Energy Efficiency and the Mould and Tool Industry
Best Practice Guide
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1.1 Energy Efficiency

The mould, tool and die industry is one of the most important sectors in the EU, but is currently facing major challenges.

If you use less power you can spend less money on your energy costs and emit fewer carbon emissions. Reducing your overheads through energy saving can help with increasing your cash flow, and in times of economic uncertainty this can be a great benefit. Furthermore, the increasing amounts of new legislation make it even more important that you do not ignore your energy use.

This guide is about how to manage your energy and case studies and methods on how to implement measures and new techniques and technologies to consider.

There are a number of low- and no-cost measures you can implement, for example lighting can account for between 20-40% of total electricity costs for many organisations. Use timers and occupancy sensors, don’t light empty rooms and ask staff to turn off unnecessary lights. This can help to reduce lighting costs by up to 30%.

Businesses can also benefit from examining the heating and cooling within a building. An annual reduction of 8–10% of the heating bill can be achieved by simply lowering the temperature by 1°C. By ensuring that you have good control of your utilities and building services you will be able to save energy and money while maintaining a comfortable environment for your employees and customers.

Consider employing an Energy Manager or appointing an existing member of staff with the role. Monitor your energy consumption. Read and record the energy metres on a regular basis to help verify your bills and examine any major changes.

It is also worth carrying out a site survey to gain an overview of the site energy use. This helps to determine your current position and set goals and priorities for future improvement. Look at motors and machines left running but not in production, heating, lighting, office equipment, lines that are shut down by ancillary equipment is still running, variable speed drives and air compressors.

Attention to energy efficiency can often highlight deficiencies in other areas such as maintenance, process yield and quality therefore giving significant additional productivity benefits. 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 increasing
role in helping to manage the new challenges in a changing business climate.

1.2 Energy Efficiency and the Mould and Tool Industry

Moulds, tools and dies are involved in the design and manufacturing supply chain of almost all industrial products from aeronautical and automotive to electronics and household products. They are on the critical path of the product development process and are the key to short ‘time to market’. The tooling and machining industry is critical to the economy of the EU as it supports nearly all other manufacturing industries, including the plastics sector.

Increased pressure from low cost countries, new technologies and the demand for short cycle time and limited quantities are putting pressure on an intensively competitive industry. Furthermore the industry, which is dominated by SMEs, is experiencing an increase in fuel costs.

Energy and environmental management are important issues that are already on the agenda for many leading European businesses. There are many reasons why you should look to improve the energy and environmental impact of your organisation but for many companies the financial benefits is the key motivator. Simply by managing and understanding your energy use and investing in some low cost measures, most companies can save 20% on their fuel bills.

This Guide, written for all levels of management and operational staff, aims to bring together case studies and energy efficiency and energy management information to provide one important resource for the mould and tool industry as well as the polymer supply chain.
2.1 Power Factor

Power factor can be defined as the cosine of the angle between the voltage and current in a circuit or the ratio of the resistance to the impedance of the circuit and also the ratio of the real to the apparent power. It is a dimensionless number between 0 and 1, and frequently expressed as a percentage.

\[
\text{Power Factor} = \frac{\text{Real Power (kW)}}{\text{Apparent Power (kVA)}}
\]

It is known that reactive loads such as inductors and capacitors dissipate zero power, yet the fact that they drop voltage and draw current gives the deceptive impression that they actually do dissipate power. This is called reactive power (Q), and it is measured in a unit called Volt-Amps-Reactive (VAR), rather than watts. The actual amount of power being used, or dissipated, in a circuit is called true power, and it is measured in watts (W). The combination of reactive power and true power (P) is called apparent power (S), and it is the product of a circuit’s voltage and current, without reference to phase angle. Apparent power is measured in the unit of Volt-Amps (VA).

As a rule, true power is a function of a circuit’s dissipative elements, usually resistances. Reactive power is a function of a circuit’s reactance. Apparent power is a function of a circuit’s total impedance.

![Power Triangle](image)

These three types of power are trigonometrically related to one another. In a right triangle, \( P \) = adjacent length, \( Q \) = opposite length, and \( S \) = hypotenuse.
length. The opposite angle is equal to the circuit’s impedance (Z) phase angle. The angle of this “power triangle” graphically indicates the ratio between the amount of dissipated (or consumed) power and the amount of absorbed/returned power. It also happens to be the same angle as that of the circuit’s impedance in polar form. When expressed as a fraction, this ratio between true power and apparent power is called the power factor for this circuit. Because true power and apparent power form the adjacent and hypotenuse sides of a right triangle, respectively, the power factor ratio is also equal to the cosine of that phase angle.

For the purely resistive circuit, the power factor is 1, because the reactive power equals zero. Here, the power triangle would look like a horizontal line, because the opposite (reactive power) side would have zero length. For the purely inductive circuit, the power factor is zero, because true power equals zero. Here, the power triangle would look like a vertical line, because the adjacent (true power) side would have zero length. The same could be said for a purely capacitive circuit. If there are no dissipative (resistive) components in the circuit, then the true power must be equal to zero, making any power in the circuit purely reactive. The power triangle for a purely capacitive circuit would again be a vertical line (pointing down instead of up as it was for the purely inductive circuit).

Power factor is an important aspect to consider in an AC circuit, because any power factor less than 1 means that the circuit’s wiring has to carry more current than what would be necessary with zero reactance in the circuit to deliver the same amount of (true) power to the resistive load. The poor power factor makes for an inefficient power delivery system.

Poor power factor can be corrected, by adding another load to the circuit drawing an equal and opposite amount of reactive power, to cancel out the effects of the load’s inductive reactance. Inductive reactance can only be annulled by capacitive reactance, so it is necessary to add a capacitor in parallel to the circuits as the additional load. The effect of these two opposing reactance’s in parallel is to bring the circuit’s total impedance equal to its total resistance (to make the impedance phase angle equal or at least closer, to zero).

Apparent power will be larger than true power if the power factor is less than 1. Thus the current that must be supplied will be larger for power factor lower than 1. Even though the average true power supplied is the same in either case. A larger current cannot be supplied without additional cost to the utility company. Thus, it is in the power company’s and its customer’s best interest that major loads on the system have power factors as close to 1 as possible.

In order to maintain the power factor close to unity, power companies install banks of capacitors throughout the network as needed. They also impose an additional charge to industrial consumers who operate at low power factors. Since industrial loads are inductive and have low lagging power factors, it is beneficial to install capacitors to improve the power factor.

Power factor correction may be applied by an electrical power transmission utility to improve the stability and efficiency of the transmission network. Correction equipment may be installed by the industries to reduce the costs charged to them by their electricity supplier.
An automatic power factor correction unit can be used to improve power factor. A power factor correction unit usually consists of a number of capacitors that are switched by means of contactors. These contactors are controlled by a regulator that measures power factor in an electrical network. To be able to measure power factor, the regulator uses a current transformer to measure the current in one phase.

Depending on the load and power factor of the network, the power factor controller will switch the necessary blocks of capacitors in steps to make sure the power factor stays above a selected value (usually demanded by the energy supplier 0.9).

Improving the power factor has innumerable advantages for industries and the utility bill will be smaller. Low power factor requires an increase in the electric utility’s generation and transmission capacity to handle the reactive power component caused by inductive loads. With power factor correction, the electrical system’s branch capacity will also be increased.

### 2.2 Electric Motors

An electric motor converts electrical energy to mechanical energy. Electric motors are extremely important to modern industries, services and domestic life, being used in many different places.

The major physical principles behind the operation of an electric motor are known as Ampere’s law and Faraday’s law. The first states that an electrical conductor sitting in a magnetic field will experience a force if any current flowing through the conductor has a component at right angles to that field. Reversal of either the current or the magnetic field will produce a force acting in the opposite direction. The second principle states that if a conductor is moved through a magnetic field, then any component of motion perpendicular to that field will generate a potential difference between the ends of the conductor.

Electrical motors fall into two broad categories, depending on the type of electrical power applied direct current (DC) and alternating current (AC) motors. The first DC electrical motor was demonstrated by Michael Faraday in England in 1821. These motors were used for both low power and high power applications, such as electric street railways. It was not until the 1890s, with the availability of AC electrical power that the AC motor was developed, primarily by the Westinghouse and General Electric corporations.

The operation of a DC motor is dependent on the workings of the poles of the stator with a part of the rotor, or armature. When a DC current flows through the winding, a magnetic field is formed. The armature also contains a winding, in which the current flows. This armature current interacts with the magnetic field in accordance with Ampere’s law, producing a torque which turns the armature. If the armature windings were to rotate round to the next pole piece of opposite polarity, the torque would operate in the opposite direction, thus stopping the armature. In order to prevent this, the rotor contains a commutator which changes the direction of the armature current for each pole piece that the armature rotates past, thus ensuring that the
windings passing. The commutator generally consists of a split contact ring against which the brushes applying the DC current ride.

The rotation of the armature windings through the stator field generates a voltage across the armature which is known as the counter EMF (electromotive force) since it opposes the applied voltage: this is the consequence of Faraday’s law. The magnitude of the counter EMF is dependent on the magnetic field strength and the speed of the rotation of the armature.

AC motors are much more common than the DC variety because almost all electrical supply systems run alternating current. There are three main different types of motor, namely polyphase induction, polyphase synchronous, and single phase motors. Since three phase supplies are the most common polyphase sources, most polyphase motors run on three phase. Three phase supplies are widely used in commercial and industrial settings, whereas single phase supplies are almost always the type found in the home.

The main difference between AC and DC motors is that the magnetic field generated by the stator rotates in the AC case. Three electrical phases are introduced through terminals, each phase energizing an individual field pole. When each phase reaches its maximum current, the magnetic field at that pole reaches a maximum value. As the current decreases, so does the magnetic field. Since each phase reaches its maximum at a different time within a cycle of the current, that field pole whose magnetic field is largest is constantly changing between the three poles, with the effect that the magnetic field seen by the rotor is rotating. The speed of rotation of the magnetic field, known as the synchronous speed, depends on the frequency of the power supply and the number of poles produced by the stator winding. In the three phase induction motor, the windings on the rotor are not connected to a power supply, but are essentially short circuits. The most common type of rotor winding, the squirrel cage winding, bears a strong resemblance to the running wheel used in cages for pet gerbils. When the motor is initially switched on and the rotor is stationary, the rotor conductors experience a changing magnetic field sweeping by at the synchronous speed. From Faraday’s law, this situation results in the induction of currents round the rotor winding and the rotor experiences a torque and starts to turn. The rotor can never rotate at the synchronous speed because there would be no relative motion between the magnetic field and the rotor windings and no current could be induced. The induction motor has a high starting torque.

In squirrel cage motors, the motor speed is determined by the load it drives and by the number of poles generating a magnetic field in the stator. If some poles are switched in or out, the motor speed can be controlled by incremental amounts. In wound-rotor motors, the impedance of the rotor windings can be altered externally, which changes the current in the windings and thus affords continuous speed control.

Three-phase synchronous motors are quite different from induction motors. The rotor of a synchronous motor will usually include a squirrel cage winding which is used to start the motor rotation before the DC coil is energized.

To calculate a motor’s efficiency, the mechanical output power is divided by the electrical input power:
where \( \eta \) is energy conversion efficiency, \( P_e \) is electrical input power, and \( P_m \) is mechanical output power. In simplest case \( P_e = V I \), and \( P_m = T \omega \), where \( V \) is input voltage, \( I \) is input current, \( T \) is output torque, and \( \omega \) is output angular frequency. Efficiency is highest in the middle of the torque range, so an oversized motor runs with the highest efficiency.

When optimally designed for a given active current (i.e., torque current), voltage, pole-pair number, excitation frequency and core flux density, all categories of electric motors or generators will exhibit virtually the same maximum continuous shaft within a given physical size of electromagnetic core. Some applications require bursts of torque beyond the maximum operating torque, such as short bursts of torque to accelerate an electric vehicle from standstill. Always limited by magnetic core saturation or safe operating temperature rise and voltage, the capacity for torque bursts beyond the maximum operating torque differs significantly between categories of electric motors or generators.

### 2.3 Compressed Air: Energy in form of pressure

Compressed air is the second form of energy consumed in manufacturing industry and although the most expensive it is often treated with less importance than it deserves.

Compressed air for manufacture industry can have numerous applications as energy form, like drill, cut open shut, push, pull, paint, clean, blow, mix, etc. For this publication the focus will be on pneumatic systems. Pneumatic systems use compressed air to transmit power throw cylinders or pneumatic motors. Pneumatic systems in manufacture industry can be found mostly on manual tools like drillers, paint pistols, impact tools, hammers, grinders, sanders, and other similar equipments. Comparing pneumatic tools with electric tools for the same function and power shows that the pneumatic tools weight five times lesser than its electric equivalent. By its lighter weight and for the smaller volume and less risks for the operator (absence of electric shocks), pneumatic systems acquired an unmatched place in manufacture industry.

Specifically for the plastic and moulds and tools industry compressed air is essential for the following activities: tool powering, clamping, controls and actuators, forming, mould press powering, injection moulding.

Compressed air systems consist of a supply side, which includes compressors and air treatment, and a demand side, which includes distribution and storage systems and end-use equipment. The compression of air is performed in compressors that are powered by electric motors in the manufacture industry. The objective of compression is to output a high pressure gas from an initial low pressure state.
There are two distinctive types of compressors: dynamics (continuous flow) and positive-displacement (intermittent flow). Dynamic compressors input kinetic energy to continuously flowing air or gas by means of impellers rotating at very high speeds. The kinetic energy is transformed into pressure both by the impellers and the discharge volutes or diffusers. In positive-displacement compressors a quantity of air or gas is trapped in a compression chamber and the volume which it occupies is mechanically reduced, causing a corresponding rise in pressure prior to discharge. At constant speed, the air flow remains essentially constant with variations in discharge pressure. In the next picture is shown the variety of compressors types that are available for the industry.

![Compressors Diagram](image)

**Fig. 2.** Variety of compressors types that are available for the industry

Outstanding energy costs and energy inefficiencies are in most cases related with the low competitiveness of industries that are not aware of energy efficiency measures. In some cases these costs represent 20 % of the production costs, depending on company’s degree of modernization.

One of the most frequent problems of compressed air systems are the leaks. Although the raw material of compressed air is the free atmospheric air, the electricity consumption of the compressor’s electric is not free and its costs cannot be neglected. Leaks can be a significant source of wasted energy in an industrial compressed air system, sometimes wasting 20 to 30 percent of a compressor’s output.

In the next table are represented some leaks dimensions and the power that is needed to sustain the pressure. These values were taken from industries.
Leaks are a very serious problem, because it consumes energy continuously until the leak is fixed. One hole of 1 mm will lead to an extra consumption of 0.3 kWh during one hour, the same as 5 lamps of 60 W each in the same period. In addition to being a source of wasted energy, leaks can also contribute to other operating losses. Leaks cause a drop in system pressure, which can make air tools function less efficiently, adversely affecting production. In addition, by forcing the equipment to run longer, leaks shorten the life of almost all system equipment (including the compressor package itself).

Despite some leaks of compressed air are unavoidable, and some are consequence of the functional principle of equipments, like the pneumatic equipments), nowadays it is possible to avoid most of them intensive and permanent maintenance. To implement a maintenance plan is essential because valves, with time, could be degraded, rubber tubes and synthetic materials can develop fissures, and metallic leagues can suffer corrosion. The most common problematic areas are:

- Couplings, hoses, tubes, and fittings;
- Pressure regulators;
- Open condensate traps and shut-off valves;
- Pipe joints, disconnects, and thread sealants.

The water condensation in the equipments is the major motive for leaks appearance.

### How can the amount of leakage be measured?

As long as the totality of pneumatic equipment is without utilization the leakage can be measured by two methods:

<table>
<thead>
<tr>
<th>Diameter of the hole (mm)</th>
<th>Losses at 6 bar ( (m^3/\text{min}) )</th>
<th>Power necessary for compression (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.06</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>0.37</td>
<td>1.17</td>
</tr>
<tr>
<td>3</td>
<td>0.61</td>
<td>3.1</td>
</tr>
<tr>
<td>4</td>
<td>1.16</td>
<td>5.5</td>
</tr>
<tr>
<td>5</td>
<td>1.58</td>
<td>8.3</td>
</tr>
<tr>
<td>6</td>
<td>2.27</td>
<td>11.8</td>
</tr>
<tr>
<td>8</td>
<td>4.04</td>
<td>21.1</td>
</tr>
<tr>
<td>10</td>
<td>6.31</td>
<td>33</td>
</tr>
</tbody>
</table>

**Tab. 1** - Leaks dimensions and the power that is needed to sustain the pressure.
1. In the deposits: measuring the time taken between the differential of pressure drop;

\[
L = \frac{V_d \cdot (P_{max} - P_{min})}{t \cdot P_{atm}}
\]

- \(L\) – Leakage (m³/min);
- \(V_d\) – Deposit volume (m³);
- \(P_{max}\) – Maximum pressure (bar);
- \(P_{min}\) – Minimum pressure (bar);
- \(P_{atm}\) – Atmospheric pressure;
- \(t\) – Duration of pressure drop (min).

2. In the compressor: measuring the time of charge in a specific period.

\[
L = \frac{C_c \cdot t}{T}
\]

- \(L\) – leakage;
- \(C_c\) – Compressor capacity (m³/min);
- \(t\) – Operational time with the compressor on-load (s);
- \(T\) – Total time (s).

These operations should be performed outside the normal labour period of a facility. The percentage lost to leakage should be less than 10 percent in a well maintained system. Poorly maintained systems can have losses as high as 20 to 30 percent of air capacity and power. Proactive leak detection and repair can reduce leaks to less than 10 percent of compressor output.

Since air leaks are almost impossible to see, other methods must be used to locate them. The best way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high-frequency hissing sounds associated with air leaks. These portable units consist of directional microphones, amplifiers, and audio filters, and usually have either visual indicators or earphones to detect leaks. A simpler method is to apply soapy water with a paint brush to suspect areas. Although reliable, this method can be time consuming.

Compressed air is probably the most expensive form of energy available in an industry. Compressed air is also clean, readily available, and simple to use. As a result, compressed air is often chosen for applications for which other energy sources are more economical. Users should always consider more cost-effective forms of power before considering compressed air.

Many operations can be accomplished more economically using alternative energy sources. Inappropriate uses of compressed air include any application that can be done more effectively or more efficiently by a method other than compressed air. Examples of potentially inappropriate uses of compressed air include:

- Open blowing:
- Sparging;
- Aspirating;
- Atomizing;
- Padding;
- Dilute-phase transport;
- Dense-phase transport;
- Vacuum generation;
- Personnel cooling;
- Open hand-held blowguns or lances;
- Diaphragm pumps;
- Cabinet cooling;
- Vacuum venturis.

Regarding the plastic industry one potential inappropriate use of the main system of compressed air is its application for cleaning moulds and tools. For this operation it is recommended a pressure of utilization of 2 or 3 bar and it should never come through the main grid.

2.4 Ventilation Systems

In all organisations, factory buildings (factory, warehouses, offices) produce heat from production, machine tools, equipment and lighting systems. Ventilation systems are installed for the efficient removal of this heat, where appropriate. These ventilation systems may be natural and mechanical.

The use of natural ventilation systems, when sufficient, offers many advantages, amongst which are: reduced energy consumption, noise-free operation, reduced investment, low maintenance costs, etc.

The use of mechanical ventilation systems is recommended when the amount of heat to be removed and renewed air intake from the outside are important requirements.

Interior air in ventilation systems is replaced with atmospheric air using ventilators and electric motors as a driving force.

The use of electricity in ventilation systems can be improved as follows:

- Type of motor and control system;
- Transmission system;
- Pipes;
- Type of ventilator and pipe shapes;
- Preventive maintenance programme.

Induction motors represent 90% of energy consumption, which means that motor-driven systems have the potential to save more energy.
Electric motors in ventilation systems contribute to high energy consumption and consequently to the emission of polluting agents into the atmosphere. Therefore, high performance motors with the appropriate power must be used.

When selecting/replacing ventilation systems in high performance electric motors (category EFF1) (Energy-Efficient Motors - EEMs), motors with higher performance and power factors than those of conventional ones are recommended. The use of these high performance motors with the appropriate power results in considerable energy efficiency gains and, consequently, important gains in the organisation’s electricity consumption.

Another important gain may be achieved if the organisation installs control mechanisms (e.g. programmable timer) to optimise the ventilation system’s operating period.

The organisation should also control the ventilator flow pursuant to its specific needs, through installing a control mechanism (ESCs - electronic speed controllers and an automatic device with an appropriate sensor). The use of electronic speed controllers, where recommended, also offers the following advantages: reduced number of power points/limited power surges, longer-lasting motors due to reduced mechanical shocks and longer mechanical lifespan allow for smooth start-ups and an improved power factor.

With regard to the transmission system, replacement of trapezoidal belts with flat belts saves significant amounts of energy. The right choice of ventilator and the shape of the pipes also improve energy efficiency in ventilation systems. Ventilators with airfoil blades and tubular pipes are the most efficient option.

The efficiency of the ventilation systems is closely related to their preventive maintenance. Therefore, it is recommended a preventive maintenance schedule, focused on continuously improving the efficiency of the ventilation system.

In short, we could say that the advantages gained from the rational use of electricity in ventilation systems are: reduced electricity costs and compliance with the organisation’s environmental mission, more specifically, the organisation knowing that it is helping to reduce to a minimum the emission of polluting agents associated with the conversion of electricity consumed.

2.5 Load Moving Equipment

Load moving equipment, motorized or not, is used for moving intermittent loads on different routes with the appropriate surfaces and space. The primary function is to transport and/or to carry out operations.

In the mould industry, the most common types are: travelling cranes and forklifts.

They are used in production and storage processes to transport loads and also to place them in a suitable position.
With regard to motor-driven equipment, electric motors are responsible for a large amount of the companies’ total energy consumption, which is the result of an unpremeditated choice of equipment installed.

Electric motors are classified as direct current (DC), synchronous alternating current (AC) and asynchronous alternating current or induction (AC). In industry, squirrel cage AC induction motors have higher installed capacities.

Induction motors became the most popular for use in industry. Compared with direct current motors, induction motors have the advantage of being simple, which results in low cost, maximum efficacy and minimum maintenance. Performance is high for medium and maximum loads and ensures a good power factor with correct selection.

Energy consumption in this type of equipment may be considerably reduced by combining different technologies. There are new types of ESCs (electronic speed controllers) that allow energy from braking to be injected into the source, namely regenerative ESCs.

The use of electronic speed controllers (ESCs) enables alterations to motor load conditions to be met by controlling their speed.

By regulating the revolution speed of the motor, ESCs provide better process operating conditions, reduced wear and tear of mechanical components, less operating noise and, more importantly, substantial electricity savings. There are different types of configurations for ESC electronic circuits according to the type of motor and power range. Most ESCs are based on AC-DC-AC converters.

2.6 Air Conditioning Systems

With regard to air conditioning systems, the primary concern should be the design of the building where the air conditioning is to be installed and its thermal characteristics, such as the direction in which the building is facing, thermal quality of the area surrounding the building, appropriate location and type of glass and thermal inertia, as these will be reflected in the thermal load to be supplied in both winter and summer. Other important factors are the level of occupation, manufacturing process and materials used for the building’s interior and the right selection of air conditioning equipment. The latter should consider:

- Correct dimensions of air conditioning apparatus;
- Choosing those with the best energy efficiency, considering the equipment’s life cycle costs;

A particularly important aspect for air conditioning equipment is the COP (“Coefficient of Performance”) defined as:

\[
\text{COP} = \frac{\text{Thermal Power}}{\text{Electric Power}}
\]

Air conditioning equipment is now available with high COP values (over 5) for medium and large facilities.

The most efficient equipment has ESCs to control compressors and improve performance with partial loads. Some equipment is revertible and can produce hot or cold air, accordingly.
Care should be taken when installing this apparatus, especially concerning pipe and tube insulation.

Normally, air conditioning systems are divided into:

- Centralised,
- Semi-centralised and
- Individual systems,

All with the following common tasks:

- Thermal production,
- Thermal transport and thermal diffusion.

The different forms of thermal energy correspond to the different ways in which it is produced.

In industry, the most popular are semi-centralised systems in which thermal energy is produced outside the place where the air conditioning is to be installed, but there are two thermal heat exchanging fluids. Thermal fluid in the primary circuit (energy production) and thermal fluid in the secondary circuit (energy diffusion).

Equipment powered by renewable energy may also be used.

### 2.7 Artificial Lighting Systems

Artificial lighting must not be considered an alternative but an addition to natural light. This is the environment’s friendly attitude that leads to reduced energy consumption.

From amongst the different forms of energy consumption, lighting has the potential to generate major savings. More efficient technologies and good practice with regard to the rational use of energy produce savings in electricity of between 30 and 50%. Lighting electricity consumption is a global concern.

In Europe, the European Commission is preparing a voluntary agreement with the industry in this field. This is because lighting in industrial facilities, in general, consumes a considerable amount of electricity, more specifically 12% of overall electricity consumption, and it is one of the most important causes of CO2 emissions from the use of energy.

This is why lighting equipment must be installed that provides the lighting levels required/recommended for operation but which has low electricity consumption and reduced maintenance costs.

The use of incandescent light bulbs, which are still the most popular, is one of the main sources of energy waste as they only convert 5% of the energy consumed into light and 95% into heat that is wasted. The more efficient the artificial lighting system, the lower the light bulb’s conversion of energy into heat and the lower the consumption of the air conditioning systems.
Replacement of incandescent light bulbs with more efficient bulbs and the installation of pressure gauges for lighting network supply are two examples of good practice in the rational use of electricity for lighting.

Standard EN 12464-1 was published in order to efficiently ensure the appropriate lighting levels for activities. This Standard establishes recommendable lighting levels for workplaces. This is not obligatory but serves as a lighting energy efficiency guide. This is also the aim of the light bulb energy labels in Portugal, established by Decree-Law no. 18/2000, as it allows users to choose the most efficient and cheapest light bulb. Light bulb energy labels provide us with the following information:

- Energy efficiency category (A to G);
- Light flow in lumens (lm)
- Power absorbed by the light bulb in watts (W)
- Duration of light bulbs;

The value that best assesses the energy efficiency of light bulbs is luminous efficiency (lm/W) as it provides us with the amount of light produced by each Watt consumed.

The most efficient alternative is taking the greatest advantage of natural light. Even in these cases and due to their variability during the day and year, natural lighting may not be sufficient or adequate in certain circumstances, where lighting levels must be complemented with artificial lighting. Fluorescent or sodium vapour lamps are more efficient than incandescent light bulbs and produce a return on investment in only a few years due to the longer service life of the bulb and reduced maintenance costs.

Light bulbs with different energy efficiency levels are available on the market. The less efficient ones are incandescent, then fluorescent, which consume 20% less electricity than the former. Discharge lamps are also available on the market, which include mercury vapour, metal iodide and sodium vapour lamps. The energy efficiency level of sodium vapour discharge lamps is the highest.
3.1 The ‘Cost of Ownership Model’ developed during the European Project RECIPE

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. 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. Energy efficiency offers short- and long-term benefits and by increasing the efficiency of a business the bottom line can be strengthened.

RECIPE (Reduced Energy Consumption in Plastics Engineering) aimed 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.

A consortium was drawn together of eight European research and technology transfer institutes from six of the major plastics processing nations with a high profile and reputation for excellence within the target group.

The main results of this project may be found on the web site:  

www.eurecipe.com

One of the tasks was the development of a “Cost of Ownership Model”, devoted to the cost assessment of injection moulded parts. This tools helps the injection moulders to compare the production costs with different kinds of moulds and machines, taking into account the energy costs and the costs of the tooling and equipment.

The RECIPE COM (Cost of Ownership Model) is an easy to use software tool, enabling the production engineer to

- Calculate the cost of an injection moulding plastic part;
- Calculate the lifetime cost of a part;
- Analyze different cost elements;
- Make a comparison between different injection moulding machines and moulds.

The RECIPE COM uses 6 categories to estimate the lifetime cost of a specific piece of equipment:
1. Materials costs
2. Running costs (including energy)
3. Investment costs
4. Installation costs
5. Maintenance costs
6. Disposal costs

Below are listed the input values asked to the user to make the estimation.

<table>
<thead>
<tr>
<th>User data input</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Name and reference codes of a part</td>
<td>14. Machine buying estimated cost</td>
</tr>
<tr>
<td>2. Name and reference codes of machine</td>
<td>15. Machine term depreciation</td>
</tr>
<tr>
<td>4. Number of cavities</td>
<td>17. Machine disposal estimated cost</td>
</tr>
<tr>
<td>5. Expected hour per year</td>
<td>18. Machine maintenance (every year until term depreciation)</td>
</tr>
<tr>
<td>6. Machine yield</td>
<td></td>
</tr>
<tr>
<td>7. Mould yield</td>
<td>19. Type of machine (hydraulic, electric, hybrid)</td>
</tr>
<tr>
<td>8. Scrap</td>
<td>20. Rate money cost</td>
</tr>
<tr>
<td>10. Consumption energy data</td>
<td>22. Mould term depreciation</td>
</tr>
<tr>
<td>- Machine energy cost hour – If it is known</td>
<td>23. Material reference</td>
</tr>
<tr>
<td>If not – Machine installed power</td>
<td>24. Material price</td>
</tr>
<tr>
<td>Energy factor</td>
<td>25. Masterbatch cost</td>
</tr>
<tr>
<td>11. Personnel direct cost</td>
<td>26. Masterbatch percentage</td>
</tr>
<tr>
<td>12. Labour rate</td>
<td>27. Weigh part</td>
</tr>
</tbody>
</table>

**Tab. 2 - User data input**

After that, the software is able to produce different kinds of reports, giving the breakdown of costs for each solution, and giving also access to comparison tools, which help to identify, for each kind of mould, machine or operating conditions, the most important cost elements. Therefore the user can try to reduce the overall costs by playing on the different elements.

The first diagram shown here below compares 3 different situations for the production of the same plastic part: The first one uses one Battenfeld injection machine and a mould with one cavity. The second one uses another kind of injection machine (Billion, a bigger one) and an injection mould with 8 cavities, with the use of hot runners. The last one is using also an 8 cavities mould, but without hot runners.

The overall cost of the part is compared, taking into consideration a production of 6,000 parts.
Fig. 3. The overall cost of the part (production of 6000 parts)

In the next diagram, the same conditions—and elements are compared, but for a 1,000,000 parts production

Fig. 4. The overall cost of the part (production of 1,000,000 parts)
It is also possible (see next diagram) to compare the different elements of the cost, in order to identify the most important ones and visualize the effect of each modification on the different cost elements.

In the above example, and with the use of COM, it is very simple to identify the size of production for which one solution becomes more interesting than another.

![Diagram showing cost comparison](image)

**Fig. 5.** The different elements of the cost

**Examples of applications and feedback on the use of the Cost of Ownership Model**

The software has been tested on several applications, in different sectors of the industry (automotive, food, medical), with various materials (PP, PEEK, PS) and for different sizes of parts (from 9 gr to 5.5 kg).

The members of the RECIPE project have also tested the software for real applications, through a program of industrial testing in all the European countries participating to the project. The conclusions were that:

- This tool gives similar results than other cost calculation tools already available, so it seems to be reliable.
• Compared to other tools, this tool will enable purchase decisions to be made on a whole cost of ownership basis. Thus equipment that may appear more expensive to purchase may actually be shown to be a cheaper option over the lifetime of the machine. This may encourage the purchase of lower energy consumption machinery such as electric machines as opposed to hydraulic machinery.

3.2 Technologies, techniques and methodologies to develop and efficient mould or tools (R&D results, etc.)

3.2.1 Conformal Cooling (HIPERMOLDING)

HIPERMOLDING (Contract No: COLL-CT-2003-500319) was a European collective research. The main goal of this project was to achieve cycle time reduction in injection moulding by positioning the cooling channels in an optimal way near the surface of the injection moulds. These channels are called “Conformal Cooling Channels” or CCC and are freeforms, requiring a generative process.

The efficient thermal management of the mould reduces cooling time and consequently reduces the energy consumption. It reduces the durability of the moulds and improves quality of injection moulded parts. Finally, in spite of a light over cost on the mould, it reduces the injected parts costs.

![Conventional and HIPERMOLDING moulds](image)

Fig. 6. Conventional and HIPERMOLDING moulds

During three years, six countries were present in this project with their corresponding industrial Associations/Groups (IAG’s) similar than AGORIA for Belgium, twelve Core-SME’s and six RTD’s organizations from The Netherlands, Belgium, UK, Spain, Portugal and Poland.

The IAG’s were mainly responsible for the management and diffusion, the RTD’s for the development and the SME’s to position the project in the good way depending of their expectations.

The HIPERMOLDING project was managed around seven work packages with interactions.

• TNO from NL was the leader project and was responsible for the WP1 (Thermal management) and WP7 (Project management).
• SIRRIS from BE was responsible for WP2 (Manufacturing of Hipertools).
• PERA from UK was responsible for WP3 (High performance injection moulding).
• ASCAMM from SP was responsible for WP4 (Cycle time and cost analysis).

• WP5 and 6 (Training-Dissemination and exploitation) were in charge by CAMT from PL, CENTIMFE from P and PVT from NL.

All companies, which may be interested in getting more technical information about this project, must contact their corresponding IAG or RTD (see http://www.hipermoulding.com). There are also possibilities to train by E-learning sessions (see http://hipermoulding.camt.pl/). A HIPERMOLDING software is also available to define the CCC and calculate the cycle time and costs.

One of the main goals was to validate the theoretical results by real industrial applications. Four case studies were selected function of predefined parameters:

• Size in correlation with possibilities of the additive processes
• Real industrial case in production
• Problems to solve (fine thickness, warpage, cooling, cycle time…)
• Different application sectors
• Different injection materials

For each of the selected cases, the work consisted to:

• Adapt and complete drawing of the mould for inserts integration
• Build inserts by additive technologies
• Mill the mould plates including the receiving cavities for inserts and their integration
• Test the conventional mould and compare with the Hipermoulding mould

**Polish Case Study**

The POLISH CASE is a LV switch cover from the electrical sector, made in PA6 GF25 with a size of 44x44x16mm.

![LV switch cover](image)

*Fig. 7. LV switch cover from the electrical sector*
The production is 22,300 parts per year. The main problems were variable thicknesses from 2.6mm until 4mm causing big local warping and global torsion deformation. To obtain the best result possible the cycle time was 32.4s and this was considered too long.

Taking into account the relatively low production, a soft lbmm (Layer Based Mould Manufacturing; or additive process) insert (bronze dm20 from EOS) was tested. A second insert by slm (steel 1.2344 from MCP) was tested in the same mould. The first insert caused leakage due to the porosity, even with epoxy infiltration. The second insert was very difficult to machine because the high hardness.

The cycle time by conventional mould is 32.4s. The estimated HM cycle time was 17.9s and the real HM cycle time is 22.4s. The first conclusion is that for this case, the HM software is not accurate enough to compute the cycle time and we had to improve it. The second conclusion is that there is a significant reduction of cycle time of 31% in accordance with a similar quality of the injected parts. But, unfortunately, this saving time doesn’t compensate the over cost due to the HM tooling taking into account the low production.

**Belgian Case Study**

The BELGIUM CASE is a container from the medical packaging sector, made in PP with a size of 26x36x53mm.

![Fig. 8. Container from the medical packaging sector](image)

The production is 100,000 parts per year. The main problem was the difficulty to eject the part due to the tiny ribs in the bottom of the part and the narrow space for the internal cooling. To obtain the best result possible the cycle time was 27.2s and this was considered too long.

In the first concept, the ribs had a thickness of 3mm and the cycle time given by simulation was 45s. This was not in accordance with the customer requests concerning costs and cycle time. A second version was designed including a decreasing of the thickness from 3mm to 1.5mm and integrating an additional functional rib. More optimized cooling channels were not possible due to the very narrow remaining space into the functional area. This conventional mould has been built with a conventional cooling baffle. With the same injection parameters, the thermal analysis by Moldex show that the temperature of the core is decreased by 25°C and the calculated cooling time is reduced by 15s. The cycle time is reduced from 45s to 30s. The temperature of the extremity of the insert (in front of the hot nozzle) reaches
more than 100°C during the moulding operation leading to a cycle time around 30s. Below this cycle time, the quality of the part is not acceptable due to deformation and bad visual aspect.

Using the HIPERMOLDING concept, a new design of the core insert cooling channel is used to increase the heat exchange in the molding area. This new insert include four narrow cooling channels (1.5mm diameter) in the functional area. Such 3D cooling channels are impossible to realize with a classical manufacturing technology. The thermal analysis show the cooling time is reduced by 7.5s and the temperature during the injection should be around 30°C.

The cost of the additive processes to build the insert is function of the Z axis. That’s the reason why we have to minimize the high of the insert. In this case, the insert is split of two blocks. The base is produce by conventional machining, and the second element including the CCC is made up directly on the base by Concept Laser process in steel 1.2344. The slots finishing is made by EDM.

To allow finishing, an over dimension of 0.3mm was used. The first step of the finishing is a CNC machining and the second step is a heat treatment to increase the hardness in accordance with the properties of the conventional materials of the production tools. Due to the geometry of the slots in the core inserts, EDM is required to improve the finishing them and finally the grooves are finishing by hand with paper.

The cycle time by conventional mould is 27.2s. The estimated HM cycle time was 17.7s and the real HM cycle time is 17.9s. The first conclusion is that for this case, the HM software is accurate to compute the cycle time. The second conclusion is that there is a significant reduction of cycle time of 34% in accordance with a similar or even better quality of the injected parts by suppressing hot spot in some mould area. And this saving time give an annual
total profit of 8.600€ despite the over cost due to the HM tooling. By using CCC, HIPERMOLDING has reduced the thickness and volume of material used. This reduction of volume should be added at the total profit. And finally, 50,000 shots performed last year, at the end of the project, without any sign of wear out.

**Portuguese Case Study**

The PORTUGUESE CASE is a TS carrier from the automotive sector, made in PA6+30%GF with a size of 54x48x36mm.

![TS carrier from the automotive sector](image1)

Fig. 10. TS carrier from the automotive sector

The production is 600,000 parts per year. The main problems were the complexity of a tiny part with narrow space for the internal cooling needed to prevent warpage and dimensional conformance. To obtain the best result possible the cycle time was 26s and this was considered too long.

The principle of the conformal cooling and build insert is similar than the previous case. It would be too long to discuss all cases in details. That’s why we give just the results.

The cycle time by conventional mould is 26s. The estimated HM cycle time was 21.15s and the real HM cycle time is 22s. The first conclusion is that for this case, the HM software is accurate to compute the cycle time. The second conclusion is that there is a good reduction of cycle time of 15% in accordance with a similar quality of the injected parts. This saving time give an annual profit of 8.600€ despite the over cost due to the HM tooling.

**Spanish Case Study**

The SPANISH CASE is a gestap from the food sector, made in HDPE with a size of Dia 60x35mm.

![Gestap from the food sector](image2)

The production is 600,000 parts per year. The main problems were the complexity of a tiny part with narrow space for the internal cooling needed to prevent warpage and dimensional conformance. To obtain the best result possible the cycle time was 26s and this was considered too long.

The principle of the conformal cooling and build insert is similar than the previous case. It would be too long to discuss all cases in details. That’s why we give just the results.

The cycle time by conventional mould is 26s. The estimated HM cycle time was 21.15s and the real HM cycle time is 22s. The first conclusion is that for this case, the HM software is accurate to compute the cycle time. The second conclusion is that there is a good reduction of cycle time of 15% in accordance with a similar quality of the injected parts. This saving time give an annual profit of 8.600€ despite the over cost due to the HM tooling.
The production is 6,000,000 parts per year. The main problem was the long cycle time of 38s.

The principle of the conformal cooling and build insert is similar than the previous case. Like the previous case, it would be too long to discuss in details and we give just the results.

The cycle time by conventional mould is 38s. The estimated HM cycle time was 19s and the real HM cycle time is 32s. The first conclusion is that for this case, the HM software doesn’t is not accurate enough to compute the cycle time and we had improve it. The second conclusion is that there is a good reduction of cycle time of 16% in accordance with a similar quality of the injected parts. This saving time give an impressive annual profit of 222,000€ despite the over cost due to the HM tooling.

Conclusions

All of the industrial case studies give a good and even drastic cycle time reduction with generally annual total profit depending mainly of the annual production. For the most of the cases, the quality of the injected parts is more or less similar than with the conventional method, except for the Belgium case with a real improvement of the quality and reduction of the thickness and thus reduction of volume injected. These reductions of cycle time lead a global reduction of energy per injected part and consequently a reduction of CO² production.

3.2.2 Inductive Heating of Injection Moulds

“Inductive heating of injection moulds” revolutionises injection moulding:

High demands on the surface quality of moulded parts can be fulfilled by using this method of vario-thermal process management while drastically accelerating production processes. A “bottle opener” demonstrator, which was developed by the Kunststoff Institut, provides an impressive presentation of the achieved quality. This demonstrator is an up to 10mm thick-walled foamed part. The demands placed on the demonstrator can be described as sink mark and streak free with a high-gloss surface.

It is impossible to mould thick-walled thermoplastic parts without sink marks when using conventional injection moulding. The use of chemical or physical propellants – so-called structural foam moulding – can help to significantly reduce shrinkage in thick-walled areas and thereby prevent sink marks.

No surface defects via the new method

However, this goes along with a dramatic deterioration of the surface quality (porosity and silver streaks). Thus far, these defects have rendered conventional injection moulding in combination with chemical or physical propellants useless for decorative parts with high-gloss or structured surfaces. The defects that are caused by the propellants can be avoided by heavily
increasing the mould wall temperature. This, in turn, drastically increases the cycle times and thereby the cost of production. The solution to the problem is as follows: The mould wall temperature is elevated as fast as possible to the required level within an injection cycle, which is to be cooled down then to the base temperature immediately thereafter. While these so-called variotherm processes have long been deemed state-of-the-art, they often involve excessive heating and cooling times, regardless of the technological principle that is applied. This, in turn, often causes unacceptable cycle times. Inductive heating can for the most part eliminate these disadvantages.

Heat enters the mould quickly and precisely

At this point, we would like to introduce the basic idea of the inductive heating of injection moulds. The use of this technology brings about several advantages with a direct impact on production and yield compared to the conventional temperature control systems.

- Unlike conventional temperature control systems, the heat does not need to be conducted through a pipe, in which it can be transferred onto the mould surface in a contactless manner.
- The inductive heating of injection moulds offers the possibility of achieving very high temperature differences on the mould wall within a very short time.
- The heat can be applied locally to where the bordering areas are only minimally heated.
- Depending on the position of the inductor, the necessary mould wall temperature can be generated near the surface (skin effect) with the advantage that much lower amounts of heat are introduced into the mould. In the case of fluid-based temperature control systems, the heat must be conducted from the heating tunnels through the pipes towards the mould wall. As a result, larger areas of the mould are also unwanttely heated.
- Inductive heating can keep increases in the cycle time low or even completely avoid them, since the heat introduced can also be quickly dissipated.

The picture below shows a cover plate with a number of weld lines, due to the apertures and need for multi-point gating, which during mirror finishing become visible in the form of notches.
Different inductor layouts

In principle, there are several possible inductor layouts for the inductive heating of injection moulds, two of which will be presented hereunder:

1. Use of an external inductor:

   This method offers the largest possible freedom, since the mould conditions only play a minor role. Unlike method two, the injection mould design does not have to be adapted, since the inductor is positioned in the opened mould in front of the area that is to be heated, by use of a handling device.

2. Integration of the inductor into the injection mould:

   This method is much more complicated in terms of integrating the inductor into the injection mould. It is important make sure that the design allows for the integration of the inductor as well as the necessary lines (power and water) into the mould in order to heat the desired area, but without heating the other areas.

   The different temperature control systems along with the selection of suitable temperature measuring systems are crucial to the heat management of the mould and, therefore, also to the quality of the product.

Wide range of applications

Inductive heating can be used wherever high mould wall temperatures can be expected to improve the quality of the moulded part or the production process. The advantages at a glance:

- Elimination of surface defects
  - Weld lines
  - Streaks and blooming
- Improved accuracy in the reproduction of surface detail
• Matter surfaces in the case of structures
• Reproduction of microstructures
• Optical parts (e.g. lenses)

• Easier manufacturing of:
  • Thin-walled parts
  • Micro injection moulded parts

• Reduction of tension close to the surface
• Thinner electroplated coatings and shorter electroplating bath times
• Foamed parts with excellent surfaces.

**Induction services offered**

• Testing of general feasibility.
• Selection of method - external or internal inductor.
• Execution of preliminary tests by means of
  • devices and
  • moulds.
• Production of a test specimen.
• Support during the mould’s design regarding the inductor integration and layout.
• Consideration of the environmental conditions (machine + periphery). Layout of the necessary periphery.
• Production of a mould-specific inductor as well as its installation into the mould.
• Support during the sampling phase.
• Appropriation of the necessary periphery.

### 3.2.3 Development of innovative high performance anodised aluminium moulding tools for the thermoplastic processing sector to achieve competitive advantage

Aluminium tooling can be used for many polymer moulding techniques, for both thermosets and thermoplastics. The formulations of the basic alloys have been gradually developed to give improved properties such as hardness, machinability, purity, castability, etc. However, for some applications, the basic good properties of aluminium would benefit from improvement and the EU project ALAMO has pioneered the development of anodised aluminium tooling.

**Applications and Limitations**

Most polymer processing technologies can utilise aluminium tooling. ALAMO concentrated on thermoplastics, specifically injection and rotational
moulding but it can be used for blow moulding, RIM, RTM, Vacuum moulding, compression moulding and hot or cold press moulding. However, whatever tool is made needs to be anodised in a series of tanks presenting a further limitation.

Anodised aluminium tooling would not be suitable for tools expected to have high level localised, rough operator handling, rubbing metal inserts and so on.

**Anodising**

For the ALAMO project two types of aluminium alloy were specified:

- 6082 was specified for the rotational moulding tools
- 7010 was specified for the injection moulding tools

Anodising is essentially an oxidation process that relies on the natural tendency of aluminium to form a very hard oxide film on its surface when exposed to the atmosphere. It is this oxide film that protects the underlying metal and gives aluminium its durability.

Anodising is the thickening up of the oxide film by electrolysis. It also has the effect of increasing the metals naturally good corrosive resistance which is especially a benefit when anodising it utilised in the manufacturing of moulding tools.

**Overall Summary of the Findings**

Following the extensive and detailed investigation into rotomoulding with ALAMO treated aluminium it was found that typically there is a 20 – 25% saving on overall cycle time when compared with non-treated conventional aluminium. There were no differences observed between the two mould materials in terms of impact, shrinkage or surface properties.

The development carried out through the ALAMO project has shown that anodised aluminium tooling has definite and measureable advantages in some applications. In any tooling and moulding application there are many variables and these must be considered in relation to the specific item being made. Anodised tooling will certainly help many applications, improve efficiency, reduce wastage, improve profitability and give competitive advantage.

4.1 Impact of Rational Use of Energy

Why should companies make energy savings?

Companies in plastic chain consume on average a very significantly high amount of energy per unit of production. High ‘energy intensity’ can pose a threat to growth prospects of polymer industry and its supply chain, especially in light of the rapidly rising energy prices. Timely investments into energy efficiency will prevent energy costs from eating into companies’ profit margins and will help companies maintain their competitive edge.

Energy efficiency investments are also becoming increasingly profitable as energy prices continue to increase. For example, a recent energy audit conducted by the EBRD at one of its industrial clients helped to identify a mix of energy efficiency improvements with total investment cost of €50 million. These investments, if implemented, could reduce the company’s energy bill by nearly 30 per cent, with payback of individual projects (primarily from the achieved cost savings) ranging from one to four years.

Finally, high energy consumption and inefficiency may become a bottleneck for future capacity and production growth, as companies are faced with high charges for new power grid connections and tight limits on energy consumption.

How much more competitive could energy savings make a company?

Let’s assume a company with energy representing 20 per cent of total production costs, which can be typical for many of the energy intensive sectors. Cutting its energy consumption by 25 per cent (which some EBRD clients were able to achieve) through investments into more efficient energy and process equipment will allow the company to reduce its total production cost by 5 per cent. Such a reduction can significantly improve the company’s profitability or competitive power. More importantly the risks of these investments are low and returns easily predicted, in contrast to many other types of investments. It is also important to note that investments into efficient equipment and processes often bring other positive “side effects,” such as improved product quality or increased productivity.

Could it make European companies in polymer supply chain more competitive and attractive to investors?
Leading companies around the globe become increasingly aware of the need for environmental protection, rational energy use and climate change. They respond to these challenges by raising environmental standards in order to minimise the negative impacts of their economic activity on the environment. An increasing number of companies participate in voluntary carbon emissions trading schemes to offset the ‘carbon footprint’ of their business.

Europe becomes increasingly integrated into the world economy, with EU companies increasing their exports and acquiring assets abroad, creating JVs with foreign sponsors and listing stocks on foreign stock exchanges. Having ambitions to become global players, European companies need to adhere not only to high international standards for corporate governance or transparency, but also high environmental and social responsibility standards. Poor energy utilisation practices, such as coal mine methane venting or associated gas flaring can pose substantial environmental, reputational and technical risks for investors. The attention to the issues of energy efficiency and rational energy use will certainly be an essential value driver going forward.

- High-energy intensity and inefficiency reverberates negatively through the whole European economy:
- Energy demand is outstripping supply, thereby constraining further economic growth.
- The lack of energy efficiency also presents a threat to Europe’s energy security i.e. the ability to meet export obligations while satisfying the growing domestic demand for energy.
- Such energy deficit creates a need for costly investments in additional energy generation capacities and infrastructure upgrades.
- ‘Wasting’ energy domestically minimises the amount of energy resources available for exports at world prices.

All of the above problems can be addressed as Russia is believed to be able to save 25-30 per cent of its current annual energy consumption through enhanced efficiency.

10 Steps to Reduced Energy Consumption

Here, in summary, are 10 important points on how to make significant savings, with improvements boosting productivity and reducing emissions.

1. **Provide incentives that support your primary goals**

   When it comes to reducing power consumption and increasing energy efficiency, one way to help achieve this is to pay people to make it happen. Human nature being what it is, ENER-Plast recommends incentivizing the appropriate people by linking a part of their compensation to improvements in energy efficiency. Doing so will help ensure engineers are encouraged to take energy efficiency seriously.

2. **Invest in understanding your equipment workload and behaviour**

   Understanding your company equipment, the way it interact with each other, and the material flow they generate in your company is a tricky task because
every organization is unique. But if you have suitably skilled staff, you can build up this understanding, and use it to evaluate new hardware, optimize your process and make the most of new technology as it emerges. "If you don’t start with efficient processing equipment, you’re just going to pass inefficiencies down the line”.

3. Focus on effective resource utilization

Essentially this means using as close to 100 percent of a company’s resources as is practical before extending or building more production halls. This may seem obvious, but don’t forget there’s a hidden energy cost to unused capacity because it takes energy to make process supporting equipment that aren’t fully used.

4. Right-size your production hardware to meet your application requirements

For large organizations, this means working with manufacturers to specify the exact machine you want them to produce, with high efficiency power supplies and advanced power management features, and without excess items.

Most companies won’t have the buying power to influence manufacturers’ designs, however. If you fall into this category then this means developing the specifications you need for machines to meet your requirements and ensuring that you don’t buy equipment that exceed these specs. If you understand your workloads, you can pick the right machine and avoid unnecessary expenditure. (ENER-Plast doubts the conventional wisdom that it is worth buying above your current needs to protect your investment in the future — technology changes so quickly that buying what you need when you need it is probably a better strategy.)

5. Evaluate and test equipment for performance, power, and total cost of ownership

The message here is test, test, test. Test power and performance on all equipment you are considering purchasing, then calculate the TCO and power consumption.

And don’t rely on manufacturer supplied data — test the servers in your environment with your workloads. If you can’t do your own testing in house, ask people who already have similar or even the same equipment.

6. Converge on as small a number of stock-keeping units (SKUs) as you can

By buying only a limited of material and reselecting them month or even week, you can benefit from volume discounts from vendors. This also helps reduce operational expenditures, as a limited number of SKUs is easier to support and maintain, and makes it easier to repurpose processing machines.

7. Use simulation to improve mould utilization and increase operational efficiency

Mould and dies that don’t use previous simulation often have more than 20 percent utilization, higher energy consumption. It’s this simple piece of math that means simulating injection moulding or any other polymer processing technique rises energy efficiency and reduce power costs significantly.

8. Drive quality up through compliance
Many company’s processes are driven by the need to meet regulatory and security requirements. The extended value that can be offered by standardized, consistent processes that address compliance will also help you achieve higher quality benefits.

9. Embrace change management

Every company requires changes from time to time, but poorly managed, ill-thought-out or inadequately tested changes can have disastrous results in terms of downtime and equipment unavailability. They can also have a negative effect such as resulting in lower energy efficiency and poor use of resources. Standardized procedures for the request, approval, coordination and execution of changes can greatly reduce the number and severity of unplanned outages. These should include reviewing proposed changes, identifying risks and developing work-arounds in advance and scrutinizing roll-back plans.

10. Take advantage of competitive bids from multiple manufacturers to foster innovation and reduce costs

Energy efficiency, power consumption, cost effectiveness and application performance per watt each play key roles in hardware selection. Competition between vendors is an important way that you can get energy efficient and low TCO machines for less.

4.2 Decentralised Electricity Production

Decentralized electricity production or distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from many small energy sources.

What determines whether electricity generation is Decentralized electricity production is not so much how electricity is generated rather where power is generated. Decentralized electricity production technologies generate electricity where it is needed. Central generation on the other hand generates electricity in large remote plants and power must then be transported over long distances at high voltage before it can be put to use. It does not matter what technology one employs, whether it is used in connection with an existing grid or in a remote village, or whether the power comes from a clean renewable source or from burning fossil fuel; if the generator is ‘on-site’ it is Decentralized electricity production. This means that, strictly speaking, Decentralized electricity production could imply technologies that are not necessarily cleaner for the environment such as diesel generators without heat recovery. More often that not, however, Decentralized electricity production is synonymous with cleaner electricity—indeed that is one of Decentralized electricity production’s main benefits.

Currently, industrial countries generate most of their electricity in large centralized facilities, such as coal, nuclear, hydropower or gas powered plants. These plants have excellent economies of scale, but usually transmit electricity long distances.

Most plants are built this way due to a number of economic, health & safety, logistical, environmental, geographical and geological factors. For example,
coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace, in addition such plants are often built near collieries to minimize the cost of transporting coal. Hydroelectric plants are by their nature limited to operating at sites with sufficient waterflow. Most power plants are often considered to be too far away for their waste heat to be used for heating buildings.

Low pollution is a crucial advantage of combined cycle plants that burn natural gas. The low pollution permits the plants to be near enough to a city to be used for district heating and cooling.

Distributed generation is another approach. It reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed.

Typical distributed power sources in a Feed-in Tariff (FIT) scheme have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers, and large, complex plants to pay their salaries and reduce pollution. However, modern embedded systems can provide these traits with automated operation and clean fuels, such as sunlight, wind and natural gas. This reduces the size of power plant that can show a profit.

### 4.2.1 Renewable Energy

Renewable energy is energy generated from natural resources—such as sunlight, wind, rain, tides and geothermal heat—which are renewable (naturally replenished). In 2006, about 18% of global final energy consumption came from renewables, with 13% coming from traditional biomass, such as wood-burning. Hydroelectricity was the next largest renewable source, providing 3% of global energy consumption and 15% of global electricity generation.

Wind power is growing at the rate of 30 percent annually, with a worldwide installed capacity of 121,000 megawatts (MW) in 2008, and is widely used in European countries and the United States. The annual manufacturing output of the photovoltaics industry reached 6,900 MW in 2008, and photovoltaic (PV) power stations are popular in Germany and Spain. Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 MW SEGS power plant in the Mojave Desert. The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18 percent of the country's automotive fuel. Ethanol fuel is also widely available in the USA.

While most renewable energy projects and production is large-scale, renewable technologies are also suited to small off-grid applications, sometimes in rural and remote areas, where energy is often crucial in human development. Kenya has the world's highest household solar ownership rate with roughly 30,000 small (20–100 watt) solar power systems sold per year.
Some renewable energy technologies are criticised for being intermittent or unsightly, yet the renewable energy market continues to grow. Climate change concerns coupled with high oil prices, peak oil and increasing government support are driving increasing renewable energy legislation, incentives and commercialization. New government spending, regulation, and policies should help the industry weather the 2009 economic crisis better than many other

4.2.2 Practices and technologies for efficient usage of electrical energy

Servo electric drive system for injection moulding

Common technological equipment in the plastics processing plants are injection moulding machines with hydraulic drive systems. This type of drive has relatively low energetic efficiency ranging between 50-60 %. This is caused by the fact that the main hydraulic pump is running during whole injection cycle regardless on instantaneous energy consumption of the machine. The new servo electric drive utilizes electric energy with much higher effectiveness utilizing recuperation energy during braking period. By application of this technology energy savings ranging from 25 to 50 % can be reached in comparison with hydraulic drive.

Additional energy losses in hydraulic drive systems are added by viscosity effects of the hydraulic oil, respectively losses caused by friction due to the flow of the hydraulic oil in the piping system (hoses, pipes, valves etc.). In contrary to the latter hydraulic systems servo electric drive systems due to their high acceleration and high limiting velocities of parallel running movements electrical injection machines reaching into shorter tick over times, i.e. better economical performance. With respect to the hydraulic drive machines new hydraulic oil (product of Swiss based company Natoil) based on natural ecological bases preserve high stability and low viscosity in the wide range of application temperatures. Tests show that by application of these oils the energy consumption decrease ranges between 5 to 25 % in comparison to currently used standard types of hydraulic oils class 46.

4.2.3 Practices and technologies for efficient usage of thermal energy

Microwave heating, drying, joining and recycling

Microwave processes are applied in plastic industry mainly for drying, polymerization, jointing, forming, shrinkage, recycling and preheating. Advantages of the microwave heating can be summarized as follows:

- Excellent heating homogeneity, precise temperature control, fast achieving of the target temperature in the whole volume.
- Approx. 30% energy savings for certain application due to selective heating of co-solvents and not effecting substrate.
- Bulk products and larger section profiles can be treated despite their poor thermal conductivity.
• Treatment can be done at low external temperatures – the operation is product friendly preventing overheating
• Enables precise process driving in the volume cross section preventing build up of stress and tension in the matrix.

Dielectric heating
Plastics are most often very poor thermal conductors. Conventional heating enables energy input only due to the thermal gradient that can deteriorate the product properties. The microwave field influences the volume and does not depend on the conductivity.

Drying operations
Drying is probably the most spread MW application in plastic industry. The mechanism is very different from the conventional drying. It brings its specific advantages such as same moisture and thermal gradient, water pump and capillary effects, preventing the surface crust, etc. Applied design is enabling treating of various shapes, pieces or powder material without difficult line or chamber adjusting.

Bonding operations
Bonding and welding of plastic parts brings benefits especially when using radio frequency radiation range. The achieved progress enables very effective automation of the welding cycle also for complicated parts. Welding by microwaves can improve the mechanical properties substantially.

Recycling of plastics and waste treatment
Microwave recycling is environment friendly. The unique application was tested recycling originally flammable plastic material to the new material with enhanced fireproof properties that could be used for thermal insulation.

Forming of plastic parts
Microwave heating enables fast forming of plastic parts. Preheating enables better volume heating for certain materials.

Plastic half-product shrinking
Plastic foils, tubes, sheets etc. can be shrunk by microwaves with the advantage of relatively stable temperature allocation. Practical use is especially for treating packaging, food staff storage and pharmaceuticals.
5.1 Introduction

The EU is “committed to reducing its greenhouse gas emissions by at least 20% from 1990 levels by 2020, and by 30% if a satisfactory international agreement is reached - notably at the UN climate conference in Copenhagen in December 2009.”

As a result of the 20% cut from 1990 levels, the European Union is committed to increasing the share of “renewables in its overall energy mix to 20%.” By switching to renewable energy, the cut in fossil fuels could be as much as 200-300m tonnes, corresponding to a 600m – 900m tonne reduction in CO2 annually.

Improving energy efficiency is one of the best ways of cutting emissions and increasing sustainable development, reducing costs and increasing efficiency. “By saving 20% of energy consumption by 2020, the EU hopes to cut emissions by almost 800m tonnes a year and save as much as €100bn.”

Buildings, transport and manufacturing account for 91% of EU energy requirements, with manufacturing accounting for 25% of all requirements.

The success of an energy management programme within an organisation is dependent upon many factors, above all the union between technology and management. The results of however are many fold, with companies able to benefit from an increased manufacturing efficiency and resulting cost savings thereof, but also environmental awareness – as well as compliance with national or regional regulations.

To understand what is driving sustainable production, we have to look at cost. There are two key questions for any company to answer:

1. What is the cost financially of inefficient manufacture?
2. What is the environmental cost of these inefficiencies?

At the forefront of this issue is the promotion of leadership and behavioural change, as well as delivering sustainable benefits to both the company and the broader economic / environmental field. This section of the document focuses on the strong business case for sustainable development, which could therefore:

- Increase company profitability, ensuring resources are used effectively

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1 http://ec.europa.eu/climateaction/eu_action/less_greenhouse_gases/index_en.htm
2 http://ec.europa.eu/climateaction/eu_action/renewable_energy/index_en.htm
3 http://ec.europa.eu/climateaction/eu_action/energy_efficient/index_en.htm
- Raise awareness and use of innovative products, services and ways of working
- Enhancing company image and profile within your market sector and address issues such as Corporate Social Responsibility (CSR).

Attention to energy efficiency can often highlight deficiencies in other areas such as maintenance, process yield and quality, therefore giving significant additional productivity benefits.

### 5.2 Environmental Benefits

Within the UK for instance, there is an over-arching target of reducing total UK CO2 emissions by “at least 60% on 1990 levels by 2050 and by at least 26% by 2020.”

Areas such as waste minimisation, recycling and re-processing will all contribute to reducing CO2 emissions whilst increasing competitive advantage, increasing manufacturing efficiency, reducing costs. A study produced by DEFRA [Department for Environment, Food and Rural Affairs] estimates that overall resource efficiency gains available to UK business, from energy, waste, and water are £6.4billion per year, with energy accounting for 52% and water 41%.

Overall trends within the EU-25 have shown energy efficiency progress of 14% between 1990 and 2004, corresponding to approx. 150 Mtoe energy savings in 2004.

![Fig 13: Energy efficiency progress in the EU-25 (Source: ODYSSEE)](http://www.berr.gov.uk/files/file46535.pdf)

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Results of a survey carried out by the British Plastics Federation (BPF) in the mid-1990's suggests that the total 'accounted for' electricity use in injection moulding can be broken down as follows:

![Chart showing electricity use breakdown in injection moulding]

**Fig 13: Total 'accounted for' electricity use in injection moulding - mid. 1990's.**

Proper mould design incorporates the interaction between several key parameters, including geometry, mould material selection, process constraints and polymer processing constraints. Several case-studies have been conducted as part of the euRECIPE project, which are relevant in this study.

The 'Mould Design Aspect to Minimise Energy Consumption' case study states that design considerations...need to include:

- Heat content in the plastic material
- Heat conduction in the mould
- Heating of coolant
- Allowable temperature differences in mould and coolant
- Pressure drop in cooling

Another important factor in energy saving field is the monitored values on individual machines, with clamp force being closely related to energy use. In conjunction with clamp time, clamp energy accounts for a large part of the energy cycle, with a corresponding reduction in energy consumption as the clamp force is optimised. As clamp time is related to the polymer type, moulding cross-section/weight and to the moulding shot weight/cooling efficiency, it can be said that to maximise energy efficiency of your production process it is necessary to:

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6 British Plastics Federation Energy Consumption Report; Thermoplastics: Energy use in injection moulding

7 www.eurecipe.com
• Establish the minimum clamp force value actually needed for a particular product and polymer;
• Selecting the machinery with the hydraulic system that most closely matches the necessary clamp force;
• Adjust the clamp force to a practical minimum; many examples have been seen where machines are consistently run at maximum pressure irrespective of the mould/polymer.

Innovations and energy savings within the mould tool industry are continuing to be developed across Europe, with groundwater cooling being used by a Danish manufacturing of tools.

5.3 Case Study-Mould Design Aspects to Minimise Energy Consumption – euRECIPE Fact Sheet A

Danish manufacturer of tools for plastics machinery as well as extruded plastic products introduced groundwater cooling in 1998. The company required cooling for their production system and air ventilation. The previous cooling system was based on traditional mechanical refrigeration with relatively high energy consumption. The cooling system based on groundwater cooling provided an energy reduction of approximately 85%. Furthermore, the injection moulding machines are running steadier with cooling from the groundwater plant compared to cooling from compressors.

5.4 Economic Benefits

The economic benefits of a “low carbon economy” to which all companies (and indeed Governments) strive, provides significant economic savings. Energy now is one of the largest variable costs a business can have, especially with energy supplies no longer totally secure.

Across manufacturing, all sectors have an opportunity to narrow the productivity gap with their competitors by increasing investments in technological improvements and processes.

Energy efficiency is an important step-change and one which isn’t as complex as many would imagine. Ensuring that companies reach their full potential requires effective adoption of new processes and stimulates new investment opportunities. Firms in the UK, and indeed other developed economies within the European Union, are increasingly investing in knowledge-based assets such as software and other developments such as software and design.

Energy management is a cost effective and highly important exercise – improving performance on many levels – but to be effective, it cannot be just a ‘one-off’ process, it must be continuous. With over 75m tonnes of solid waste going to landfill (plus the associated cost of land-fill tax) in the UK each year, there is a clear benefit to us all to ensure efficiencies are maximised.

Significant financial savings can be achieved by implementing simple routines, for example:

Non-productive Energy Usage
• Energy is being used when machines are idle; ensure hydraulic pumps and granulators are shut off, with heat settings reduced
• Define an ‘idling’ more for machines
• Accelerate job changes, tool and mould settings
• Undertake preventive machine maintenance before breakdowns occur

Productive Energy Usage; regularly measure and record the following:
• Temperatures;
• Screw speeds;
• Clamp force
• Cycle sequence
• Air pressure;
• Coolant temperature
• Flow

Effective control of energy consumption is achieved through a combination of sound engineering principles and good operation practice in the manufacturing plant. When energy saving measures are adopted, measuring and reporting systems must be in place to provide information to staff on the reasons for implementation and the end results.
Chapter 5 References

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