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Plastics Industry – A Contribution towards Ireland's Kyoto Targets

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Plastics Ireland:

Plastics Ireland is the representative body for the Plastics Industry in Ireland and is a central business sector within IBEC. The association's principal role is to enhance the competitive position of its members by influencing the business environment in which the industry operates. Plastics Ireland promotes, supports and encourages the further development of the multinational and indigenous plastics sector in Ireland. Plastics Ireland achieves this by building and maintaining excellent relations and a positive profile with Government, public agencies, other representative organisations and international bodies.

Tel: 01 6051574

E mail: gerry.farrell@ibec.ie





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Byrne Ó Cléirigh, 30a Westland Square, Pearse Street, Dublin 2, Ireland.
Telephone: + 353 – 1 – **6770733**. Facsimile: + 353 – 1 – **6770729**. Email: Admin@boc.ie. Web:
www.boc.ie



Chairman's Note:

As Chairman of Plastics Ireland, I am happy to present our report "The Plastics Industry – A Contribution towards Ireland's Kyoto targets". This is the first report commissioned by Plastics Ireland since its formation in December 2004, and hopefully will be the first of many reports of interest on our industry in the future.

One of the first areas which the Plastics Ireland Council decided to look at, following its formation, was the area of all electric injection moulding machines. Given the recent increases in the cost of electricity, the energy savings attributed to all electric moulding machines and Ireland's impending targets under the Kyoto agreement to reduce CO² emissions, it seemed a worthwhile exercise to quantify the potential environmental benefit of electric machines in the Irish injection moulding industry.

This report quantifies the electricity usage of the Irish injection moulding industry and calculates the potential energy savings achievable if the current stock of hydraulic machines were replaced by their all-electric equivalent. The report has shown that the introduction of the new all electric machines in the plastics industry could reduce Ireland's annual electricity consumption by the equivalent of 76,000 tonnes of CO² emissions. It is estimated that the use of all electric machines could lead to a two-thirds reduction in electricity consumption by the industry when compared to the use of hydraulic machines.

The National Climate Change Strategy has targeted a one million tonne reduction in CO² emissions for the Irish industrial sector. Therefore, 8% of this target could be achieved through the introduction of the new all-electric machines in the plastics injection moulding industry alone. This will reduce the need for the Government to purchase this amount of carbon credits in the future. We have already seen a substantial increase in the cost of carbon traded under the E.U emissions trading scheme.

The report also clearly identifies the high capital cost of the new equipment as the major barrier to investment. Plastics Ireland therefore calls on Government to support the sector in introducing the new technology into plastics moulding companies. The report has pointed to incentives for energy-efficient equipment that exist in the UK and the U.S. in the form of capital write-offs, interest-free loans and rebates and grants assistance.

The Government has an opportunity to save the taxpayer very considerable amounts of money. Rather than paying financial penalties for not reaching our climate change targets, we would encourage the Government to assist industry to invest in manufacturing equipment that uses less electricity. Ireland will be a three-way winner on this. The investment in new energy efficient technology will assist Ireland to meet its Kyoto commitments, will improve industry competitiveness and will also go some way to addressing the future lack of generating capacity in Ireland.

I would like to take this opportunity to recognise the support we received from industry and Sustainable Energy Ireland for the compilation of this report. I also thank the consultants, Byrne O'Cleirigh, for their professional approach in carrying out the report.

A handwritten signature in blue ink, appearing to read "David Moffitt".

David Moffitt
June 2005

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APPENDIX 1: Energy Survey Questionnaire

Executive Summary

- This report was produced by Byrne Ó Cléirigh (BÓC) on behalf of Plastics Ireland. It provides an analysis of the environmental benefits of increasing the use of all-electric injection moulding machines in the Irish plastics and related industries.
- The report addresses the technical issues, and particularly the energy consumption, associated with hydraulic and electric machines. By reference to published case studies and unpublished data collected in firms surveyed as part of the study, we found that reported energy savings attained by switching from hydraulic to electric moulding machines vary from 42% to 71% with the median saving being 66%.
- All- electric moulding machines have become available over the last 10 to 15 years. Initially they were developed in Japan in response to regulations and constraints on the use of hydraulic oil. Direct electric drive machines do not have the energy loss and cooling requirements associated with hydraulic machines and are consequently more energy efficient.
- In 2002, a survey of the injection moulding industry in Ireland¹ was carried out and information on the number of machines, range of machine sizes and approximate output was collected. The total number of moulding machines in Ireland is about 2,000 and about 63,000 tonnes of plastic are processed in moulding machines each year.
- As part of this study we conducted a survey of ten of the largest companies involved in injection moulding. The companies surveyed represent about 20% of the total industry by number of machines and by production output.
- The data collected was analysed to determine the average electricity use by machines in different size categories and the average distribution of machine sizes. We then extrapolated from this data to estimate the total electricity consumption in the injection moulding industry using data from the 2002 survey. The total electricity consumption in the injection moulding industry is estimated at 218 GWh/yr.
- Assuming a saving of 66% in direct electricity consumption for all-electric machines, the potential total electricity saving is 144 GWh per annum. An additional 2 GWh/annum in indirect energy use (cooling) can also be attained. This represents 76 kilotonnes of carbon dioxide (CO₂) per annum. This is 7.6% of the 1 million tonnes CO₂ emissions reduction targeted in the National Climate Change Strategy for the entire industrial sector.
- This saving applies only to the injection moulding sector, which was the focus of this study and accounts for some 26% of total polymer use. Comparable savings could possibly be achieved in other sectors of the plastics industry.
- Electric machines are between 40% and 70% more expensive than the equivalent hydraulic machine. Balanced against this are lower energy costs and slightly lower maintenance costs. The payback period for the additional investment in

¹ Applied Market Information, Guide to the Injection Moulding Industry in Ireland, Upgrade 2002.

electric machines ranges from 8 years for 100T (tonne clamping force) – 200T machines to over 15 years for smaller (<50T) machines.

- Two case studies were also assessed, based on actual electricity consumption and other data measured at facilities in Ireland. In one case study a 150T electric machine achieved 71% savings with an 8 year payback. In the other a 300T electric machine achieved a 42% reduction in electricity consumption with a 12 year payback period.
- The average specific energy consumption in the injection moulding industry in Ireland is 2.95 kWh/kg plastic. This is higher than the good practice range of specific energy consumption of 1.2 kWh/kg to 2.2 kWh/kg. This indicates that there is significant scope for increased energy efficiency in the plastics industry in general.
- Although the use of all-electric machines offers reasonable payback periods, in many cases their penetration into the Irish market has been very limited to date. From discussions with personnel in the industry and in the companies surveyed, the main barrier to the use of all-electrics is the higher capital cost. Secondary reasons are a lack of focus on energy efficiency and a lack of in-house expertise on operating and maintaining all-electric machines.
- The types of incentives that are generally used to overcome capital cost barriers are tax concessions, low cost loans and grants. For example, in the UK, zero interest loans and enhanced capital allowances (to allow investment cost to be written off against tax) are available for investment in energy efficient technologies. In the USA various forms of capital subsidies are available based on reduced electricity consumption and capital costs.
- The cost of carbon abatement for an interest free loan scheme would be in the order of -€0.65/tonne CO₂ below an assumed value of €10 per tonne.
- Another means of promoting a transition to more energy efficient technologies that has been successfully used in some European countries are voluntary or negotiated agreements.
- The introduction of such schemes has the potential to yield low or even negative cost reductions in greenhouse gas emissions and would benefit the economy by reducing the number of carbon credits the Government will have to buy on the market. An effective scheme would be likely to be based on a combination of economic incentives together with a target based agreement. This would achieve the direct electricity savings through using electric machines and also include other general energy efficiency measures.
- Such a form of incentive could also be made available to the plastics industry in general rather than just the injection moulding industry.
- Pending the development of schemes to promote energy efficiency in the plastics industry, existing schemes such as the EPA's Cleaner Greener Production Programme could be used to promote energy efficiency in the sector.

1. Introduction

Byrne Ó Cléirigh (BÓC) were appointed by Plastics Ireland to carry out a study, and produce a report, on the environmental benefits of increasing the use of all-electric injection moulding machines in the Irish plastics and related industries.

The report primarily addresses the potential for energy savings which can be achieved by replacing the stock of hydraulic machines with all-electric machines in the injection moulding industry, but also addresses energy savings which can be achieved in other sectors of the plastics industry, including thermoforming and blow moulding. These savings are addressed in Section 10 of the report.

2. The Plastics Industry in Ireland

2.1 General

According to information supplied by Plastics Ireland, an estimated 247,000 tonnes of thermoplastics were used in Ireland in 2002. There are about 350 companies in the plastics and associated industries employing about 22,500 people.

The largest single user of plastics is the injection moulding process, which used 63,000 tonnes of plastic, or 26% of the total polymer use. The remaining plastics were consumed in film extrusion (37 kt), pipe extrusion (41kt), cable/wire extrusion (12 kt), other extrusion (35 kt), blow moulding (35 kt), PP fibre (7 kt) and other processing (23 kt).

The industry is divided between in-house and contract moulders and covers a broad range of sectors including medical devices, electronics, packaging, appliances and tool making. The medical devices sector is particularly important in Ireland with 12 of the top 15 medical device manufacturing companies having sites in Ireland.

2.2 2002 Survey Data

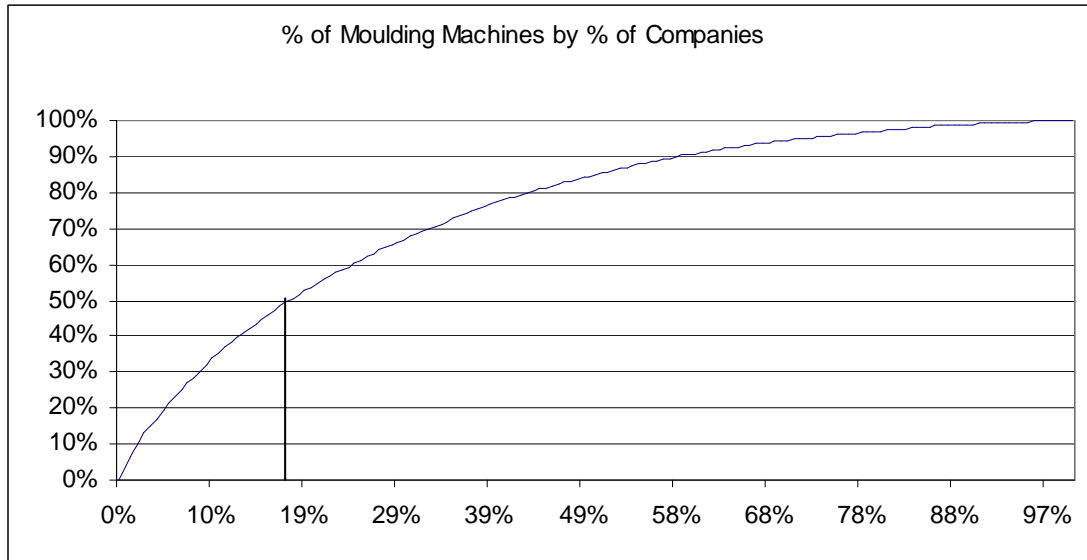
From a survey of companies involved in injection moulding in Ireland carried out in 2002², there were some 153 companies engaged in injection moulding activities at the time. There has been no significant change in the industry since then, although there have been some closures and new entrants, and the data in the survey is considered to be current. The companies vary in size from small companies with one moulding machine and an output of less than 50 tonnes per annum, to large companies with over 50 machines and an output of thousands of tonnes per annum.

In total, there are about 2,000 injection moulding machines ranging in size from 10T (tonnes clamping force) to over 2,000T. The majority of the machines are within the 50T to 300T range, a range over which alternative electric machines are available.

² Applied Market Information, Guide to the Injection Moulding Industry in Ireland, Upgrade 2002.

The machine clamping force is generally indicative of electricity consumption; however, other factors such as cycle duration and shot size also affect electricity consumption.

Figure 1: Distribution of moulding machines in companies



Although there are over 150 companies engaged in injection moulding in Ireland, many of these are relatively small operators and the majority of the moulding machines, and the majority of the production output, are accounted for by a minority of the companies. As can be seen from Figure 1, over 50% of the total stock of moulding machines are contained in under 20% of the companies.

2.3 Industry Survey for Present Study

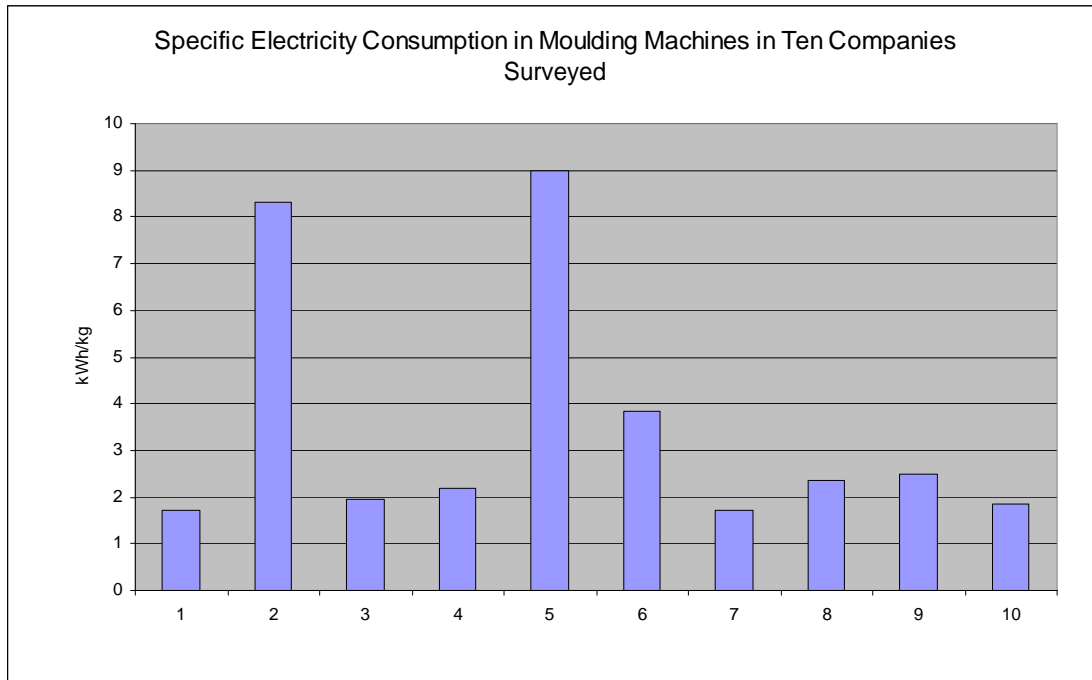
In consultation with Plastics Ireland, thirteen of the largest companies involved in injection moulding in Ireland were surveyed to ascertain their electricity use and machine profile and usage. Ten companies responded, representing about 20% of the injection moulding market in Ireland in terms of number of machines and in product output. The brief survey questionnaire is contained in Appendix 1.

A number of companies did not respond due to concerns over commercial confidentiality and all companies who did respond expressed similar concerns. The data from the survey is, therefore, presented in aggregate form to ensure that no confidential information relating to any single company is released.

The information collected included the electricity consumption, the production output, and the specific energy consumption. The specific energy consumption is a useful indicator of general energy efficiency and can also be used as a means of estimating energy use based on total production output. These data are presented in Figure 2, which shows a wide variation in specific energy consumption data. The average specific energy consumption is 2.95 kWh/kg plastic. This is higher than the range of

specific energy consumption of 1.2 kWh/kg to 2.2 kWh/kg of plastic³ referenced in a UK Good Practice Guide, indicating that there is scope for electricity savings on existing hydraulic machines.

Figure 2: Specific Electricity Consumption Reported in the Survey



Information on the number of machines, operating hours and rated power consumption was also gathered in the survey. This information is important in developing a methodology for estimating the total electricity consumption for injection moulding based on the data available in the 2002 survey (i.e. the number of machines and range of machine sizes).

Figure 3 shows the distribution of machine sizes in the 380 machines owned by the companies surveyed, and shows that the majority of the machines are within the 50T to 200T size range. (The majority of machines are around 100T). Table 1 shows the average rated power for machines in different size ranges.

³ UK Good Practice Guide 292, Energy in Plastics Processing – A Practical Guide

Figure 3: Distribution of Machine Sizes in Companies Surveyed

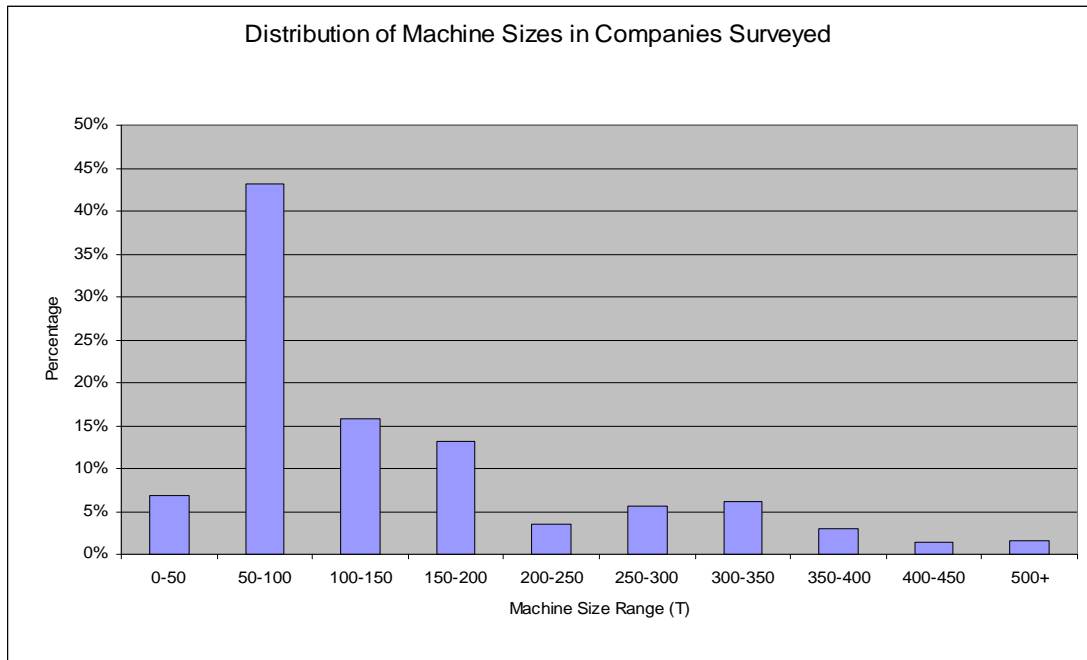


Table 1: Average Rated Power Consumption in Machines Surveyed

Size Range (T)	<50	50-99	100-149	150-199	200-299	>300
Average Rated Power (kW)	13.2	22.8	38.9	46.8	61.9	79.4

3. Energy Use in Injection Moulding Machines

3.1 General

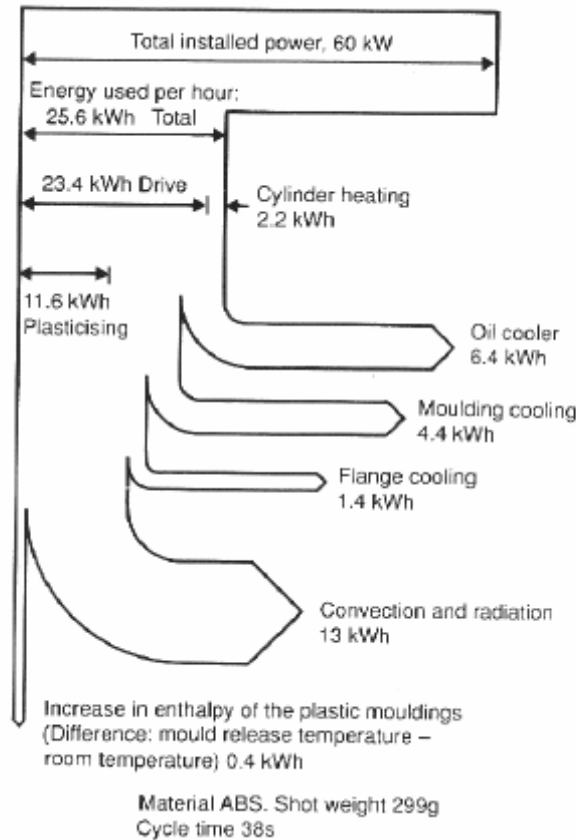
There are two main categories of injection moulding machines being covered in this report: hydraulic drive machines and direct electric drive machines.

In hydraulic machines, hydraulic power is used to transmit the energy used to operate the screw within the barrel and the clamp unit. This hydraulic power is created by a pump driven by an electric motor. Some power packs include a hydraulic accumulator to store energy during low-load operation parts of the cycle and provide peak injection power over a very short period.

Energy generated within the hydraulic system heats the oil, changing its viscosity and reducing its efficiency. To keep the system within an acceptable temperature range, the oil must be cooled either by air blast coolers, cooling water or chilled coolant. About 33% of the energy used by the machine is dissipated as heat in the cooling system. Due to the very variable nature of the electrical load over the injection moulding cycle, the motors tend to be underloaded, resulting in lower efficiency and lower power factor.

Specific energy consumptions reported for hydraulic injection moulding machines typically range from 1.2 kWh/kg to 2.2 kWh/kg of plastic⁴. For hydraulic drive machines, a typical distribution of energy use and losses is shown in Figure 4, reproduced from the UK Good Practice Guide 48, *Reducing Electricity Use in Injection Moulding*.

Figure 4: Sankey diagram showing energy consumption in an injection moulding machine



Electric machines have become available over the last 10 to 15 years. Initially they were developed in Japan in response to regulations and constraints on the use of hydraulic oil. Direct electric drive machines do not have the energy loss and cooling requirements associated with hydraulic machines and are consequently more energy efficient.

In electric machines the power consumption is more evenly matched to the moulding energy requirements over the cycle and hence the direct energy consumption is reduced. Electric moulding machines also operate at a much higher power factor than hydraulic machines.

⁴ UK Good Practice Guide 292, Energy in Plastics Processing – A Practical Guide

3.2 Case Studies

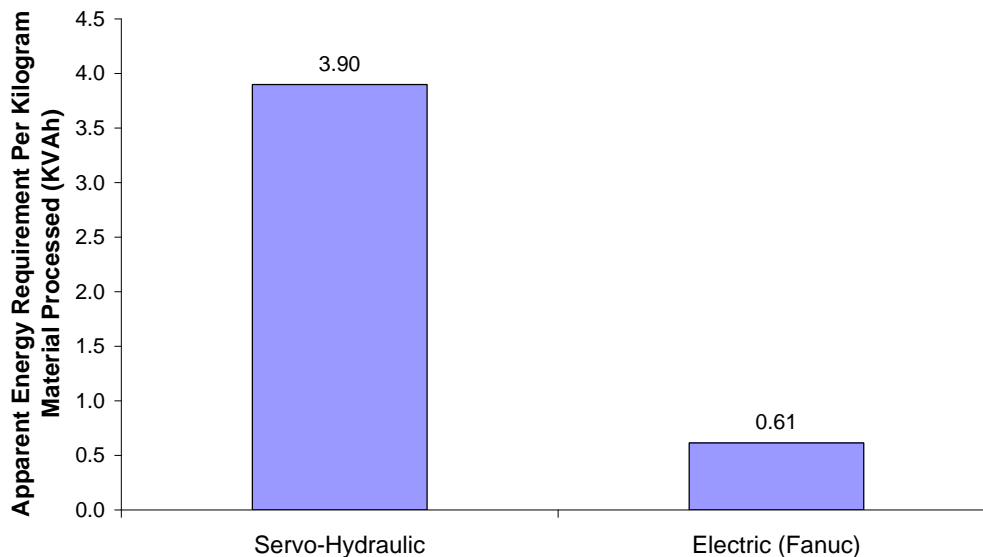
Although all-electric drive machines are a relatively new technology, a number of comparative studies have been carried out between the two. Following is a list of case studies carried out and the comparative energy consumptions reported.

Action Energy

Action Energy in the UK hosted a conference to increase awareness of energy efficiency improvements due to the use of electric machines.

Figure 5, reproduced from a presentation⁵ given at the conference, shows an electricity use of 3.9 kVA/kg for hydraulic machines and 0.61 kVA/kg for electric machines. In the same presentation, power factors of about 0.5 and about 1.0 are given for hydraulic and electric machines respectively. The electricity consumption for hydraulic machines is therefore about 1.95 kWh/kg, while the electricity consumption in electric machines is about 0.6 kWh/kg, or almost 70% less.

Figure 5: Specific electricity use for electric and hydraulic machines



Mitsui Machine Tool Europe

Mitsui Machine Tool Europe (MMTE) are European distributors for Fanuc electric moulding machines (in the 50T – 350T range) and Mitsubishi Heavy Industries (MHI) 350T and 450T machines. In a press release, MMTE cited a case study using a Mitsubishi 450T ME-II machine to produce fax housings.

The case study is based on production of 769,000 parts/year for the ME-II and 720,000 parts/year with a hydraulic machine of similar size. Annual product costs were estimated as being cut by €19,000. Electricity consumption of 33% (down from

⁵ Detailed Energy Measurements in Injection Moulding, A.J.Dawson, H.S.Rajamani, R.Collis, L.Owen, D.Owen, P.D.Coates, <http://www.faraday-plastics.com/energy/energy.htm>

26 to 10 KWh) and water consumption of 12.5% (down from 80 to 10l) compared to consumption by the hydraulic machine were the most significant cost saving factors.

On the MMTE website⁶, electricity savings of between 66% and 75% are reported for Fanuc machines and savings of 62% for MHI machines. The data from the website is reproduced in Table 2.

Table 2: Electricity and cooling water consumption for electric and hydraulic machines

		Fanuc Roboshot 100T	Hydraulic	
			125T	50T
Power- consumption	kWh/h	2.6	10.2	7.8
Cooling water	l/h	63	754	458

CADDET

Similarly, in a case study on an *AI-controlled electric moulding machine* published by the Centre for Analysis and Dissemination of Demonstrated Energy Technologies (CADDET)⁷, direct electricity savings of 66% and a 90% reduction in cooling load are cited.

Irish Case Study 1

In a comparative study, carried out in one of the Irish plants surveyed, between a 150T hydraulic machine and a 150T all-electric machine the electricity consumption shown in Table 3 was measured.

Table 3: Measured electricity consumption for electric and hydraulic machines in a plant in Ireland

Electric Machine	kWh/h	Hydraulic	kWh/h
Cold Start	9.0	Cold Start	21.0
Continuous running	5.7	Continuous running	19.8

This indicates a reduction in electricity consumption of 57% while warming up from a cold start (about 30 to 60 minutes) and a reduction of 71% during continuous operation.

Irish Case Study 2

A similar comparative study between a 300T electric machine and a 280T hydraulic machine in another of the plants surveyed found an average continuous running load of 29.9 kW for the electric machine and 51.9 kW average continuous running load for the hydraulic machine. This represents a saving of over 42%.

⁶ www.mmte.de

⁷ www.caddet.org

Summary and Average Electricity Saving

The electricity saving due to using all-electric machines depends on a number of factors such cycle duration, type of plastic and the complexity of a mould. The reported electricity saving from all the above case studies varies from 42% to 71%, with data in literature indicating electricity savings generally in the region of 60% to 70%. The median of the seven percentage reductions in electricity consumption reported is 66%, and it is therefore considered that an aggregate figure of 66% is a reasonable, conservative, aggregate electricity saving that would arise from replacing a hydraulic machine with an electric machine.

3.3 Indirect Energy Use

In addition to the direct reduction in electricity consumption in the injection moulding machine, the use of all-electric machines also reduces the demand for utilities such as machine and room cooling.

Machine Cooling

Cooling of the mould after injection of plastic and before opening the mould is required in both electric and hydraulic machines. An additional cooling load, to cool the hydraulic oil, exists in hydraulic machines. In the comparative studies cited above, a reduction in cooling water consumption of about 90% is cited. For a 100 T machine this equates to a reduction in cooling water use from 600 l/hr to 60 l/hr.

Production Room Cooling

Many of the injection moulding machines being used to produce components for the medical devices and electronics hardware sectors operate in a cleanroom environment. The heat radiated from the machines places an additional load on the chillers used to maintain the room at satisfactory temperature. An estimated 30% less heat is dissipated to the room by electric machines compared to hydraulic machines.

In a case study on *Energy Use in Cleanrooms* published by Sustainable Energy Ireland, energy savings of 2.5% in chillers were cited for a 25% reduction in room heating through lighting. This can be approximately extrapolated to a 3% reduction in electricity consumption in chillers for a 30% reduction in heat dissipated by moulding machines.

4. Environmental and Process Factors

4.1 Oil Consumption

The hydraulic oil used in hydraulic machines degrades over time and has to be changed regularly. Typically the oil is changed once a year. The quantities of oil vary according to the size of the machine. For example a typical 150 T machine contains about 350 litres of oil and a typical 80 T machine contains about 270 litres.

Assuming an average oil content of 300 litres, the total hydraulic oil inventory in the 2,000 machines in Ireland is 600 m³. With a yearly oil change this produces 600 m³ of waste oil per annum. Assuming a disposal cost of €100 per m³ this equates to an annual cost of €60,000 to the moulding industry.

4.2 Process and Quality Control

The uniformity of the product and cycle time are crucial considerations for operators of injection moulding machines. In comparative studies electric machines have been found to perform at least as well as the equivalent hydraulic machines in terms of all the key process parameters monitored.

4.3 Maintenance and Service

As electric machines have fewer moving parts than hydraulic machines they are generally acknowledged to be less prone to failure and require lower level of preventative maintenance.

Despite this, due to the novelty of electric machines in Ireland and the lack of a distributor and service infrastructure in Ireland, the availability of service personnel is seen as a barrier to the use of electric machines in Ireland by many of the companies surveyed.

Likewise the lack of in-house personnel experienced in operating and maintaining electric machines was cited as a barrier to their use by companies surveyed.

4.4 Noise

All-electric injection moulding machines are quieter than hydraulic machines, with sound power level reductions of up to 20 dBA being cited. This is significant from a workplace health and safety perspective. However, given that the machines are contained within buildings, often in cleanroom environments it is not significant from an environmental perspective.

5. Energy Consumption in the Injection Moulding Industry in Ireland

5.1 Methodology

The survey of the injection moulding industry carried out in 2002 gathered information on number of machines, range of machine sizes (T) and approximate output (tonnes per annum).

It is estimated that the average continuous running load in injection moulding machines is about 50% of the maximum rated demand⁸. Based on this assumption, and the average maximum rated power data collected in the energy survey, the average power consumption for different machine sizes contained in Table 4 is estimated.

Table 4: Average Power Consumption in Machines Surveyed

Size Range (T)	<50	50-99	100-149	150-199	200-299	>300
Average Power Consumption (kW)	6.6	11.4	19.5	23.4	30.9	39.7

For each of the 153 companies in the 2002 survey the data collected on machine sizes in the energy survey and the aggregated machine size distribution from Section 2 are used to estimate the range of machine sizes for each company.

The annual power consumption for each company in the 2002 survey is then calculated by estimating the number of machines in each of the above ranges, for which an average power consumption has been estimated; and, based on 6,000 operating hours per annum, multiplying the number of machines by the average power consumption. The 6,000 operating hours per annum is estimated based on 15 shifts per week for 50 weeks per annum which is a general operating regime reported in the companies surveyed.

This entailed calculating the estimated power consumption for 153 companies and the data is not presented here in the interests of brevity and clarity.

5.2 Electricity Use in the Moulding Industry

Based on this methodology, and the data on the number of machines and range of sizes for each of the 153 companies in the 2002 survey, an estimated 218,000 MWh per annum is used in injection moulding machines in Ireland.

⁸ UK Good Practice Guide 48, *Reducing Electricity Use in Injection Moulding*.

5.2.1 Validation of Methodology

Application of methodology to the companies surveyed

In order to check the validity of the above methodology, the data for these companies in the 2002 survey was used with the above methodology to estimate the electricity consumption in these companies.

The estimated annual electricity consumption in the 10 companies who provided sufficient data is 47,412 MWh, whereas the reported annual electricity consumption was 40,959 MWh. The above methodology and estimated total electricity consumption are therefore considered to be reasonably accurate.

Specific Energy Consumption

An alternative means of estimating the total electricity consumption in moulding machines is to apply the average specific energy consumption from the ten companies surveyed to the estimated annual output from the entire industry. The estimated total annual output is 63,000 tonnes and the average specific energy consumption is 2.95 kWh/kg giving an estimated total electricity consumption of 186,100 MWh per annum in the injection moulding sector. This is of the same magnitude as the estimated energy consumption of 218,000 MWh, and reinforces the fact that this is a reasonable estimate of the annual electricity consumption in injection moulding in Ireland.

6. Potential for Energy Savings

6.1 Energy Consumption in Injection Moulding Machines

As discussed in Section 2, the average continuous electricity consumption in a machine varies depending on a number of factors such as shot size, cycle time, type of plastic and complexity of the mould. Likewise, the difference in electricity consumption between electric and hydraulic machines varies.

In all the comparative studies referenced in Section 2, electricity savings of between 42% and 71% have been reported. Based on all the comparative studies referenced, the median electricity saving of 66% is considered a reasonable average saving to apply to the aggregated, estimated electricity consumption data. There is no apparent correlation between electricity savings and size of machines.

This represents a potential saving of about 144,000 MWh per annum if every hydraulic machine were replaced with an all-electric machine.

6.2 Indirect Energy Consumption

The primary indirect energy demands are for cooling for hydraulic oil and for air conditioning in clean room environments.

An estimated 30% of the total energy input into hydraulic machines is dissipated as heat through the hydraulic oil. It is necessary to cool the oil to maintain its viscosity and to prevent premature degradation of the oil. For a mid range, 150T, machine this equates to an estimated cooling water requirement of about 600 l/h. The corresponding requirement for an equivalent electric machine is about 60 l/hr or 10% of this figure.

The average rated power consumption of the machines surveyed is about 40 kW. Based on the 50% assumption this equates to an average continuous power consumption of 20 kW. The approximate proportion of heat dissipated to the cooling water is about 30% so the average thermal load is 6 kW per machine.

In the Integrated Pollution Prevention and Control reference note for cooling⁹ an average benchmark power consumption for circulating pumps and cooling towers of 30 kW_e per MW_{th} cooling is cited. For 2,000 machines with an average thermal load of 6 kW_{th} this equates to an aggregate thermal load of 12 MW_{th}. This equates to an average electrical load of 360 kW_e or 2,160 MWh/yr based on 6,000 operating hours per annum.

It should be noted that the figure of 30 kW_e per MW_{th} is a good practice benchmark and the actual energy use is likely to be somewhat higher.

6.3 Energy Management

In terms of electricity savings it is also worth noting that the average specific energy consumption in the ten companies surveyed is 2.95 kWh/kg, which is considerably higher than the 1.2 – 2.2 kWh/kg range from the UK Good Practice Guide cited in Section 2. This indicates that there is a general scope for reducing energy consumption beyond the reduction that can be attained solely by replacing hydraulic machines with electric machines. These reductions could arise through the implementation of better housekeeping measures and other general energy saving measures.

⁹ Reference Document on the application of Best Available Techniques to Industrial Cooling Systems, European Commission, December 2001

7. Greenhouse and Acid Gas Emissions

7.1 Context

7.1.1 Greenhouse Gas Emissions

Ireland is a signatory of the Kyoto Protocol the first commitment period, 2008 – 2012, of which is now approaching. The Kyoto Protocol entered into force and became legally binding on 16th February 2005. As part of Ireland's burden sharing agreement within the EU commitment, Ireland is limited to a 13% increase in greenhouse gas emissions over 1990 levels during the first commitment period.

Due to high economic growth in Ireland in the 1990s greenhouse gas emissions have grown steadily and were 25% above 1990 levels in 2003. Despite reductions in 2002 and 2003 emissions levels are expected to increase again and rise steadily to 2012.

Projections contained in the National Allocation Plan indicate that emissions for the 2008 – 2012 period will exceed the 1990 emission levels by about 30%. In absolute terms this equates to emissions of 9.2 million tonnes of CO₂ per annum above Ireland's Kyoto target level.

On a European level emissions have increased in recent years following a decrease in the early 1990s. In 2001 emissions were 2.3% below 1990 levels. It is projected that emissions in 2010 will be 0.5% below 1990 levels or some 7.5% short of the EU's target.

These data indicate that significant progress on emission reductions will be required in Ireland and in the EU if we are to meet our Kyoto targets. There are a number of flexible mechanisms allowed for under the Kyoto protocol (e.g. emissions trading) which allow for trading in carbon. EU Allowances (one tonne of carbon dioxide) are currently trading for about €19 and Certified Emission Reductions at €5 - €10 per tonne CO₂. A figure of €10 per tonne CO₂ is generally considered a reasonable estimate of the cost of CO₂ emission credits under the flexible mechanisms of the Kyoto Protocol.

The Government has signalled its intention to purchase credits to make up for the anticipated gap to our Kyoto commitment, which will give carbon emission reductions a definite monetary value.

7.1.2 Acid Gas Emissions

Acid gases, primarily SO₂ and NO_x, present both local and regional environmental impacts. Since the mid 1980s the problem of acidification and acid rain have been recognised and increasingly onerous emission ceiling thresholds have been, and are continuing to be, set. The latest of these is the Directive of the European Parliament and of the Council on National Emission Ceilings (NECs) (2001/81/EC).

The NECs for Ireland are shown in Table 5. To put these limits for 2010 in context they are compared to the 1990 levels and the 2002 levels¹⁰.

Table 5: Ireland's Obligations under the National Emissions Ceilings Directive

	1990 emissions (kt)	2002 emissions (kt)	2010 ceiling (kt)	kt reduction vs. 2002	% reduction on 2002 to meet 2010 Ceiling
NO _x	115	121	65	56	46 %
SO ₂	178	96	42	54	56 %

7.2 Carbon Emission Factor and Estimated Emission Reduction

The carbon emission factor for electricity usage is dependant on the mix of fuels and renewable energy sources used to generate the electricity. As this mix changes so too does the carbon emission factor. The latest reported CO₂ emission factor is 0.65 kg/kWh which is based on 2003 data.

However, as the generation mix changes, particularly with more gas-fired generation and renewable energy sources being added, the carbon emission factor is expected to change. Based on the projected mix of primary fuel consumption and electricity generated from the ESB's *Generation Adequacy Report*, together with carbon emission factors from the EPA, the carbon emission factor is expected to decrease from its current level of 0.65 kg/kWh to 0.52 kg/kWh by 2010.

Table 6 shows the estimated potential electricity savings (from a replacement of the stock of hydraulic machines with electric machines) and the corresponding CO₂ emissions reductions for both the current emission factor and the projected future emission factor.

Table 6: Estimated total potential electricity savings and CO₂ emission reductions

Parameter	Value
Estimated annual electricity use (MWh)	218,000
Estimated annual direct electricity saving (MWh)	144,000
Indirect savings (cooling) (MWh)	2,160
Estimated total annual electricity saving (MWh)	146,000
Estimated annual CO₂ saving (2003 emission factor) (tonnes)	95,000
Estimated annual CO₂ saving (2010) (tonnes)	76,000

An indication of the value of the estimated 76 to 96 kilotonnes per annum reduction in CO₂ emissions that can be achieved through switching to all-electric machines is between €760,000 and €960,000 per annum based on a €10 /tonne CO₂ price.

As 2010 is the mid point of the 2008 – 2012 Kyoto commitment period, the projected carbon emission factor of 0.52 kg/kWh is more pertinent to the greenhouse gas emission reduction value of electricity savings. This is therefore the figure used throughout the report.

¹⁰ The 2002 emission values for NO_x, SO₂ and VOC's are from the EPA 2002 Inventory

7.3 Acid Gas Emission Factors and Estimated Emission Reduction

The emission factors for SO₂ and NO_x, based on data from the ESB and from the EPA, are 0.55 g/kWh and 0.57 g/kWh respectively. Based on the potential electricity saving of 146 GWh per annum, the potential SO₂ and NO_x savings are 80 tonnes and 84 tonnes respectively.

8. Financial Analysis – Costs and Benefits to Industry

As with many energy efficient technologies there is a balance between higher capital cost for the energy efficient option and lower operating costs. From price lists for electric and hydraulic machines provided by Plastics Ireland, electric machines are between 40% and 70% more expensive than the equivalent hydraulic machine. Balanced against this are the lower energy costs detailed above and a slightly lower maintenance cost; the annual maintenance cost for hydraulic machines is about 2% of the capital cost while the cost for electric machines is about 0.5% of capital cost.

Table 7 shows the relative capital, electricity and operating costs for electric and hydraulic machines. The payback period, calculated for a 10% discount rate (DR), is also shown. In this we have disregarded the installation costs based on the assumption that the costs would be similar and, if anything, higher for hydraulic machines.

Table 7: Costs for electric and hydraulic machines and estimated aggregate payback period

	Capital Cost		Annual Electricity Cost ¹		Annual Maintenance Cost		Payback Period ²
	Electric	Hydraulic	Electric	Hydraulic	Electric	Hydraulic	
50 T	€80,000	€45,000	€1,385	€4,074	€400	€900	>15
100 T	€93,500	€65,000	€2,399	€7,056	€468	€1,300	8
200 T	€120,000	€80,000	€3,641	€10,710	€600	€1,600	8
300 T	€180,000	€110,000	€4,341	€12,768	€900	€2,200	14

1 Assuming an average electricity cost of 7 c/kWh and 6,000 operating hours per annum. 7 c/kWh was the average electricity cost reported by the companies surveyed. However, as the larger companies in the sector were surveyed, it is likely that the average cost across the whole sector may be higher.

2 10% Discount Rate

From discussions with operators of facilities it appears that some of the larger companies operate a seven year change-out policy, whereby machines are changed every seven years and any residual value is realised through selling the machine. Smaller operators tend not to have such a policy and will continue to operate older machines. We understand that the lifetime of hydraulic machines is about 60,000 hours and that the lifetime of electric machine may be somewhat more.

It is evident that machines in the approximate 100T to 200T range may offer a viable means of reducing energy consumption and achieving CO₂ emission reductions, albeit not within the typical lifetime of 7 years. The difference in capital cost between electric and hydraulic machines less than 50T and greater than 300T is, at present, too big to be justified by the electricity savings.

As about 70% of the moulding machines in Ireland are within the 100T – 200T size range this does not unduly reduce the scope for electricity savings across the industry.

9. Case Studies

The above financial analysis was carried out using average, general, data and demonstrates the average typical savings, costs and carbon emission reductions that can be achieved on an aggregate basis. However, as discussed above, both the electricity use in moulding machines, and the electricity savings that arise due to switching to all-electric machines are dependant on diverse factors such as shot size, cycle time, type of plastic and complexity of moulds. In order to demonstrate specific cases two case studies, based on information submitted as part of the survey are detailed following.

Case Study 1

This case study is based on a comparative analysis, carried out by one of the companies surveyed, of a 150T electric and a 150T hydraulic machine. The analysis comprised operation of both machines and logging power consumption and process parameters.

The electricity consumption for the electric and hydraulic machines is summarised in Table 8. The electric machines operate for 8,000 hours per annum.

Table 8: Electricity consumption for electric and hydraulic machines – case study 1

	Electric (kWh/h)	Hydraulic (kWh/h)
Cold Start	9.0	21.0
Continuous Running	5.7	19.8

Case Study 2

This case study is based on a comparative analysis, carried out by one of the companies surveyed, of a 300T electric and a 280T hydraulic machine. The analysis comprised operation of both machines and logging power consumption and process parameters.

The electricity consumption for the electric and hydraulic machines is summarised in Table 9. The machine operates for 6,000 hours per year.

Table 9: Electricity consumption for electric and hydraulic machines – case study 2

	Electric (kWh/h)	Hydraulic (kWh/h)
Continuous Running	29.9	51.9

Comparative Analysis

The capital costs for electric and hydraulic machines are taken from the price lists supplied to us, as the companies who furnished the electricity consumption data did not wish to disclose either the vendors of the specific equipment used or the relative costs. The maintenance cost assumptions of 2% and 0.5% of capital cost are used and an average electricity price of 7 c/kWh is assumed. Table 10 contains the summarised costs and payback periods for both case studies.

Table 10: Costs and payback period for electric and hydraulic machines – case studies

	Capital Cost		Annual Electricity Cost		Annual Maintenance Cost		Payback Period for 10% DR
	Electric	Hydraulic	Electric	Hydraulic	Electric	Hydraulic	
Case 1	€80,000	€45,000	€3,192	€11,088	€600	€1,500	8
Case 2	€93,500	€65,000	€12,558	€21,798	€900	€2,200	12

The payback periods for case study 1 and case study 2 are unlikely to be attractive, although the cost over a 10 year period may not be unreasonable if a long term view is taken and the value of the carbon is made available to an operator in the form of incentives.

10. Energy Efficiency in the Plastics Industry

As stated above, the specific energy consumption in the injection moulding industry, at 2.95 kWh/kg is significantly higher than the range of 1.1 to 2.2 kWh/kg cited in the¹¹ UK good practice guide. This indicates that there is significant scope for general energy savings apart from those that can be attained through replacing hydraulic machines with all-electric machines.

It is notable that, despite being the single largest process used, injection moulding only accounts for 63,000 tonnes of the 247,000 tonnes of polymer processed in Ireland each year.

Although no data on specific energy consumption for other process is published, the energy intensity of different processes has been ranked in the UK Good Practice Guide. This data, reproduced in Table 11, indicates that injection is one of the more energy intensive processes, but that other processes such as extrusion and thermoforming use comparable amounts of energy, while other processes such as blown film are more energy intensive.

Assuming, as a rough estimate, that the specific energy consumption for plastics process in general is the same as that for injection moulding, the total electricity consumption in plastics processing is estimated at 740 GWh per annum.

¹¹ UK Good Practice Guide 292, Energy in Plastics Processing – A Practical Guide

Although the nature of energy use, and hence the potential for energy savings, differ for different processes there is scope for energy saving in all processes. For example, in blow moulding savings can be achieved through reducing the melt temperature of the plastic and also through optimising the supply and use of compressed air.

The potential savings throughout the plastics industry cannot be quantified without a detailed study and survey of companies using different plastic processes, however it is evident that even a moderate reduction in energy consumption could yield significant savings.

Table 11: Energy intensity of plastics processes

Process element	Blend compound	Plasticise	Expand surface area	Heated mould	Cooled mould	Cure	Total process intensity
<i>Main processes</i>							
Extrusion	4	2	–	–	2	–	8
Blown film	4	2	3	–	3	–	12
Injection moulding	3	2	–	2	2	–	9
Compression moulding	–	1	1	3	–	5	10
<i>Lesser used processes</i>							
Thermoforming	1	–	1	3	2	–	7
Foam	1	1	2	–	–	2	6
GRP lay-up	1	1	–	–	–	3	5
Dough moulding	2	1	2	3	–	3	11
Compounding	3	1	–	–	2	–	6
Rotational moulding	2	1	1	2	2	–	8
Calendering	3	1	–	–	1	–	5
Spreading	2	2	–	–	2	–	6

For some processes other than injection moulding an all-electric alternative technology also exists, namely thermoforming and blow moulding. Although these account for a small percentage of the plastics processed in Ireland, they are examples of other areas where energy savings can be achieved in the plastics industry.

11. Barriers and Incentives

11.1 Barriers to Widespread Use of Electric Machines

Although the use of all-electric moulding machines can offer reasonable payback periods and lifetime cost savings in a number of cases, the penetration of electric machines into the Irish market has been very low to date. At present there are an estimated 75 all-electric machines in Ireland, representing less than 4% of the total number of machines. From discussions with personnel in injection moulding facilities, we found that the primary reason given for this is the higher capital cost of all-electric machines. This is particularly true for the smaller moulding companies who have more cash flow constraints and make investment decisions over shorter timeframes.

Likewise, in the smaller companies, the age profile of the machines is much older as they are less likely to operate a change-out policy and tend to continue operating old machines until failure.

Finally, as electric machine represent a new and very different technology and require new skills to operate and maintain, the lack of in house skills also presents a barrier to the introduction of electric machines into companies with experienced personnel with a long history of operating and maintaining hydraulic machines.

11.2 Incentives

As the primary barrier to the widespread use of all-electric injection moulding machines is the higher initial cost, obviously an incentive in the form of a capital investment subsidy, grant or interest free loan would make the use of all-electric machines more attractive. This barrier is effectively a capital market failure, and the National Climate Change Strategy, 2001, suggests that tax concessions, low cost loans and grants are the main means of addressing this failure.

11.2.1 Incentive Schemes in Operation Abroad

We carried out a review of incentive schemes operating in other countries in order to evaluate what models for an incentive scheme might be appropriate for an Irish context.

UK - Carbon Trust - Action Energy

Enhanced Capital Allowances

The Enhanced Capital Allowance (ECA) scheme is designed to assist organisations invest in energy saving equipment and allows organisations write off the entire cost of the energy saving equipment purchased within the first year of investment. This would apply to the full cost of the equipment and would offer a substantial incentive by reducing payback periods. However, given the low rate of corporation tax in Ireland this form of scheme would be less likely to promote investment in energy efficient equipment here than elsewhere.

Interest Free Loans Scheme

The Carbon Trust in the UK offers interest free loans over 5 years to SMEs for investment in energy saving equipment with a payback of five years or less. Loans of between £5,000 and £100,000 are available.

There are limitations to the availability of interest free loans which derive from EU State Aid Guidelines. For example certain sectors are excluded, there is a limit on the total value of benefits and the scheme is confined to SMEs.

The EU defines a SME as a company with:

- 1) Less than 250 employees
- 2) Less than €40m turnover or
- 2b) Less than €27m assets
- 3) No controlling interest more than 25% by a non-SME (i.e. it is not part of a larger organisation)

Where significant energy savings have been identified, these loans will effectively provide the capital for investing in energy efficient technologies which is repaid at zero cost to the company over a period of under five years.

Energy Surveys

Free energy surveys by specialist consultants are available to all companies with an annual energy bill in excess of £50,000 (€75,000).

Incentives in the US

Throughout the US, there are incentive schemes in place to promote reduced energy consumption and the efficient use of energy. These are primarily made available and administered by local electricity authorities and the extent and type of incentives available is therefore very regionalised. The drivers for the programmes also vary, but are generally a combination of reducing demand to avoid upgrading infrastructure and environmental concerns.

The form of incentives also varies from rebates based on annual energy savings to grants which subsidise the difference in capital cost between different technologies. A number of electric machine suppliers in the USA have actively pursued funding opportunities for increased energy efficiency and have reported increased sales of electric machines as a result.

Incentives in Other European Countries

Voluntary or negotiated agreements have been successfully used in some European countries (most notably the Netherlands and Denmark) as means of promoting a transition to more energy efficient technologies. These are often coupled with a financial incentive to meet the agreed performance or targets. Agreements can take the form of target based agreements, where there is a definite penalty for not meeting set targets or performance based agreements where no definite penalties or incentives apply.

11.3 Models for Irish Incentives

The primary barriers to the widespread use of all-electric machines are the greater capital cost of electric machines and short term investment cycles of plastic companies and the low level awareness of energy efficiency in the sector. This low level of awareness is demonstrated by the fact that specific energy consumption in the sector is significantly higher than best practice benchmark data.

Therefore, the optimum form of a measure from the point of view of promoting the use of electric machines and other energy efficient technologies in the plastics industry is likely to be a combination of economic measures coupled with a voluntary or negotiated agreement framework.

The most effective incentives to address the greater capital cost of all-electric machines are likely to be either a capital subsidy or interest free loan based on the price differential between hydraulic and all-electric machines. The incentive for investing in all-electric machines (e.g. interest free loan or tax allowance) could then be coupled to general performance targets and the implementation of energy efficient technologies throughout the industry.

A voluntary energy agreement for the plastics sector together with a programme for promoting energy efficiency in the plastics sector (workshops, case studies, guides etc) would address the information and awareness barrier.

Pending the development of schemes to promote energy efficiency in the plastics industry, existing schemes such as the EPA's Cleaner Greener Production Programme could be used to promote energy efficiency in the sector.

12. Financial Analysis – Costs and Benefits to the Economy

The costs and benefits of implementing two different incentive schemes: an interest free loans scheme and a voluntary agreement scheme are presented here.

12.1 Interest Free Loans

A zero interest loan would offer a cost effective means of promoting reduced CO₂ emissions. At present, approximately 50 new injection moulding machines are purchased in Ireland each year. Assuming that an incentive of a €30,000 interest free loan over five years was available for the purchase of all-electric machines and that 50 all-electric machines were purchased, the cost to the Government would be €1,500,000 per annum. For each year's tranche of loans the Government would recover €300,000 per annum over the following five years. Assuming each machine saves an average of 38 tonnes of CO₂ per annum (the average saving that can be achieved), annual CO₂ savings of 1,900 tonnes CO₂ will be achieved for each tranche of 50 all-electric machines. At €10 per tonne CO₂ the annual value of these savings is €19,000.

The Net Present Value of revenues, based on a 3.5% rate of return over a ten year period, of €1.5 million in interest free loans is €1,512,000. This indicates that such a scheme would offer a cost effective means of achieving a reduction in CO₂ emissions with a cost of carbon abatement of -€0.65/tonne CO₂ below the assumed value of CO₂ of €10 per tonne. Obviously the scheme would be more attractive for a higher cost per tonne CO₂ and less so for a lower cost.

Furthermore, the scheme could be designed so that the loans are only available for all-electric machines where a higher level of CO₂ savings will be achieved, which would further improve the cost effectiveness to the scheme.

12.2 Voluntary Agreements

Voluntary agreements have proven to be a successful means of improving the efficiency with which energy is used. For example SEI's LIEN long term voluntary agreements annually report 1.5% increases in energy efficiency. The Dutch voluntary energy agreements have reported annual energy efficiency improvements up to 1.8%, and long term savings of 22%. The Danish energy agreements programme reports savings in the scheme of 10-15%.

Assuming an electricity consumption of 740 GWh per annum (see Section 10) in the sector and a 20% annual energy saving, a voluntary agreement scheme could save 150 GWh per annum. This would result in an annual reduction in CO₂ emissions of about 78,000 tonnes per annum, with a value of €780,000 per annum based on a cost of €10 per tonne CO₂. These figures are only a general indication of the magnitude of savings that might be achieved and more exact estimates of the energy consumption in the plastics sector and the energy savings that could be achieved through a voluntary agreements scheme could form the basis of a further study.

The cost implementing and administering a voluntary agreements scheme cannot be quantified, however Sustainable Energy Ireland are currently implementing a voluntary agreement scheme, and the plastic industry could be incorporated as a sector in the scheme.

13. Conclusions

An estimated c. 145,000 MWh of electricity consumption can be saved per annum by replacing the existing stock of hydraulic moulding machines in Ireland with electric machines. This would result in an estimated reduction in CO₂ emissions of 76,000 tonnes per annum.

To place this in context, Ireland's target under the Kyoto protocol is 60 million tonnes of CO₂ equivalent per annum, and the expected shortfall is estimated at 9 million tonnes CO₂ per annum. In the National Climate Change Strategy a reduction of 1 million tonnes of CO₂ in the industrial sector is targeted. Replacing all the hydraulic machines with all-electric machines, reducing would therefore achieve 7.6% of the target CO₂ reduction for the entire industrial sector.

The attainment of these savings would best be promoted through the implementation of an incentive scheme based on a combination of economic incentives and a voluntary agreement arrangement. Economic incentives could take the form of grants or low interest loans as described in Section 11.

Carbon emissions will have a real cost to the economy from 2008, from which time the Government will have to procure carbon credits for any emissions in excess of our Kyoto target. Therefore the use of all-electric machines would reduce the quantity of carbon credits that the Government will have to purchase on the international carbon market and the costs associated with a grant aid or zero interest loan scheme would be recovered through the value of the reduced CO₂ emissions.

By linking incentives to negotiated agreements, the incentives would be drivers for general savings that can be achieved through typical energy efficiency measures and the scheme could be extended to the entire plastics industry to allow all cost effective energy, and CO₂ emission, savings in that sector to be realised. When devising the form of the voluntary agreement, more detailed studies into energy savings technologies, such as all-electric technologies in the thermoforming and blow moulding industries, would be warranted.

APPENDIX 1

Survey Questionnaire

Plastics Industry Energy Study – Survey Questionnaire

- 1. Has an audit of energy use at your site been carried out _____ Y/N
(If so can you provide us with a copy?)
- 2. Annual electricity use 2003 and 2004 _____ kWh
- 3. Are these years representative of output for period 2005-2010 Yes/No
- 4. Electricity use for moulding machines _____ kWh
- 5. Maximum Import Capacity/ Maximum Demand _____ kW
- 6. Annual production output from moulders _____ Tonnes
- 7. Specific Electricity Consumption _____ kWh/Tonne
- 8. Cost of electricity in 3rd Quarter 2004 _____ c/kWh (day)
_____ c/kWh (night)
- 9. Do the machines operate in a clean room environment _____ Y/N
What class is the clean room _____
- 10. Do you have electricity meters on moulding machines _____ Y/N
(If so can you provide us with data on energy consumption?)
- 11. Have you recently purchased moulding machines (in last 2 years) _____ Y/N
Were they been electric or hydraulic _____
Summary of reason for selection:.....
.....
.....
(Can you provide us with any details of a cost-benefit analysis
of electric vs hydraulic machines?)
- 12. Size and number of moulding machines – please fill in table on following page.

[Note where there are several virtually identical machines on site with same size, model number, age etc. indicate the number of replica machines in column 8 and an average for the annual run hours for these type of machines in column 7. Distinguish between machines with different cooling systems.]



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