD is approached, higher loads can be avoided.

### 2.6.6 Tariffs

All of the above factors contribute to the tariff on your electricity bill. The tariff is designed to ensure that electricity is used when the supplier has a greater capacity or is expecting usage. It will be made up of a basic price per unit of energy (€/kWh), plus additional fixed costs that depend on the four key factors of:

- Maximum demand
- Maximum power requirement
- Load factor
- Power factor
### Act Now! 10 Tips for an Energy Efficient Operation

1. If it doesn’t need to be on, turn it off.

2. If it must be on, optimise its operation.

3. Find out how much you are spending on energy, this will give a base figure to monitor the success of your energy saving measures.

4. Compile an energy checklist.

5. In a large business, a twenty percent cut in energy costs can represent the same bottom line benefit as a five percent increase in sales.

6. Check process heating and cooling controls to ensure they are set at the appropriate temperatures, speeds and timings.

7. Carry out a site survey to identify the major energy consumers.

8. Monitor energy consumption to see how effective your energy saving measures have been.

9. Measure your SEC and compare with the benchmark.

10. Check your energy bill for maximum power requirement, power factor, load factor and maximum demand.
Energy is often taken for granted. We rely on it for transport, powering factories and homes, heating in the winter and cooling in the summer. Fuel shortages and power cuts are currently rare, however, many energy sources are finite. This section will provide you with an understanding of:

- the European renewable energy policy
- different types of renewable energy technologies

### 3.1 The European Commission White Paper on Renewable Energy Sources

Some 80% of the energy the EU consumes is from fossil fuels – oil, natural gas and coal, and a significant and increasing proportion of this comes from outside the EU. Dependence on oil and gas, which is currently 50%, could rise to 70% by 2030. This increases the EU’s vulnerability to cuts in supply or high prices resulting from international crises. The EU also needs to burn less fossil fuel in order to reverse global warming. The way forward is a combination of energy savings through more efficient energy use, alternative sources and more international cooperation. (Source: European Commission)

In 1997 the European Commission issued the White Paper on renewable energy sources with the objective to achieve a share of 12% of total EU energy consumption by 2012. In the White Paper, the EC recognised that renewable energy sources are essential to tackle climate change, not only within the EU, but all over the world.

In order to reach the 12% aspiration set out in the White Paper, the EC has implemented several directives as part of its renewables policy:

- 2001 Directive on the promotion of electricity from renewable energy sources, which has a target of 22 per cent of electricity from renewables by 2010.

- 2002 Directive on energy performance in buildings, which aims to exploit the 20 per cent savings potential in the building sector, which represents 40 per cent of the total energy consumption in the EU.

- 2003 Directive on the promotion of the use of biofuels for transport, which proposes a target of 5.75 per cent for the share of biofuels in the transport sector by 2010.

### 3.2 Renewable Energy Sources

Renewable energy comes from energy sources that are constantly being replaced and are usually less polluting than energy from fossil fuels. Types of renewable energy technologies include solar, wind, geothermal, biomass and hydro.
3.2.1 Biomass

Biomass, also known as biofuels or bioenergy, is obtained from organic matter, either directly from plants or indirectly from industrial, commercial, domestic or agricultural products. The use of biomass is generally classed as a ‘carbon-neutral’ process, as the carbon dioxide released during the generation of energy is balanced by that absorbed by plants during their growth.

3.2.2 Geothermal Energy

Geothermal energy involves the exploitation of different grades of thermal energy stored within the earth. In certain geological areas, heat from within the earth’s interior can rise up to the surface. When water enters fissures in this hot rock, it can become heated and emerge on the surface as hot springs, steam, vents, geysers, mud springs or geothermal reservoirs.

3.2.3 Ground-Source Heat

Ground-source heat is extracted from the low-temperature heat (10-20°C) that is found at relatively shallow depths within the earth’s crust. This source of heat remains at a constant temperature throughout the year and can be taken from the ground itself or from groundwater. Heat pumps can be used to increase the temperature to approximately 40-50°C, which is useful for low-temperature heating systems such as underfloor heating and radiant panels.

3.2.4 Wave Energy

As ocean waves are created by the interaction of wind with the surface of the sea, waves have the potential to provide an unlimited source of renewable energy. Wave energy can be extracted and converted into electricity by wave power machines. They can be deployed either on the shoreline or in deeper water offshore. The main problem with wave power is that the sea is a very harsh, unforgiving environment. An economically viable wave power machine will need to generate power over a wide range of wave sizes, as well as being able to withstand the largest and most severe storms and other potential problems such as algae, barnacles and corrosion.

3.2.5 Tidal Energy

Tidal energy exploits the natural ebb and flow of coastal tidal waters caused principally by the interaction of the gravitational fields of the earth, moon and sun. The coastal water level fluctuates twice daily, alternatively filling and emptying natural basins along the shoreline. The currents flowing in and out of these basins can be exploited to turn mechanical devices to produce electricity. In order to produce practical amounts of electricity, a difference between high and low tides of at least five metres is required.

3.2.6 Hydroelectric Power

Hydroelectric power is the energy derived from flowing water in rivers, and for man-made installations where the water flows from a high-level reservoir down through a tunnel away from the dam. Waterpower
is mainly used to generate electrical energy. Turbines placed within the flow of water extract the kinetic energy and convert it to mechanical energy. This causes the turbines to rotate at high speed and drive a generator that converts the mechanical energy into electrical energy.

3.2.7 Wind Energy

The use of wind as a renewable energy resource involves harnessing the power contained in moving air. Wind represents a vast resource of energy that has been harnessed for hundreds of years. The UK has the largest potential wind energy resource in Europe and wind power is currently one of the most developed and cost-effective renewable energy technologies.

![Figure 3.1 Wind power](image)

3.2.8 Solar Energy

Solar energy involves capturing and harnessing the sun’s energy. The three main ways of doing this are:

- Passive solar design – the application of design principles to make sure that excess heat loss is avoided and solar radiation is captured, in order to minimise the need for heating and lighting.

- Active solar water heating – converts solar radiation into heat, which can be used directly or stored.

- Solar photovoltaic (PV) panels - convert energy from daylight into electricity using a semiconductor material such as silicon.
Figure 3.2 PV panels

Figure 3.3 Solar photovoltaic panels
4 Injection Moulding

4.1 The Injection Moulding Process

Injection moulding is one of the prime manufacturing processes for making parts from plastic material. It is a fast process and used to produce large numbers of identical items from high precision engineering components to disposable consumer goods. The process involves clamping two moulds together into which a molten polymer is injected. High pressure is used to obtain fast filling speeds and to ensure the mould is completely filled. Once the polymer has been cooled in the shape of the cavity, the mould is opened, the part ejected and the process restarts. There are six main stages in the injection moulding process as shown in Figure 4.1.

Figure 4.1 The 6 stages of the injection moulding process

As the plastic material needs to be heated, forced into the mould at high pressure and then cooled, the injection-moulding process is quite energy intensive.

4.2 Reducing Energy Consumption in the Injection Moulding Process

In an increasingly competitive environment, injection moulders are driven to reduce their costs per part by every available means. There are many other operational elements to consider in achieving this, however, energy consumption is an important factor to address. The energy use in injection moulding can be viewed as occurring in two phases: a high power requirement over a short time as polymer is injected and parts are ejected and a low power requirement over a long period of time as the injected polymer cools.
The power required to manufacture an injection-moulded part depends on many factors: the design, size and complexity of the mould dictate the size of the machine. The higher the clamping force, the higher the energy consumption.

The use of hot runners, hydraulic cores or inserts.

Ancillary equipment such as dehumidifiers, dryers and mould heaters.

The type of plastic material used as some materials have a higher melt temperature.

The cycle time dictates the length of time the pump or electric motor is running during the injection moulding process.

Once the part has been injected there are many handling processes that consume energy, e.g. robots, belt conveyors and packaging lines.

Energy is required, not just to melt the polymer, and subsequently cool it down again, but to generate the pressure to force the polymer into the mould. Additionally energy is used to open, close and hold the mould under pressure while the part is formed and cooled.

**Figure 4.2** shows how energy is used in a typical moulding plant. About 60% of the energy cost can be assigned to the injection moulding machines and their operation presents the greatest opportunity for energy savings.

**Figure 4.2** Typical example of energy consumption at an injection moulding plant

The power required to manufacture an injection-moulded part depends on many factors:
The majority of energy consumed by the injection-moulder is through the heaters and electric drive. The remainder is absorbed by the peripherals and plant equipment where the consumption is dependent on the amount and type of product being processed. In order to start reducing the energy consumption of the moulding machine, it is important to look at where the energy is being used (see Figure 4.3).

### Act Now! 10 Tips For Reducing Energy Wastage

1. Is the energy source the most efficient for the process?
2. Do you have the best contract with your supplier?
3. Is the installed power suitable for the type and volume of production?
4. Are there any energy recovery systems in place?
5. How does your energy usage compare against the benchmark?
6. Are the hot and cold pipes insulated?
7. Do you have enough power for maximum demand without too much surplus?
8. Is the plant layout optimised for the volume of production?
9. Have all the systems in the plant been optimised?
10. Are you following the material/machinery suppliers recommended operating instructions?
Hydraulic vs. Electric vs. Hybrid Machines

The initial cost of a moulding machine is less than the cost of the energy used during its lifetime but the energy cost will be even more for machines that are not energy efficient. Energy efficient machines will save money in the long term and the initial purchase cost should not be the dominant factor in the decision making process.

Hydraulic Machines

- Hydraulic drives normally require continuous operation with minimum start-ups and shut downs making it difficult to improve energy savings.
- Machine control is vulnerable to hydraulic fluid temperature.
- Hydraulic system flow and pressure requirements vary throughout the cycle and in many cases excess fluid that is not required by the process is throttled back to the reservoir, wasting motor energy and producing additional thermal load on the cooling system.

All-electric Injection Moulding Machines

- All-electric machines have the potential to reduce the energy usage in injection moulding by between 30 and 60% depending on the mould and machine used.
- All-electric machines do not require a hydraulic system as the power requirement is provided by the direct electrical drive.
- All-electric machines eliminate the need for the cooling of hydraulic oils.
- All-electric machines have lower power consumption at start up leading to lower maximum demand requirements.

Hybrid Machines

- Uses both servomotors and hydraulic pumps
- Common configuration is using the hydraulic pump for clamping and the servomotors for the screw movements.
- Hybrid machines are generally lower in cost than the all-electric machines, however, they are not as energy efficient nor as quiet.

There are many opportunities to save money by reducing your energy consumption in the injection moulding process.

4.2.1 Barrel Insulation Jackets

Barrel insulation jackets are an economical method of reducing the energy consumption and running costs of the heating elements by as much as 50%. They work in exactly the same way as the lagging jacket on a domestic hot water tank by reflecting back the heat radiated from the barrel.
The benefits of fitting a jacket to the moulding machine barrel includes:

- Shorter start up times
- Reduction of electrical consumption
- Can reduce peaks and total metered heat energy load
- Personnel protection
- Consistent operating temperatures
- Short return on investment – generally 6-12 months
- Improved Health and Safety
- Reduced operating costs

**Retrofit one injection-moulding machine within a plant and measure the ‘before’ and ‘after’ energy consumption per part produced. The annual energy savings, cost effectiveness and payback of the retrofit project can then be easily demonstrated.**

| **Comparison of Cylinder Heater Bands With and Without Insulation Jackets** |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| **WITHOUT insulation jackets**   | **WITH insulation jackets**     |
| **Consumption kW** | **Emission Temp °C** | **Consumption kW** | **Emission Temp °C** |
| 33.67                          | 110                             | 26.28                          | 55                             |

Temperature Emission Difference: 50%; Energy Saving: 22%

*Source: Nickerson Europe Ltd.*

### 4.2.2 Conformal Cooling

A basic fact of injection moulding is that the heat from the molten plastic must first be removed from the mould cavity before the part will solidify enough to be ejected. The amount of time it takes to make a part is defined by how quickly the tools can be opened and closed (cycle time), and typically, the longest part of a mould cycle is cooling. Cooling the molten material is where conformal cooling can pay big dividends.

The traditional method for cooling moulds is to drill straight holes through the block of material and run water thorough them. This is very inefficient; the cooling water cannot follow the shape of the part or change shape or location based on cooling requirements. The result is a poorly cooled mould that has hot and cold spots throughout, increased internal stresses within the part, longer cycle times and warped or distorted parts that may be out of tolerance.
Conformal cooling is the ability to create cooling channels in the mould that follow the contours of the part cavity. The objective is to cool the part rapidly and uniformly and typical cooling time reductions of 20-50% can be achieved over conventionally cooled tools. Additionally, a reduction in cycle times and scrap levels result in significant part cost savings.

### 4.2.3 Variable Speed Drives

Injection moulding machines typically employ large hydraulic pumps to inject material and open, close and clamp the moulds. The force required by the injection/clamping mechanism varies throughout the production cycle. To accommodate the variable load with a constant speed motor, excess fluid is typically bypassed back to the reservoir. In most applications, the injection/clamping mechanism requires full load for only a small part of the production cycle and fluid is bypassed to the reservoir during most of the cycle. Unfortunately, the hydraulic pump usually draws 1/2 to 3/4 of rated power while bypassing fluid at low load or no load conditions.

A variable speed drive (VSD) is one of the best ways to save energy with motors that need to operate at a range of speeds. A VSD adjusts the electric motor velocity to match the power requirement and can be used to optimise the volume of fluid being pumped by the injection moulding machine hydraulic system. Energy is saved as the motor uses significantly less power.

In addition to the potential for large energy saving, the use of variable speed drives has other important benefits:

- Improved process control
- Facility to control multiple motors
- Reduced motor noise and lower power loss
- On typical start-up, constant speed motors are subjected to high torque. VSDs offer a ‘soft start’ capability that gradually builds up a motor’s operating speed.
- Reduced demand on the hydraulic system so that the hydraulic oil runs at a lower temperature and requires less cooling.
- Reduce wear and tear on the motor and related components, which not only reduces maintenance costs but also prolongs the life of the motor.

The annual energy cost of running a motor can be up to ten times its initial purchase cost. The benefits of retrofitting existing equipment with variable speed drives or installing new equipment that contains VSDs are real and measurable. You will reduce energy consumption, cut energy costs and improve efficiency.
**CASE STUDY: Potential Savings When Fitting a Variable Speed Drive**

*Source: Maintenance Department of a Thermoplastic injection moulding company*

<table>
<thead>
<tr>
<th>Part Material</th>
<th>Polypropylene (PP)</th>
<th>Holding Pressure</th>
<th>65 bar</th>
<th>Maximum Power</th>
<th>55kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Weight</td>
<td>457 g</td>
<td>Injection Pressure</td>
<td>110 bar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clamping Force</td>
<td>440 tm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Injection Cycle**

![Graph showing injection cycle with and without VSD](image)

- **Cycle Time:** 31.5 s
  - Injection: 3.2 s
  - Cooling: 12 s
  - Closing: 3 s
  - Plasticizing: 10.7 s
  - Holding Pressure: 3.5 s
  - Opening: 3 s
  - Ejection: 3.5 s

*Figure 4.4* Comparative injection cycle – with & without VSD

<table>
<thead>
<tr>
<th>Without VSD</th>
<th>With VSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement hours</td>
<td>8</td>
</tr>
<tr>
<td>No. Injected parts</td>
<td>872</td>
</tr>
<tr>
<td>Consumption kWh</td>
<td>331.2</td>
</tr>
<tr>
<td>Average power</td>
<td>41.36</td>
</tr>
</tbody>
</table>

**Annual Cost Analysis**

<table>
<thead>
<tr>
<th>WITHOUT a variable speed drive</th>
<th>WITH a variable speed drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>(331.2 kWh / 8) x 4000 hours x €0.0782 kWh</td>
<td>(331.2 kWh / 8) x 4000 hours x €0.0782 kWh</td>
</tr>
<tr>
<td>= €12,950 per year</td>
<td>= €6,577 per year</td>
</tr>
</tbody>
</table>

**Cost saving per year:** €6,373 (49.21%)
The installation of a variable seed drive in a hydraulic powered injection-moulding machine can provide a total saving of approximately 50% of the energy consumption.

### Cost Analysis per Part

<table>
<thead>
<tr>
<th>WITHOUT a variable speed drive</th>
<th>WITH a variable speed drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>331.2 kWh / 872 parts = 0.38 kWh / part</td>
<td>168.2 kWh / 839 parts = 0.2 kWh / part</td>
</tr>
</tbody>
</table>

**Energy saving per part: 0.18 kWh/part (47.22%)**

### Act Now! 10 Tips to Reduce Your Energy Consumption When Injection Moulding

1. **Is the process stable and run with consistent settings?**
   *Check the parameters of the injection moulding and ancillary equipment to ensure they are constant. Inconsistencies may mean an unstable process that can lead to defective parts and increased consumption of energy.*

2. **Are the parameters optimised for the part being produced?**
   *Check that the clamping force is not higher than required and that the cooling time and holding pressure are not excessive.*

3. **Is the cycle time optimised?**
   *Shorter cycle times mean less absorbed power.*

4. **Are scrap levels reviewed periodically?**
   *Implement procedures to reduce scrap. There are injection-moulding ‘expert systems’ available that communicate with the machine to automatically correct parts. Reducing scrap levels can help to reduce your energy consumption.*

5. **Is mould performance reviewed periodically?**
   *Some scrap parts may be caused by damage to, or the incorrect design of, the mould. Reviewing mould performance can help to reduce your scrap levels.*

6. **Is the machine suitable for the type of product being moulded?**
   *Some products need a specific screw (e.g. PVC products)*

7. **Are you running the correct ancillary equipment?**
   *Has the most suitable drying, chilling or heating system been selected?*

8. **Is there a regular maintenance procedure for the injection-moulding machine and ancillary equipment?**
   *When reducing your energy consumption it is good practice to carry out routine maintenance on heat exchangers and cooling channels in moulds.*

9. **Do you have a procedure for energy saving during long down times?**
   *When reducing your energy consumption it is good practice to carry out routine maintenance on heat exchangers and cooling channels in moulds.*

10. **Conduct a time and motion study to see if it is possible to reduce the process cycle time through the introduction of a new technology such as robotics and automation systems.*
5 Extrusion

This section of the Best Practice Guide describes some practical ways of improving your energy efficiency when processing thermoplastic materials by extrusion. It covers:

- the extrusion process
- reducing energy consumption in the extrusion process
- action points for an energy efficient operation
- case studies illustrating best practice and potential savings

5.1 The Extrusion Process

Extrusion is a continuous process used for the production of semi-finished goods such as films, sheet, profiles and pipes. Although the design of the die and some components of an extrusion line differ depending on the type of extruded product, in each case, the same stages of production can be found.

Plastic pellets are fed into an extruder through the hopper and continuously fed to a heated barrel and carried along by a rotating screw. As it is conveyed it is compressed and melted. The softened plastic is then forced out thorough a die and directly into cool water where the product solidifies. An extrusion line typically involves six main stages (Figure 5.1).

From the above stages, it can be seen that the extrusion process uses electricity in motor drives, extruder line ancillaries (e.g. heaters and handling), and general utilities such as cooling water, vacuum or compressed air.

5.2 Reducing Energy Consumption in the Extrusion Process

The first step, when implementing an energy reduction programme, is to detect where, when and why energy is being used and how much is being consumed.
The main components responsible for energy consumption in the extrusion process are the motors, drives, heaters, cooling systems and lighting systems. Look at the time of day the energy is being used and plot the total demand against time. This will show you any unusual peak variations or if the energy is being wasted when there is little or no production. Ask your energy supplier for this information, it is often supplied free of charge.

In addition to the energy that is used to process the material, extra energy is used and often wasted throughout the day. When implementing an energy efficiency programme look at what extra energy is being used. For example, are you running the extruders, heaters or compressors when they are not being utilised?

In any extrusion process the efficiency of the extrusion screw is essential to obtain the maximum value of outputs as well as maintaining a good product. Most of the energy used during the extrusion process is directly related to the extruder operation. **Figure 5.2** illustrates the main components of a conventional extruder.

There are many opportunities to save money by reducing your energy consumption in the extrusion process.

---

**Produce an energy site map – this will help you discover the points at which the greatest amount of energy is being consumed.**

---

**Act Now! Where Are You Wasting Energy**

<table>
<thead>
<tr>
<th>1. Which areas have the largest load?</th>
</tr>
</thead>
<tbody>
<tr>
<td>The largest extruders are most likely to have the largest motors and create the largest load when used.</td>
</tr>
</tbody>
</table>

| 2. Are the extruders adequately insulated? If not, why not? |
| 3. Are the machines left idle during the day? |
| 4. Is the compressed air system left running when there is no production? |
| 5. Are motors the correct size or would a smaller one be more efficient? |
| 6. Are there any water, air or steam leaks? |
| 7. Is compressed air being used when another solution could be cheaper? |
| 8. Does the compressed air pressure need to be so high? |
| 9. Are there any maintenance measures that could be taken to reduce energy? |
| 10. Are there clear setting instructions for all machines? |
5.2.1 Flat Film Extrusion

Flat film extrusion is a significant sector of the plastics processing industry. The polymer melt is extruded through a die that gradually changes the cross section from circular, at the end of the screw, to a wide, thin, flat profile. The lips of this (coat-hanger) die are flexible enough to allow the gap between the lips to be controlled to obtain the desired thickness in the final film. Once the film exits the die, it is cast onto rollers, which can be used to cool the film, or to further control its thickness and surface finish by use of additional rolls where the surface temperature is controlled. By adjusting the relative speed of these rollers the film can be uniformly stretched to enhance certain properties. The finished film is then wound onto a roll ready for final processing into packaging, bags, display materials, etc.

### Points of Major Energy Consumption in Flat Film Extrusion

- **Cooling water for refrigeration of the extruder feeding zone**
  
  Optimise and control the water amount and temperature to obtain maximum efficiency.

- **Heating of the die**
  
  Energy consumption can be reduced significantly by setting the die temperature at the lowest possible, but ensuring that the melt flow is uniform.

- **Heating/cooling of the nip rollers**
  
  Optimise the water circulation system in order to set the most suitable temperature for the rollers during processing.

- **Ensure that the winder motors and other downstream equipment are sized to match extruder capacity.**

---

*Figure 5.2 Main components of a conventional extruder*
5.2.2 Blown Film Extrusion

Blown film extrusion is the process by which most commodity and specialised plastic films are made for the packaging industry.

![Figure 5.3 A blown film extrusion line](image)

### Points of Major Energy Consumption in Blown Film Extrusion

- Cooling water for refrigeration of the extruder feeding zone
  
  *Optimise and control the water amount and temperature to obtain maximum efficiency.*

- Heating of the die
  
  *Energy consumption can be reduced significantly by setting the die temperature at the lowest possible, but ensuring that the melt flow is uniform.*

- Heating/cooling of the nip rollers

- Compressed air supply for the internal and external air
  
  *This can be the most costly production input in blown film extrusion. Check that the pressure is set at the minimum required.*

- Air flow temperature
  
  *Check the temperature of the internal and external air flows*

- Where possible use ‘free cooling’

- Maintain good ventilation in the upper winder area to assist in cooling the fan

- Ensure that the winder motors and other downstream equipment are sized to match extruder capacity.
Plastic melt is extruded through an annular slit die, usually vertically, to form a thin walled tube. Air is introduced via a hole in the centre of the die to blow up the tube like a balloon. Mounted on top of the die, a high-speed air ring blows onto the hot film to cool it. The tube of film then continues upwards, continually cooling, until it passes through nip rollers where the tube is flattened to create a ‘lay-flat’ tube of film. This is then taken back down the extrusion tower via more rollers. On the higher output lines, the air inside the bubble is exchanged; this is known as an Internal Bubble Cooling system, (IBC).

### 5.2.3 Profile Extrusion

Profile extrusion is used to manufacturer plastic products with a continuous cross-section. The plastic is fed in pellet form into the hopper and conveyed continuously forward by a rotating screw inside a heated barrel and is softened by both friction and heat. The softened plastic is then forced through a die and directly into cool water where the product solidifies. When the profile has cooled it exits from the calibrator and is cut to the required length.

<table>
<thead>
<tr>
<th>Points of Major Energy Consumption in Profile Extrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cooling water for refrigeration of the extruder feeding zone</td>
</tr>
<tr>
<td>Optimise and control the water amount and temperature to obtain maximum efficiency.</td>
</tr>
<tr>
<td>• Heating of the die</td>
</tr>
<tr>
<td>Energy consumption can be reduced significantly by setting the die temperature at the lowest possible, but ensuring that the melt flow is uniform.</td>
</tr>
<tr>
<td>• Cooling the profile</td>
</tr>
<tr>
<td>It is important to control how much water is circulated and the temperature required for optimum energy efficiency. Check that the water is not colder than it needs to be.</td>
</tr>
<tr>
<td>• Vacuum supply</td>
</tr>
<tr>
<td>Check that the vacuum supplied is the minimum required and it is generated and distributed efficiently. When the vacuum is assisted with metal sleeves the thermal contact with the extrudate is improved. This can be a large contributor to the initial cooling of the profile.</td>
</tr>
<tr>
<td>• Haul off systems</td>
</tr>
<tr>
<td>Ensure they are not oversized for the extruder capacity.</td>
</tr>
</tbody>
</table>

### 5.2.4 Motors and Drives

Motors and drives are large consumers of energy, accounting for over two-thirds of power used in industry, and are an important target for energy and cost savings. The electricity bill for a motor for just one month can be more than its purchase price. For example, a motor running for 11 hours a day (4,000 hours a year) costs 10 times more in electricity than its capital cost. (Source: The Carbon Trust, UK). Savings on individual motor drives will vary, however savings of up to 70 per cent are common.
When a new motor is needed, the capital costs of a motor can be relatively small, the high lifetime running costs mean that it is important to consider carefully the options that exist when replacing or installing new motor drives.

Motors are generally at their most efficient when their load equals, or is slightly higher than, the rated capacity. If the extruder is larger than necessary, the motor will not reach the design load and will not run at its optimum efficiency.

### 5.2.5 Compressed Air

Compressed air is very expensive, and at its point of use costs more than ten times the equivalent quantity of electrical power. Additionally, the air must be treated before use to remove moisture, oil or dirt. One of the easiest methods to save energy when using compressed air is to minimise demand and optimise the supply.

---

**Act Now! How to Reduce Energy Consumption of Compressed Air Systems**

- Reduce leakage: repair as soon as possible
- Reduce usage: is it essential for the application or just convenient?
- Do not use compressed air for ventilation or cooling: fans are more efficient and cheaper
- Reduce generation costs: the higher the air-pressure the higher the costs. In some cases, twice the pressure means four times the energy consumption and cost.
- Switch off compressors during non-production periods. If you have a process that requires more compressed air than the rest, install a separate compressor just for this use so that the others can be switched off when not needed.
- Improve distribution: avoid long pipelines as the longer the line the higher the pressure loss and the greater the cost. Avoid sharp corners and elbows as they can cause turbulences and pressure drops.
- Reduce treatment process: treat the air to the required quality. Test the filters regularly to ensure that the pressure drop does not exceed 0.4 bar as the cost of power to overcome this is usually more than the filter.
- A 2-psi decrease in compressor pressure can reduce operating costs 1.5 percent.
5.2.6 Free Cooling

When the ambient temperature falls 1°C below the temperature of the water returning to the chiller e.g. water return temperature 15°C, ambient temperature, 14°C, free cooling can be activated. Before going to the chiller, return water is automatically diverted through the free cooler. This pre-cools the water, reduces the load on the chiller and the energy consumed by the compressors. The lower the ambient falls below the return water temperature, the greater the free cooling effect. Payback is fast and energy savings year on year are considerable.

CASE STUDY: Increasing Efficiency Through Innovative Machine Technology

The development to new extrusion equipment has been focused, not only on improving the final product but also achieving economic benefits through low specific investment and operating costs. This includes increasing the energy efficiency of the machines.

Retrofitted high-speed screws are a cost-effective method of increasing throughput. New machine concepts have been developed for high-speed screws including the development of a new extruder through the cooperation between esde Maschinentechnik, Bad Oeynhausen and ETA Kunststofftechnologie, Troisdorf. It has a screw diameter of 35mm and an effective screw length of 27D. The table below illustrates the energy losses of a conventional extruder and the energy-optimised one.

The new extruder is characterised by its direct drive, which works without the use of a conventional reducing gear system between the drive motor and the screw drive. The use of a direct drive improves the energy efficiency, and the use of a brushless drive motor simplifies services and maintenance.

The new plasticizing unit consists of a divided barrel with a grooved bush, which is temperature controlled by heating/cooling fluid. Additionally, it has a barrier screw with homogenising elements that is adapted for operation at high screw speeds.

The results obtained from tests with polyethylene and polystyrene show that the specific throughput rate (material throughput related to screw speed) remains constant even at high screw speeds. Therefore, it is possible to achieve high material throughputs without increasing the melt temperature, thus reducing the operating costs.

![Figure 5.4 Cost of running a compressed air system](image-url)
### Energy Losses of Nominal Drive Rating at Full Load Operation (Expressed in %)

<table>
<thead>
<tr>
<th>Drive mechanism</th>
<th>Single screw extruder</th>
<th></th>
<th>Energy optimised extruder</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power converter</td>
<td>0.75</td>
<td></td>
<td>Frequency Converter</td>
<td>2</td>
</tr>
<tr>
<td>DC motor</td>
<td>12</td>
<td></td>
<td>Asynchronous motor</td>
<td>6 – 8</td>
</tr>
<tr>
<td>V-belt package</td>
<td>3 – 5</td>
<td></td>
<td>Toothed gearing</td>
<td>2</td>
</tr>
<tr>
<td>Spur gear</td>
<td>3 – 4</td>
<td></td>
<td>Thrust bearing</td>
<td>0.5</td>
</tr>
<tr>
<td>Thrust bearing</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18 – 21</strong></td>
<td></td>
<td><strong>Total</strong></td>
<td><strong>10 – 13</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plasticizing unit</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooled grooved bush</td>
<td>10 – 20</td>
<td></td>
<td>Cooled grooved bush</td>
<td>5</td>
</tr>
<tr>
<td>Heat loss</td>
<td>5 – 10</td>
<td></td>
<td>Heat loss</td>
<td>0 – 5</td>
</tr>
<tr>
<td>Barrel cooling</td>
<td>0 – 20</td>
<td></td>
<td>Barrel cooling</td>
<td>0 – 20</td>
</tr>
</tbody>
</table>

### Act Now! 10 Tips to Reduce Your Energy Consumption in Extrusion

1. Select the right extruder for the job.  
   \[Choose \text{ the correct length/diameter ratio and screw design. Using large extruders for small dies or outputs is highly inefficient.}\]

2. Run the extruder at its most efficient speed with the extrusion rate as close to the maximum as possible.

3. Size and control the electric motor to match the torque required by the screw.

4. Ensure the barrel is adequately insulated.

5. Keep the melt temperature at the minimum required to obtain a homogenous melt at the end of the extruder.

6. Check the controls periodically during the process to ensure the heating and cooling systems work.

7. When possible, turn off the barrel heaters and cooling fans between runs.

8. Increase the frequency of the maintenance of the extruders.

9. Use dedicated air blowers for water removal not compressed air.

10. Turn off ancillary equipment when the extruder is not running.
This section covers the blow-moulding process and practical methods for reducing energy consumption:

- The blow-moulding process
- Reducing energy consumption in the blow moulding process
- Actions points for an energy efficient operation
- Case studies demonstrating best practice

### 6.1 The Blow Moulding Process

Blow moulding is used to manufacture hollow objects; molten plastic is blown into the final shape by air, in the same ways as a balloon. The main blow moulding processes are:

- Extrusion blow moulding – a tube is extruded; the mould closes round the polymer tube which is expanded by the injection of air.
- Injection blow moulding – the resin is first moulded into a preform then transferred to a blow mould where it is reheated and then expanded by the injection of air.
- Stretch blow moulding – a temperature conditioned preform is inserted into the mould and rapidly stretched in length and diameter.

Extrusion blow moulding is a continuous process that is used mainly to manufacture small, thin walled parts but can produce parts as large as 200 litre drums. There are 6 main stages in the blow moulding process are shown in Figure 6.1.

An extrusion blow-moulding machine consists of an extruder that melts the plastic and forms it into a molten tube (called a parison or preform) through a conventional type die and a split body mould. The die closes around the parison, sealing both ends and a blow pin is inserted to inflate it, causing it to expand and conform to the shape of the mould cavity. The mould is cooled and once the part has solidified, the mould opens and the part is removed.
6.2 Reducing Energy Consumption in the Blow Moulding Process

European blow-moulding companies can improve their competitiveness, productivity and profits by taking steps to make their industrial processes and equipment more energy efficient. There are many machine functions that influence energy usage during the blow moulding process and identifying these will provide opportunities to reduce consumption and increase profits. Start by looking at the following areas.

6.2.1 Polymer Melt Temperature

The heat from the barrel combines with the mechanical shear from the extruder screw to raise the temperature and soften the polymer. Is the process optimised to ensure the polymer leaves the die in the correct state and in the most efficient time possible?

6.2.2 Parison Control

Control the wall thickness of the part by adjusting the die and distributing the polymer evenly. This can lead to shorter cooling times and a reduction in the amount of polymer and energy used.

6.2.3 Mould Closing

Hydraulic cylinders close the mould and keep it closed against the blowing pressure. Check that the hydraulic force is not in excess of what is required as this is wasting energy. Use only enough energy to complete the job.

6.2.4 Product Cooling

The heat transferred to the polymer while in the barrel and die must be removed from the part when released from the mould. The cooling rate depends on the heat transfer rate from the cooling media to the mould and the mould to the product. Water has a higher heat transfer rate than air and air bubbles within the system can decrease the cooling efficiency of the water. It is recommended to seal and pressurise the system to avoid air bubbles becoming trapped.

6.2.5 Product Trimming

Recycle cuttings from parts to avoid unnecessary waste. Keep the trimmings to a minimum with good design practices.

Energy efficiency should be a key corporate objective for businesses. If you don’t need it, turn it off. If you do need it, make it more efficient.
6.2.6 Compressed Air for Parison Support and Blowing

Air is usually released at low pressure from the centre of the extrusion die to ensure that the parison remains tubular and does not collapse before it is enclosed in the mould. The main blowing nozzle is inserted as the mould closes and expands the parison using compressed air at around 6 – 10 bar for large barrels and plastic fuel tanks and up to 40 bar for PET bottles. Using unnecessarily high pressures waste energy and is expensive to run.

Methods for saving energy when blow-moulding can be split into three categories:

1. No-cost (machine run-time, product cooling and setting the machine parameters)
2. Low-cost (controlling process parameters and air compressors and systems)
3. Capital expenditure (new machinery)

6.2.7 Machine Run-time

Extrusion blow moulding machines are rarely allowed to run without making a product as the extruder can be damaged if the barrel is run empty. Additionally, polymer can be degraded if it is stopped while at processing temperature. It is impractical to stop the extruder for short periods of time; however, the hydraulic system used to drive the mechanical movements of the machine can usually be shut down when output stops as it can easily be re-started when required.

Switching off the hydraulics should become standard practice for all but the most minor of stoppages

Switching off the extruder and ancillary equipment represents a high percentage of the total load. This is particularly true for machines with two (or more) extruders. Unfortunately it is not generally possible to simply switch off the extruder without reducing the barrel temperature and/or emptying or changing the polymer in the barrel. Nonetheless, by understanding the costs associated with shutdown and start-up, standard routines may be developed to minimise waste of both energy and polymer.

6.2.8 Product Cooling

Cooling capacity is generally the rate-determining factor of the blow moulding process. The extrusion rate of most products can easily be increased but the cycle time cannot be reduced as the previous component is often still cooling. Product cooling time usually exceeds half of the machine cycle. Good contact between the cooling water and mould channels is essential. Cooling efficiency is reduced if air gets into the system and pressurising the system can often lead to reduced cycle times through better cooling.
### Act Now! Optimise Your Energy Consumption

The control unit of a blow-moulding machine drives the five main processes: hydraulic drive, cooling system, extruder, mould unit and compressed air.

**Control unit**

Close process control is needed for an energy efficient operation. In recent years control improvements have been made providing more precise process information and allowing effective and rapid corrections to be made more easily. Review and revise your control unit settings to provide more informative data that in turn can lead to increased throughput, increased product quality and cost and energy savings.

**Hydraulic drive**

Hydraulic power is normally generated by an integral power pack providing the power to various motions of the mould and, on some machines, to the extruder screw and die head. Stability is maintained by controlling the temperature of the hydraulic fluid via a heat exchanger connected to a cold water system. This offers opportunity for heat recovery.

**Cooling system**

The refrigeration system provides a controlled supply of chilled water that flows through the mould and cools the product. The efficiency of the cooling system has a major effect on the overall process time and energy used. Optimise the cooling system: design a system where the difference of temperature between the water in the entry and exit is not more than 5°C.

**Feed and extrusion unit**

Polymer is fed from an overhead hopper into the extrusion unit where it is plasticized by a combination of mechanical shear and electrical heat. Heat must be removed from the extruders quickly to maintain a good quality product. To maintain close control of the polymer temperature as it passes along the extruder screw towards the die, there is often a water-cooling circuit within the barrel wall and within the extruder screw supplemented by external cooling fans. This arrangement of heating and cooling is balanced to provide the required temperature profile in the polymer as it moves from the throat to the die. Additionally the screw can be cooled with an integral oil circuit.

**Moulding unit and compressed air**

The mould unit has 2 principal functions; to shape the product and extract heat from the product. High pressure within the sealed parison expands the polymer quickly to the shape of the mould. The pressure is maintained within the mould so that it remains in contact with the mould and is cooled efficiently. The compressed air pressure should be set at the minimum level for machine performance and product quality. Heat from the polymer is transferred to the metal mould and the cooling water that flows through a series of channels under the mould surface. The coolant is piped to the moulds cooling system from the chiller unit and returned in a closed circuit.
6.2.9 Setting the Machine Parameters

Modern control systems can set the machine conditions by following instructions from the microprocessor. Control of wall thickness by adjusting the die aperture ensures that the container weight is optimised and extruder capacity is not wasted. Control of parison length also ensures that tops and tails are minimised and that polymer is not extruded unnecessarily, thereby wasting energy.

6.2.10 Controlling Process Parameters

Controlling the process parameters can generate the greatest energy savings. Good practice requires that just enough energy should be used for every stage of the process. An awareness of the need to achieve set cycle times is often offset by the inability to determine how the parameters can be adjusted to make this possible.

Exceeding product weight increases the amount of energy wasted.

6.2.11 Air Compressors and Systems

Over 60% of the energy cost for stretch blow moulding can be attributed to the compressed air system. Economic use is dependent on three factors:

1. Selecting the correct type and size of compressor or pump to match the anticipated levels of use
2. Operating at the appropriate pressure for optimum production
3. Rigorous maintenance procedures to minimise leaks

State of the art control systems enable compressors can be sited at different parts of the circuit and switched from a central signal. This is a more economic and energy efficient method of controlling compressed air systems than the cost of running a single, large compressor idling for long periods.

6.2.12 Moulding Machines

Until recently the majority of blow moulding machines used a hydraulic unit, at least to drive the machine movements. A pump provides the power to the hydraulic machine and keeps running to maintain the hydraulic pressure. When the machine is in operation the hydraulic system does not take into account the breaks in the cycle and continues to run. Additionally, the hydraulic system heats the oil, which then must be cooled with a chiller. In contrast, electric machines do not use energy during any breaks in the cycle, therefore reducing consumption and costs.

The all-electric machine is currently the most energy-efficient solution as it not only eliminates energy loss in the electro/hydraulic interface but also improves accuracy and cycle times by enabling the microprocessor control to communicate directly with the various drives. The potential savings of using an electric machine have been estimated to be between 30 and 40%.
6.2.13 The Air Supply System in Injection Blow Moulding

Figure 6.2 illustrates the distribution of costs for blow moulding PET bottles. Approximately 84% of the total costs relate to the preform, with 50 – 85% of them raw material costs. 16% of the overall costs are blow moulding and 16% are energy related costs.

![Figure 6.2 Distribution of costs for blow moulding PET bottles](Source: PET Planet print, Vol. 3, Stretch Blow Moulding – A Hands on Guide)

CASE STUDY: ‘Air Wizard’ Optimisation

(Source: Krones AG, Germany, www.krones.de)

The ‘Air Wizard’ optimisation package developed by Krones consists of three modules aimed at cutting PET bottle making costs. It comprises of a variety of technical upgrades enabling air consumption in stretch blow moulding machines to be substantially reduced. The reduction in compressed air leads to savings in operating costs, so that even with an average machine capacity utilisation there are considerable savings to be made.

The ‘Air Wizard’ is made up of three modules:

1. For reducing the volume of dead space  Modifications enable the volume of the valve block and the blowing nozzles to be downsized from 500ml to 250 cc. Potential energy savings in air consumption are more than 7%.

2. For reducing the final blow moulding pressure  By optimising the process, the blowing air pressure can be reduced to suit the bottle requirements, with a potential cost saving for compressed air of up to 25%.

3. For active recycling of the final blow air  After the moulding, the blowing air in the pressure relief phase can be used for other functions such as pre-blowing and stretching. This can save up to 25% more in air consumption.
For above example the potential costs savings are approximately €30,000 per annum.

**Figure 6.3** Energy costs for Contiform S10 blow moulding machine at 13500/bh for 1000 bottles (2l bottle). **A** - Energy consumption without ‘Air Wizard’, **B** - Energy consumption with reduced clearance space, **C** - Energy consumption with ‘Air Wizard’ module air recycling for pre-blowing and stretching

**Act Now! 10 Tips to Reduce Your Energy Consumption in Blow Moulding**

1. Can any work by transferred to machines with a capacity closer to the parison weight?
2. Are tool changes planned into production schedules?
3. Is a complete set of accessory parts available for each mould to minimise idle time?
4. Are hot surfaces insulated, especially the extrusion die?
5. Is the polymer re-dried during any part of the process? Is it possible to use waste air?
6. Are cooling times optimised?
7. Are losses from the compressed air system minimised?
8. Are regular no-load checks carried out?
9. Is it possible to use advanced blowing air recycling systems?
10. Do you use ‘free cooling’ for your chiller system?
This section of the Best Practice Guide describes some practical ways of improving your energy efficiency when rotational moulding. It covers:

- the rotational moulding process
- reducing energy in the rotational moulding process
- action points for an energy efficient operation
- case studies illustrating best practice and potential savings

### 7.1 The Rotational Moulding Process

Rotational moulding (or rotomoulding) is a simple process for manufacturing stress-free, hollow plastic products. It involves the slow tumbling, heating and melting of a thermoplastic powder in a biaxially rotating mould to produce seamless, hollow plastic parts. The process is typically used to mould hollow parts, especially those with complex and varied shapes not easily obtained by other processes. (Figure 7.1)

![Figure 7.1 The 4 main stages of the rotomoulding process](image)

It is a virtually shear and pressure free process. The wall thickness uniformity and part weight can be easily maintained and there is very little waste of material due to scrap. All the plastic placed in the mould is used to make the part. Rotational moulding is unique amongst plastic moulding processes as the heating, shaping and cooling of the plastic all take place inside the mould with no application of pressure, (Crawford, 1996).

### 7.2 Reducing Energy Consumption in the Rotational Moulding Process

Energy efficiency projects can deliver large returns to your organisation and it can often be as simple as adjusting a dial. Generally energy reduction and conservation efforts can be classified into three steps:

- Good housekeeping
- Equipment improvement
- Process improvement
Taking a systematic approach to your energy saving opportunities can net impressive results.

7.2.1 Good Housekeeping

Good housekeeping and maintenance helps ensure an efficient and reliable operation as well as being essential to avoid wasting energy and it often costs nothing! Every employee can make a contribution to saving energy particularly through attention to housekeeping issues.

Quick Points for Good Housekeeping

- Is equipment being used effectively?
- Are hot and cold supply lines well insulated?
- Are heaters turned off when the machine is not in use?
- Is waste heat being recovered?
- Are baffles fitted to direct the hot air onto the mould?

7.2.2 Equipment Improvement

Energy loss in any industrial process or plant is inevitable; but the economic and environmental impacts are not to be taken lightly. Overall energy losses can result from designs that do not incorporate energy efficient specifications such as heat recovery, operations that run on inefficient methods and a poor maintenance programme. Reducing these losses will substantially increase the plant’s efficiency, but they must first be identified and quantified.

The rotomoulding heating process is best described in two stages:

1. Induction time – the time taken to heat the mould and the plastic particles. This is dependent on the method of heating, the melting temperature of the polymer and the thermal conductivity of the mould material.

2. Fusion time – the time needed for the melt to fuse at the mould wall and form the part. Parameters that affect the fusion time are wall thickness, thermal conductivity and diffusivity of the plastic and mould and the process set temperature.

The rotational moulding process is unique in that the mould and plastic must be heated from room temperature to over 200°C (400°F). This stage in the process is slow using conventional convection heating because the polymer is a poor conductor. This is particularly evident when a large mass of polymer has to be heated. In recent times other methods of heating have been proposed to improve the heat transfer: open gas flame, re-circulating hot air ovens, hot-oil jacket moulding systems, IR and electrical conduction. The most common method, for convenience and cleanliness is the re-circulating hot air oven. However, studies have shown that these ovens are often inefficient and have a prolonged heating time.

If your business is wasting energy it is causing avoidable pollution and reducing your profitability.
7.2.3 Process Improvement

The rotomoulding process lacks the basic mould temperature control and largely relies on time and oven temperature for control. As the quality and properties of a rotationally moulded part are highly affected by the processing temperature it is important that mould temperature is considered when trying to optimise the process.

7.2.4 Materials

In the rotomoulding industry, over 80% of the moulded parts are made from PE. Metallocene grade of polyethylene offers opportunities for this process and studies have shown that using Metallocene polyethylene in rotomoulding leads to reduced cycle times, lower energy consumption and a wider processing window.
7.2.5 Heating and Cooling

Oil heating and cooling of the mould offers reduced cycle times and a much higher thermal efficiency. An important area for design and development concerns heating the oil which flows round the mould. This design has the potential to allow close control of heating rates and oil temperature to different areas of the mould therefore significantly reducing both the amount of thermal energy used and process cycle time.

Figure 7.2 Oil heating and cooling rotational moulding machine

<table>
<thead>
<tr>
<th>Act Now! 10 Tips to Reduce Energy Consumption in Rotational Moulding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Consider using electric mould heating which uses 5% of the energy used in convection heating. Unfortunately this has a longer cycle time but for some applications, especially small moulds this is more cost effective.</td>
</tr>
<tr>
<td>2. Metallocene PE gives faster cycle times and lower energy consumption over normal PE; however, this is sometimes at the expense of the processing window.</td>
</tr>
<tr>
<td>3. Oil heating and/or cooling of the mould has energy saving advantages over convection heating.</td>
</tr>
<tr>
<td>4. Good design of the convection chamber can save up to 50% of your heating costs.</td>
</tr>
<tr>
<td>5. Closed loop heating and cooling systems claim to dramatically reduce energy consumption.</td>
</tr>
<tr>
<td>6. Particle size and distribution is important. Smaller and narrower distribution cuts cycle times by faster melting as well as reducing bubble formation.</td>
</tr>
<tr>
<td>7. A higher melt flow index (MFI) gives faster bubble removal and a better balance of properties whilst reducing cycle time.</td>
</tr>
<tr>
<td>8. Investigate mould material for your application. Steel plate is generally better than aluminium tools, but not for every application.</td>
</tr>
<tr>
<td>9. Use heat shields and directors for intelligent heating.</td>
</tr>
<tr>
<td>10. Reinvest – new machinery is more energy efficient.</td>
</tr>
</tbody>
</table>
8 Thermoforming

8.1 The Thermoforming Process

Thermoforming is among the oldest of the plastic shaping techniques and is a manufacturing process for thermoplastic sheets or film. The sheet or film is heated to its forming temperature and stretched over, or into, a temperature controlled, single surface mould. The sheet is held against the mould surface unit until cooled and the formed part is trimmed from the sheet. There are several categories of thermoforming including vacuum, pressure, twin-sheet, drape forming, free blowing and simple sheet bending. The five main steps when thermoforming are shown in Figure 8.1.

![Figure 8.1 The 5 steps of thermoforming](image)

8.2 Reducing Energy Consumption in the Thermoforming Process

Thermoforming is an energy intensive business and energy management is a key to productivity improvement, quality and positive public image. Energy efficiency has been shown to be one of the most cost-effective mechanisms to address these issues, as well as greenhouse gas reduction.

8.2.1 Heating the Plastic Sheet

There are many ways in which to heat the plastic sheet. The type of energy source is dependent on the nature of the polymer and the sheet thickness and the optimum energy source may not be the most economic. Care must be taken when considering a simple substitution, as other non-energy cost factors must be taken into consideration, such as maintenance, time-dependent energy efficiency of the heating unit and installation costs. However, the long-term energy and savings can far outweigh the initial purchase and maintenance costs.

*When deciding to replace current heaters with more efficient units, carry out an energy audit and consider the ‘total cost of ownership’ of the equipment, not just the initial purchase costs.*
No heating process is 100% efficient. Regardless of the type of polymer, all heating systems must input more specific energy than the amount needed.

8.2.2 Quality of the Final Product

Thermoformed parts are recognised as having a large surface area to thickness ratio, as well as a non-uniform wall thickness across their surface. As with other processes, such as blow moulding and rotational moulding, commercial thermoformed part wall thickness variation is typically +/- 20 to 30%.

The use of computer simulation tools has increased in popularity over recent years. Computer aided multi-axis CNC trimming machines are being extensively used in heavy-gauge thermoforming to ensure accurate peripheral and mating surface dimensions. Additionally, software is available for predicting heating and cooling cycles for diverse polymers.

Many optimisation process investigations have been studied by using commercial software such as Polyflow and T-SIM. These studies have focused on enabling the determination of optimal processing parameters as well as those that have a major influence on product quality. Optimisation concepts can be used to obtain the optimal heater temperature pattern to produce specific sheet temperature distribution after a predetermined heating time. The number of heater elements can significantly influence the ability to realise a desired sheet temperature distribution. The higher the number of heater elements, the closer the desired sheet temperature field.

8.2.3 Optimisation of Cycle Time

It is important to remember that the mould and transfer mechanics in the forming station represent considerable mass that must be accelerated and decelerated. Accelerating the numerous mechanical steps of the thermoforming process is an important way in which to reduce cycle time and in turn energy consumption.

Using the finite element method, several manufacturers of thermoforming machines performed extensive calculations and simulations to optimise every component of the entire machine design. The goal is to reduce the moving masses to the minimum needed. It is also possible to avoid an excessively high increase in power requirement and energy consumption for faster cycle times.

A further development for vacuum-forming machines is the clamping frame system for fast preparation, single workstation systems. The construction of the clamping frame system is stable so that a compressed air pre-stress can be applied when processing semi-finished material that has a large initial thickness. Advantages of the system are a wider adjustment range and low energy consumption for heating parts compared with usual systems.

8.2.4 Infrared Technology

New developments in the field of IR technology have led to reductions in energy consumption. Phillips and Geiss developed ‘speedium’, a new radiator that is distinguished by a very short response time, lower operating temperature and therefore lower energy consumption.
Thermoforming

Elstein-Werk M. Steinmetz (Germany) developed a high power emitter with a parabolic gold reflector. The HLS short delay ceramic heater of the emitter is integrated into a gilded ceramic parabolic reflector. Thermal and mechanical stability is associated with a good spectral energy distribution. According to the manufacturer, the emitter reached a working temperature of 1000°C in less than one minute and reaches a power density up to 90kW/m² with a radiation efficiency of 80%. This makes it possible to have high passing through speeds with plastic sheets.

8.2.5 Using Gas for Thermoforming

Gaz de France and PEP (2003) carried out studies on the use of gas for thermoforming. Several materials were tested (ABS, PMMA, PS, PEHD, PP, PC and PET) and the results are presented below.

<table>
<thead>
<tr>
<th></th>
<th>PS Smooth black surface</th>
<th>PP Smooth clear surface</th>
<th>PEHD Smooth black surface</th>
<th>PMMA Smooth clear surface</th>
<th>PET Smooth clear surface</th>
<th>PC Smooth clear surface</th>
<th>ABS Smooth black surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz heating time (s)</td>
<td>60</td>
<td>90</td>
<td>103</td>
<td>82</td>
<td>65</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Time to heat gas (s)</td>
<td>27</td>
<td>65</td>
<td>55</td>
<td>48</td>
<td>38</td>
<td>52</td>
<td>60</td>
</tr>
<tr>
<td>Electricity consumption (kWh)</td>
<td>529</td>
<td>737</td>
<td>825</td>
<td>582</td>
<td>561</td>
<td>737</td>
<td>739</td>
</tr>
<tr>
<td>Gas consumption (kWh)</td>
<td>738</td>
<td>1122</td>
<td>1039</td>
<td>939</td>
<td>903</td>
<td>1021</td>
<td>1089</td>
</tr>
</tbody>
</table>

The study concluded that:

- Gas and electric both provide a good forming quality solution
- There is reduction of the heating time when using a gas solution
- Energy consumption is reduced by 30 – 40% when using quartz heating

8.2.6 Servo-motors

There are many advantages to using servo-drives as a replacement for hydraulic or pneumatic drives:

- Greater control of the scissors toggle of thermoforming machines by replacing the hydraulic or pneumatic motion with servo electric drives
• High reproduction accuracy of the production data for machines or units with frequent format changes
• Lower energy consumption
• Increased cycle rates with
• Longer equipment life
• More precise draws and less wasted material

<table>
<thead>
<tr>
<th><strong>Act Now! 10 Tips to Reducing Energy Consumption in Thermoforming</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Install electric power meters on each unit</td>
</tr>
<tr>
<td><strong>2.</strong> Carry out an energy audit before deciding to replace existing heaters with more efficient units</td>
</tr>
<tr>
<td><strong>3.</strong> Natural gas can be 3 – 7 times cheaper than electricity on the same energy unit</td>
</tr>
<tr>
<td><strong>4.</strong> Gas solutions can reduce heating time</td>
</tr>
<tr>
<td><strong>5.</strong> Thin sheets are heated efficiently with radiant heaters</td>
</tr>
<tr>
<td><strong>6.</strong> Thick sheets are best heated in forced convection hot air ovens</td>
</tr>
<tr>
<td><strong>7.</strong> Use computer software for predicting heating and cooling cycles</td>
</tr>
<tr>
<td><strong>8.</strong> Accelerating mechanical steps can be an important way to reduce cycle times and in turn energy consumption</td>
</tr>
<tr>
<td><strong>9.</strong> Infrared technology can give a short response time and a lower operating temperature</td>
</tr>
<tr>
<td><strong>10.</strong> The use of servo drives as a replacement for hydraulic or pneumatic drives provides high reproduction accuracy and low energy consumption</td>
</tr>
</tbody>
</table>
Composites

It is not easy to give an exact definition of composite materials. Many definitions exist; some of them being too wide ranging with a lack of precision while others are too restrictive. The notion of ‘composite materials’ refers to an association of materials where the components are juxtaposed, without interaction between them. Moreover, a synergy exists between these materials. Their properties are combined in an intimate, complimentary assembly which gives rise to heterogeneous material with improved properties.

9.1 Manufacturing With Composite Materials

The manufacturing of thermoset-based composite materials appeared at the beginning of the 1960’s and techniques were derived from processes used in other industries, including textiles and metals. Many manufacturing processes are now used and the choice of process depends upon the type of part being manufactured, the type of material used and the size of the production run. Manufacturing processes include:

- Hand lay-up
- Spray-up
- Filament winding
- Vacuum bag moulding
- Resin transfer moulding
- Compression moulding (cold)
- Compression moulding (warm)
- Compression of sheet moulding compounds (SMC)
- Bulk moulding compounds (BMC)
- Pultrusion

9.2 Reducing Energy Consumption When Manufacturing Composite Materials

The energy consumption in the manufacturing of composite materials is highly dependent on the process used. In the table below, a comparison is made, taking into account the energy used for different stages in the manufacturing process.

Worthwhile savings can be made through energy management – savings that contribute directly to your bottom line. The major uses of energy are for process heating, electric motors and compressed air. Factories require artificial lighting and many spaces are heated and cooled.
### Act Now! 10 Tips to Reducing Energy Consumption When Manufacturing Composite Materials

1. To obtain the pressure required by the process, it is essential to set the machine parameters for optimal energy use. Achieving good processing is, for example, dependent on the quality of the material processed and of the surface state of the mould.

2. When the quality of the material is controlled, and if the mould has good surface quality, the optimisation of the energy use will be obtained by a careful setting of the process parameters.

3. The heating of the mould, which is one of the most energy consuming factors, can be minimised by minimising the distance and maximising the materials conductivity between the heat source and the part.

4. Improve the installation between the heated part and the environment.

5. Manage the idle times of the machines and reduce the number of short idle periods.

6. Optimise the number of tooling changes.

7. Select the most energy efficient option to deliver the required performance. Take into account running costs when making your decision – if a more efficient unit has a higher purchase price, energy savings will usually pay for it.

8. Energy savings have the double effect of improved profit margins in a competitive market and reduced environmental emissions.

9. Ensure heating processes are optimised. Choose the most appropriate combination of temperature, time and quantity and regularly check that these parameters are being maintained.

10. Ensure that regulators and thermostats are adequately maintained and correctly adjusted.
10 Compression Moulding

10.1 The Compression Moulding Process

Compression moulding is one of the oldest plastic moulding methods. The process consists of heating a plastic material, which can be in the form of granules or powder, in a mould that is held in a press. When the material becomes ‘plastic’ the pressure forces it to conform to the shape of the mould. It is a high-volume, high-pressure method suitable for moulding complex, high strength fibreglass reinforcements. Products manufactured by compression moulding include bottle caps; jar closures, electric plugs and sockets, toilet seats and trays.

The compression-moulding machine comprises of a control unit that manages five main elements:

- A hydraulic alignment controlled high speed press
- A heating and cooling system for the mould
- An extruder or plasticizing unit for processing un- and reinforced thermoplastics
- A mould unit
- A transfer unit for putting the plasticized material into the mould

10.2 Reducing Energy Consumption in Compression Moulding

In order to reduce energy consumption and costs, increase productivity and enhance corporate competitiveness, organisations should focus on optimising the manufacturing process in compression moulding.

10.2.1 Control Unit

When processing polymer, the control system has to meet safety requirements to protect the operator from unexpected closure of the press. Process control is necessary for an efficient operation, especially the alignment of the mould parts.

10.2.2 Hydraulic Drive

Hydraulic power is normally generated in a power pack to ensure precise co-ordination and repetition of the machine motions. The power pack provides the power and pressure to work the various motions of the mould. Separate hydraulic drives are needed in most cases for the additional peripheral equipment, including the extruder screws and cutting edges. Stability is maintained by temperature control of the hydraulic fluid, via a heat exchanger connected to a cold water system that offers an opportunity for heat recovery.
### 10.2.3 Heating and Cooling System

A heating and cooling system provides the controlled supply of thermo oil that flows through the mould and heats up or cools down the mould and the product. The efficiency of the system has a major effect on the overall process time and the energy consumed. When looking to reduce energy consumption across the process, consider using a pendulum storage facility rather than a direct heating and cooling system.

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#### Pendulum Storage

In the case of long cycle time and large moulds, it is necessary to use a pendulum storage facility to reuse the heat and energy input to the mould. The principle of the pendulum storage facility is shown below.

![Diagram of Pendulum Storage](image)

At the start of the heating phase the mould is at a lower temperature. The thermo oil is then heated by the heat exchanger with the stored energy in the pendulum storage. The thermo oil and the mould in the press heat up until no further heat flow from the storage facility is possible. The system is switched to direct heating of the thermo oil with the heating system until the final mould temperature is reached.

After the pressing process, the thermo oil and mould is cooled with the pendulum storage facility until the temperatures are at nearly the same level. The heat in the mould heats up the storage facility and some of the energy is saved for the heating phase of the next cycle. When it is not possible to cool down any further with the pendulum storage, the system is switched to direct cooling of the oil.

With such a system approximately 45% energy savings can be made when producing large parts with long cycle times.
10.2.4 Mould Unit

The mould unit has two main functions:

- To shape the product
- To bring heat to, and extract heat from the product

To allow the flow of the thermoplastic polymer material, the mould has to be hot during the pressing process and closing of the form. After closing, the mould will be cooled to a temperature where it is possible to remove the part.

<table>
<thead>
<tr>
<th>Machine Functions Influencing Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Polymer Melt Temperature</strong></td>
</tr>
<tr>
<td>Depending on the temperature and mass of the dough mould compound coming from the extrusion process, and being transferred into the press, the moulds in the press have to be heated or cooled to a greater degree during the production process.</td>
</tr>
<tr>
<td><strong>Mould Closing and Holding Pressure</strong></td>
</tr>
<tr>
<td>Hydraulic cylinders close the mould and hold it together against the blowing pressure (e.g. 300 bars for larger presses). The hydraulic force is delivered from the hydraulic press storage; the pressure is necessary to hold the mould parts exactly aligned and to shape the part until it is ready. Holding the high pressure too long over the optimal value uses a lot of unnecessary energy because of several additional pump cycles. In some cases it is also sufficient to apply the high pressure only during form filling and then to continue with lower pressures.</td>
</tr>
</tbody>
</table>

10.2.5 Control of the Machine Run-time

Hydraulic presses are easy to stop when it is not needed to produce a plastic products as the polymer compound is made in the extruder. The heating and cooling system for the thermo oil of the mould can also be stopped during non-production phases.

Switching off the extruder and ancillaries represents a high percentage of the total load. This is particularly true for machines with two (or more) extruders. Unfortunately it is generally not possible to simply switch off the extruder without reducing the barrel temperature and/or emptying or changing the polymer in the barrel. Nevertheless, by understanding the costs associated with shutdown and start-up, standard routines may be developed to minimise waste of both energy and polymer. Practical options for energy saving during short delays are limited, however, machines must be carefully maintained so that operating runs can be uninterrupted.

The simplest option for energy saving is to switch off the hydraulics. This should become standard practice for all but the most minor stoppages.
10.2.6 Setting the Machine Parameters

Modern control systems are able to set the machine conditions by following microprocessor instructions. Control of the pressure cycle is essential for the control of energy consumed during the pressing process. The pressure should only be as high as necessary and used for the minimum time required. Unnecessarily long pressure cycles use a lot of additional energy therefore increasing costs.

10.2.7 Controlling Process Parameters

Controlling process parameters can generate the greatest energy savings. Good practice requires that only just enough energy be used for each stage of the process. An awareness of the need to achieve set cycle times is often offset by the inability to determine how parameters could be adjusted to make this possible. Additionally, exceeding product weights lead to energy wastage.

10.2.8 Insulation of the Mould

If there is no insulation of the mould against the ground plate or the machine body, there is unnecessary heat flow from the mould to the surroundings. During long cycle times the energy losses can be significant. Additionally, the mould can be insulated against the ambient temperature. This shortens production time and increases productivity. The costs are normally low compared to the potential energy savings and the payback time can be less than one year.

10.2.9 New Process Design: LFT-D/ILC Process

In previous years the relevance of long fibre reinforced thermoplastics in the European automotive sector has grown significantly. State of the art technologies are: processing of semi-finished products such as glass mat reinforced thermoplastics (GMT) by compression moulding and long fibre granulates (LFT-G) mainly by injection moulding. However, the so-called ‘long fibre direct process technologies’ (LFT-D) are gaining market share. These technologies enable manufacturers to produce components directly employing the base materials such as glass fibres, thermoplastic resins and additives by utilising an in-line compounding process prior to compression moulding.

The most compelling advantage relates to the cost and energy savings by avoiding the step of manufacturing semi-finished products such as LFT-G pellets of GMT plates. The economic advantage is derived from the efficiency of the process, its reliability and from the use of raw materials such as plastic pellets, reinforcing fibres and additives. Maintaining inventories of multiple grades of pre-compounded pellets of LFT-GMT-plates are not necessary and save on additional logistic costs. Thermoplastic glass fibre reinforced material is produced on demand.

Unlike pre-compounded pellets or plates, thermoplastic polymers entering the in-line system have undergone a single heat history. This reduced exposure to thermal degradation leads to improved initial and long-term properties for moulded composite components produced with the LFT-D/ILC process. The total energy consumption to produce a composite component is significantly less compared to the alternative processes. The energy that is used transforming raw materials into LFT-pellets of GMT-plates, transporting the pellets or plates to the component manufacturer and subsequent reheating of the pellet or plate feedstock prior to compression or injection moulding, are completely eliminated in the direct process.
Separation of compounding thermoplastic polymers prior to the incorporation of fibres reduces screw wear significantly and extends the useful lifetime of compounding feed screws, as fibres are not present at the solid/melt interface compared to processing LFT-pellets.

LFT-D/ILC is perfectly suited to match the material formulation to the requirements of the application. The selection of materials is not set by the efficiency of a semi-finished material suppliers’ production. The glass fibre content and the composition of the moulding material can be continuously adjusted as required and is achieved by computer controlled gravimetric feeders and screw speed or by the number of rovings fed into the mixing extruder.

An additional advantage of compression moulding is the high productivity due to the short cycle times. For example, front-end carriers can be produced with a cycle time of 30 seconds versus injection moulding with a cycle time of approximately 50 seconds. In addition, the mechanical properties are significantly higher due to the high fibre length obtained in the part by gentle incorporation of glass fibres.

![Diagram of compression moulding process](attachment:image)

**Figure 10.2** Process equipment for long fibre reinforced direct production of structural parts

### 10.2.10 Energy Optimised Press Systems

A new generation of press systems have been developed to increase competitiveness by reducing energy consumption. One example is the ‘COMPRESS PLUS’ by Dieffenbacher, which offers cost advantages through low energy consumption and even shorter cycle times for the user.

A new closing concept was developed to reduce energy consumption by at least 50%. After the opening feed, the cylinders are mechanically locked so that the press pressure is built up by a piston stroke of approximately 200mm. Increased closing speeds, up to 1,200mm/s enable even shorter closing times at high press strokes and lower quantities of oil significantly reduce the energy required for cooling hydraulic system.
<table>
<thead>
<tr>
<th>Act Now! 10 Tips to Reduce Your Energy Consumption When Compression Moulding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Can work be transferred to machines with a capacity closer to the weight of the part?</td>
</tr>
<tr>
<td><strong>2.</strong> Are the hydraulic pressure cycles optimised to the production process?</td>
</tr>
<tr>
<td><strong>3.</strong> Are hot surfaces insulated, particularly the mould against the machine body?</td>
</tr>
<tr>
<td><strong>4.</strong> Is the mould insulated against the ambient air?</td>
</tr>
<tr>
<td><strong>5.</strong> Is it possible and applicable to use a pendulum storage system?</td>
</tr>
<tr>
<td><strong>6.</strong> Is the process design suitable for the component and state of the art?</td>
</tr>
<tr>
<td><strong>7.</strong> Are hydraulic pumps automatically shut off when there is no production?</td>
</tr>
<tr>
<td><strong>8.</strong> Can in-line compounding be implemented? (Direct process technology)</td>
</tr>
<tr>
<td><strong>9.</strong> Can an energy optimised press system be used?</td>
</tr>
<tr>
<td><strong>10.</strong> Is ‘free cooling’ being utilised to cool the hydraulic oil?</td>
</tr>
</tbody>
</table>
A survey of the energy consuming equipment in a single injection moulding company identified the following areas of usage:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>KWh/year</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Utilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Utilities</td>
<td>694,000</td>
<td>42</td>
</tr>
<tr>
<td>Electric heat</td>
<td>170,000</td>
<td>10</td>
</tr>
<tr>
<td>Lighting</td>
<td>87,000</td>
<td>5</td>
</tr>
<tr>
<td>Space ventilation</td>
<td>77,000</td>
<td>5</td>
</tr>
<tr>
<td>Various</td>
<td>12,000</td>
<td>1</td>
</tr>
<tr>
<td>Cooling, including pumps</td>
<td>220,000</td>
<td>13</td>
</tr>
<tr>
<td>Compressed air</td>
<td>42,000</td>
<td>3</td>
</tr>
<tr>
<td>Various</td>
<td>32,000</td>
<td>2</td>
</tr>
<tr>
<td>Material drying</td>
<td>54,000</td>
<td>3</td>
</tr>
<tr>
<td><strong>Process Equipment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Process Equipment</td>
<td>936,000</td>
<td>58</td>
</tr>
<tr>
<td>Hydraulic motors</td>
<td>301,000</td>
<td>19</td>
</tr>
<tr>
<td>Other motors</td>
<td>1,000</td>
<td>0</td>
</tr>
<tr>
<td>Process heating</td>
<td>99,000</td>
<td>6</td>
</tr>
<tr>
<td>Process fans</td>
<td>2,000</td>
<td>0</td>
</tr>
<tr>
<td>Injection moulding standby</td>
<td>533,000</td>
<td>33</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1,630,000</td>
<td>100</td>
</tr>
</tbody>
</table>

From the above it can be seen that the ‘utilities and peripherals’ actually account for 42% of the energy consumed. This figures varies according to the different processes, however, it is clearly a significant amount with a large potential for savings. Standby time, which includes peripherals, can add a further 33% and hydraulic drives account for 19%.
11.1 Heating and Lighting

The general philosophy with both heating and lighting is to ‘supply what is required to the point of need’, less but consistent light in circulation areas, but more light at the machinery and in quality control areas. Examine the areas that are being heated or lit and decide if too much or too little is being supplied.

Offices need to be periodically checked to ensure that unused rooms are not being heated to the same temperature as those that are in use. Additionally, interlocks should be fitted to large access doors to ensure heating is switched off when the doors are left open. Poor fitting windows and doors are also a large source of heat loss and routine maintenance of these items will save more money than it costs.

Lighting is one of the most important factors in our working environment and optimal levels will provide many advantages:

- Critical work is carried out under the best light conditions
- High productivity is obtained
- Improved safety on the job, especially when moving around
- Increased security and improved well-being

11.2 Light Source Selection

Fluorescent lighting is normally used in production and administration areas. These should be fitted with dimmable HF-coils in all production rooms, including those with a high ceiling, with daylight admission.

11.3 Energy Efficient Electronic Ballasts

All fluorescent tubes are provided with electronic ballasts to reduce the current through the lamp, but they can also be fitted with high frequency ballasts (HF-coils). As well as providing energy savings of approximately 25%, the HF-coils also provide quality advantages:

- 50% to 70% increased lifetime
- The tubes light up instantly – no flashing
- No flickering or stroboscopic effect
- Variable lighting regulation, e.g. after daylight radiation
- Cut-out of defect tubes

11.4 Energy Efficient Lighting Fixtures

Old lighting fixtures are often inefficient. It normally pays to replace these fixtures with HF ballasts, reduce the number of tubes and still obtain better lighting efficiency. As a general rule, fixtures with fewer tubes are more efficient. This can be further improved by fitting fixed, or loose, reflectors in the tubes. When
designing the lighting system it is important not to over-dimension as this can result in a very high maintenance factor. Over dimensioning is normally more expensive than cleaning and maintenance of the system. Therefore, it is important to find easy to clean lighting fixtures and to set up a fixed maintenance procedure.

### 11.5 Light Regulation According to Daylight Penetration

Daylight penetration should be considered when designing room and workplace lighting in industrial premises. Building regulations regarding size of the windows normally ensures ample light during normal daylight hours. Equipment for control and regulation of artificial light is being used more often to adjust the lighting to reflect the daylight penetration and the requirements of the various activities. By regulating the artificial light according to the variations in the daylight, large energy savings can be obtained.

### 11.6 Motion Sensors (PIR)

Some rooms do not require maximum light levels on a constant basis, e.g. storage room, changing rooms, canteens etc. and here it would be feasible to install motions sensors which will switch off the light when there is no activity in the room. In rooms with good daylight conditions, the sensors should have built in light sensors.

<table>
<thead>
<tr>
<th>Case Study: Installation of Motion Sensors in a Basement Storage Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>The storage area is used randomly, but at any time day or night and the general lighting in the basement was left on all of the time. It consisted of 24 fixtures, each with 2 x 36W fluorescent tubes with conventional coils. Coil loss was approximately 10w per coil, effectively making each tube 46w. Motion sensors were installed to automatically turn the lights on and off as required.</td>
</tr>
<tr>
<td>Operating time:</td>
</tr>
<tr>
<td>Energy consumption:</td>
</tr>
<tr>
<td>Energy saving:</td>
</tr>
<tr>
<td>Cost saving:</td>
</tr>
<tr>
<td>Investment:</td>
</tr>
<tr>
<td>Payback period:</td>
</tr>
</tbody>
</table>

### 11.7 Ventilation

Ventilation is important to maintain a clean working atmosphere in both the factory and offices, and good air conditioning can ensure an optimum indoor climate by removing both surplus heat and air impurities, which in turn can improve productivity.
Administration, storage rooms and production areas with no twenty-four or weekend production do not require ventilation all the time. In this case, the air-conditioning system should have an automatic time control to match the needs of the building. Additionally, if the plant is over-dimensioned or the ventilation requirement has dropped since the installation of the plant, a general lowering of the air volume may be possible.

11.8 Cooling Water

Chillers are used to supply cool water for a variety of process needs including: cooling the injection mould, controlling the temperature of the hydraulic oil, cooling baths and chill-rolls for extrusion processes. All the energy that is put into the polymer during processing must be removed again to produce a finished article at room temperature.

Choosing the correct ‘Water Chiller’ and finding the optimum operating conditions, can significantly reduce the energy requirements. Over a ten-year period, 90% of chillers costs are energy, so buy the most efficient and not the cheapest. Investigate ‘Free Cooling’ which can save energy in most European climates.

![Figure 11.1 Free cooling installation](image)

Decide what your water temperature should be and raise it by 1°C. A possible 3% reduction in the chillers power can be achieved.

11.8.1 Energy Savings With Free Cooling

When the ambient temperature falls 1°C below the temperature of the water returning to the chiller e.g. water return temperature is 15°C, ambient is 14°C, free cooling can be activated. Before going to the chiller, return water is automatically diverted through the free cooler. This pre-cools the water, reduces the load on the chiller and the energy being consumed by the compressors. The lower the ambient falls below the return water temperature, the greater the free cooling effect. Payback is fast and energy savings year on year are considerable.
### Energy Savings With Free Cooler Option

<table>
<thead>
<tr>
<th></th>
<th>Chiller</th>
<th>New &amp; Existing</th>
<th>Cooling capacity kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power input kW</td>
<td></td>
<td>141.6</td>
<td>Energy cost €/kW/hr</td>
</tr>
<tr>
<td>Full free cooling ambient air temperature</td>
<td></td>
<td>9</td>
<td>Water supply temp</td>
</tr>
<tr>
<td>Cost of Free Cooler</td>
<td></td>
<td>€23,400</td>
<td>Approach</td>
</tr>
</tbody>
</table>

Operation – 24 hours per day, 7 days a week, 50 weeks per year

Total Savings: €23,627.04 pa
Payback: 11.9 months
Project minimum energy savings over 10-year life cycle: €236,270.26

### 11.9 Compressed Air

Compressed air is used in many different situations throughout a plastics processing factory, but it is a very inefficient source of energy (3 – 4% efficiency). The cost of compressed air energy is about 10 times that of electricity.

The energy consumption of a compressed air plant can be optimised by:

- Reducing the air demand
- Improving the efficiency
- Correct dimensioning and sighting of the plant
- Regular maintenance of the plant
- Use of alternative energy, e.g. direct electric drive
Reducing the air demand can be achieved by, reviewing the compressed air lines, noting their use and removing those where compressed air is not required. Look for situations where compressed air is used for blast cleaning when a brush would suffice.

To improve efficiency, check the pressure levels, air intake conditions and control of the compressor. Assess the pressure requirement and reduce the working pressure if possible.

Keep the air intake as cold as possible, with a 3°C reduction on the air intake the power consumption will fall by 1%. Ducting to allow fresh air intake rather than air from the compressor room could reduce intake temperature by 15°C and reduce energy usage by 5%.

Understand the controls on the compressor system: piston and screw compressors have different control systems, but major savings can be made by optimising the control of a plant made up of different size and types of compressors. Intelligent control can calculate the air consumption in the factory from the pressure drop speed and from the amount of air pumped into the system; it then connects the compressor that has the best match to the actual air consumption. The advantages of intelligent control are:

- Same low cut-in pressure for all compressors
- No unnecessary cut-in for an instantaneous pressure drop
- Minimum partial-load due to correct compressor size
- Different pressure levels dependent on the time of day

Always site the air compressor close to where the air is needed and keep the pipe runs and pressure drops to a minimum. Using several small compressors with intelligent control, sited near to the demand may be more efficient than one large one with long pipe runs. Always document your requirements and consult the supplier before deciding what type of equipment is required.

Good maintenance is essential to high efficiency. Air leaks in a poorly maintained plant can account for 30 - 50% of the compressed air consumption. Check for leaks during a quiet, shutdown period, or use leak detection equipment that picks up the sound waves. Automatic cut-off valves that operate when a production machine is shut down can result in payback within a year.

### 11.10 Hydraulic Motors

All-electric injection moulding machines use less energy for basic machine operation than the equivalent hydraulic machine as electric machines use energy only when the motion is required. In contrast, hydraulic machines consume energy even when idle. Pumps are required to generate the hydraulic pressure, even when motion is not required and auxiliary chillers are needed to cool the hydraulic oil. Additionally, less maintenance is required by electric drives when compared with hydraulic drives.
11.12 Standby Time

Standby time can include many things; lines at a standstill but with equipment at processing temperature, ancillary equipment kept running just in case it is needed, support infrastructure left on overnight, and the cyclical operation of the injection moulding machine. All of these issues must be addressed to reduce energy consumption.

Intelligent hydraulic motor control can be utilised to reduce energy loss on hydraulic machines. The hydraulic pump motor within the machine is only on load for a relatively short period of the total machine cycle; the period when the material is injected into the moulding tool. During the rest of the cycle the control ensures that the motor runs only at around 5% load instead of 100%. In one instance this control was shown to reduce total energy consumption by 16% without affecting the quality and cycle time.

<table>
<thead>
<tr>
<th>Act Now! 10 Tips to Reduce Your Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Supply what heat and light is required at the point of need</td>
</tr>
<tr>
<td>2. Use dimmable HF-coils</td>
</tr>
<tr>
<td>3. Vary artificial light to supplement natural light</td>
</tr>
<tr>
<td>4. Make use of ‘motion sensors’</td>
</tr>
<tr>
<td>5. Automate and review ventilation requirements</td>
</tr>
<tr>
<td>6. Review chilled water temperature</td>
</tr>
<tr>
<td>7. Consider using ‘free cooling’</td>
</tr>
<tr>
<td>8. Check the compressed air installation…examine usage and leaks</td>
</tr>
<tr>
<td>9. When purchasing new machinery, consider electric rather than hydraulic drives</td>
</tr>
<tr>
<td>10. Reduce standby time for all ancillary equipment</td>
</tr>
</tbody>
</table>
The success of an energy management programme within an organisation depends upon a union between technology and management. Technology alone cannot achieve optimal savings, but coupled with operational and management practices can lead to significant savings. The key attributes to a successful energy management programme include:

- Commitment from top-level management
- Development of management strategies
- Clearly stated goals on energy efficiency
- Communication of goals, tactics and achievements throughout all levels of the organisation
- Delegation of responsibility and accountability to the appropriate personnel
- Sustained tracking and assessment of energy use and technology application
- Continuous investigation of potential energy reduction projects
- Application of business investment models to energy projects
- Establishment of an internal recognition and reward programme for achieving energy goals

Energy management is highly cost-effective but it is important to remember that it is not a one-off exercise, to be effective it must be an ongoing process.

This section will help you to assess the current state of energy management in your organisation and give you advice about how to review your own effectiveness, define where you are at the moment and where you want to get to.

12.1 The Advantages of Energy Efficiency

There are many reasons why an organisation should take energy efficiency seriously, from improving the economic health to helping to reducing damage to the environment. Many measures can also bring substantial benefits in terms of employee comfort through improved heating, insulation and the avoidance of cold spots. This can reduce staff turnover and improve productivity. Attention to energy efficiency can often highlight deficiencies in other areas such as maintenance, process yield and quality, therefore giving significant additional productivity benefits.

Additionally, an increasing amount of regulations and directives at both a national and European level is being applied to drive improvements in energy efficiency. It is not just a matter of operating efficiently; it can also be a factor in operating legally.
12.2 Energy Awareness Survey

Before embarking on an energy management programme, an awareness survey should be conducted within the company and repeated at regular intervals to measure change. This will help you learn about your organisation's knowledge and commitment to reducing energy consumption.

<table>
<thead>
<tr>
<th>Energy Awareness Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>By allocating scores to the responses for the questions below, you will obtain an ‘energy awareness score’. This provides a measure of how you are performing in managing energy usage. The maximum score available is 16.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>3 pts</th>
<th>NO</th>
<th>0 pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you employ a full-time energy manager?</td>
<td>YES</td>
<td>3 pts</td>
<td>NO</td>
<td>0 pts</td>
</tr>
<tr>
<td>Is energy management the specific responsibility of one member of your senior management team?</td>
<td>YES</td>
<td>2 pts</td>
<td>NO</td>
<td>0 pts</td>
</tr>
<tr>
<td>Does your company adhere to a written energy/environmental policy?</td>
<td>YES</td>
<td>1 pt</td>
<td>NO</td>
<td>0 pts</td>
</tr>
<tr>
<td>Does your company have ISO 14000 certification?</td>
<td>YES</td>
<td>1 pt</td>
<td>NO</td>
<td>0 pts</td>
</tr>
<tr>
<td>Does your company have EMAS registration?</td>
<td>YES</td>
<td>1 pt</td>
<td>NO</td>
<td>0 pts</td>
</tr>
<tr>
<td>Have you had an energy audit at this site in the last 5 years?</td>
<td>YES</td>
<td>3 pts</td>
<td>NO</td>
<td>0 pts</td>
</tr>
<tr>
<td>Have you employed the services of an energy consultant in the last 5 years?</td>
<td>YES</td>
<td>2 pts</td>
<td>NO</td>
<td>0 pts</td>
</tr>
<tr>
<td>Do you monitor and review the energy consumption of individual plastics processing machines?</td>
<td>YES</td>
<td>3 pts</td>
<td>NO</td>
<td>0 pts</td>
</tr>
</tbody>
</table>


12.3 Effective Implementation

Fundamental to the effective implementation of an energy efficiency programme is good management. Like any resource that an organisation employs, energy will only be used efficiently if it is managed properly. Good energy management saves energy in itself, but is also necessary for getting the most out of technical energy saving measures. A report published by the ‘UK Energy Efficiency Best Practice Programme’ entitled ‘Maintaining the momentum – Sustaining energy management’ found that there are six critical factors for successful energy management:

- Top-level commitment
- Leadership
- Company awareness
- Communication
- Empowerment
- Recognition
12.4 Top-level Commitment

- It is possible for an unwritten set of guidelines to masquerade as an energy policy, but for a policy to be effective it must be formal with commitment from senior management. An energy policy should be a formal statement (ideally integrated into an overall environmental strategy) of the organisation’s objectives, demonstrating senior management’s commitment to continuous improvement in the efficient use of energy. It should explain the key approaches that the organisation will take to achieve these objectives. An effective energy policy provides the foundation for setting the culture within an organisation, and should be clearly communicated to all levels of employees.

- When an initiative is seen to have top-level support there is a natural driving force that helps to sustain long-term achievements. Conversely, when senior management are perceived to be lukewarm about a project little long term, progress can be made.

- Appointing an Energy Manager can often be a critical component of a successful energy programme as their appointment can help an organisation achieve its goals by establishing energy performance as a core value. Successful energy managers understand how energy management helps the organisation achieve its financial and environmental goals and objectives. Depending on the size of the organisation, the Energy Manager role can be a full-time position or an addition to other responsibilities.

- Within large organisations, appoint ‘energy champions’ within each shift or department to further the energy reduction programme. Energy champions will ideally be those who already have a commitment to the environmental policy and will continually pursue new initiatives to reduce energy.

- An allocation of finances to carry out energy reduction initiatives will demonstrate to employees that there is top-level commitment to the programme.

<table>
<thead>
<tr>
<th>Key Objectives of an Energy Management Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Set out an organisation’s objectives for energy management</td>
</tr>
<tr>
<td>• Demonstrate commitment to managing energy in a way that both supports good business performance and takes due regard for environmental effects</td>
</tr>
<tr>
<td>• Commit the organisation, when capital investments are planned, to giving energy efficiency due regard in the selection and configuration of the plant, and adopting the most energy efficient equipment available</td>
</tr>
<tr>
<td>• Recognise the need for adequate resources and reporting throughout the company</td>
</tr>
<tr>
<td>• Identify the individual within the organisation with overall responsibility for the energy policy and its implementation</td>
</tr>
<tr>
<td>• Commit the company to a regular review of policy</td>
</tr>
</tbody>
</table>

12.5 Leadership

- Initial savings can be made fairly quickly while the impetus from the launch of an energy saving programme is still there, but to consolidate that success requires support from all parts of an
organisation and a lot can depend on the ethos that can be generated within the workforce. The key to continued success rests on good, committed and enthusiastic leadership at all levels, with support from senior management. The role of Energy Manager cuts across all aspects of a business and they will need to work with managers and staff at all levels.

### 12.6 Company Awareness

- The entire workforce should be made aware that an energy saving initiative is in place and that it emanates from senior management. Many energy saving measures involve changing long established practices and unless the programme is maintained, old habits will emerge.

- Energy training sessions should form an important part of communicating the energy efficiency message to an organisation. Make training sessions enjoyable as well as informative, seek input and ideas from those being trained and foster an attitude that is receptive to energy reduction suggestions.

- At the start of a programme it is easy to raise awareness levels within an organisation, however, it can be difficult to maintain that level. New initiatives and regular news updates can help keep energy to the fore.

- Many staff will be aware of, and interested in environmental issues in their home life, so there can be a natural desire to see success within a company scheme. Awareness needs to build upon this general interest. Good publicity within the local community regarding the progress of the energy programme will also help enhance awareness. Place emphasis on how well the company is doing against government targets for reducing carbon emissions, or the Kyoto Protocol.

### 12.7 Communication

- Communication is important both internally and externally. Regular updates and reports should appear on notice boards and staff newsletters illustrating the targets set, savings made and new initiatives taking place. Externally, good energy management can be a positive marketing tool. Company employees often respond to positive marketing and take pride in their achievements resulting in further improvements.

- Ongoing energy training will help to reinforce the message and keep the organisation aware and committed. This does not need to be time consuming – integrate into regular management briefings, company forums or reviews.

### 12.8 Empowerment

- An energy management policy and its manager must be empowered to implement changes; otherwise the programme will lose credibility within the organisation. Additionally, the Energy Manager must have support from senior management.

- Energy saving proposals may need to be treated differently to other projects with respect to ‘pay back time’ and capital investment. The long-term view that energy prices are going to continue to escalate must be factored into any proposal.
Where savings can be quantified, a portion could be used to the general benefit of the workforce, such as a bonus scheme, annual barbeque, etc. Regular reports on the savings made, the subsequent effect on company finances and the benefits to the organisation will raise awareness and show those involved that their efforts have been recognised.

<table>
<thead>
<tr>
<th>Act Now! 10 Tips for Good Energy Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Measure the organisations current level of energy awareness</td>
</tr>
<tr>
<td>2. Write a company Energy Policy and integrate it into an environmental policy and Business Plan</td>
</tr>
<tr>
<td>3. Appoint an Energy Manager with the power to act</td>
</tr>
<tr>
<td>4. Allocate funds for energy reduction schemes</td>
</tr>
<tr>
<td>5. Make the whole organisation aware of an energy reduction programme</td>
</tr>
<tr>
<td>6. Publicise the organisations energy reduction programme</td>
</tr>
<tr>
<td>7. Review and recognise all the achievements made</td>
</tr>
<tr>
<td>8. Keep employees aware with regular updates as to the success of the programme</td>
</tr>
<tr>
<td>9. Encourage ownership of energy at all levels</td>
</tr>
<tr>
<td>10. Work with everyone within the organisation to identify opportunities for savings</td>
</tr>
</tbody>
</table>