

An Energy Saving Guide for Plastic Injection Molding Machines

A practical guide to energy saving by

Mobil[™]

Produced by Applied Market Information
in association with Tangram Technology

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Why manage your energy use?

Plastics injection molding is an energy intensive process. And, because energy carries both an environmental and financial cost, it makes sound sense not to waste it.

Energy spending in a typical plastics injection molding plant often approaches the cost of direct labor. But, while labor ranks high among management concerns, little effort is expended on controlling energy spending.

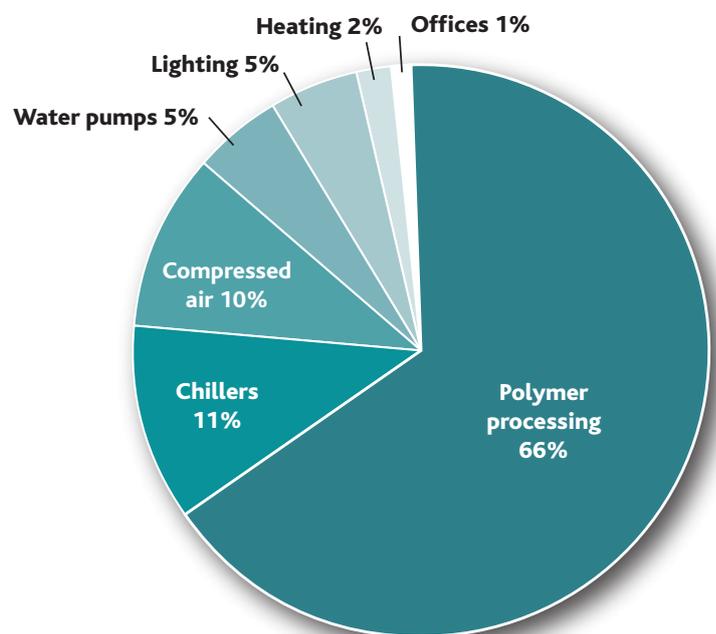
The potential savings are considerable, however. For an injection molding plant that has implemented no effective energy reduction measures, experience shows some 30% of total energy use is discretionary. This is avoidable energy spending that can be clawed back through practical management, maintenance and investment actions.

The rules for saving energy are simple: spend time and effort where the returns are the greatest. That calls for a structured energy management system. Such systems will vary from one molding plant to another but will include:

- A company energy policy;
- A nominated person responsible for energy management;
- A method for monitoring and targeting short and long-term performance;
- An identified, costed and approved list of energy-saving projects;
- A reporting system to show the status of projects;
- And an auditing system to drive actions and improvement.

Read on to learn more about developing a strategy for saving energy in your injection molding operation.

Energy use by application in a typical injection molding operation





Your energy 'fingerprint'

Energy use in injection molding is variable, controllable and directly related to production. The key to understanding your energy consumption is the **Performance Characteristic Line (PCL)**, which provides a unique 'energy fingerprint' of your plant. Armed with this, you can predict plant energy usage for any period based on actual or anticipated production volumes and integrate that data into your business accounting system for reporting and monitoring purposes.

To determine your plant's PCL, plot energy use (kWh) against production volume (kg) over at least 12 months then find the linear best fit (Figure 1) to determine 'base' and 'variable' loads.

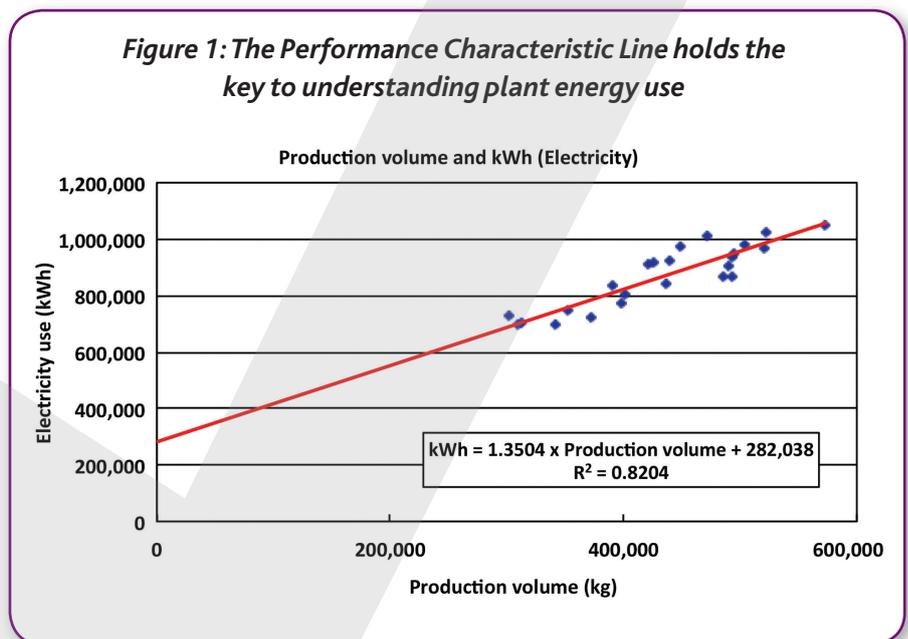
$$\text{ENERGY USAGE} = (\text{VARIABLE LOAD} \times \text{PRODUCTION VOLUME}) + \text{BASE LOAD}$$

Base load is the energy used at zero production and is determined where the PCL intersects the vertical axis. For most molding sites it will be between 20% and 40% of total energy usage. In the example in Figure 1 it is 282,038 kWh.

Variable load is determined from the slope of the PCL and is the energy needed to produce one kilogram of product. It is dependent on the injection molding process and will typically range from 0.9 to 1.6 kWh/kg. In the Figure 1 example it is 1.3504 kWh/kg.

Base load savings can be quite readily achieved; variable load savings are more difficult as they require fundamental process improvements.

The PCL can also be used to determine the plant's **correlation coefficient (R^2)**. An R^2 value of >0.7 indicates good operational consistency and suggests energy efficiency measures will also be consistent and effective. An R^2 of <0.7 indicates the opposite.





Energy management theory

Map your energy use

To identify where your energy is going you need an 'energy map' for your molding plant. This will list your main energy users, typical power drawn (kW) and operating hours and will help you identify the biggest consumers.

Your energy supply bills can help you save money and energy but you need to understand and analyze the information they contain then make informed management decisions.

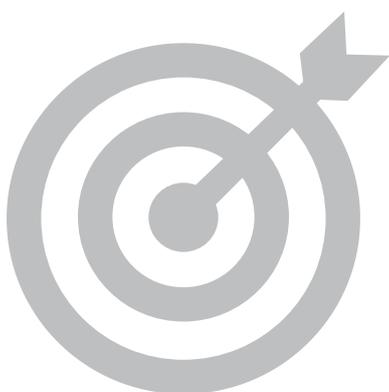
Available capacity (measured in kVA) is the maximum amount of power that can be drawn from the supply and is paid for whether it is used or not. **Maximum demand** (also measured in kVA) is the maximum amount of power actually drawn. If maximum demand greatly exceeds

available capacity you will pay penalties; if much less you are buying capacity that is not needed. Select an appropriate capacity figure.

Power factor ($\cos \phi$) is the ratio of 'useful power' (kW) to 'apparent power' (kVA). The ideal is a value of 1.0; for most plastics processors it is around 0.95. If your power factor is very low you will need more available capacity and may be charged for **reactive power** (kVARh). In such cases, it may be worth investing in power factor correction equipment.

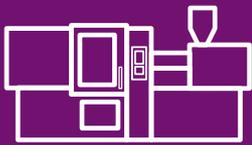
Interval data can be used to analyze energy use by time and is a good way to check for costly usage patterns, such as shut-downs and start-ups. It is usually available free from your supplier.

Benchmark your performance



While your PCL formula allows you to monitor your plant effectiveness, benchmarking allows you to compare it against other injection molding operations or machine types. Tangram Technology, which compiled this guide, has carried out energy surveys of more than 200 injection molding sites around the world and has compiled benchmark curves¹ allowing site or machine performance to be benchmarked against global averages.

¹ More details of the Tangram Technology Ltd benchmarking method are provided in the book referred to at the end of this publication.



Plastic injection molding machines

Spend to save

Today's plastic injection molding machine technology is far more energy efficient than that of 20 years ago. At a conservative estimate, modern hydraulic plastic injection molding machines are 25% more energy efficient than those manufactured in 1997. Meanwhile, today's best all-electric machines may be up to 80% more energy efficient than their 20-year old hydraulic predecessors. It will pay you to make use of these machinery developments.

Using old machinery is not saving you money; it is costing you more to run your processes and placing your business at a permanent cost disadvantage to competitors.

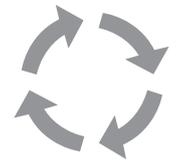
In almost every case, the cost of energy required to run a plastic injection molding machine over a 10-year period will be greater than its initial purchase cost. This cost gap will only widen as energy prices increase. For this reason, energy assessment must become part of the purchasing process for every new plastic injection molding machine.

Considering the whole life cost of a machine is difficult but it is the only way to control future energy expenditure. It will help ensure that an attractive low cost machine does not become an energy hog that raises production costs through its entire lifetime.

Remember, there is no conflict between energy management and production rate. Being efficient does not mean slowing the process down; the reality is that the energy efficiency of a plant and its machines gets better as production rate increases because the base load is amortized into a greater

“Old machinery is not saving you money”

A circular graphic with a white background and a dark blue border. Inside the circle, the text is written in a bold, italicized, dark blue font.



Plastic injection molding machines

The molding cycle

Monitoring the power drawn by a plastic injection molding machine presents a picture of the molding cycle (Figure 2) and can be divided into two elements: base load and process load.

For **standard hydraulic machines**, the base load (energy consumed when the machine is idling such as during cooling phases) can amount to 75% or more of total energy consumption. A high base load can indicate that the machine is too large for the job. In the example in Figure 2, the base load is 64%.

The high base load of standard hydraulic machines means it is essential that the main motor is switched on as late as possible during start-up and off when production is interrupted or shut-down. The latter can be automated using controls linked to platen movement.

For **all-electric and hybrid machines**, the base load is much lower as motors are only running when required. Typical base loads are in the region of 10-20% and are largely accounted for by barrel heating.

Process load can also be explored through examination of a machine's power draw. Figure 3 shows an expanded view of the 38.6s cycle in Figure 2 (the large peak shows the injection phase and the smaller peaks platen movement and cooling). Using graphs such as this, energy use can be optimized by adjustment of process settings such as barrel temperatures and profile, injection speed, back pressure, clamp force, hold pressure, hold time, cooling time and screw back speed while preserving process consistency, production rate and production quality.

Figure 2: Plastic injection molding machine power draw plotted against time showing a base load of 64%

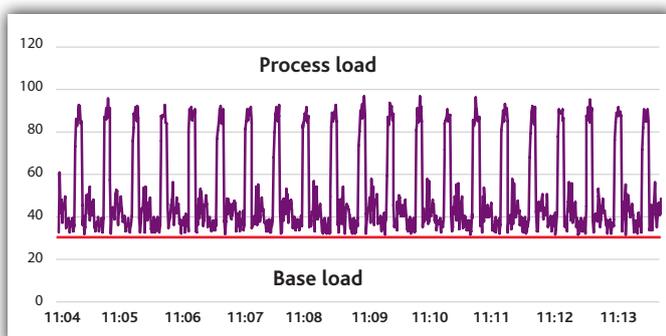
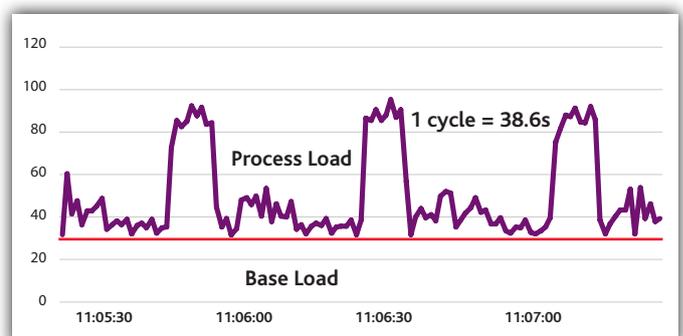


Figure 3: This expanded view of injection machine power draw shows detailed cycle stages





Plastic injection molding machines

The right drive technology

Plastic injection molding machine drive technology has changed dramatically over the past couple of decades. In energy terms, the most significant change is the arrival of all-electric and hybrid machines. However, even traditional hydraulic machine drive design has evolved with an extensive choice of motor and drive options.

Hydraulic machines have traditionally used a fixed speed motor continually running a fixed volume pump but this arrangement has largely been superseded by new designs that aim to adapt oil volumes to demand. Fixed speed motor/variable volume pump machines use an adjustable swash plate on the pump to adjust the delivery of high-pressure oil. Variable speed motor/variable volume pump machines use a variable speed drive (VSD) to add further flexibility. Servo motor/fixed volume pump combinations take flexibility and energy saving even further.

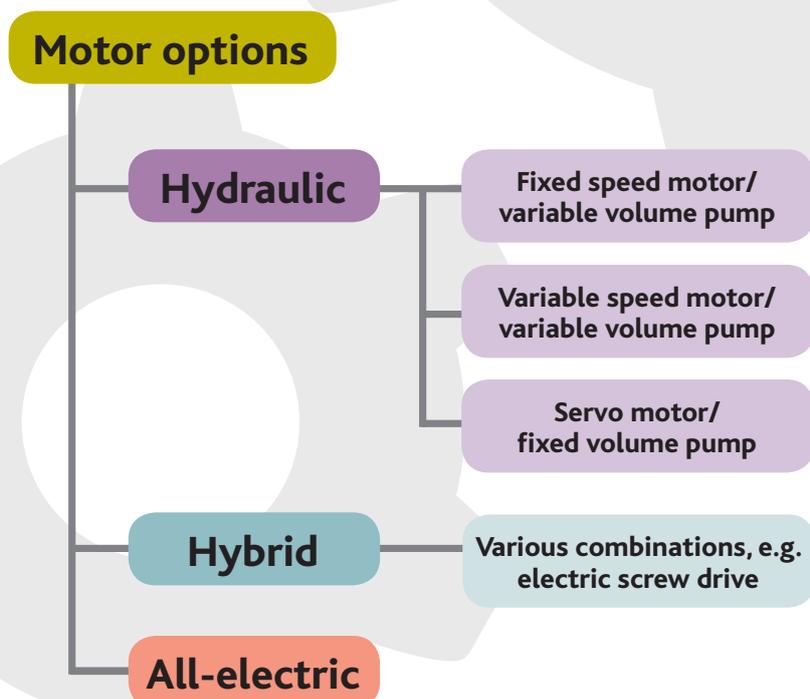
Hybrid machines use a combination of hydraulic and servo motor drive

technologies, with a typical configuration combining hydraulic machine operation with servo motor drive on the plasticizing screw. This allows a smaller hydraulic drive system to be used, reducing the base load of the machine.

All-electric machines use servo motor drive technology on all the main machine movements (but not always on minor movements such as

nozzle pressure and ejectors). By only using energy when a movement is required, base loads are dramatically reduced and overall energy savings of up to 60% are possible. Initially limited to smaller clamp capacities, motor improvements have gradually lifted the size limits while economies of scale in production have reduced the price premium.

Know your machine drive technology





Plastic injection molding machines

Check your hydraulic oil

Hydraulic oil expenditure represents a fraction of the cost of running plastic injection molding machinery. But a small change in hydraulic oil can result in big performance breakthroughs, such as prolonged component life, improvements in overall equipment efficiency and reduced cycle times.

Operating challenges: In injection molding, hydraulic oil is generally exposed to compression, shear stresses and a wide temperature range. This can trigger the oil's molecular breakdown, which reduces its lubricity and component protection. This means your equipment has to work harder, is less protected and may use more energy. High temperature operation can lead to oil oxidation, which can result in corrosion, a build-up of damaging lacquer and an increase in viscosity. Hydraulic oils can also become contaminated with process materials, water, dust and wear debris. This can trigger pump failures while increasing filtration costs.

Switch to advanced hydraulic oil: To combat all of these issues, it is important to use a hydraulic oil with excellent shear stability and a high viscosity index. High performance hydraulic oils maintain their optimum viscosity across a wide range of operating conditions, helping to protect equipment, improve energy efficiency and extend oil drain intervals. That, in turn, can help to reduce maintenance, cut costs and enhance operational safety by reducing employee interaction with machinery. Extending oil drain intervals can also cut waste lubricant disposal, improving a company's overall environmental credentials.

Used oil analysis: Maintenance can be further reduced by the use of a used oil analysis program, such as Mobil ServSM Lubricant Analysis. By analyzing oil samples, it is possible to gain invaluable insights into how both the equipment and lubricant is performing. Issues can also be detected before they become a problem, helping maintain peak operational efficiency and productivity.

In the field

A leading plastics manufacturer reduced energy consumption by 5.1% after switching to Mobil DTE 10 ExcelTM 46, a high performance hydraulic oil.

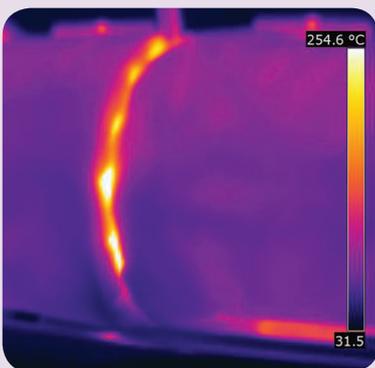
The Mobil lubricant was trialled in one of the manufacturer's Arburg Allrounder 820S plastic injection molding machines. The test showed Mobil DTE 10 Excel 46 enhanced the overall productivity of the machine compared to the previous lubricant, and improved its energy efficiency.

² This Proof of Performance is based on the experience of a single customer. Actual results can vary depending upon the type of equipment used and its maintenance, operating conditions and environment, and any prior lubricant used.

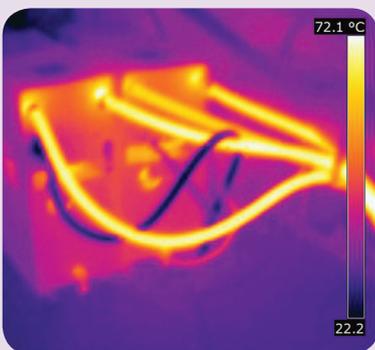


Plastic injection molding machines

Check your peripherals



Infrared images show how barrel insulation can reduce energy losses. It will also improve operator safety



Energy losses from mold temperature controller piping can be considerable

Compared with the main injection machine drive, decisions on peripherals such as barrel heaters or temperature controllers may seem relatively straightforward. However, these can be significant energy consumers and can present real energy saving opportunities.

Barrel heating uses 10-25% of the energy input of a typical injection molding machine. Heat losses from uninsulated barrels are high due to the elevated temperatures involved; uninsulated barrels are also a health and safety issue. Fitting barrel insulation improves safety and can reduce barrel heating energy requirements by up to 50%. Ensuring that heater bands are bedded-in and using conductive metal heat transfer compounds between the heater and barrel also helps to optimise thermal efficiency.

Mold temperature controllers can consume a considerable amount of energy but are rarely given detailed consideration. In most injection molding operations the pipework carrying hot water (sometimes oil in very high temperature systems) to the mold is left uninsulated and heat is lost to the environment. And where the pipework is carrying cooling water, energy is lost through parasitic heat gain. In cases where losses or gains are significant, it can be worth installing low cost insulation.

Downstream ancillary equipment, such as conveyors, granulators, assembly machines and automation systems, is often left running in molding plants when the injection machine is stopped. This is a waste of energy that can easily be eliminated by linking downstream equipment into the machine control or using other forms of automated monitoring.



Molding plant services

Minimize & optimize

Services such as compressed air, chilled water and dryers are vital in any plastic injection molding plant and account for an estimated 30-35% of energy used. But despite presenting some of the easiest opportunities for energy saving, they are rarely given much thought.

There are two basic steps to effective energy management of any service:

1 Ensure target demand is appropriate for the requirement of the plant. It makes little sense to attempt to optimize supply of any plant service if the assumed demand is unrealistic or unnecessarily large from the outset.

2 Optimize equipment to supply the required demand at the minimum energy usage and cost. This requires a holistic approach in which the entire system is examined in detail to determine areas of potential improvement.



Compressed air

Compressed air is a convenient but expensive utility that accounts for up to 10% of total energy cost in an injection molding plant. An effective compressed air management program can result in energy savings of up to 50%.

Reduce leakage Leaks can account for as much as 50% of the compressed air

generated in a badly maintained system and 20-40% in most typical injection molding plant.

Reduce use Compressed air costs around \$1.17/kWh at the point of use, more than ten times the equivalent quantity of electrical power. Use it only when essential.

Reduce generation costs Reduce system pressure to the minimum. Halving system

pressure decreases cost by three quarters.

Reduce treatment costs Treat the bulk of your compressed air to the minimum level necessary. Replace manual condensate traps with electronic types.

Improve distribution If the distribution pipework is too small, flow will be restricted and higher pressures required.



Molding plant services

Manage resources

Providing chilled water for molds and cooling water for machines consumes between 11-16% of the total energy used in a typical injection molding plant.

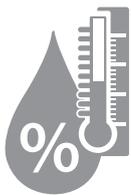
Reduce heat gain Allowing chilled water to gain heat from the plant environment or circulating it through inoperative machines wastes energy. Use insulated piping between chiller and mold and isolate circuits that are not in production.

Increase temperatures Chilled water temperatures should be maximized; raising set temperature by 1°C decreases chiller operating costs by around 3%.

Optimize running costs Cooling towers can be fitted with VSD fans linked to the sump water temperature, which will cut energy use and improve temperature consistency. Where external temperatures allow, use ambient air to provide 'free' pre-cooling. Convert distribution pumps from fixed to VSD operation.

Some words about motors

Motors are big energy users; every kW of fully loaded motor will cost you around \$1,000 a year. Cut that cost by turning off motors that are not contributing to production, installing VSDs to match motor speeds to demand, practice good maintenance, and upgrade to new technology when possible.



Control drying

Drying polymers can use up to 15% of total process energy so should only be performed when and as little as necessary.

Dry the right materials Limit drying to the materials that need it: hygroscopic polymers.

Store materials correctly Hygroscopic polymers will

absorb less moisture if stored in a warm and dry environment in a sealed container. Proper storage pays off for non-hygroscopic materials, too, as surface condensation can occur if moved from a cold storage area to a warm molding shop.

Improve control systems Replace temperature/time or

process air dew point control with systems that monitor material moisture content to save energy and avoid overdrying, which can harm the resin.

Cut drying costs Install insulation and improve sealing. Recover heat and, where possible, recycle it for space or water heating.



Managing the operation

People

Energy efficiency is not all about hardware; the way a molding plant is operated plays a key role, too. Management and operational improvements can be made at low cost but, as they require changing the way people work, can be difficult to implement and sustain.

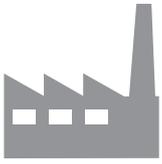
Empower your people Training staff and empowering them to switch off machines, processes and services can lead to energy reductions of up to 20%.

Make a good start Use check sheets to ensure machine start-ups are correctly sequenced to bring the biggest energy users, such as main motors, on line at the latest possible time. This applies to services, too; don't turn on chilled water until the mold requires cooling.

Manage processes Process setting has a major impact on energy use as well as quality and productivity. So apply 'scientific molding' principles; determine optimum settings then ensure they are recorded and applied. And make sure machine settings are not changed without management approval.

Minimize consumption Machines should be placed in stand-by mode during temporary production interruptions (main motors and downstream equipment switched off and heaters set back). Shut-down completely during extended stoppages.

Improve maintenance All production plant must be well maintained and controls fully functioning to achieve efficient production. Machine monitoring can provide early warning of essential maintenance; a preventative maintenance programme is even better.



Managing the operation

Improve your buildings

Buildings and their associated services account for around 8% of total energy use in a typical plastic injection molding operation. It is a relatively small contribution but there is scope for savings.

Lighting is not a major energy consumer but lighting upgrades can carry an additional benefit in providing a clearly visible sign of management commitment to energy saving. LED lamps are highly energy efficient, offer a long life, provide high quality illumination and require very little maintenance.

Heating has traditionally been a low energy priority for injection molding sites as process losses provide considerable amounts of space heating. However, the PCL techniques described earlier in this guide can be used to monitor and target heating – and cooling – energy use. Improvement measures include air leakage reductions, better insulation and optimized setting and control.

Survey your site

Site surveys are a key element in an energy management strategy allowing current site status to be determined, improvement options to be identified, and reference points for future progress to be set.

Your basic energy consumption data and plant energy map will provide the insight needed to allow targeting of the largest energy use areas. Improvement projects should be prepared and implemented based on this data and reported in financial terms to gain top management support.

Few injection molding operations today do not operate a quality management system; this same approach can be used as a model for energy non-conformance reporting.



Glossary

cos ϕ	power factor (active power/apparent power)
kg	mass, kilogram
kVA	apparent power, kilovolt.amps
kVArh	reactive power, kilovolt.amps.reactive hours
kW	active power, kilowatt
kWh	energy consumption, kilowatt.hour
LED	light emitting diode
PCL	Performance Characteristic Line
R ²	correlation coefficient
VSD	variable speed drive

About this guide

This short guide has been produced for ExxonMobil by Applied Market Information Ltd in association with Robin Kent, Founder and Managing Director of Tangram Technology Ltd. Robin is a recognized authority on energy management in plastics processing and has carried out energy surveys and assessments for more than 450 companies throughout the world. Robin holds a BEng(Hons) degree in Materials Engineering from Monash University (Australia) and a PhD in Polymer Physics from the University of Surrey (UK). He is also Fellow of the Institute of Materials, Minerals and Mining, a Fellow of the Energy Institute, a Chartered Engineer and a Chartered Energy Manager.

More detailed information about energy efficient plastics processing can be found in the author's book 'Energy Management in Plastics Processing - strategies, targets, techniques and tools', Elsevier, ISBN: 978-1906479107.

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