Resource Efficiency in

Ireland's Dairy Processing Sector

Benchmarking Resource Efficiency in Irish Dairy Processing

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1.0 Executive Summary

Ireland has been dairy farming for 6,000 years and has been a major exporter of dairy products since the 16th century. Today the industry, which comprises some of the world's most successful food companies, especially in the areas of dairy ingredients and infant nutrition, accounts for 30% of Ireland's agricultural output and enjoys an annual turnover of €3.4 billion. In the coming years, due to increasing market demand, CAP reform, the abolition of the milk quota system and enhanced milk production, the dairy processing sector is poised to expand and extend its market reach. Because of its overwhelming reliance on exports, which account for nearly 75% of turnover, it is vital that the sector meet customer expectations of resource efficiency and environmentally sustainability. For this reason, Environment & Green Technologies Department of Enterprise Ireland undertook a review of the sector in order to measure performance in Ireland and benchmark this against international best practice. The review assessed data from 15 plants representing over 90% of Ireland's milk processing capacity.

Between 2006 and 2009, the Irish dairy sector invested significantly in energy conservation including the recovery of heat from condensate/evaporate/ effluent/pasteuriser water), low energy cleaning/disinfection systems, insulation of pipes and tanks, economisers, lighting control, variable speed motor drives, etc. and the implementation of energy management systems. This resulted in a 20% reduction in mean annual energy use per plant (204,682 MWh to 163,771 MWh) which equates to a mean emission reduction of 11,000 tonnes of CO_2 per plant. Despite only accounting for 15% of total energy use, reductions in electrical use per tonne of product were double that of thermal use per tonne due to the relatively low cost of metering and implementing change. Between 2005 and 2009, mean water consumption per tonne of production fell by 28% (20.7 – 14.9 m^3/tonne) representing an average annual saving of 200 million litres of water per plant.

Ireland's average annual domestic milk production in 2009 was 5,173,000 litres of which 9.5% was sold as liquid milk. The remainder (4,681,000 litres) was processed into dairy ingredients and commodity products. 15 plants processed 94% of this milk (4,416,662 litres) into 863,588 tonnes of product comprising yellow products (cheese, butter, spreads - 304,228 tonnes), powder products (265,000 tonnes), whey products (124,700 tonnes), casein (33,000 tonnes) and a range of others including chocolate crumb, lactose, cream products, skim/whey concentrates, whey alcohol and UHT (136,630 tonnes). In 2009, the Irish sector consumed 2,431,676 MWh of energy, 97% of which can be accounted for in terms of processing (direct & indirect) and utilities. This energy can be divided into electricity (390,225 MWh; 451.9 kWh/tonne) and thermal energy (2,041,451 MWh; 2,364 kWh/tonne). 57% of electricity was sourced from on-site generation (primarily CHP) while the remainder was sourced from the National Power Grid. Three fuels – natural gas (69%), fuel oil (20%) and coal (8.7%) – provided most thermal energy.

The following is the mean energy use per tonne and the relative proportion of electricity use to thermal energy use for each of the 5 main product outputs from Irish dairy processing:-

- Butter - 363 kWh/tonne (40% electrical/60% thermal)
- Cheese - 814 kWh/tonne (40% electrical/60% thermal)
- Milk Powders - 4,012 kWh/tonne (12% electrical/88% thermal)
- Whey Powders - 4,613 kWh/tonne (18% electrical/82% thermal)
- Casein - 6,803 kWh/tonne (30% electrical/70% thermal)

Whey alcohol production consumed 10,704 kWh/tonne (10% electrical/90% thermal). Mean energy use in the manufacture of butter and cheese was 363 kWh/tonne and 814 kWh/tonne respectively (40% electrical/60% thermal). Data from Irish dairy processors in 2009 compared favourably with industry benchmarks for the UK, USA, Australia, Holland, Scandinavia and with European BAT guidelines. The industry continues to explore ways to improve resource efficiency and to substitute fossil fuels with renewable alternatives, with a view to safeguarding Ireland's position as one of the most sustainable locations in the world for dairy processing.

In 2009, the 15 plants representing 94% of Ireland's dairy processing sector produced generated 469,471 tonnes of CO_2 (tCO_2) or 543.6 $kgCO_2$/tonne of product. This can be allocated to electrical (169,104 tCO_2; 196 $kgCO_2$/tonne) and thermal (300,369 tCO_2; 348 $kgCO_2$/tonne). This averages out at 31,298 tCO_2 per plant although the actual range was 8,000 – 88,000 tCO_2, depending on the product range in each plant. Energy consumption per tonne, and corresponding CO_2 emissions per tonne depended on the relative proportion of yellow to powder products. Yellow products such as butter, cheese & dairy spreads have a significantly lower energy intensity than powder products such as milk/whey powders and casein as follows:-

- Butter – 139 $kgCO_2$/tonne
- Cheese – 280 $kgCO_2$/tonne
- Milk powder – 875 $kgCO_2$/tonne
- Whey powder – 1,337 $kgCO_2$/tonne
- Casein – 2,067 $kgCO_2$/tonne

Plants which have access to on-site CHP-generated electricity and steam (i.e. 7 of 15) generated, on average, 569 kg/tonne of product compared with 724 kg/tonne of product for dairy plants which generate steam on site using standard boilers and which source electricity from Ireland's power generation grid (0.553 $kgCO_2$/kWh). The difference is more pronounced in CO_2 emissions associated with thermal use (489 v 569 $kgCO_2$/tonne) than with electrical use (225 v 236 $kgCO_2$/tonne). This is due to the convention which assigns the conversion loss to the electrical fraction.

This independent study indicates that the sustainability performance of the Irish dairy processing sector compares favourably with international competitors. It also clarifies where the energy is used in production and ancillary processes such as utilities, and how this is dependent on the product/process mix in the individual plants. It is expected that this information will identify those plants with superior performance, encourage those with scope for improvement and that all will use the data as a benchmark against which future improvements can be measured.

2.0 Introduction

2.1 The origins of dairy farming in Europe

From the beginning, Ireland was endowed with all of the natural advantages for dairying such as good soil, mild climate under the influence of the Gulf Stream and moisture bearing south-westerly winds[1]. It could be said that the blueprint for dairy farming and processing is encoded into our genes. As recently as 6,000 years ago, most of stone age Europe was lactose intolerant and, therefore, could not consume milk beyond infancy. However, around 5,800 years ago, a mutated form of the lactase gene appeared in Northern Europe which allowed milk proteins to be digested[2]. Archaeological evidence from the Ceide Fields in the west of Ireland, the world's most extensive Stone Age monument and the earliest evidence of dairy farming anywhere in Europe, prove that there were dairy farmers in Ireland as early as 5,700 years ago. The site, which is preserved under 5m of peat bog, consists of ten square kilometres of enclosed highly-organised dairy farmland divided up into regular field systems bounded by dry stone walls. The theory is that the early dairy farmers evolved the ability to consume dairy products into adulthood and, given that Irish dairy farmers were among the first in Europe, it is not unreasonable to assume that Irish farmers were among the first Northern Europeans to exhibit this new trait.

By the turn of the 1st millennium, milk and dairy products were staple foods throughout Ireland. Under the Brehon Laws, one of the world's earliest codified legal systems, a divorced woman was entitled to one sixth of the produce of the churn. By the 16th Century, the seasonality of milk supply had far reaching implications on Ireland's defences. Sir George Carew in 1596 suggested that the Irish were most vulnerable to attack in February when our dairy stocks were at their lowest. By the mid-17th Century Irish butter had emerged as a significant export commodity. Ireland's dairy herd of 600,000 cows (compared with 1.1 million today) annually yielded 1.8 million tonnes of milk. In 1685 the Government sought to regulate the trade and to eliminate abuse. The Industrial Revolution resulted in increased demand for butter and, from around 1760 onwards, England began to import Irish butter in quantity quickly becoming our main export market. In 1769, merchants in Cork formed a voluntary organisation to oversee the public inspection, branding and marking of butter for export. For over a century the price of graded butter on the Cork Butter Market was the recognised world price and ships from Sweden, Denmark, Holland, France, Portugal and Spain regularly called in to Cork to purchase butter for their respective colonies.

In the 17th and 18th centuries Ireland dominated the export of butter to northern Europe and the Americas in the same way that Holland dominated the cheese market at that time. The great bulk of this butter was shipped from Cork and Waterford. Cheese making, which had been well-established in Ireland, began to decline amongst the native Irish population during this period. By the 19th century domestic cheese production was negligible and Ireland faced competition from Great Britain where the population had become more urbanised and which had started to produce its own butter in response to market demand for a lighter salted butter product. As demand in these overseas markets dwindled, and consumer preferences closer to home changed, Irish dairy farmers and traders were slow to adjust to the new conditions. France, Holland and eventually Denmark all emerged as successful exporters to the British market. Ireland's modern Irish agribusiness sector emerged with the establishment of the dairy co-op movement in Ireland in 1889, and the formation of the first dairy co-operative. Since then, the dairy industry has evolved into its present-day structures, with 30 societies registered here for the year ended 2009.

2.2 Dairy Products and Processing in Ireland

Raw milk consists of milk solids, including proteins, carbohydrates, organic acids and minerals, dispersed in water. Dairy processing mostly involves the concentration and separation of these solids using techniques based on weight, molecular structure and boiling/freezing points, or by using micro-organisms to effect separation or impart characteristics. The national dairy herd comprises ~1.1 million dairy cows and domestic intake by Irish dairies (creameries and pasteurisers) in 2010 was 5,173 million litres, an increase of 8% on 2009. Only 9.5% (492 million litres) of this was sold as liquid milk for human consumption while the remainder was processed into high-value dairy ingredients and commodity products. These include butter, cheese and milk powders such as infant nutritional products, skimmed milk powder (SMP) and fat-filled milk powder (FFMP), whey products and casein products (see Table 1). Traditionally individual plants would have produced either cheese and whey products OR butter/butteroil and powder products. However, today certain plants specialize in the production of powders, cheeses or whey products. Whey, a by-product of cheese-making, is often concentrated and transferred to specialised plants for fractionating and processing into whey powders and other products such as whey butter, alcohol and whey-based cheese products. Others plants respond to market demand by producing a range of different products at different times of the year including cheese, butter, powders, whey, casein, etc in order to maximize utilisation capacity.

Dairy Products	Production in 2009 (tonnes)
Total yellow products (butter, cheese, spreads, butteroil)	*304,228*
Butter	135,100[7]
Cheese	162,600[7]
Total Powders (infant nutrition, milk powders, whey powders)	*265,000*
Milk powder (skim milk powder, fat-filled milk powder, etc.)	181,000
Infant nutritional products	84,000
Whey products	*124,700*
Others (lactose, chocolate crumb, cream products, whey alcohol, skim/whey concentrates, UHT)	*136,630*
Casein	33,000

Table 1 Dairy production in 2009/2010 by Ireland's Dairy Processing Sector. Estimates, apart from the CSO figures for cheese and butter, are based on production figures from the companies participating in the benchmarking study

2.3 Ireland's Dairy Industry Today

Today, Ireland's dairy industry has regained its position in the forefront of world dairy processors. With a turnover of €3.4 billion, €2.5 billion of which derives from exports, and 7,000 direct employees, dairy processing is one of Ireland's key exporting industries again and one of our biggest employers. Furthermore, it supports 19,000 dairy farmers and accounts for 30% of Ireland's agricultural output. Competitive pressures resulted in the consolidation of many major processors in the 1990s and early 2000s, although not to same extent as in other countries with major export-oriented dairy countries such as New Zealand, Denmark and Holland which each have one dominant processor[5]. In Ireland, six companies process 80% of milk produced - Glanbia, Kerry Group, Dairygold, Carbery Foods, Lakeland Dairies and Tipperary Co-op. Other major processors include Arrabawn and Connacht Gold. The industry is heavily export-orientated with 80% of production destined for international markets such as the UK and Europe which account for 35% and 28% of exports respectively. Only 9.5% of domestic milk intake by processors in 2010 (i.e. 5,173 million litres) was consumed as liquid milk (492.2 million litres) while the remainder was processed into yellow products such butter, butteroil, cheese and dairy spreads (302,228 tonnes), powder products (265,000 tonnes) such as infant nutritionals, skim milk powder, fat-filled milk powder, whey products (124,700 tonnes), casein (33,000 tonnes) and a wide range of other products (136,630 tonnes) including lactose, chocolate crumb, cream products, skim/whey concentrates, whey alcohol and UHT milk. The industry attracts significant foreign direct investment and, over the last two decades, due to investment by Abbott, Danone and Pfizer, Ireland has become one of the world's leading producers of infant nutritional products accounting for 15% of the global supply.

Annual growth of 2.5% in worldwide dairy consumption, combined with the ongoing reform of CAP and the abolition of the milk quota system in 2015, will provide Ireland's dairy exporters with significant growth opportunities, especially in the developing world where populations are predicted to double by 2050[4]. Capitalising on this market growth will require a coordinated approach by dairy processors to improve their processing efficiencies, in terms of plant size and utilisation of capacity. It will also require an increase in production of commodities (powders, butter and bulk cheddar) while, at the same time, reducing overall dependency on these commodities by boosting production of higher-value, market-led products such as speciality cheeses, food ingredients and innovative functional foods. This shift to higher-value, market-led products is important due to anticipated reductions in intervention prices for butter and skim milk and to the elimination of export subsidies which currently range from 30% - 40%. Fully capitalising on this market growth will also require a sustained investment in marketing, highlighting both Ireland's sustainable farming and processing techniques[5]. To this end, Enterprise Ireland is assisting the industry to adopt Lean Manufacturing and other sustainable manufacturing practices as a means of enhancing its international reputation through improved resource efficiency and cost-competitiveness. Enterprise Ireland is also working closely with the dairy industry to exploit the health-giving benefits of Irish dairy produce by developing leading-edge, market-led products under the Food for Health Ireland programme. Under this programme, the health benefits of bioactive ingredients derived from milk are being explored in early infant development, colorectal cancer, metabolic syndrome, infection and immunity.

2.4 The Irish Dairy Board (IDB)

Established in 1961, the IDB's main function is to market the products of its member manufacturing co-operatives and dairy companies. The IDB accounts for 50% of Ireland's dairy exports. As owner of the renowned Kerrygold brand, the IDB exports consumer products, food ingredients and commodities to 93 countries, primarily the EU[6]. The fact that Ireland's dairy herd is predominately grass-fed confers distinct advantages, in terms of sustainability, in the export markets.

2.5 Environmental Issues in Dairy Processing

The main environmental impacts associated with dairy processing relate to the sector's use of water and energy and to the generation of waste water. All of the plants included in this study are licensed by the EPA under the IPPC Directive and are required to engage continuously in the application of integrated preventative environmental strategies to processes with a view to reducing their environmental impacts. All processing plants are required to have in place an Environmental Management Plan contained in their Annual Environmental Report (AER) which sets out impact reduction targets for the coming year. The AER, which is submitted annually to the EPA, also describes improvements that have been made in the previous 12 months.

2.6 Benchmarking Environmental Performance

Benchmarking is a powerful tool to indicate how much room there is for improvement by establishing best, worst and mean levels of performance in terms of energy/water use per tonne of product or per m^3 of milk processed. Benchmarking can be used to compare the performance of plants within Ireland, or to compare Irish plants with their international competitors. Establishing Ireland's performance relative to international best practice, however, has proved difficult due to a relative paucity of in-dept, comparative energy studies focussing on the dairy industry elsewhere. This is due to a wide variation in products and processes, coupled with a lack of reliable data. This despite the rapidly expanding nature of the industry which generates a higher turnover than any other food business[9] and consumes large quantities of energy and water worldwide.

2.7 Objectives

This study aims to

(i) measure improvements in energy and water efficiency across the Irish dairy processing sector between 2005 and 2009 by comparing energy/water use per tonne of production and per cubic meter of milk processed.

(ii) conduct an in-depth analysis of 2009 energy use within the dairy sector with a view to dividing energy use into its thermal and electrical components and then to further sub-divide each into its component parts, i.e. direct processes (e.g. evaporation, drying, ultrafiltration), indirect processes (e.g. standardisation, intake, separation, distribution, CIP) and utilities (refrigeration, compressed air, effluent treatment, etc.).

(iii) produce energy maps for each of the main product groupings – butter, cheese, milk powders, whey powders and casein, and to use this data to calculate energy benchmarks and best practice guidelines for use by the industry in comparing their performance with their Irish and international competitors and for determining which processes/utilities to target for investment with a view to improving efficiencies, reducing costs and limiting environmental footprint.

3.0 Methodology

Initially, 18 IPPC-licensed, dairy processing plants representing 12 companies were invited to participate in this study. Of these, 15 plants (owned by 10 companies) agreed to participate. Each plant was visited and data was collected on production, milk consumption, energy (fuel + electricity) and water use between 2005 and 2009. Where available, metered data was collected on energy use in each process (direct and indirect) and in each utility (refrigeration, compressed air, effluent, etc.). Where metered data was not readily available, as was the case with thermal energy distribution in most plants, shares of total thermal (i.e. total annual MWh of fuel consumed) were allocated to processes (direct and indirect) and utilities which, in turn were allocated to individual products. Such estimates were calculated in conjunction with the energy personnel at each plant and related to (a) the average quantity of steam per hour required by a particular process, (b) the number of hours of processing time allocated to a particular product and (c) the share of utilities allocated to that product.

Direct Process Thermal Use = [fuel used/tonnes of steam **x** tonnes of steam/hour used in process **+** fuel/hour used in direct heating] **x** processing time per product;

Indirect Process Thermal Use = fuel used/tonnes of steam **x** tonnes of steam/hour used in intake/separation **x** relative proportion of intake/separation allocated to a given product;

Utility Thermal Use = fuel used/tonnes of steam **x** tonnes of steam/hour used in effluent treatment **x** proportion of effluent treatment allocated to a given product.

Total Thermal Use = Direct Process + Indirect Process + Utility

Where metered data for electrical was not available, total electrical usage was allocated to individual products in the same way. These figures were then divided by (a) the tonnes of product and by (b) the m^3 of milk processed to yield basic energy maps for each plant allowing easy cross comparison.

Pursuant to Objective 1 of the study, figures for total annual energy and water use for each plant between 2005 and 2009 were determined. All IPPC-licensed plants maintain accurate records of annual water, fuel and electricity use. Sources of water include local authority supplies, on-site groundwater wells, and surface water abstracted from rivers and lakes. Sources of electricity include the national power generation grid and on-site CHP. Sources of thermal energy include boiler fuels (natural gas, fuel oil, coal, etc.) consumed to generate high-pressure steam, fuels burned to produce direct heat (natural gas, propane) used in evaporation/drying and, in the case of 7 of the 15 plants in the study, natural gas CHP. In each case, thermal energy use (hereinafter **"thermal"**) was determined by summing the calorific value of the fuels consumed (see Conversion Factors in Appendix I). In the case of plants with CHP, **thermal** was calculated by subtracting the MWh of electricity generated (either for export or for use on-site) from the total fuel consumed by the CHP operator. Electrical energy consumption (hereinafter **"electrical"**) was determined by adding electricity imported from the national power generation grid to electricity generated on site. CHP termal was calculated as follows:-

CHP **thermal** = CHP Fuel Use (MWh) – Electricity Generated (MWh)

This calculation takes into account the use of waste heat in steam production and provides a fuel-to-steam conversion factor that is similar to the that achieved by regular steam boilers (70 – 80%). It takes on average 1,000 kWh of fuel to produce 1 tonne of steam, however, 1 tonne of steam represents about 690 kWh of energy.

Pursuant to Objective 2 of the study, participants were asked to provide all available data on the distribution of **thermal** and **electrical** use in each plant in 2009. Direct processes include evaporation, drying, membrane treatment, ultrafiltration, crystalisation, cheese making, etc. Indirect processes include intake, separation, pasteurisation, cleaning-in-place, etc. Utilities include refrigeration, effluent treatment, compressed air, water, chilled water and cold stores. In most cases, while **electrical** was metered, **thermal** was estimated by multiplying the quantities of steam consumed per hour of operation of each process by the number of hours that the plant was in operation.

Pursuant to Objective 3 of the study, having divided 2009 **thermal** and **electrical** into their component processes & utilities, these components were further sub-divided between each of the products from each plant (butter, cheese, whey, casein, etc.). Direct process **electrical** and **thermal** allocations related to the processing time allocated to each product. Intake/separation **electrical** and **thermal** allocations depended on the range & ratio of products produced at each plant (e.g. in a Casein:SMP:Butter plant, intake/separation **electrical** was allocated using the ratio 40:50:10 respectively, while in a typical cheese/whey plant, the allocation was 40:60 to Cheese:Whey).

Utility **electrical** was also allocated to each product based on the share of refrigeration, compressed air, effluent treatment, etc. allocated to each product (e.g. in a casein/SMP/butter plant, refrigeration **electrical** was allocated to SMP:Casein in the ration 55:45). The allocation of other utilities depended on the relative proportion of each product and varied from plant to plant. Allocation of utility **thermal** to each product was determined by the contribution of wastewater by each product to the plants wastewater treatment plant (WWTP), e.g. 16:84 to Cheese:Whey.

4.0 RESULTS

4.1 Objective 1: Energy Used v Energy Accounted for in 2009

As described in the previous section, total annual energy use per plant was determined by adding **thermal** and **electrical**. This energy was then allocated to the various products/processes in order to realise objectives 2 and 3 of the study. Due to a lack of metering and specific knowledge of where energy was used, there were discrepancies between the overall energy used on-site and the quantities of energy use allocated to individual products. These disparities range from -10% to +12% (except in the case of Plant 3) where either less or more energy was accounted for than was consumed. Figure 1 compares energy used to energy accounted for. In most cases there is a close correlation with one major exception, i.e. plant 3, where 42% of the total energy consumed on site in 2009 was not accounted for in products/processes.

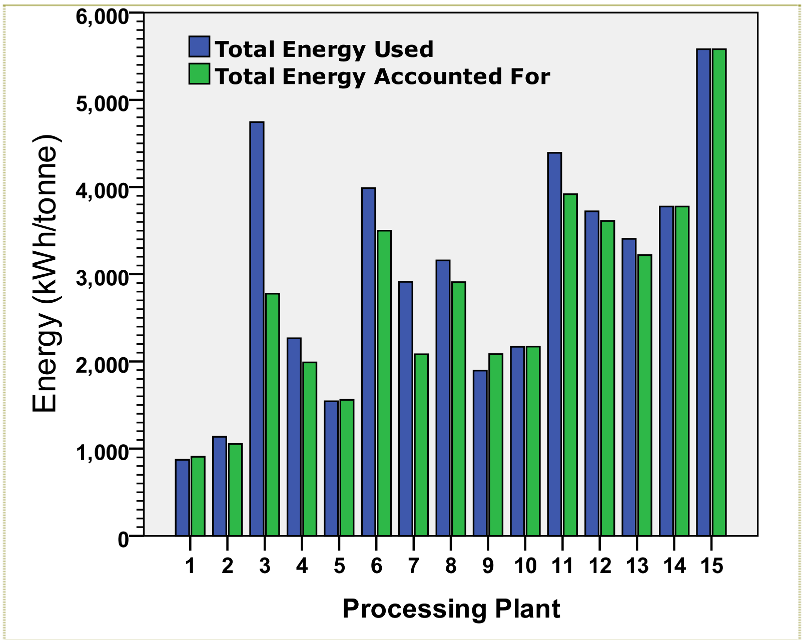

Figure 1 A comparison of the total energy used in 2009 (kWh/tonne of product) with the amount of energy that was allocated to products/processes and, therefore, accounted for in product/process benchmarks.

4.1.1 Improvements in energy and water efficiency between 2005 and 2009

Energy Use

Based on the available data, mean energy use increased between 2005 and 2006 by 8% (188,764 – 204,682 MWh). Thereafter, mean energy use per plant was reduced each year for the next 4 years from 204,682 MWh (2006) to 163,771 MWh (2009) representing an annual saving per plant of 40,910 MWh (20%). This saving represents an 18% reduction in electrical (5,621 MWh per plant per annum) and a 20% (17%) reduction in thermal of 35,290 MWh per plant per year. When measured relative to tonne of product manufactured, this saving represents a 16% reduction in energy use (i.e. 3,370 – 2,816 kWh/tonne). This energy reduction sub-divides into a 22% reduction in mean **electrical** (579 – 452 kWh/tonne) and a 15.3% reduction in mean **thermal** (2,790.9 – 2,364 kWh/tonne). The disparity between 2005 and 2006 energy data can be explained by the fact that certain data sets were incomplete and that the sample population was small enough that one figure could skew the results.

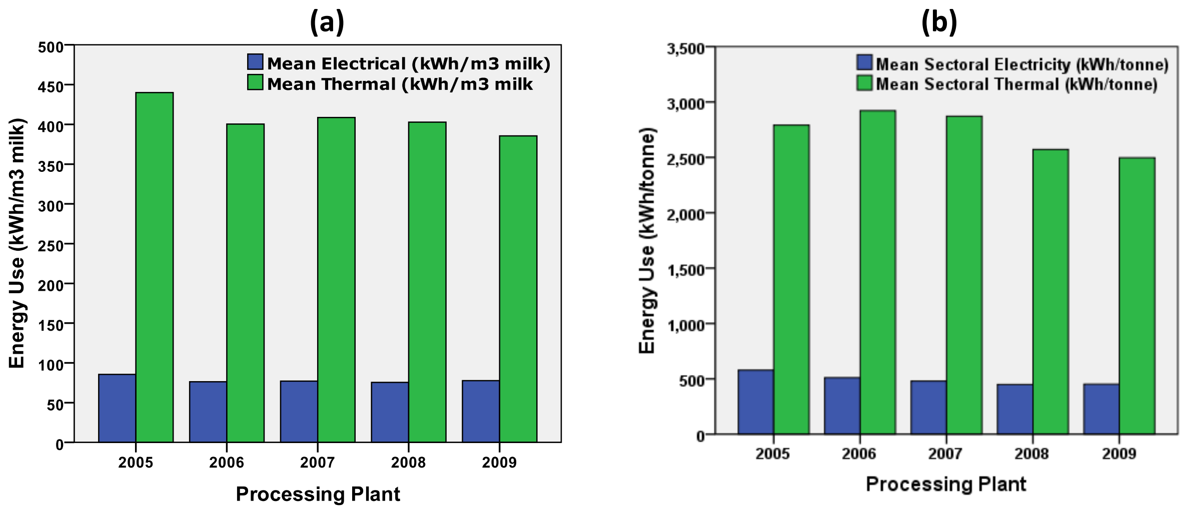

Figure 2 Mean sectoral energy use from 2005 to 2009 measured (a) in kWh/m^3 of milk and (b) in kWh/tonne of product

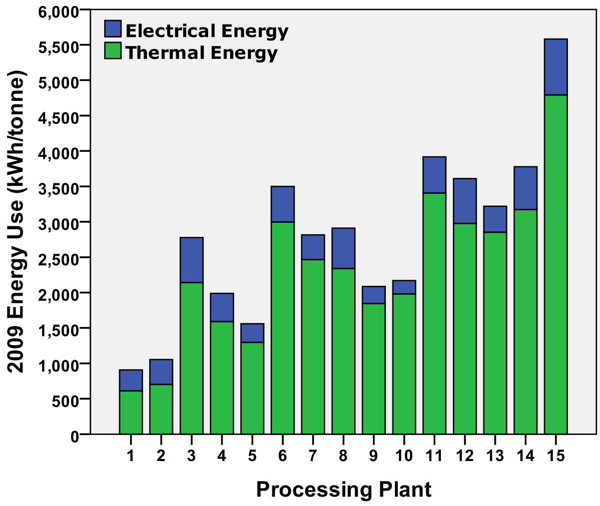

Figure 3 A comparison of energy consumed in 2009 that has been accounted for and allocated to products/processes (kWh/tonne of product) in each of the 15 dairy plants.

Figure 3 shows the energy use that can be accounted for across the 15 plants for which data was available. Plants 1 to 15 are arranged from left to right such that those on the left of the graph are predominantly yellow product plants (butter & cheese) while those on the right of the graph are predominately powder manufacturers. Not surprisingly, the trend is towards increased **thermal** per tonne of product from plant 1 to 15 due to the higher energy intensity of powder products (906 - 5,590 kWh/tonne). However, as can be seen in Figure 4(a), there is no corresponding increase in **electrical**.

On average, **thermal** accounts for 85% of total energy use by the sector with **electrical** accounting for the remaining 15% However, depending on the product range in any given plant **electrical** can vary from 30% of total (as in butter and cheese making) to 9% for certain powder-only operations.

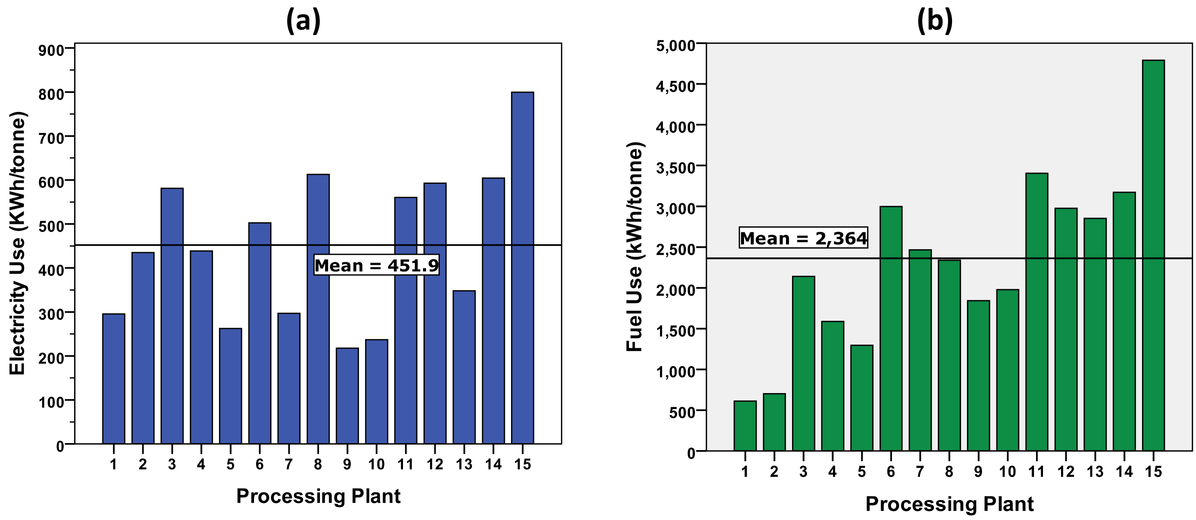

Figure 4 Accounted for (a) electrical energy use and (b) thermal energy use in 2009 by Irish dairy processing plants numbered 1 - 15.

Figure 4 shows total 2009 (a) **electrical** and (b) **thermal** that has been accounted for and allocated to different products/processes in each plant.

4.1.2 Energy breakdown by fuel type

Thermal derives from the combustion of a three main fuels, i.e. natural gas (69%), fuel oil (20%) and coal (8.7%). Biogas, diesel, LPG and peat combined account for <3% of total fuel use by the sector in 2009 (Figure 5). In 2009, 57% of the total electricity consumed by the 15 plants in this study was generated by on-site (mostly CHP) while the remainder was purchased from the Irish power generation sector. In 2009, 7 of the 15 plants in the study operated on-site CHP, however, since 2009, one additional plant has installed on-site CHP.

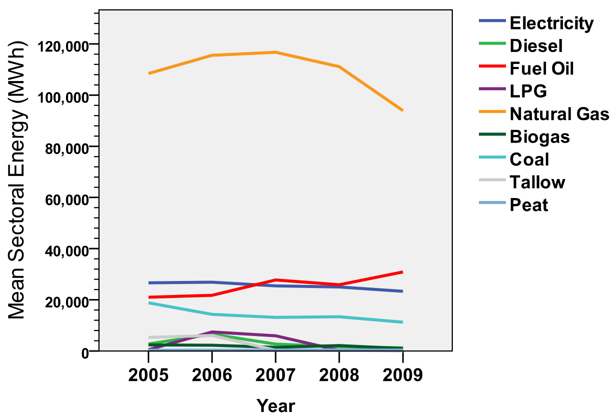

Figure 5 The fuel consumption profile of the Irish dairy industry between 2005 - 2009.

4.1.3 Carbon Dioxide Emissions in 2009

In 2009, 57% of **electrical** was sourced from on-site CHP operators while the remainder was sourced from the national power generation grid. The corresponding annual CO_2 emission was 90,689 tonnes from CHP **electrical** (12,956 tonnes per plant) and 83,324 tonnes from national grid **electrical** (10,415 tonnes per plant). The total CO_2 emission in 2009 from **electrical** was 174,013 tonnes (234.4 $kgCO_2$/tonne OR 46.6 $kgCO_2/m^3$ of milk processed). The emission factor for electricity from the Irish Power Generation sector in 2009 was 0.553 $kgCO_2$/kWh, whereas the average conversion factor for CHP electricity in 2009 was sector is 0.397 $kgCO_2$/kWh (see Appendix I).

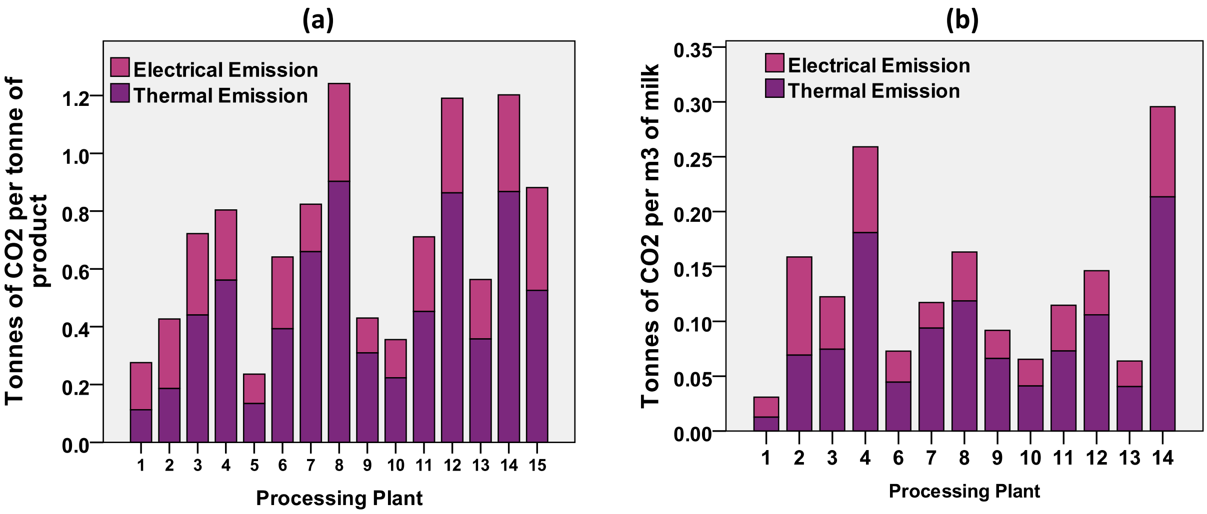

Figure 5 Carbon Dioxide Emissions from each plant 2009

In 2009, the CHP-associated **thermal** CO_2 emission in 2009 totalled 136,430 tonnes or 19,490 tonnes/plant. The non-CHP-associated **thermal** CO_2 emission in 2009 totalled 192,776 tonnes or 23,820 tonnes/plant. The total **thermal** CO_2 emissions in 2009 was 329,206 tonnes or 21,947 tonnes CO_2/plant (466 $kgCO_2$/tonne OR 87.2 $kgCO_2/m^3$ milk processed). In total, the mean CO_2 emission for the Irish sector in 2009 was 700.5 $kgCO_2$/tonne OR 130.9 $kgCO_2/m^3$ milk processed. CO_2 emissions for each plant relative (a) to production in tonnes and (b) relative to cubic meters of milk processes are shown in Figure 5.

4.1.4 Water Consumption

Between 2005 and 2009, average annual water consumption per plant was reduced by 20% from 1,094,421 m^3 to 874,828 m^3 representing a saving of ~200 million litres per plant (see Figure 6a).

During this period, mean water use fell by

- 28% from 20.7 m^3/tonne to 14.9 m^3/tonne product (see Figure 6b) and by
- 18% from 3.09 m^3/m^3 milk to 2.5 m^3/m^3 milk processed.

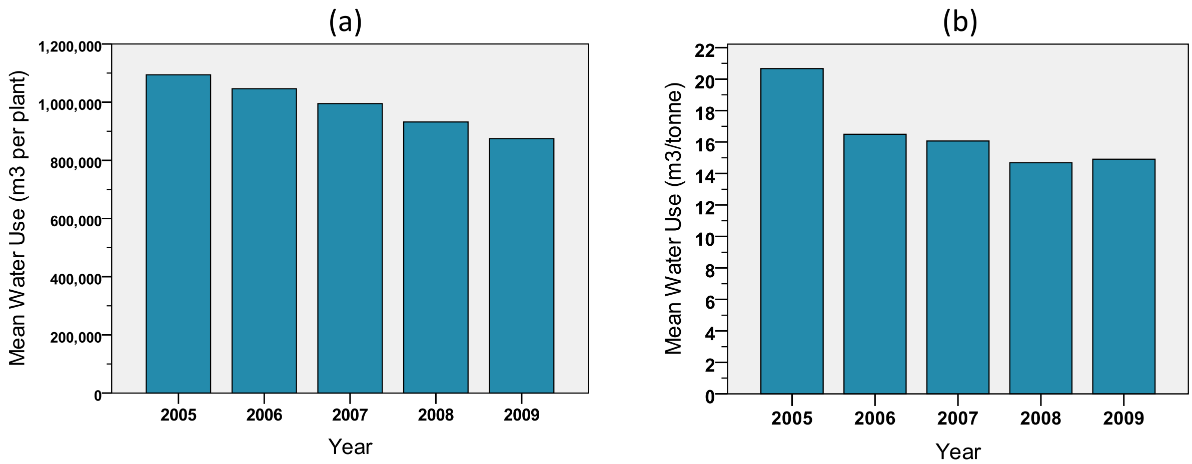

Figure 6 Changes in mean sectoral water consumption in cubic meters (a) combined between 2005 and 2009 and (b) per tonne of product. The trend was towards less water use per tonne with the exception of 2009 where there was a slight increase per tonne reflecting a downturn in throughput with consequent effects on water efficiency.

4.2 Objective 2: Allocation of 2009 Processes & Utilities Energies

Thermal can be accounted for in direct processing (steam and direct heating), indirect processing (intake, pasteurisation and CIP) and utilities (effluent treatment). Figure 7(a) provides a overview of mean **thermal** by the sector in 2009. On average, direct processing accounted for 72.2% of **thermal** (i.e. 1,707 kWh/tonne). Intake & separation accounted for 13% (306.4 kWh/tonne), effluent treatment accounted for 6.9% (162 kWh/tonne) and cleaning in place (CIP) accounted for 4.4% (104 kWh/tonne). Together boilers and administration/canteen accounted for the remaining 3.5% of **thermal**.

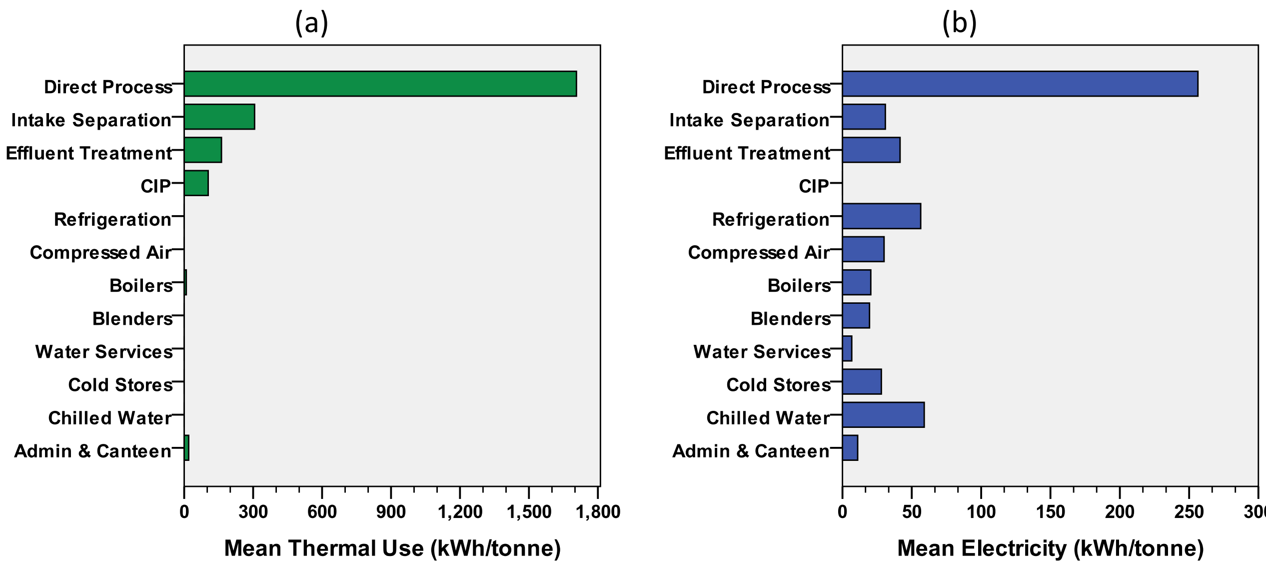

Figure 7 Breakdown of (a) thermal and (b) electrical energy use in kWh/tonne of product. Direct processing accounts for 72.2% of fuel consumption and 57% of electrical use.

Electrical can be accounted for in direct processing (57%; 292 kWh/tonne); utilities (30%); intake & separation (4.9%); boilers (3.1%) and blenders (3%).

Figure 7(b) provides a breakdown of **electrical**. Utility **electrical** can be sub-divided into refrigeration (12.7%), effluent treatment (8.9%), compressed air (6.8%) and water services (1.8%). Allocations of **electrical** to cold stores and to chilled water relate specifically to butter and cheese plants only.

4.3 Objective 3: Product Energy Benchmarks

Objective 3 was to calculate mean sectoral **electrical** and **thermal** benchmarks for each of the 6 main products/product groupings as follows:-

- butter
- cheese
- skimmed milk powder
- general milk powders (e.g. infant nutritional products, WMP, FFMP, FCMP)
- whey powders (e.g. demineralised whey, milk protein isolates, etc.)
- casein (acid, rennet, etc.)

Product Energy Intensity	Energy Type	*Mean Direct Process*	*Mean Intake & Separation*	*Mean Utilities*	Mean Total Energy	Energy Range (kWh/ tonne)
Butter (kWh/ tonne)	Electrical	*66.6*	*10.6*	*64.2*	142	50 – 324
	Thermal	*137.6*	*72*	*10.7*	221	47 – 438
Cheese (kWh/ tonne)	Electrical	*242.8*	*4.6*	*91.9*	326	203 – 501
	Thermal	*475*	*3.7*	*9.5*	488	355 – 670
SMP (kWh/tonne)	Electrical	*274*	*44.5*	*186*	492	238 – 958
	Thermal	*2,994*	*487*	*112*	3,620	2,666 – 5,878
Milk Powders (kWh/tonne)	Electrical	*303*	*34.9*	*148*	479	228 – 789
	Thermal	*3,029*	*418*	*78.7*	3,533	2,662 – 5,878
Whey Powders (kWh/tonne)	Electrical	*562*	*16.9*	*253*	833	430 – 1,459
	Thermal	*3,264*	*272*	*243.5*	3,780	2,320 – 5,544
Casein/ Caseinate (kWh/tonne)	Electrical	*908*	*317.5*	*756*	2070	945 – 3,217
	Thermal	*2,908*	*1,647*	*524*	4,733	3,905 – 6,031

Table 2 Breakdown of mean electrical and thermal energies consumed per tonne of each product. Mean Total Energy is not always equal to the sum of the mean direct, intake/separation and utility energies because not all plants were able to provide detailed breakdowns of Total Energy for each product so the sample size varies.

This was achieved by allocating shares of process, intake/separation and utility **thermal** and **electrical** to each product (see Figure 8 and Tables 2 & 3). The sectoral means were then compared to available EU BAT levels and international benchmarking data from Australian Dairies (Table 4), Nordic Dairies (Table 5) and Dutch, British and American Dairies (Table 6).

Such benchmarks establish best practice guidelines for the sector allowing each plant to compare their performance on a product–by-product basis to the average for the sector. This, in turn, allows plants to determine where best to target their efforts to reduce waste. Energy benchmarks for each of the main product types also allows for closer comparisons with the levels of energy efficiency being achieved internationally, and the impact on production efficiency of the high levels of consolidation that have been achieved in many of the major dairy processing economies such as Holland and Denmark.

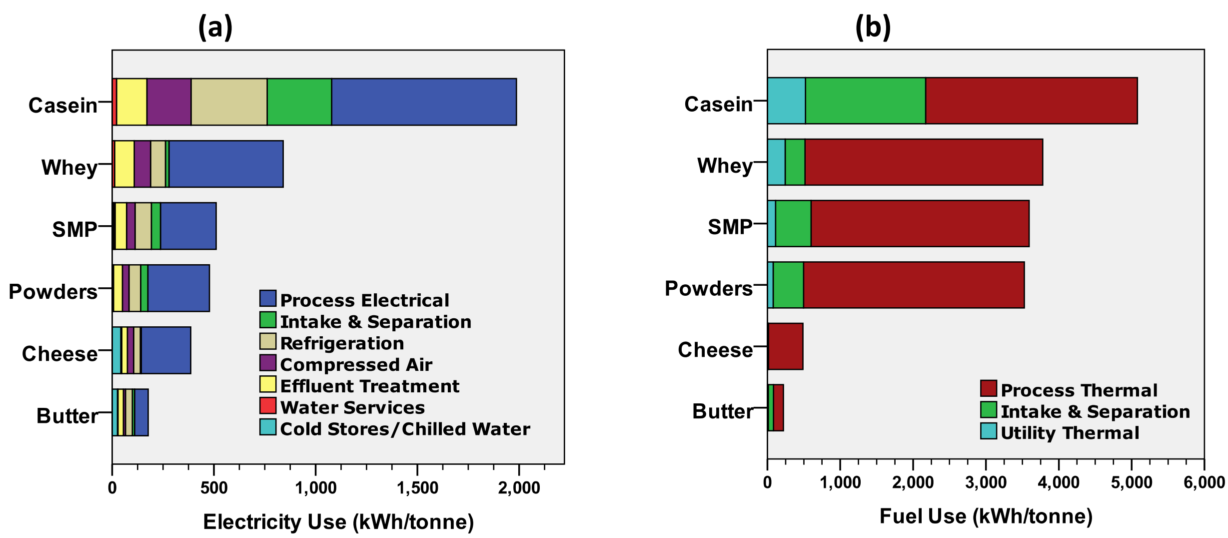

Figure 8 Breakdown of (a) mean electrical and (b) mean thermal energies used in the production of butter, cheeses, milk powders, SMP, whey powders and casein. Energy is measured in kWh/tonne of each product.

The breakdown of utilities **electrical** data for each product/product group is listed on Table 3. Refrigeration is the biggest user followed by effluent treatment, compressed air and water services. In each case, casein consumes the most utility **electrical** followed by whey powders, milk powders and yellow products.

Utilities Electricity	Refrigeration (kWh/tonne)	Compressed Air (kWh/tonne)	Effluent (kWh/tonne)	Water (kWh/tonne)
Butter	33.7	10.4	26.7	2.3
Cheese	33.1	30.5	28.1	4.5
SMP	80.3	41.4	56.7	7.1
Milk powders	57.9	32.4	43.5	3.8
Whey powders	73.5	80	96.6	11.4
Casein	374.1	216.9	149.1	21

Table 3 Breakdown of average electrical energy consumed per tonne in each of the 4 main utilities – refrigeration compressed air, effluent treatment and water services.

4.3.1 Butter and Cheese Products

On average, **thermal** accounts for 85% of total energy use by the Irish sector. In butter and cheese manufacture, however, the **electrical**:**thermal** ratio is 40:60. **Electrical** utilities account for ~40% of total **electrical** in each case, whereas **thermal** utilities only account for 2-3% of total thermal.

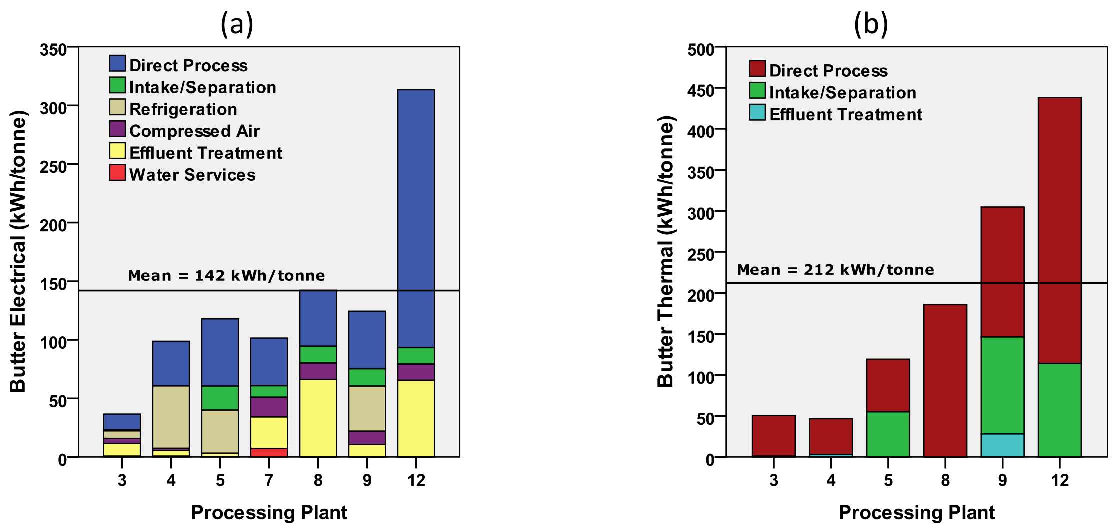

Figure 9 Butter (a) electrical and (b) thermal consumption profiles

The trend from plant 1 to 15 is from predominately yellow products to predominately powder products. As can be seen in Figure 9 (a) **electrical** and (b) **thermal** intensity increases from plant 3 to plant 12 in line with increases in the proportion of powder to yellow products.

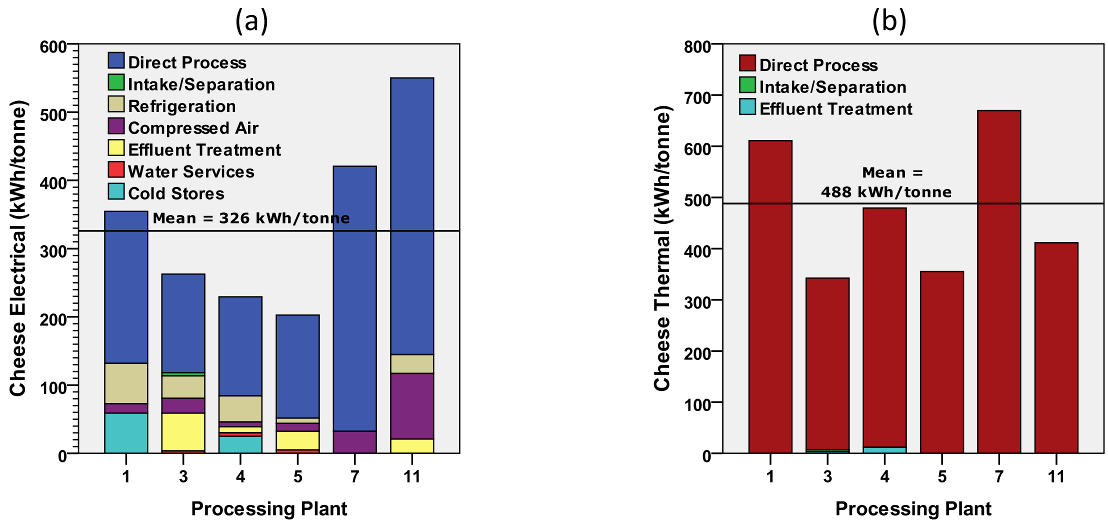

Figure 10 Cheese (a) electrical and (b) thermal consumption profiles

This is most likely due to the misallocation of a **thermal** from powder production suggesting that the actual energy benchmarks for Irish butter manufacture, especially **thermal**, are lower than those described in this study.

In cheese making (Figure 10) there is a much narrower range of both electrical and thermal energy intensities than is the case for butter production. Plant 11 would appear to be worthy of further analysis from the point of view of potential electrical energy savings, especially in process and compressed air. In butter making, indirect and utility energy account for a high proportion of overall **electrical** (50%) and **thermal** (37%). By comparison, in cheese making, indirect and utility energy only account for 25% of **electrical** and 3% of **thermal**.

4.3.2 Milk Powder Products

In milk powder manufacture, the **electrical**:**thermal** ratio is 12:88. **Electrical** utilities account for 31% of total **electrical**, while **thermal** utility only accounts for 2% of total thermal. Intake/separation **thermal** accounts for 12% of total thermal (see Figure 11).

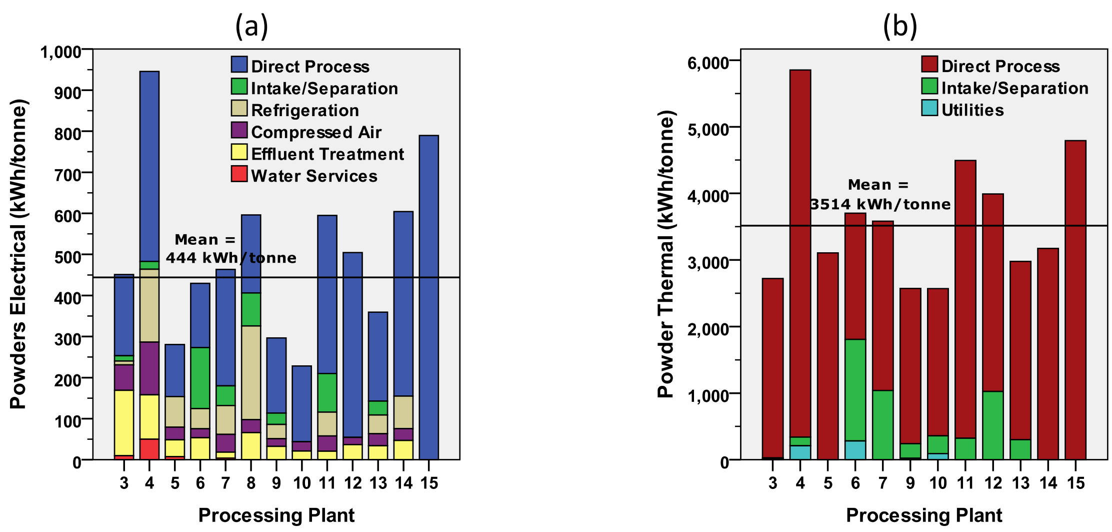

Figure 11 Powders (a) electrical and (b) thermal consumption profiles

In powder production, there is a greater range of **electrical** data than **thermal**. As a proportion of total **electrical**, utility **electrical** (especially refrigeration & effluent) and intake/separation **electrical** vary more significantly than process **electrical.** In some cases, utility **electrical** accounts for more than 50% of total electrical.

Data for skimmed milk powder (Figure 12) doesn't vary significantly from data for powder manufacture (Figure 11).

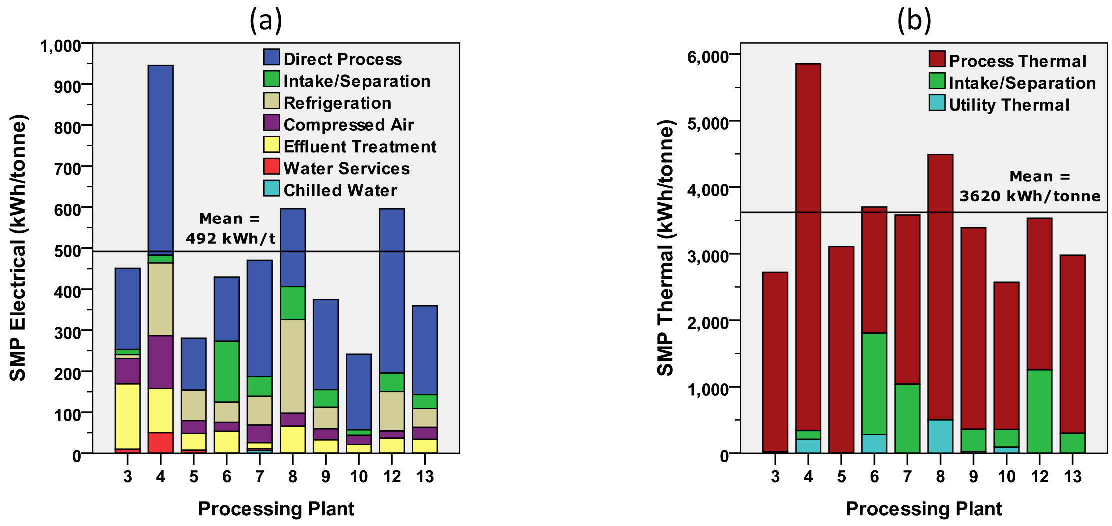

Figure 12 SMP (a) electrical and (b) thermal consumption profiles

4.3.3 Whey Powders

In whey powder manufacture, the **electrical**:**thermal** ratio is 18:82. **Electrical** utilities account for 30% of total **electrical**, while **thermal** utility only accounts for 6% of total thermal. Intake/separation accounts for 2% of **electrical** and 7% of **thermal**.

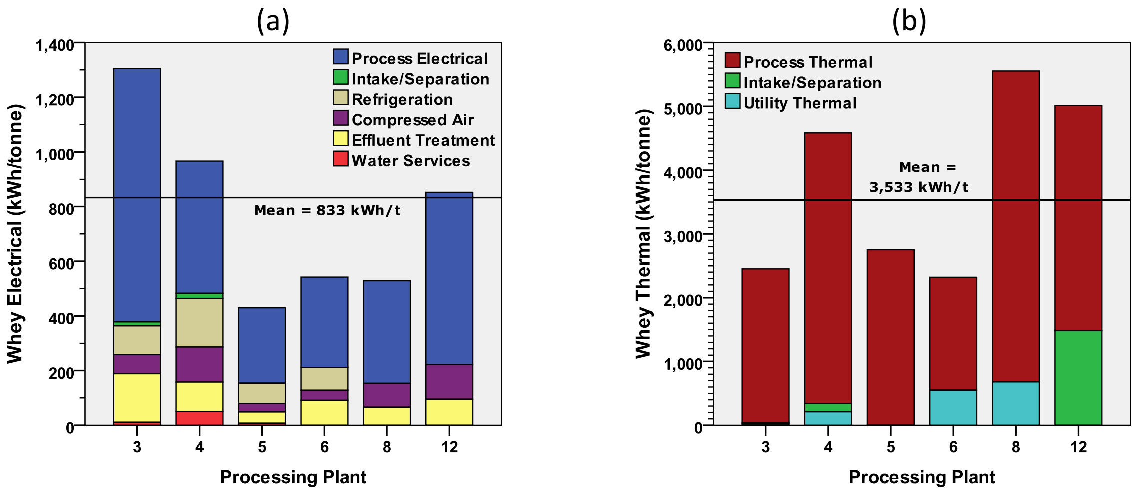

Figure 13 Whey (a) electrical and (b) thermal consumption profiles

Thermal data for whey powder production, Figure 13(b), closely correlates with **thermal** data for powder manufacture (Figure 12(b), i.e. similar means and similar trends. **Electrical** data, however, especially process **electrical** from whey powder manufacture does not closely correlate. On average, whey production consumes 53% more **electrical** than powder manufacture with direct processing accounting for a much larger share of **electrical** than indirect processing and utilities.

4.3.4 Casein/caseinates

The product that consumed by far the most **electrical** per tonne is casein (Figure 14). Similar to the other high energy products, there is a much greater range of values for **electrical** than **thermal**. Plants which consume less **electrical**/tonne of casein than the sectoral mean (i.e. plants 4, 5 & 6) differ from those that consume less **thermal**/tonne casein than the sectoral average for casein (plants 2, 4 & 8). While the sectoral mean casein **thermal** is 35% higher than the sectoral mean powder **thermal**, **electrical** in casein manufacture is 366% higher that that for milk powders.

In casein manufacture, the **electrical**:**thermal** ratio is 30:70. **Electrical** utilities account for 37% of total **electrical**, while **thermal** utility only accounts for 11% of total thermal. Intake/separation accounts for 15% of **electrical** and 35% of **thermal**. Casein is the most energy intensive dairy product, consuming almost twice as much energy as milk powders, almost ten times more than cheese and twenty times more than butter. Process **thermal** in casein production is equivalent the process **thermal** in powder manufacture, however, process **electrical** is 2 – 3 times higher that the average for powder.

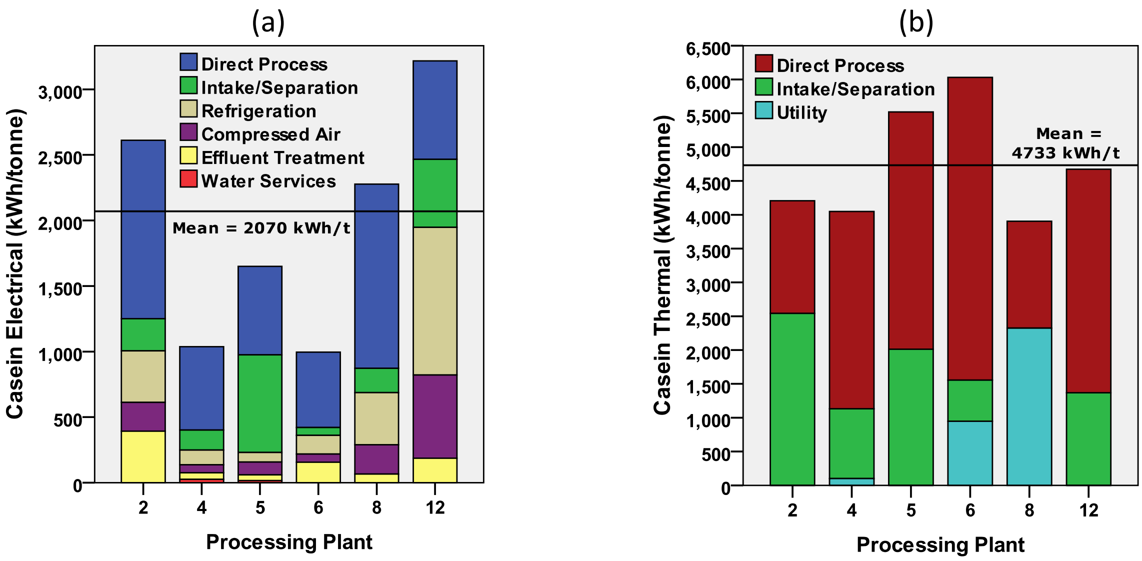

Figure 14 Casein (a) electrical and (b) thermal

4.3.5 Comparisons with International Benchmarks and Best Practice Guidelines

An extensive search of the literature published between 1990 and 2010 yielded only 8 useful sources of international benchmarking data and best practice guidelines. The first, and oldest, source examined **thermal** and **electrical** by the Australian dairy industry[10] in butter, cheese and powder production (see Table 4).

Energy	Product	Australian Dairies	UK Dairies[12]	Irish Dairies
Electricity[10] (kWh/tonne)	Butter Cheese Powders	197 211 397		142 326 444
Fuel[10] (kWh/tonne)	Butter Cheese Powders	981 1,206 5,722		221 488 3,514
Total Energy[11] (kWh/litre)	Cheese & Whey	0.17 [0.11 - 0.21]	0.23	0.1 (cheese only) 0.43 (cheese, SMP, whey powders + casein)
Total Energy[11] (kWh/litre)	Mainly Powders	0.37 [0.13 - 0.842]	0.6	0.39
Total Energy[10] (kWh/m^3 milk)	Milk Processing	139 - 555		102 - 417

Table 4 This table provide 1993[10] and 2004[11] data from dairy plants in Australia and the UK. Data relates to energy consumed per tonne and per litre of milk processed in plants specialising either in cheese/whey products or powders.

Not surprisingly, the 2004 data[11] from the Australian dairies, especially for mainly powder manufacturers, is far more in line with current data from the Irish plants than the 1993 data[10]. There are quite a few “mainly powder” plants in Ireland which allows for meaningful comparisons. Mean energy use by mainly powder plants (i.e. 0.39 kWh/litre) is comparable with the corresponding figures for Australia and the UK, 0.37 and 0.6 kWh/litre respectively.

The cheese & whey plant data[11] is not directly comparable as few, if any, Irish plants fit this criteria. Most Irish plants in this category produce either cheese only (0.1 kWh/litre) or a mix of cheese, SMP, casein and whey powders (0.43 kWh/litre; i.e. 0.079 kWh/litre **electrical** & 0.35 kWh/litre **thermal**). Nevertheless, the numbers, however, are in the same ballpark. The 2004 study[11] compared the performance of Australian dairies with UK dairies[12], however, the UK data dates from 1998. Casein production, in particular, significantly increases overall energy use per tonne and precludes meaningful comparisons.

The next sources of international benchmarking data (see Table 5) are a 2006 IPPC reference paper on BAT in European dairies[13] and a 2001 BAT guide for the Nordic dairy industry[14]. Again, the categories of plants cited in these studies i.e. (1) cheese/whey and (2) powders/cheese/liquid products don't have close Irish counterparts. Most Irish plants produced either powders only, cheese only or a mix of butter, cheese, powders, whey powders and casein. Given that powders and casein can consume up to 10 times more energy per tonne than yellow products, the relative proportion of powder to yellow products significantly impacts on overall energy use for any given plant. This explains why Irish averages fall slightly outside the industry benchmarks as outlined in BAT for the Nordic Dairy Industry (2001).

Product Types	European BAT[13] (kWh/litre)	Industry[14] Benchmark (kWh/litre)	Norway Dairies[14] (kWh/litre)	Finnish Dairies[14] (kWh/litre)	Swedish Dairies[14] (kWh/litre)	Irish Dairies (kWh/litre)
Cheese & Whey	0.06–2.08	0.2–0.3	0.21	0.27-0.82	0.15-0.34	0.1–0.38
Powder, cheese and liquid products	0.85–6.47	0.3–0.4	0.29-0.34	0.28–0.92	0.18-0.65	0.4–0.7

Table 5 This table provides data from European dairy plants[15] on the average amount of energy consumed in kWh per litre of milk processed in plants specialising in cheese/whey products or in powder, cheese and/or liquid products.
Meaningful comparisons are difficult without knowing the exact product portfolio in each case.

Nevertheless, the data on Table 5 indicate that, despite a sector-wide focus on exportable, high-energy powder products, Irish dairies use less energy per litre of milk processed than the guidelines laid out in the IPPC BAT reference document for European dairies[13] and use similar energy levels to BAT practice in Norwegian, Finnish and Swedish dairies[14].

The final set of benchmarking data comes from a series of studies conducted by Xu et al at the Lawrence Berkeley National Laboratory[16 & 17] which investigated the potential for energy savings and carbon emission reductions in the global dairy industry. They found that energy figures varied significant from product to product and that energy intensities for each product varied significantly from plant to plant and from country to country. Xu et al indicated that there are significant savings to be made worldwide including an estimated annual reduction of 9 – 14 million tonnes of carbon.

Dutch contributors to the studies by Xu et al provided the only relatively complete set of data. The Dutch data suggests that, although Irish dairies manufacture butter, cheese and milk powders to similar levels of energy efficiency as Dutch dairies, whey powder manufacture in Irish dairies consume more than twice as much energy as in Dutch dairies. This is an area that would benefit from further analysis to determine if there is a like-for-like comparison.

Total Energy Consumption	GBR[16]	NLD[16]	DNK[16]	NOR[16]	USA[16]	Mean[17]	IRE
Butter (kWh/kg)		0.58					0.40
Cheese (kWh/kg)		1.36			2.22	1.4 - 2.5 (by country) 0.5 – 18.9 (by plant)	0.87
Milk Powders (kWh/kg)		3.55					4.0
Whey Powders (kWh/kg)		2.05					4.5
Primary Energy Intensity (kWh/litre)	0.35	0.39	0.58	0.84			0.45

Table 6 This table provide data from European dairy plants on the average amount of energy consumed in kWh per tonne of commodity products. Also provided is data on primary energy use in kWh per litre of milk processed.

5.0 Summary

Objective 1

Objective 1 of this study was to measure mean energy and water use in 2009 in the Irish dairy processing sector (a) per plant, (b) per tonne of product and (c) per litre of milk processed.

The purpose of this was (a) to compare the performance of the Irish dairy sector with international benchmarks and BAT guidelines and (b) to allow Irish dairies to compare their performance against each other and the national average in order to highlight both areas of strong performance and areas to target for improvement.

The sector continuously invests in systems to improvements energy and water efficiency, as described in the Environmental Management Plans in their Annual Environmental Reports. Some of the measures adopted by the sector are described in Table 7.

• heat recovery e.g. from condensate/evaporate, using dryer exhaust to heat air intake, steam traps, recovering heat from effluent streams to meet discharge temperature requirements; recovering heat from 20°C pasteuriser water
• using electrolysis (chlorine generation) as a low-energy disinfection alternative in effluent treatment
• optimising flue gas mixtures
• consolidation of refrigeration, sealing/switching off refrigeration during peak electricity consumption
• reducing evaporator idle times
• water conservation e.g. recycling water from condensate/evaporate, improving efficiency in cleaning cycles, metering consumption & setting targets for cleaning staff
• improving energy efficiency in CIP by rinsing at 10°C between caustic (75°C) and acid (65°C) steps

• insulating pipes and tanks
• fitting boilers with economisers
• installing lighting control and switching to low energy lighting (e.g. from sodium to fluorescent)
• using variable speed drives and frequency inverters to control the speed of fan & pump motors and vary liquid/air flows more efficiently than valves/dampers
• maintaining and upgrading of motors and compressors
• air compressor leak testing (also in valve activation, silo agitation, bag house filter cleaning and pneumatics on packing/bagging off lines)
• solids recovery from wash water to prevent material from entering effluent treatment process.

Table 7 Methods adopted by the Irish dairy processing sector to improve water and energy efficiency.

The overall impact of these efforts between 2005 and 2009 was a 20% reduction in energy use (12.5% reduction in energy/tonne of product) and a 28% reduction in water/tonne. These efficiency improvements resulted in annual savings per plant in 2009, relative to 2005, of 40,910 MWh of energy and 220 million litres of water. It is intended to further review water consumption and effluent discharges in the dairy industry in a future study.

With tight profit margins and high energy costs, the dairy sector has traditionally led the way in maximising process energy efficiency. The first commercial plate heat exchangers were developed in the 1930's for use as pasteurisers in dairy processing and then later modified for use in other industries. It is not surprising, therefore, that during a period where both the direct and indirect (e.g. carbon) costs of energy have increased dramatically, Ireland's dairy processing sector has invested heavily in reducing energy use while maintaining product quality. As part of an industry-wide sustainability effort, dairy processors recognise that effective energy-management starts with a top-down commitment and to the identification and sharing of best practices across the sector. Sharing best practices based on each other's experience helps each processor identify the energy-efficient practices and technologies most suitable to their specific needs. A few of these best practices fall under the category of energy recovery and recycling, which are highly cost-effective means for producing energy, and can be implemented on a broad scale at both new and existing facilities.

Although, **thermal** accounts for the majority of dairy processing energy, the sector achieved a higher degree of improvement in **electrical** efficiency due to the capital investment and testing to ensure quality is not compromised.

Objective 2

Process **thermal** in the form of steam and, to a much lesser extent, direct heating, accounts for the majority of **thermal** use in Irish dairy processing (i.e. 72%). Evaporation/drying accounts for the majority while the remainder is due to intake/pasteurisation (13%), effluent treatment (7%) and CIP (4.4%) and boilers/administration/canteen (3.5%). By comparison, of **electrical** is more widely distributed with direct process accounting for 57%, utilities for 30% (refrigeration 12.7%; effluent treatment 8.9%; compressed air 6.8%; water services 1.8%), intake & separation for 4.9%, boilers for 3.1% and blenders for 3%.

Objective 3

The 15 plants included in this study each manufacture distinct ranges of products which can include butter/butteroil, cheeses (cheddar, emmental, processed cheese, imitation cheese), powders (SMP, FFMP, FCMP, WMP, infant formulated powder products), carbohydrates (e.g. lactose), casein/caseinates and whey products (demineralised powders, protein isolates, whey butter, whey alcohol, sweet whey, whey concentrates, etc.).

Some plants produce narrow product ranges (cheese only, powder only) while others produce wide product ranges (e.g. butter/SMP/whey/casein). Plants specialising in whey processing generate the most diverse range of products. Due to the variation in product energy intensities, product ranges and production levels, it is difficult to compare and contrast energy performance based on total energy use/tonne of product. Product-specific energy intensity benchmarks and graphical representations of this data (Figures 9 to 14) provide a much more useful means of making such comparisons.

6.0 References

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7.0 Appendix I

Net calorific values

Liquid Fuels

	kWh/litre or MWh/m3
Diesel Oil/Gas Oil	10.17
Heavy Fuel Oil	10.8 – 11.4
Light Fuel Oil	11.2
Fuel Oil	10.74 – 10.96
LPG	6.84 - 7.4

Gaseous Fuels

	kWh/m3
Natural Gas	11.02 – 11.84
Liquid Propane	6.84
Biogas	9.67

Solid Fuels

	kWh/kg or MWh/tonne
Coal	7.0833
Tallow	9.722
Peat	4.0

Carbon emissions per unit of energy

	kgCO2/MWh
Diesel/Gas Oil	263.9
Fuel Oil	273.6
LPG	229.3
Natural Gas	204.7
Biogas	0
Coal	340.6
Milled Peat	420
Natural Gas 2009*	184
CHP Thermal 2009*	184
CHP Electricity 2009*	367
Electricity 2009*	553

* Varies annually (see below).

Electricity CO_2 Emission Factors

The CO_2 emission factor for electricity depends on the electricity generation mix in any particular year. The SEAI CO_2 emission factors for electricity are calculated from the generator inputs (public thermal plants and CHP units) thus inherently including any generator own use electricity and system losses (transmission and distribution). The electricity emission factor may differ from that produced by the Commission for Energy Regulation (CER) and Eirgrid depending on whether the figures quoted use gross or net electricity generation and also whether or not CHP is included.

Natural Gas CO_2 Emission Factor

The natural gas CO_2 factor emission depends on the mix of imported and indigenous gas used for any particular year. The Environmental Protection Agency (EPA) provides the natural gas emissions factor to SEAI.

CHP CO_2 Emission Factors

As described above, the CHP thermal and electricity emission factors relate directly to the CO_2 emission factor for natural gas given that 100% of CHP energy derives from natural gas use. When dividing the CO_2 emissions between thermal and electrical CHP outputs and dairy plant consumption, a convention is used in the dairy sector whereby the conversion inefficiency is assigned to the electrical fraction. For example, if 100,000 MWh of natural gas is used to generate 20,000 MWh of electricity and 56,800 MWh of heat, the conversion loss (100,000– 20,000 – 56,800 = 23,200 MWh) is assigned to the electricity fraction. Thus the CO_2 emission in tonnes (i.e. tCO_2) from 100,000 MWh natural gas (i.e. 100,000 MWh x 184 $kgCO_2$/MWh = 18,400 tCO_2) is allocated as follows:-

- 10,451 tCO_2 to thermal (56,800 MWh x 184 $kgCO_2$/MWh)
- 7,949 tCO_2 to electrical ([20,000 MWh + 23,200 MWh] x 184 $kgCO_2$/MWh)

This gives a revised CO_2 conversion factor for CHP electrical of 397 $kgCO_2$ per MWh of CHP electricity used. Any import of electricity from or export to the national power grid alters the conversion factor.

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