Industrial Energy Efficiency Accelerator

Guide to the dairy sector
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1. Executive summary

At the Carbon Trust, we believe that it’s possible for industry to significantly reduce its CO₂ emissions by improving the efficiency of sector-specific manufacturing processes. Through our Industrial Energy Efficiency Accelerator we have therefore been working with a number of sectors to deliver a step change reduction in industrial process emissions. We aim to accelerate both innovation in process control and the uptake of low carbon technologies.

The UK dairy processing industry produces over 13 billion litres of liquid milk each year, providing a variety of dairy products, from powered whey protein supplements to cheese, cream and liquid milk for supermarket shelves. The sector has over 100 sites, although seven large milk companies account for around 40 of these.

The total carbon footprint for the UK dairy sector, including emissions from dairy farms, transport, distribution, processing and end use, is estimated to be 15.5 million tonnes CO₂/year, with the bulk of this (84%) generated at the farm. Emissions that fall under the control of the dairy processing industry are estimated to be 5% of this, totalling 860,000 tonnes CO₂/year.

Dairy manufacturing processes vary greatly from one product to the next, but most share the initial steps of raw milk processing: separation, standardisation, pasteurisation and homogenisation (for the liquid milk industry); as well as requiring supporting utilities such as refrigeration, steam generation and Clean-in-Place (CIP) systems.

The milk industry’s competitive nature, energy-intensive operations, environmental targets and customer demand have resulted in a proactive approach to energy efficiency and cost reduction. The specific energy consumption per m³ of milk has been steadily shrinking as different energy saving measures are continuously implemented.

There is still a wide range in specific energy performance across dairies, with the most efficient using 32 kWh/m³ raw milk and the least efficient over 1,000 kWh/m³ raw milk. This difference arises because sites vary widely in how far they have implemented best practice energy efficiency measures. Additionally, some sites carry out energy-intensive evaporation and spray drying.

In 2009 and 2010 the Carbon Trust worked closely with the dairy sector to understand energy use in raw milk processing and to identify opportunities to improve efficiency. Detailed data collected from sub-metering indicates that there are opportunities for significant carbon savings across the sector. These opportunities fall into three broad concepts:

- Low temperature pasteurisation
- Alternative homogenisation techniques
- Reduction in CIP water consumption and temperature.

There are also other potentially cost-effective good practice improvements already available to the dairy industry, including scope for further process optimisation and the use of heat pumps to recover energy from refrigeration units.

This guide presents the data and information gathered to demonstrate the likely impact of investment in energy efficiency and carbon reduction in the liquid milk sector.

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1 DEFRA the Environmental, Social and Economic Impacts Associated with Liquid Milk Consumption in the UK and its Production, December 2007.
2 DEFRA the Environmental, Social and Economic Impacts Associated with Liquid Milk Consumption in the UK and its Production, December 2007.
The Carbon Trust has a key role to play in helping to accelerate the new technologies and the market conditions that will deliver them.
2. **Background to the Industrial Energy Efficiency Accelerator**

The Industrial Energy Efficiency Accelerator aims to deliver a step change reduction in industrial process emissions by accelerating innovation in process control and the uptake of low carbon technologies.

Industry is responsible for 25% of the UK’s total CO₂ emissions\(^3\). The Carbon Trust’s experience supports the view of the Committee on Climate Change, which indicated that savings of 4-6MtCO₂ (up to 4% of current emissions) should be realistically achievable in industry with appropriate interventions\(^3\).

We believe that by demonstrating the available opportunities to organisations, far greater CO₂ savings than those set in current policy targets are possible. It is also possible to accelerate and increase the impact of policy by helping industry sectors to understand their energy use. In this way we can achieve a step change reduction in emissions, rather than having an incremental effect. Direct intervention can also help embed a culture of innovation and good energy management, resulting in a long-term impact.

We believe we can significantly reduce industry emissions by working with a range of medium-scale industry sectors that are outside the EU ETS scheme but are impacted by either Climate Change Agreements or the Carbon Reduction Commitment. These industries are moderately energy intensive and, in total, account for 84MtCO₂ emissions per year.

The Carbon Trust’s existing approach to working with industry is through our Advice activities, supporting companies to reduce their carbon emissions. This is applied across a range of industries but is not able to look in-depth at sector-specific manufacturing processes. More energy-intensive industries frequently cite as a reason for not implementing survey recommendations, that they do not address the majority of their energy use. Between 50%-90% of a site’s energy consumption could typically be used by a sector-specific manufacturing process.

In addition, the Carbon Trust Applied Research scheme has supported the development of a number of industry related technologies. This scheme works in response to applications for support, rather than proactively looking for high-opportunity technologies in development. The Industrial Energy Efficiency Accelerator will complement and extend the existing advice by including support for industries to tackle the significant emissions from sector-specific processes.

Recognising the challenge of reducing CO₂ emissions from industry, and the potential impact of targeting sector-specific processes, we investigated how we could best engage with industry to deliver significant increases in carbon reduction, beyond those delivered by existing Carbon Trust services. In 2008 the Carbon Trust launched the Industrial Energy Efficiency Accelerator.

The Industrial Energy Efficiency Accelerator approach focuses on identifying and addressing the barriers preventing industries from improving the efficiency of their processes. There are three stages to the approach:

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\(^3\) Committee on Climate Change Report, December 2008.
In 2008/2009 we undertook the investigation and solution identification stage with three pilot industry sectors: animal feed milling, asphalt manufacture and plastic bottle blow moulding. This led to six stage 2 implementation projects which we supported in 2010. In 2009 we commissioned a further three sectors: dairies, confectionery and bakeries.
3. Background to the dairy sector

This section offers a brief description of the dairy sector in the UK, describing the major raw milk processes used throughout the sector. Key energy performance statistics are presented and we discuss the key technological changes that have been introduced. We conclude with the business drivers for the dairy companies and we identify suppliers of dairy manufacturing equipment.

The UK dairy industry processes 13.3 billion litres of raw milk\(^4\) each year. It is made up of over 100 processing sites, though the sector is dominated by seven large milk companies operating around 40 major processing sites.

What they manufacture

The processing segment of the dairy sector is divided into three distinct facility types characterised by their final products:

- Liquid milk
- Cheese
- Mixed dairy (a mix of the above two, but also including yogurts, butter, spreads and speciality products).

Sector outputs can be categorised into four main product areas: liquid milk; cheese; condensed milk/powders; and ‘other’ (comprising butter (2%), cream (2%), yogurt (2%), and other miscellaneous products). Production breakdown in terms of the percentage of raw milk consumed is shown in Figure 1.

![Figure 1: Raw milk volume by end use](image)

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\(^4\) DEFRA 21 July 2009.
How they manufacture

For the purpose of this study we have simplified the dairy industry into three tranches to categorise emissions:

- **Raw milk processing:** raw milk is brought into the processing facility from the farm in tankers, separated, pasteurised (and sometimes homogenised)

- **Secondary processing and packaging:** the processed milk is either packaged and transported to the retail market or goes on to further processing to make products such as cheese, cream, yogurts, butter, and condensed and powdered milks

- **Support processes:** Clean-in-Place (CIP), heating and cooling systems supporting the primary and secondary processing.

Figure 2 shows the main heat, chill and electrical demands in a typical mixed dairy: raw (liquid) milk processing followed by an example cheese process.

![Diagram of milk and cheese production](image)

**Figure 2: Simplified energy demands in milk and cheese production**

**Raw milk processing**
The first raw milk stage is common to virtually the whole industry and includes:

- **Separation:** after being held in storage tanks at the processing site, raw milk is heated to separation temperature in the regeneration zone of the pasteuriser. The milk (now hot) is standardised and homogenised by sending it to a centrifugal separator where the cream fraction is removed. The skim is then usually blended back together with the cream at predefined ratios so that the end product has the desired fat content. Surplus hot cream is cooled and usually processed in a separate pasteuriser ready for bulk storage and transportation to a cream packing plant.
- **Pasteurisation**: this process involves killing most of the bacteria within the raw milk to increase its shelf life. This is done by rapidly heating the incoming standardised milk to the pasteurisation temperature in a simple holding tube, ensuring that the pasteurisation temperature is held for the correct time (e.g. 72°C for 25 seconds) to destroy the bacteria. The hot milk is then passed through the regeneration zone, giving up its heat to the incoming cold milk, and cooled to a level where the growth of any surviving bacteria is slowed to a minimum, partially sterilising the milk and increasing shelf life. Typically, this is an in-line process with the heating and cooling conducted in a plate heat exchanger. Finally, chilled water is used to control the milk exit temperature from the pasteuriser at approximately 2°C.

As the milk is heated and cooled within a few seconds there are intense heating and cooling demands. This process is therefore one of the largest emissions sources within the industry, even though much of the heat is regenerated and re-used in the pasteuriser.

- **Homogenisation**: this is a mechanical treatment to prevent a layer of cream from separating out in finished milk. Milk is pumped at high pressures through narrow tubes, breaking up the fat globules into small particles which do not recombine, so that the resulting homogenised milk has a consistent texture and taste. Electricity drives the pumps, creating a pressure drop across the homogeniser tubes. This process is typically used by liquid milk processors.

The main electrical emissions from raw milk processing are from the homogeniser and separator machines as well as cooling loads from pasteurisation and intake chilling.

**Secondary processing and packaging**

The supply and demand for milk are closely balanced, which means that any surplus milk in the supply chain is usually dried to produce a lower value, but longer shelf-life powdered product. The energy required to evaporate liquid from large quantities of milk far exceeds the energy needed to heat and cool it during pasteurisation, but the process is specific to a minority of sites within the sector.

Cheese making is the other common process after initial pasteurisation. This mechanical process involves a whey separation drying technique for the harder cheeses, or a texture process for the softer varieties.

**Supporting processes**

Heating and cooling energy supply (i.e. boiler and refrigeration plants) are not considered as discrete elements in this study. Further information on these technologies can be found in Carbon Trust publications.

Clean-In-Place (CIP) is the method of cleaning the interior surfaces of pipes, vessels, process equipment, filters and associated fittings without needing to remove them. It is common throughout the industry, as the processing facilities must be constantly cleaned to prevent microbes from growing and to remove fouling/scaling. CIP typically includes an initial rinse of recovered water to remove heavy soiling, followed by a hot detergent wash of caustic or acid solution, and a final rinse of clean potable water. Sometimes a high-temperature sterilisation or terminal disinfectant is also used. Emissions associated with CIP are predominantly due to the heating of the processing equipment that is being cleaned as well as the heating of water which is subsequently wasted. CIP is a large consumer of water so there is a cost incentive to reduce CIP water usage as well as minimising heat and chemical consumptions.
Dairies and other key stakeholders

The interests of the dairy sector are represented by Dairy UK, which has an environmental steering group that meets quarterly.

There are currently seven large dairy companies in the UK:
- Arla Foods
- Dairy Crest
- Glanbia
- 1st Milk
- Milk link
- Robert Wiseman
- United Dairy Farmers.

The main equipment suppliers (OEMs) actively supplying the UK dairy sector include:
- Alfa Laval
- APV
- GEA
- Tetrapak.

Dairy plants tend to be purchased as a complete plant through these turnkey suppliers and typically have a life expectancy of over 30 years.

Business drivers

Market drivers

As dairy processing is both energy and water intensive, the introduction of carbon-related accounting means there is strong pressure to reduce utility costs. This is compounded by the squeeze on product sales prices applied by the major customers (supermarkets) dominating the supply chain. Demand by retailers for products such as regional and organic milk may also complicate the manufacturing processes.

In addition to meeting any regulatory requirements, a dairy company may wish to show investors, the local community and the wider public its commitment to being proactive on climate change; for example, by setting voluntary carbon reduction targets; producing product carbon footprints; or investing in environmental initiatives to reduce energy use and carbon emissions.

Technological drivers

Although all the major equipment suppliers improve their plant and machinery over time and compete on the basis of quality and performance as well as price, there remains a slow pace of technological change (a common feature of basic industrial processes) within the sector. The major sources of innovation have been in homogenisation, separation and heat recovery. There are significant technological efficiencies available for new dairies where operations can be better integrated.
The nature of dairies may lend itself to combined heat and power implementation, although this tends to be site-specific and may be expensive or impractical to retrofit to existing plants.

**Regulatory drivers**

**Climate Change Agreement**
The UK dairy sector is covered by a Climate Change Agreement (CCA), under which its members receive an 80% discount on the Climate Change Levy surcharged on energy bills. Historically the dairy sector has performed well, reducing energy consumption by 16% since the start of the scheme in 2001. The CCA has been extended to 2017, although with a reduced CCL discount of 65%. As most dairy sites fall under the terms of the CCA there will be little if any participation in the Carbon Reduction Commitment.

**EU Emissions Trading Scheme**
EU ETS is an emissions reduction framework based on the cap-and-trade principle first implemented in 2005 across the EU. It covers selected energy intensive industries such as cement and steel production, as well as all thermal plants above a certain size (20MW). If a site meets one of these criteria it must join the EU ETS (even if it is also covered by a CCA). Large dairy processing sites are covered by the EU ETS on the basis of their boiler plant, which typically will be above the size threshold. Phase 3 of the EU ETS runs from 2013 to 2020.

**IPPC**
Integrated Pollution Prevention and Control (IPPC) is a regulatory system that uses an integrated approach to control the environmental effects of certain industrial activities through a single permitting process. It has been in place since 2005. UK Guidance for delivering the PPC (IPPC) Regulations in this sector is based on the Best Available Techniques (BAT) described in a European Commission BREF reference document. IPPC covers operators who are treating and processing more than 200 tonnes of milk per day. For the dairy industry, the key environmental issues managed by the permitting system are:

- Water use
- Effluent management
- Waste handling
- Accident risk
- Hygiene.

To gain a permit, operators have to show that the techniques they are using, or are proposing to use represent BAT.

**Food safety**
Dairy industry energy use is influenced by legislation that requires pasteurisation to be carried out to specific standards. Regular drinking milk must be pasteurised at 72°C for a minimum of 25 seconds (cheese making can involve a lower temperature for a longer holding period), and the milk must always be stored below 6°C. These standards put constraints on pasteuriser configuration and consequently how much energy is required to heat the milk and then cool it down to regulated levels.

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5 Further information on the European IPPC Bureau and the BREF document may be found at [http://eippcb.jrc.es/reference/](http://eippcb.jrc.es/reference/)
For example, if an alternative method for pasteurisation could be found to bring about the same level of microbial destruction, but at lower temperatures, then the Food Standards Agency would need to revise its definition of pasteurisation in its regulatory requirements before any such method could be deployed commercially. This is a key barrier to change.

Energy and carbon reduction drivers

In dairies the three main drivers for energy reduction are cost, regulation and the environment. The sector takes a progressive approach to energy efficiency, thanks to internal and external pressures to lower costs. This means that good practice in energy management is already widespread, and many of the cost-effective technology opportunities for reducing energy consumption, such as improved controls, sub-metering and more efficient motors and drives, have already been implemented. However, the good practice survey highlights that there are still significant low- and no-cost opportunities available for implementation.

Carbon emissions relating to raw milk processing are monitored and reported as part of the CCA. Relative energy consumptions and breakdown of emissions covered by the industry’s CCA are shown in Figures 3 and 4 (on a specific basis, i.e. kWh or kgCO₂ per m³ of raw milk processed).

Figures 3 and 4 show that energy performance varies widely across the sector. This is explained in part by the small number of sites carrying out energy intensive evaporation and spray drying processes. Other reasons for variance may be different technology solutions or good practice measures that are either not fully applied or are not applicable across the full range of dairy processors.

![Figure 3: Range of energy performance across the main product types (CCA data)](image-url)
Specific performance benchmarking

Performance data for the whole sector was not available. However, data (weekly energy, water and production for 2008) from 23 dairy sites across the UK allowed us to create indicative specific energy and water performance benchmarks. Figure 5 shows that typically dairies with good water consumption ratio also have a good energy ratio, as much of the energy supplied is embodied in hot water ultimately lost to drainage or as low-grade heat.

**Figure 4: Specific CO₂ emissions across the main product types (CCA data)**

**Figure 5: Relationship between specific water and energy consumption for 23 selected sites**
4. Methodology

Stage 1 of the Industrial Energy Efficiency Accelerator aimed to examine the sector-specific raw milk processes in depth to understand how the process consumes energy and interfaces with other systems. Using this evidence, we then identified possible solutions that could improve energy efficiency and carbon emissions.

Raw milk process focus

By taking the processes that were most common across the dairy industry, the Accelerator focused on specific areas that would have the most impact on the sector if savings were identified.

The raw milk process involves taking in raw milk from tankers and then processing it to a stage where it can either be sold as finished milk or sent on for secondary processing.

Since the initial raw milk stages of pasteurisation, separation, homogenisation (liquid industry) in addition to CIP are common to all dairy processing sites, any opportunities identified in these areas could potentially be replicated across the UK dairy industry.

There are other dairy processes, such as spray drying, that account for much larger energy consumption, but as these processes are only carried out at a small number of sites, we chose not to include them in the programme.

Figure 6 summarises the boundaries of the investigational activities (in white).

Figure 6: Raw milk processing technology focus areas
Site selection
To achieve a more detailed and accurate understanding of the raw milk process energy use, we selected three representative dairies.

<table>
<thead>
<tr>
<th>Dairy</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual raw milk throughput (m³)</td>
<td>374,000</td>
<td>209,000</td>
<td>468,000</td>
</tr>
<tr>
<td>Water ratio (m³/m³ raw milk)</td>
<td>1.02</td>
<td>1.38</td>
<td>0.41</td>
</tr>
<tr>
<td>Fuel ratio (kWh/m³ raw milk)</td>
<td>39</td>
<td>83</td>
<td>23</td>
</tr>
</tbody>
</table>

Methodology
The methodology used in this study included:
- Initial information gathering phase to build relationships and understanding of the process and sector.
- A self-assessment ‘good practice’ survey for dairy sites.
- Desk-based research into equipment and innovation.
- Assessing the range of information already being recorded on the sites’ SCADA systems and, where there were gaps in the data required, additional sub-metering in order to build up the complete set of data.
- Analysis of historic process and energy data and new sub-metered data to identify sub-optimal performance and quantify energy efficiency opportunities.
- Site visits and discussions with key industry contacts and site personnel.
- Workshops with equipment suppliers and dairy companies.

Findings are presented on an anonymous basis with common energy units in terms of kg CO₂ emitted per m³ of milk processed.

Metering plan
Sub-metering and data gathering used additional meters to supplement information collected from the three host sites’ SCADA systems. The metering plan for the raw milk processes was as follows:

<table>
<thead>
<tr>
<th>Process</th>
<th>Variable</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasteurisation</td>
<td>At a time interval of 1 minute</td>
<td>The parameters listed are all the details that are required to understand the heat transfer and loads at each point of the process over time. No measurement of the chilled water or steam usage directly is required, as heat loads will be derived from the heating and cooling performed on the fluid passing through the plant.</td>
</tr>
<tr>
<td></td>
<td>• Milk temp in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milk temp after regenerator heating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milk temp after homogeniser</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milk temp after heating section/beginning of holding tube</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milk temp end of holding tube</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milk temp after regenerator cooling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milk temp after cooling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pasteuriser flow</td>
<td></td>
</tr>
</tbody>
</table>
### Process Variable Rationale

<table>
<thead>
<tr>
<th>Process</th>
<th>Variable</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Process steps from SCADA</td>
<td>The parameters identified allow a full energy consumption model to be built in a cost-effective manner. Steam metering would be optimum but as the project is intended to be non-invasive we used ultrasonic flow meters, which may not be reliable when dealing with steam.</td>
</tr>
<tr>
<td></td>
<td>- Flow condition – forward/recirc/water recirc/flow to drain/CIP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Plant process step</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Heat consumption from steam or direct fuel consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Steam valve on/off position</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Outward flow temperature or hot tank temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Outward flow volume</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Return flow temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Return flow switch or volume</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Make up water volume</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Process step (usually from SCADA or controls)</td>
<td></td>
</tr>
<tr>
<td>CIP</td>
<td>At a time interval of 1 minute</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Electricity consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Process step (usually from SCADA or controls)</td>
<td></td>
</tr>
<tr>
<td>Homogenisation</td>
<td>At a time interval of 1 minute</td>
<td>Electricity is the sole parameter to monitor the homogenisation process. At each process step the pressure in the homogeniser changes, as will the electricity consumed. This makes it easy to identify what is going on.</td>
</tr>
<tr>
<td></td>
<td>- Electricity consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Process step (usually from SCADA or controls)</td>
<td></td>
</tr>
</tbody>
</table>

Data was collected through a range of invasive and non-invasive meters, installed in addition to the existing measurements. Metering data was combined with production information and process operating conditions to determine patterns and trends in energy use.

Data was collected over a six-week period. As dairy operations normally run continuously and don’t vary, this was enough time to gather representative information.
5. Key findings

Distribution of energy use in the processes

The dominant liquid milk processes in terms of energy consumption, cost and carbon emissions are pasteurisation and CIP. Figure 8 shows the relative energy intensity measured for the main processes in terms of heat and power.

**Figure 8: Relative energy intensity of raw milk processes**

**Pasteurisation**

We measured the energy consumption of pasteurisers using the temperature change across the heating and cooling sections, combined with the flow rates of the milk.

Figure 9 shows an example pasteuriser map with a combination of internal and external temperature and flow probes connected to the site’s SCADA system. Data collected from these sensors allows the energy used to heat and cool the volume of milk that passes through the pasteuriser to be calculated.

**Figure 9: Pasteuriser map showing temperature and flow sensors**
Yellow sensors are site SCADA information.
Blue sensors are additional external temperature.
F1 shows the flow coming into the pasteuriser and through the first heating section
F2 shows the flow through the second heating section and the cooling section
T3 – T2 is the temperature difference across the first heating section
T5 – T4 is the temperature difference across the second heating section
T7 – T8 is the temperature difference across the cooling section

Figure 10 shows the example pasteuriser temperature profiles over a one-week period at these points.

Figure 10: Temperature profiles of pasteuriser over a one-week period

Temperature trends
After monitoring the three sites, we looked for trends to connect specific temperature points of pasteurisation against the overall ideal specific carbon, which was calculated from measurements taken at each site.

The regeneration of a pasteuriser based on the heat added is compared to the milk’s overall temperature rise. Figure 11 shows that a higher regeneration rate leads to a lower specific CO₂ emission. The relationship charted in Figure 11 is only valid in the region investigated and cannot be used to extrapolate generally (three data points are not enough to determine the full relationship of regeneration with specific CO₂ outside the metered area).
Figure 11: Relationship of pasteuriser regeneration efficiency against specific emissions CO₂/m³ milk

The impact of temperature on pasteurisation efficiency can also be explored by comparing heating approach temperature to the specific CO₂/m³ emission. Figure 12 demonstrates how smaller heat exchanger approach temperatures (the red section of the bar) lower specific carbon emissions and increase the regeneration rate of the process.

Figure 12: Average pasteuriser temperatures showing heating approach temperature relationship to specific CO₂/m³ of milk processed
Circulation of pasteurisers

The time that a pasteuriser spends in non-productive circulation is shown below in Figure 13 for two of the three sites monitored. Time spent in circulation can be associated with wasted resources as it does not aid production.

In these cases the energy used for circulation increased the specific pasteurisation CO₂ per unit of milk by between 16% and 18%.

Figure 13: Pasteuriser circulation time split for sites measured

Figure 14 shows the time split of one pasteuriser in terms of production, circulation or neither (CIP or off) over a week. The periods of circulation are not regular or linked to periods of production, but appear to be random, mostly occurring for long periods at either the end or beginning of production. This suggests that such circulation can be avoided through improvements in operational practice and scheduling.
For sites whose pasteuriser profiles include long periods spent in circulation, installing a hibernation system could help avoid unnecessary energy use. This concept is explained in detail below.

**Key results**

- **Specific carbon:** 2.53 to 3.55 kgCO₂/m³ raw milk (heating/cooling – excludes pumping).
  
  The range in energy used per pasteuriser is influenced by the following:
  
  - Raw milk and pasteurisation temperature
  - Level of heat regeneration/heat exchanger approach temperature
  - Non-useful running e.g. during water circulation.

  Other influencing factors:
  
  - Difference in process or heat exchanger design e.g. 3 or 5 stage (this is associated with how the pasteuriser is set up and not simply the number of sections).

- **Applicability:** 100% of milk processed is pasteurised, although the holding temperature and time will vary depending on whether the milk is to be processed further (i.e. cheese making requires a lower temperature, but a longer holding time).

- **Associated carbon emissions:** an average of the three sites measured suggests a sector total of 42,000 tCO₂ per annum from the milk pasteurisation process (thermal energy input), equivalent to 4.9% of sector emissions (excluding cream and pasteuriser pumping).

- **Additional carbon emissions:** pumping energy used for circulation increases the specific pasteurisation CO₂ per unit of milk by between 16% and 18%.
• **Relationship of efficiency to carbon emissions:** From the three sites metered there is a correlation between the specific CO\(_2\)/m\(^3\) of milk processed and the level of regeneration measured in terms of heat supplied out of total temperature rise.

The gradient on Figure 11 indicates that for every 1% increase in the pasteuriser regeneration efficiency, an average saving of 0.2kgCO\(_2\)/m\(^3\) can be achieved. This can be extrapolated up 2,600 tonnes CO\(_2\) for each 1% increase in pasteuriser regeneration efficiency over the entire sector, as all milk is pasteurised in regenerative thermal pasteurisers. This interpretation will only be valid within the band investigated as the relationship may change under different conditions.

For a typical site, processing 350,000m\(^3\) of raw milk, this would equate to an annual saving of £10,100 for every 1% increase in regeneration (using an average cost per m\(^3\) of milk processed at £0.45/m\(^3\)).

**What this might mean in terms of opportunities**

The intensive use of heat and cooling in the pasteurisation process, and the impact of regeneration efficiency, suggests the following areas of opportunity:

• **Improved regeneration efficiency:** increasing the thermal regeneration efficiency of the pasteuriser through more efficient heat exchangers.

• **Pasteuriser hibernation:** up to 14% of the energy for pasteurisation is used during extended periods of circulation (periods longer than 10 minutes taken from the data represented in Figure 13). During hibernation the cooling section is typically turned off, and the heating is reduced by about 90%, reducing the heating and cooling load by approximately 95%.

• **Low temperature pasteurisation:** substituting (or supplementing) the current system of thermal pasteurisation with a lower temperature microbial destruction process. There are a number of alternative methods for this process such as using UV light, pulsed traditional light, high pressure pasteurisation and pulsed electric field pasteurisation. Not all of these technologies are more energy efficient than thermal pasteurisation (e.g. high-pressure pasteurisation).

**Homogenisation**

Homogenisation varies widely in the specific amount of carbon dioxide generated per m\(^3\) of milk processed. This is mainly due to three reasons:

• The degree to which a site partially homogenises its milk intake (i.e. rather than homogenising the entire flow).

• The amount of time that a site runs its homogenisers during non-production periods such as CIP.

• The homogeniser head design.

**Data**

Figure 15 illustrates the electrical power that homogenisers use at each site during production and CIP cycles. Between 45%-63% of the production power is drawn by the homogeniser when not in production during CIP cycles (i.e. the CIP liquid being pumped through the homogeniser with a high-pressure drop and pumping load).
Figure 15: Homogeniser load showing reduction during periods of CIP

The same set of data is depicted in a different manner in Figure 16 to show the difference in energy intensity of partial homogenisation compared to full stream homogenisation. Figure 16 also shows the percentage of full pump power needed for CIP operations. Table 1 shows the performance variation relationship as specific CO₂ per m³ of milk averaged over all production periods, compared to the amount of energy associated with CIP and non-production related times.

Figure 16: Homogeniser load during production and CIP cycles

Table 1: Homogenisation performance variation measured

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average energy intensity of homogeniser during production (kgCO₂/m³)</td>
<td>0.69</td>
<td>2.15</td>
<td>0.97</td>
</tr>
<tr>
<td>% of total homogeniser energy used for CIP during metered period</td>
<td>11%</td>
<td>27%</td>
<td>9%</td>
</tr>
</tbody>
</table>
Key results

**Specific energy:** 0.7kgCO$_2$/m$^3$ (partial homogenisation) to 2.2kgCO$_2$/m$^3$ (standard full stream homogenisation) for raw milk production.

**Energy used by the homogeniser during CIP:** CIP accounts for between 9% and 27% of homogeniser energy consumed over the monitoring period.

**Applicability:** Liquid milk products only; i.e. 51% of raw milk processed. As homogenisation is only used on milk that is to be consumed as a liquid, this will only apply to 51% of the market. For liquid milk sites in the UK, 18% of the milk is skim, which is also not homogenised, giving a total sector applicability for homogenisation of 51% x (1-18%) = 41%.

**Associated sector carbon emissions:** If all sites in the sector operated a partial homogenisation regime, this would indicate an annual sector total of 3,800tCO$_2$ for the homogenisation process. Conversely, if all sites operated on a full stream basis, the sector total for the homogenisation process would be closer to 12,000tCO$_2$ per annum. These estimates illustrate the potential energy and carbon benefits from operating a partial homogenisation process where feasible. Three of the ten respondents to the good practice survey run full stream homogenisers. If this was representative of the industry as a whole (i.e. 30% of all sites still operating a full stream homogenisation process), then the relative sector carbon emissions associated with homogenisation would be approximately 6,300tCO$_2$ per annum.

To fully estimate the potential savings associated with switching the whole industry to partial homogenisation, we will need to understand those sites running either full stream, partial homogenisation or both more clearly.

What this might mean in terms of opportunities

The relatively large amount of energy needed for homogeniser pumps suggests the following areas of opportunity:

**Partial homogenisation:** As above, reducing the homogeniser throughput by homogenising only the fat-enriched phase from the separator, and mixing this with the low-fat phase, would save considerable energy compared with homogenising the full milk throughput (even though greater pumping power is needed to homogenise the fat-enriched phase, this is more than offset by the saving achieved by passing only a fraction of the milk through the homogeniser).

A typical site producing 350,000m$^3$ milk per annum with full stream homogenisation would save almost £63,000 per annum with the introduction of the most up to date partial homogeniser system (the most up-to-date system runs with 0.48kgCO$_2$/m$^3$ of milk).

If three out of ten sites were able to move to partial homogenisation from full stream homogenisation (good practice survey finding), then the savings from using the most up-to-date partial homogenisers (that can process a fat content of 18%) would equate to 5,500 tCO$_2$ or 0.6% of the entire sector's emissions.

**Reducing head pressure:** the energy needed to drive a conventional homogeniser is proportional to the pressure at which the system runs in order to reduce the fat globule size sufficiently. Analysis of the data captured shows that if the homogeniser working pressure can be reduced through innovations in orifice design, then the associated electrical energy needed to drive the system could also be reduced. The following equation is used by the industry to calculate necessary power:

$\text{Effective kW} = \frac{\text{Flow rate of homogeniser} \times \text{homogenisation pressure in bar}}{30,600}$
Discussions with manufacturers suggest that upgrading the homogeniser head to the most efficient pressure design (180bar down to 120bar) could reduce electrical consumption by up to one third. Reductions will vary depending on the equipment installed at each site.

For a site running full stream homogenisation, this would result in an annual saving of £27,000, or £8,600 for a site that is running a partial homogenisation system.

**Reduction in CIP liquid used in homogeniser cleaning:** since up to 63% of the homogeniser full pump power is needed for CIP operations (accounting for 9%-27% of homogeniser energy), reducing CIP liquid through more precise control of the volume needed to achieve the right standard of cleanliness, or through alternative CIP processes, could lead to significant reduction in pump load and energy consumption.

**CIP systems**

On dairy sites, CIP systems focused on raw milk and finished milk are usually close to each other.

For the three sites we monitored, Figure 17 shows a strong relationship between the specific energy and water consumptions. This is because much of the water volume used at a site is heated during CIP and ultimately lost to drain.

Typically raw and finish CIP water use was approximately half the volume used for the entire CIP of the sites investigated. Therefore to estimate the total CIP heating energy used on a site basis, the figures for raw and finish milk CIP were doubled.

![Figure 17: CIP energy use versus water consumption](image)

Heat energy added to a CIP system was calculated on the basis that energy is proportional to the mass flow rate multiplied by the temperature difference across the heat exchanger.

Figures 18, 19 and 20 show operational CIP tank profiles from each site. They show that when a holding tank temperature drops below a lower set point (from either gradual heat loss through the tank walls or through the introduction of a colder fluid such as recovered caustic,
fresh water and caustic concentrate top-up), steam is sent to the heat exchanger and the tank temperature rises to the upper set point.

**Figure 18: Energy input into caustic tank on Finish CIP on Site 1**

**Figure 19: Energy input into caustic tank on Finish CIP on Site 2**
The steam valves at Site 3 opened and closed rapidly during periods of heating, and did not follow a smooth heat profile as was the case at Sites 1 and 2. This was a system fault resulting in spot loads to the steam system, which could decrease efficiency as it will cause additional boiler firing to satisfy the demand.

### CIP heat-loss bridges

The monitoring also provided access to the CIP plants’ heat balances. The metered data showed the total energy input, while tank standing losses and tank dumps to drain were based on calculations. The energy lost to drain during CIP was calculated from the amount of raw detergent added to the system (replacing losses at a given concentration). The following four figures show the results from two sites. The top bar shows the total energy added to the system over the monitoring period and the lower bars show the balance of the heat lost.
Figure 21: Site 1 raw milk CIP loss bridge

Figure 22: Site 1 finished milk CIP loss bridge
Figure 23: Site 3 raw milk CIP loss bridge (Acid CIP)

Figure 24: Site 3 finished milk CIP loss bridge
Analysis

The heat balances showed:

- In general, tank standing losses from the radiation and convection of heat away from the surface of the CIP tanks is small.

- Caustic lost to drain is the energy wasted during each CIP from hot detergent solution being sent to drain rather than recovered. This forms one of the significant losses from the systems and is largely dependent on system optimisation.

- Site 3 raw milk CIP (Figure 23) shows notably less detergent losses to drain than the other plants. This was the only CIP plant solely dedicated to using acid detergent; however it was not clear whether this should have a particular influence on the losses to drain or whether the higher efficiency was down to good management and scheduling of cleans.

- Caustic lost during tank dumps is related to the sporadic dumping of an entire tank when the tank is too contaminated with foreign material to carry on working effectively. These generally account for a small amount of losses and carbon emissions.

- Heating infrastructure includes heating pipework, tanks, valves and other conducting materials in contact with the CIP solution while in circulation, as well as the subsequent losses to the surrounding atmosphere. This forms the most significant amount of the CIP heat load.

Effect of temperature on CIP runs

The energy measured for raw and finished milk CIP is in terms of heat. Therefore as the temperature of caustic CIP is approximately 80°C (acid CIP temperatures are lower, nearer 65°C) and with ambient temperature at 20°C, then for every 1°C reduction in CIP temperature there will be a 1/60th reduction in the energy needed to heat the fluid.

If all CIP was caustic at 80°C then for every 10°C reduction in CIP temperature, there would be on average a reduction of 0.4 kgCO$_2$/m$^3$ of milk processed on site, or an annual saving of £19,000 on a typical site processing 350,000m$^3$ of milk. Replication across the sector would result in a sector-wide reduction of 5,300 tCO$_2$ for every 10°C CIP temperature reduction.

Individual CIP systems vary from site to site. Some sites operate both acid and caustic in raw and finished milk systems, whereas others run a caustic system on the finished side and an acid system on the raw side. The figures above indicate possible savings but further investigation into the design of a site’s CIP set-up would be needed before specific savings could be calculated.

Key results

The energy and carbon intensities measured across the three sites show a wide range in performance. Ultimately energy consumption of a CIP system is highly dependent on the design of the plant, how the CIP system was initially commissioned and operational practice.

- **Specific carbon:** Raw and finished milk CIP is 0.7 to 1.73kgCO$_2$/m$^3$ raw milk (heating only – excludes pumping):
  - Raw milk CIP: 0.46–0.92 kgCO$_2$/m$^3$
  - Finished milk CIP: 0.24–0.81 kgCO$_2$/m$^3$
- **Applicability:** 100% milk processed. All dairy production sites use CIP to keep their lines clean and so any opportunities involving CIP can be rolled out over the entire sector.

- **Associated sector carbon emissions:** Assuming raw/finished milk CIP accounts for half of all site CIP, associated sector carbon emissions from gas consumption associated with CIP is 19,000–46,000tCO₂ per annum (2.2–5.4 % of the sector total). There are further emissions related to CIP that have not been taken into account within the scope of this study, such as pumping and effluent treatment. These will relate to the volumes used and would be automatically reduced if the amount of CIP solution used can be reduced.

**What this might mean in terms of opportunities**

Efficiency gains associated with CIP can be classified into two areas: opportunities that optimise the current process, and opportunities that require fundamental redesign with a new system or add-on.

The CIP loss bridges show that the two largest areas of heat use are hot detergent lost to drain and heat absorbed by infrastructure in achieving system CIP temperature. Where hot detergent is wasted to drain there are opportunities for optimisation of the CIP system. In order to reduce the costs associated with heating infrastructure, a low temperature CIP system cleaning could be considered.

**CIP process optimisation**

By looking at the split of CIP energy use, we were able to identify hot detergent wasted to drain during CIP runs as one of the main causes of energy loss. The most common reasons for CIP systems to dump hot detergent are as follows:

- When cleaning valves and vents, hot detergent solution is pushed out of seals and openings.
- Parts of the system are ‘non return’ CIPs where either the age of the system, or the cost of initially setting up the return, means that the detergent used to clean these items is not reused.
- When some systems are cleaned, the amount of material that the detergent solution collects results in the detergent being dumped to drain (as it would contaminate the central detergent supply).
- Insufficient detergent tank size means that if a single system is performing multiple cleans at once, then the holding tank level may fall below the minimum point and will be refilled with fresh cold detergent and water. This then needs to be heated up to operational temperature. When the existing solution is returned from the items it has cleaned, there is insufficient tank capacity and so the hot solution is either dumped to drain, or sent to the pre-rinse tank and then to drain.
- User alteration: over time, minor adjustments or ‘tweaking’ can result in the system becoming out of balance.
- CIP systems are set for specific periods of time and if aspects of wash cycles are optimised to increase production availability then associated costs can sometimes increase. As energy prices increase this balance may tip in the other direction.

The good practice survey suggested 20% of sites may be able to achieve quick wins from optimising the heat, water and chemical demand of the CIP system.
Other CIP optimisation opportunities

- **Reduction of CIP water volume and/or temperature** would improve the energy consumption of CIP systems. It is impossible to predict how much impact this would have across the sector as each site benchmarks its CIP systems differently and each has a different set up of caustic and acid systems. Volume reduction can generally be achieved through incremental monitoring, adjusting and testing with the assistance of a commissioning engineer. The regulated aspects of CIP are the microbial levels within the pipes and not the temperature of the working fluid.

- **Reduction in the number of CIPS:** Typically CIP cycles are instigated through timers, product change and operator discretion. Of the three sites monitored, the plant with the highest CIP load had 60% more CIP units for the same volume of raw milk throughput. Reductions can be achieved in two ways: either increasing the use of the plant while keeping the CIP schedule similar; or reducing the frequency of CIP runs in areas where possible. As CIP is primarily time driven, the higher the plant operation, proportionally the less CIP carried out per unit output.

- **Understanding what constitutes clean** i.e. avoiding an unnecessary level of cleaning for a required standard of hygiene. Knowing how much energy is used to heat the fluid used for CIP enables sites to calculate potential energy savings from alternative forms of CIP that do not involve the heating of large amounts of caustic and acid for cleaning.

- **Further investigation into how the design of a CIP system** affects its energy demand will be needed to model accurately the potential savings. The data we have collected has shown the size of prize that is available in terms of heating energy reduction potential, but when taking into account chemical usage and pumping costs the overall energy consumption savings would be considerably greater.

- **Cleaning of CIP detergent solution with membrane technology** would reduce the amount of hot solution that is currently wasted to drain after becoming too contaminated to return to the main tanks. The cost savings would be associated with the amount of CIP solution lost through tank dumps and that not returned to the detergent tank due to excessive soiling.

**Infrastructure loss reduction opportunities**

It is unlikely that the proportion of heating energy used for heating up infrastructure can be simply reduced through optimisation of current CIP systems. By using an alternative system that does not use hot solution to clean, the energy that is lost to drain and the energy used to heat up the infrastructure can be saved, meaning that much of the CIP energy losses could be reduced. An alternative approach could be to minimise the heat capacity of process equipment through new equipment materials and design e.g. alternative pipe material.

**The good practice survey**

Figure 25 illustrates how, for the 10 sites that responded to the survey, nearly 30% of the 150 measures classed as ‘good practice’ and ‘possible’ have not yet been carried out and therefore could be implemented. This indicates that there is significant potential for energy savings within the industry simply based on the implementation of further low- or no-cost measures where applicable. The full analysis of survey responses is shown in Appendix 2.
The survey responses indicated that over half of the sites thought that the following generic opportunities were possible, and either easy to implement, or could lead to substantial savings:

- Use high-efficiency jet nozzles in blowing applications to reduce compressed air use
- Use high-frequency lighting fitted with optical mirrors to reduce electrical costs
- Reduce cooling loads by 0.5°C on chilling applications
- Fit variable speed drives on the forced draft fan and feed pumps on the boilers
- Reduce homogeniser pressure through an alternative head
- Run scheduling and simulation software to reduce bottlenecking
- Provide energy awareness and technical training for staff.

The survey responses suggested further emissions reduction could be achieved by implementing the following good practice process measures classified as ‘possible’ at most sites:

- **Monitoring and targeting:** Create a computer simulation of the plant for scheduling improvements
- **Process:** Install high efficiency lubrication in large gearboxes
- **Process:** Base load analysis of entire plant
- **Boilers and steam distribution:** Manage instantaneous loads on the boilers through on-site real time metering
- **Cooling and refrigeration:** Increase evaporating temperature of compressors on refrigeration plant
- **Compressed air:** Heat recovery from air compressors for space heating or hot water.

Partial homogenisation could be added to this list. Even though three out of ten sites did not carry out partial homogenisation, the potential energy and carbon saving from doing so are such that it should be seriously considered at all sites where practicable.
6. Opportunities

Summary of opportunities
The opportunities identified by this investigation fall into the following broad categories:
- Good practice implementation
- Innovation in process equipment.

Good practice implementation
Good practice process opportunities to achieve effective emissions reduction were identified from the survey responses as still ‘possible’ at most sites, or discussed during the site investigations or workshop. Specific measures for the raw milk process were found during our investigations and discussed in Section 5.

General process measures
- **Generic measures**: Lighting, variable speed drives, compressed air, energy awareness etc.
- **Monitoring and targeting**: Create a computer simulation of the plant for scheduling improvements.
- **Process**: Install high-efficiency lubrication in large gearboxes.
- **Process**: Base load analysis of entire plan.
- **Boilers and steam distribution**: Manage instantaneous loads on the boilers through on-site real time metering.
- **Cooling and refrigeration**: Increase evaporating temperature of compressors on refrigeration plant.
- **Compressed air**: Heat recovery from air compressors for space heating or hot water.

Specific raw milk process measures
- **Partial homogenisation**: Reducing the homogeniser throughput by homogenising only the fat-enriched phase from the separator, and mixing this with the low-fat phase, would save considerable energy compared with homogenising the total milk throughput. Although greater pumping power is needed to homogenise the fat-enriched phase, this is more than offset by the saving achieved by passing only a fraction of the milk through the homogeniser.
- **Upgrading homogeniser heads**: Can reduce the energy demand by up to a third.
- **Direct drive separators**: Newly available equipment uses a gearless system and offers a 30% reduction in energy consumption from previous designs.
- **Pasteurisation hibernation**: Involves reconfiguring the pasteuriser set-up so that during periods of unproductive running the energy consumed by the pasteuriser is reduced.
- **Increasing pasteuriser efficiency**: Involves enlarging the heat exchanger capacity to a maximum (depending on plant availability) of 94%.
- **High temperature hot water heat pump**: available for the recovery of waste heat from existing centralised site refrigeration systems to generate hot water. The hot water can then be used to heat dairy processes including pasteurisers, CIP and bottle washers.

- **Review and optimise the set-up and operation of existing CIP systems**: Work with plant suppliers to optimise existing CIP operations through increased metering and understanding.

Table 2 summarises the good practice opportunities available for step change reduction in CO₂ emissions from the liquid milk processes.

Opportunities may overlap, so the total reduction for the sector cannot be estimated by combining the individual CO₂ savings identified.
## Table 2: Summary of good practice implementation opportunities identified

<table>
<thead>
<tr>
<th>Opportunity summary</th>
<th>Cost of implementation (typical site)</th>
<th>Payback (years)</th>
<th>Sector saving (tCO₂/yr)</th>
<th>Readiness level</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General good practice measures</strong> see Appendix 2 for a full list of these measures.</td>
<td>N/A</td>
<td>Under three years</td>
<td>5% (conservative prediction)</td>
<td>Opportunities have been implemented elsewhere in the sector</td>
<td>Awareness, culture, finance and resource availability.</td>
</tr>
<tr>
<td><strong>Partial homogenisation</strong> allows the fat content that modern homogenisers can take to be increased to 18%, meaning that the flow through the homogeniser can be decreased accordingly.</td>
<td>£150,000</td>
<td>2–16</td>
<td>Up to 5,500</td>
<td>Commercially available</td>
<td>Cost of new equipment and process reconfiguration; however this practice is already widespread and the extent to which further roll out is possible is unknown.</td>
</tr>
<tr>
<td><strong>Direct drive separators</strong> run on a gearless system and offer a 30% reduction in energy consumption from previous designs.</td>
<td>Price TBA</td>
<td>Price TBA</td>
<td>1,900–2,100</td>
<td>Commercially available; new product</td>
<td>Cost of new equipment; pricing likely to be attractive when existing equipment is replaced.</td>
</tr>
<tr>
<td><strong>Pasteurisation hibernation</strong> involves reconfiguring the pasteuriser set up so that during periods of unproductive running the energy consumed by the pasteuriser is reduced.</td>
<td>£60,000</td>
<td>1.2–2.0</td>
<td>Further work needed</td>
<td>Commercially available product</td>
<td>Awareness of technology and capital expenditure to roll it out.</td>
</tr>
<tr>
<td>Lower pressure <em>homogeniser heads</em> can reduce the energy demand by up to a third.</td>
<td>Price dependant on site</td>
<td>1.25</td>
<td>Further work needed</td>
<td>Commercially available product</td>
<td>The rationale for moving to the most up to date equipment depends on which level of technology is already installed.</td>
</tr>
<tr>
<td><strong>Increasing pasteuriser efficiency</strong> can be done through enlarging the heat exchanger to a maximum (depending on plant availability) of 94%.</td>
<td>£150,000</td>
<td>1.5</td>
<td>17,000</td>
<td>Commercially available product</td>
<td>Cost and down-time associated with modifying pasteuriser configuration and pipe work.</td>
</tr>
<tr>
<td>Install high temperature hot water <em>heat pump</em> to recover waste heat from existing centralised site refrigeration systems and generate hot water for use in pasteurisers, CIP and bottle washers.</td>
<td>£500,000</td>
<td>2–5</td>
<td>82,000–48,000</td>
<td>Commercially available</td>
<td>May not be applicable to all sites, depending on the layout of refrigeration &amp; heating systems, more cost-effective when part of wider site refurbishments or a new process line.</td>
</tr>
<tr>
<td><strong>Review and optimise the set-up and operation of existing CIP systems:</strong> Work to optimise existing CIP operations through increased metering and understanding.</td>
<td>N/A</td>
<td>Under three years</td>
<td>5% (conservative prediction)</td>
<td>Opportunities have been implemented elsewhere in the sector</td>
<td>Awareness, culture, finance and resource availability.</td>
</tr>
</tbody>
</table>
Innovation in process equipment

The opportunities with the greatest potential for significant CO₂ emissions reduction in the raw milk processes are outlined below and summarised in Table 3.

Alternative homogenisation techniques

Current homogeniser technology is energy intensive during both production and non-productive CIP activity. Alternative homogenisation technologies with lower energy consumptions during both CIP and production operations could significantly reduce the sector’s energy consumption. This analysis suggests the sector as a whole could cut its homogenisation-related emissions by between 4,700tCO₂ and 15,000tCO₂ per year, depending on the degree to which processing sites operate a full stream or partial stream homogenisation process.

The current sector-wide split between full and partial homogenisation is not known, but three out of the 10 good practice survey respondents indicated that they operate a full stream process. Assuming that this is representative of the wider industry, this suggests that around 7,800tCO₂ a year is related to homogenisation.

This level of emissions could be reduced by around 3,100tCO₂ a year if partial homogenisation was applied universally (if possible), and potentially further still through the introduction of non-conventional, alternative techniques such as ultrasonic homogenisation. Obtaining a greater understanding of the energy and carbon saving potential of ultrasonic or other alternative homogenisation techniques would be an appropriate concept for Stage 2 of the IEEA programme.

Reduction of CIP water and heat usage

Novel forms of CIP which reduce the temperature, water or heat required by CIP have the potential to create a step change in sector energy consumption. The temperature at which CIP is carried out is not determined through legislation and therefore is usually site specific. It’s usually set when the equipment is installed, at the same time as the detergent levels and CIP times are chosen. The analysis found a sector-wide emissions estimate of 19,000 – 46,000tCO₂ per annum (2.2% – 5.4 % of the sector total), for CIP activities. Taking the middle of this range as typical, each 10°C reduction in CIP temperature, or 15% reduction in CIP water usage, would result in a sector-wide emissions reduction of 5,300 tCO₂ per year.

Most of the alternative CIP technologies identified were at the university research, start-up level, or required a commercialisation/manufacturing partner. Potential technologies could include:

- **Cleaning verification**: Investigating the whole CIP process of a plant through advance monitoring to determine when individual parts of the system are clean. This information is then used to re-model the system in order to use the minimum energy and water possible.

- **Ice pigging**: Installing cleaning pipe systems using a crushed ice slurry that can be loaded with specific compounds such as caustic or acid while maintaining sharp product interfaces to reduce product loss and water wastage. This could either run as an independent system or in conjunction with existing CIP systems, substantially reducing the load and amount of water and chemicals needed.

- **Whirlwind pigging**: This technology can clean through pipe systems using a fraction of the energy of traditional CIP systems while still providing the necessary disinfectant and sterilisation.
Ultrasonic cleaning: Ultrasonic cleaning can be used alongside traditional CIP to reduce the demand on the hot detergent by removing material from areas which are difficult to clean, and preventing material from sticking to surfaces in the first place.

Low temperature pasteurisation

Low temperature pasteurisation technologies could potentially create a step change in dairy sector emissions, but cannot currently be put in place because of legislation governing milk processing. The analysis found that milk pasteurisation processes consume thermal energy equivalent to 42,000tCO₂ a year across the UK dairy industry. This accounts for approximately 5% of the sector’s total emissions. Technologies which enable non-thermal pasteurisation can therefore make a significant impact on the sector’s emissions.

However pasteurisation is currently defined by regulators as a purely thermal process, which is a significant barrier to the implementation of such non-thermal technologies. The agencies responsible for food standards in the UK must therefore be engaged so that an alternative definition based on non-thermal process(es) can be developed, supported by the required evidence base.

Non-thermal technologies include UV pasteurisation or pulsed electric field pasteurisation.

Sector savings estimate

Throughout this report upper and lower ranges of potential efficiency savings have been presented to reflect the diversity within the sector. Using a typical dairy size of 350,000m³ of milk processed per year, we could expect the following sector-wide carbon savings if the opportunities presented were put in place. The cost of implementing the suggested range of opportunities in smaller dairies could be considerably higher and investment criteria may not be fulfilled.

Table 3: Carbon saving scenarios for sector

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>Best case savings tonnes CO₂/year</th>
<th>Worse case savings tonnes CO₂/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot water heat pump</td>
<td>82,000</td>
<td>48,000</td>
</tr>
<tr>
<td>Half of efficiency savings (only on the cooling side)</td>
<td>8,500</td>
<td>8,500</td>
</tr>
<tr>
<td>If all sites moved to partial homogenisation</td>
<td>5,500</td>
<td>5,500</td>
</tr>
<tr>
<td>If all sites then on partial homogenisation moved to ultrasonic homogenisation</td>
<td>3,000</td>
<td>-</td>
</tr>
<tr>
<td>If the parts of CIP that could not be cleaned with ice pigging were part of project Zeal to reduce CIP emissions by half</td>
<td>11,500</td>
<td>4,500</td>
</tr>
<tr>
<td>Ice pigging implemented</td>
<td>23,000</td>
<td>9,000</td>
</tr>
<tr>
<td>Good practice savings</td>
<td>86,000</td>
<td>43,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>219,500</strong></td>
<td><strong>118,500</strong></td>
</tr>
<tr>
<td><strong>Percentage saving for sector</strong></td>
<td><strong>25.5%</strong></td>
<td><strong>13.8%</strong></td>
</tr>
</tbody>
</table>

Notes

- This does not take into account pasteuriser hibernation, ultrasonic cleaning or AD due to lack of suitable information
- This presumes that ultrasonic homogenisation does not work as anticipated and does not take into account pasteuriser hibernation, ultrasonic cleaning or AD due to lack of suitable information
<table>
<thead>
<tr>
<th>Opportunity summary</th>
<th>Cost of implementation (typical site)*</th>
<th>Payback (years)</th>
<th>Sector saving (tCO₂/yr)</th>
<th>Readiness level</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasonic homogenisation using a sonotrode to agitate milk in order to reduce the particle size of the fat globules.</td>
<td>£230,000</td>
<td>3–12</td>
<td>3,000–13,000</td>
<td>Commercial product in other sectors, but not for dairy</td>
<td>Initial tests need to confirm the energy necessary to homogenise milk to desired specification, and also to identify any impact on taste/texture.</td>
</tr>
<tr>
<td>Ultra violet pasteurisation uses UV light to stop bacteria multiplying and effectively pasteurise as with thermal pasteurisation using less energy.</td>
<td>£1,100,000</td>
<td>11–14</td>
<td>13,000–26,000</td>
<td>Near commercial product</td>
<td>Awaiting trials with FSA to legitimise UV as a safe method of pasteurisation. Approval period is unknown.</td>
</tr>
<tr>
<td>Ice pigging uses an ice slurry to clean through pipe networks taking the advantages of a solid pig and a fluid at the same time.</td>
<td>£170,000</td>
<td>3–15</td>
<td>9,000–23,000</td>
<td>Prototype technology ready for trials on dairy site</td>
<td>Has been tested in other food sectors but not yet in dairy. Further work needed to understand whether standards of cleanliness can be achieved and to develop a commercial product.</td>
</tr>
<tr>
<td>Ultrasonic cleaning uses ultrasonic actuators to create cavitation within tanks and other solid structures, removing dirt and killing bacteria from inner surfaces.</td>
<td>Unknown</td>
<td>N/A</td>
<td>N/A</td>
<td>New concept and requires trials within the dairy industry to test for its applicability</td>
<td>Early stage technology, with no evidence on its potential costs or benefits to the dairy industry.</td>
</tr>
<tr>
<td>Whirlwind pigging involves sending a whirlwind down through a pipe system to clean out the pipes using less energy than required for a hot caustic system.</td>
<td>£350,000</td>
<td>7–17</td>
<td>6,000–15,000</td>
<td>Commercial product</td>
<td>Cannot clean tanks or plate pack heat exchangers. A previous demonstration project at a UK dairy site was not successful, which has created a negative view within the dairy industry.</td>
</tr>
<tr>
<td>Cleaning verification is a university research programme that has been working with industrial partners to determine what level of cleanliness is actually necessary and in doing so reduce the energy used in the process.</td>
<td>Research project: costs relate to partner contributions</td>
<td>Immediate</td>
<td>9,000–23,000</td>
<td>University looking for industrial partners</td>
<td>This is an R&amp;D project aimed at reducing cleaning costs by optimising CIP. Barriers to participation relate to availability of funds to support research, and potential concerns about confidentiality.</td>
</tr>
</tbody>
</table>
7. Next steps

Next steps for the dairy sector

The level of awareness of the need for energy saving in the dairy industry is good, and because the sector needs to keep its costs down, it has taken many steps already. However, more work should be done to raise the awareness of what is still possible at a site level.

Implement general good practice measures

Good practice opportunities can be implemented more thoroughly at all sites in the sector. Operational staff should be made more aware of the opportunities still available as indicated by the good practice survey. The following recommendations are made:

Implement good practice measures for specific processes

By working closely with suppliers, companies should consider:

- Increasing pasteuriser efficiency by upgrading heat exchangers and set-up optimisation.
- Installing hibernation controls on pasteurisers to reduce the impact of non-production related recirculation.
- Routinely replacing separators with the most up-to-date gearless, direct-drive systems.
- Improve the level of or implement partial homogenisation.
- Review and optimise the set-up of existing CIP plants.

Install hot water heat pumps

The use of high temperature hot water heat pumps on refrigeration plants may soon be a proven dairy application available commercially. If successful, companies should begin to investigate whether it’s feasible for them, as a step towards understanding whether heat pump technology can be retrofitted, or included as part of new process line installations. The Carbon Trust may publish a case study and other evidence of the technology’s potential benefits.

Engage in IEEA pilot projects

Companies should consider taking advantage of potential Carbon Trust support within the IEEA programme. This could mean participating in research or pilot projects developing the market readiness of the following innovative concepts as part of IEEA Stage 2:

- Reduction in CIP water and heat usage
- Alternative homogenisation techniques.

Given the potential risks of implementing unproven technologies at active dairy production sites, as well as the likely cost of innovative equipment not yet in commercial manufacture, any such projects should be large-scale enough to provide a realistic evidence base. Projects should be big enough to provide detailed evidence on energy performance, process integration and production
impacts, to demonstrate how applicable and cost-effective the technology is to the dairy sector as a whole, yet not so large that they are unacceptably expensive to implement as part of IEEA Stage 2.

Next steps for the Carbon Trust

Following our work as part of the Industrial Energy Efficiency Accelerator, the Carbon Trust is able to update and improve its advice to companies in the dairy sector. We also have a dedicated account manager to build relationships with the sector and ensure that opportunities for energy saving and emissions reduction are maximised.

We are hoping to support the implementation of these specific concepts described in this guide:

- Reduction in CIP water and heat usage.
- Alternative homogenisation techniques.

Throughout this work, the Carbon Trust will continue to disseminate knowledge and help replicate energy efficiency best practices across the dairy sector.
8. Acknowledgements

This guide has been produced by the Carbon Trust with support from Camco Environmental Ltd and Dairy UK.
9. Appendix – good practice survey

Methodology
The following questions were asked in the good practice survey sent to dairy industry members as part of this project. The options for response were:
- Implemented
- Possible
- Not possible
- No selection.

The checklist also had drop-down boxes where, if the measure had not been implemented, an option could be chosen as to why not. The options were:

<table>
<thead>
<tr>
<th>Reason for not implementing</th>
<th>Reason for not implementing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pay back too long &gt;12 months</td>
<td>Pay back too long &gt;24 months</td>
</tr>
<tr>
<td>Pay back too long &gt;36 months</td>
<td>Impact on production downtime</td>
</tr>
<tr>
<td>Lack of people skills</td>
<td>Lack of available capital budget</td>
</tr>
<tr>
<td>Lack of available revenue budget</td>
<td>Saving not perceived large enough</td>
</tr>
<tr>
<td>Saving not perceived large enough</td>
<td>Not relevant to our specific processes/operation</td>
</tr>
<tr>
<td>Other – please indicate to the right (in a comment box)</td>
<td></td>
</tr>
</tbody>
</table>

The good practice measures are listed in the following sections

Good practice measures by utility area

**Compressed air**
- Reduce delivery pressure
- Leak test regularly and reduce leakage
- Check and service filters (reduced pressure drop)
- Use high-efficiency jet nozzles in blowing applications
- Don’t use compressed air for cleaning
- Schedule pressure reductions outside main production hours
- Heat recovery from compressor for space heating or hot water
- Application of small weekend compressor
- Install VSD compressors or retrofit VSD on...
existing compressors

- Isolate unused areas e.g. at weekends
- Use of receivers/bufferage in air distribution system
- Correct relation between drying/filtering and quality requirements

Separated compressed air networks (high and low pressure/quality) to minimise generating costs

Correct dimensioning of compressed air pipe

Buildings/lighting

- Energy saving lamps
- Lighting on the workplace
- High frequent lighting containing fittings with an optical mirror system

Daylight dependent control

Presence sensors

Installing several light switching groups

Cooling and refrigeration

- Improve part load performance by changing compressor sequencing or retrofitting a VSD
- Use controls to operate plant at optimum set-points
- Fit VSDs to secondary pumping
- Convert liquid injected oil cooling to external cooling
- Heat recovery from oil coolers
- Floating head pressure control on condenser fans
- Adiabatic cooling on air cooled condensers
- Improve insulation
- Have large enough pipes to minimise pressure drop
- Calculate and reduce your cooling loads e.g. intake chilling setpoint (can we increase by 0.5°C?)
- Improve cold store door discipline
- Increase evaporating temperature/secondary coolant temperature
- Optimising defrost cycle
- Switch off evaporator fans with compressor
- Heat recovery (de-superheat/oil heat recovery)
- High efficiency motor or double-speed motor for evaporator fans
- Improving heat release of condenser to reduce scaling and water treatment

Prevent excess heat release in climate controlled spaces.

Reduce parasitic loads e.g. unnecessary pumping

Fit VSDs to condenser and evaporator fans

Common compressor suction and discharge piping

Check pumping for appropriate sizing

Electronic expansion valves on DX systems (eenv)

Use alternative heat sinks if available e.g. river or lake

Have large enough diameter piping to minimise pumping pressure

Improve maintenance – thoroughly review maintenance contracts and ensure they are effectively carried out; evaporators, condensers, expansion valves, compressors

Reduce cold store door openings and heat ingress

Reduce condensing temperature

Keep condenser clean

Down-scale cooled areas

Automatic air bleed

Switching on compressors with delay

Smooth loads to stabilise plant loading

Using a cooled hallway to reduce chill room heat ingress
### Boiler and steam distribution

<table>
<thead>
<tr>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimise generation and distribution pressure</td>
<td>Sequence boilers to reduce low fire running pressure</td>
</tr>
<tr>
<td>Turn off or reduce pressure of standby boilers</td>
<td>To improve burner efficiency use oxygen trim through exhaust gas analysis</td>
</tr>
<tr>
<td>Replace old burners for ones with better efficiency and turn down ratio</td>
<td>Fit VSDs to FD fan and feed pump</td>
</tr>
<tr>
<td>Flue gas economiser (preheats boiler feed water)</td>
<td>Identify and repair faulty steam traps</td>
</tr>
<tr>
<td>Measure and increase condensate return</td>
<td>Improve lagging on valves, steam and condensate pipe</td>
</tr>
<tr>
<td>Reverse osmosis make-up water treatment to reduce blowdown</td>
<td>Using closed loop dosing</td>
</tr>
<tr>
<td>Use automatic side and bottom blowdown controls</td>
<td>Use of direct firing for hot water generation</td>
</tr>
<tr>
<td>Reduce reliance on steam, then decentralise use of steam</td>
<td>Condensate flash steam injection e.g. into CIP detergent tank or high pressure condensate return</td>
</tr>
<tr>
<td>Reduce end user steam pressure to reduce flash losses</td>
<td>Increase hot-well temperature or use a de-aerator to reduce blowdown (less chemicals required)</td>
</tr>
<tr>
<td>Manage instantaneous loads or use a surplusing valve</td>
<td>Ensure steam pipe size is large enough to minimise pressure drop</td>
</tr>
<tr>
<td>Repair steam leaks</td>
<td>Boiler tube cleaning</td>
</tr>
<tr>
<td>Blowdown heat recovery</td>
<td>Use fully modulating burner</td>
</tr>
</tbody>
</table>

### Vacuum

<table>
<thead>
<tr>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detect leakage</td>
<td>Switching off pump outside of working hours</td>
</tr>
<tr>
<td>Regular maintenance</td>
<td>Optimising pressure measurement</td>
</tr>
<tr>
<td>Heat recovery from vacuum pumps</td>
<td>Frequency control of pumps</td>
</tr>
<tr>
<td>Central vacuum generation</td>
<td>Valves at point of use</td>
</tr>
</tbody>
</table>

### Waste water treatment

<table>
<thead>
<tr>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance on aeration systems</td>
<td>Maintenance on pumping stations and pumps</td>
</tr>
<tr>
<td>Intermittent aeration</td>
<td>Connecting aeration to measurement of the oxygen level</td>
</tr>
<tr>
<td>Full utilisation of biogas</td>
<td>Mechanical sludge dewatering</td>
</tr>
<tr>
<td>Decreasing sludge content (amount of sludge per m3)</td>
<td>Anaerobic (pre- or post-) treatment</td>
</tr>
</tbody>
</table>

### Process

<table>
<thead>
<tr>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasteuriser heat profile review</td>
<td>Increase milk intake temperature</td>
</tr>
<tr>
<td>Cat/fmt temps review</td>
<td>Validate CIP through</td>
</tr>
<tr>
<td>Use sensors (conductivity) instead of timers for CIP runs</td>
<td>Hot water system optimisation</td>
</tr>
<tr>
<td>Equipment efficiencies/base loads</td>
<td>Pasteuriser holding tube insulation</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Reduced pressure homogeniser head</td>
<td>Partial homogenisation</td>
</tr>
<tr>
<td>Reduce use of bactifuges/clarifiers</td>
<td>Turn off chilling on pasteuriser when on water circulation</td>
</tr>
<tr>
<td>High efficiency lubrication on large gear boxes e.g. scraped surface HE</td>
<td>Heat recovery for pre-heating/pre-cooling e.g. whey feed to evaporation, feed air</td>
</tr>
<tr>
<td>Waste water recovery and recycling e.g. dryer condensate, RO Permeate</td>
<td></td>
</tr>
</tbody>
</table>

**Other**

| Voltage reduction – fit tap down transformers | Scheduling and simulation (debottlenecking/buffer reduction) |
| Use of cogged V-belts instead of standard V-belts to transfer mechanical power | Shutting off machines when they are not needed |
| Select pumps with a high efficiency | |

**Monitoring and targeting**

| Have a written energy policy | Have a quantitative improvement target |
| An assigned carbon/energy manager at site level | Regular on site meetings to review energy use |
| Regular collection of main meter data | Extensive sub-metering on key processes |
| Regular collection of sub-meter data | Regular analysis of consumption patterns (e.g. regression analysis) |
| Utility mass balances | Carry out regular energy surveys |
| Energy awareness training for staff | Technical training for staff |
| Active reporting systems for energy waste (e.g. steam leaks) | Predicative maintenance procedures on energy consuming plant equipment |
| Good operation/practice guides | Capital procedure to take account of energy |
| Capital procedure to take account of carbon savings | Hedged budget for energy saving measures |

**Summary of responses**

This section shows the results of the survey (for the 10 sites which responded), by topic area. Most sites chose ‘other’ or ‘not relevant’ for clarifying why each response.
Compressed Air

- Cooling the cooling water of the air compressors with cooling towers instead of using chilled water
- Ensure cold feed air
- Don’t use compressed air for cleaning
- Check and service filters (reduced pressure drop)
- Schedule pressure reductions outside main production hours
- Replacement of outdated pneumatic tools
- Shutting down the compressor outside of working time
- Sequence compressors to reduce unloaded hours
- Correct dimensioning of compressed-air pipe
- Install VSD compressors or retrofit VSD on existing compressors
- Application of small weekend compressor
- Use blowers instead of compressed air
- Leak test regularly and reduce leakage
- Reduce delivery pressure
- Correct relation between drying/filtering and quality requirements
- Use of receivers/bufferage in distribution system
- Isolate unused areas e.g. at weekends
- Engineer out use of compressed air; is there an alternative?
- Separated compressed-air networks (high and low pressure/quality) to minimize generating costs
- Connect specific applications of compressed air to separate compressed air facilities. Don’t run the entire compressed air system at high pressure to satisfy one user when a booster could be used
- Use high efficiency jet nozzles in blowing applications
- Heat Recovery for space heating or hot water
- High efficiency refrigerated dyers

Legend:
- possible
- not possible
- no selection
- implemented
Buildings and lighting

- Presence sensors: 48%
- Lighting on the workplace: 48%
- Daylight dependable control: 48%
- Installing several light switching groups: 48%
- Energy saving lamps: 48%
- High frequent lighting containing fittings with an optical mirror system: 48%
Cooling and Refrigeration

- Calculate and reduce your cooling loads e.g. intake chilling setpoint (can we increase by 0.5°C?)
- Increase evaporating temperature / secondary coolant temperature
- Improve part load performance by changing compressor sequencing or retrofitting a VSD
- Fit VSDs to secondary pumping
- Check pumping for appropriate sizing
- Reduce condensing temperature
- Improve cold store door discipline
- Smooth loads to stabilise plant loading
- Automatic air bleed
- Optimising defrost cycle
- Have large enough pipes to minimise pressure drop
- High efficiency motor or double-speed motor for evaporator fans
- Reduce parasitic loads e.g. unnecessary pumping
- Adiabatic cooling on air cooled condensers
- Heat recovery from oil coolers
- Reducing heat release of condenser to reduce scaling and water treatment
- Capturing heat from condenser water
- Convert liquid injected oil cooling to external cooling
- Use alternative heat sinks if available e.g. river or lake
- Electronic expansion valves on DX systems (evv)
- Common compressor suction and discharge piping
- Use controls to operate plant at optimum setpoints
- Prevent excess heat release in climate controlled spaces
- Switch off evaporator fans with compressor
- Improve insulation
- Floating head pressure control on condenser fans
- Have large enough diameter piping to minimise pressure drop
- Optimising Defrost Cycle
- Keep condenser clean
- Switching on compressors with delay
- Down scale cooled areas
- Improve maintenance - thoroughly review maintenance contracts and ensure they are effectively carried out
- Evaporators, condensers, expansion valves, compressors

- Implementation:
  - Possible
  - Not possible
  - No selection
  - Implemented
Boilers and steam Distribution

- Use automatic side and bottom blowdown controls
- Ensure steam pipe size is large enough to minimise pressure drop
- Increase lowell temperature or use a deaerator to reduce blowdown (less chemicals required)
- Turn off or reduce pressure of standby boilers
- Reduce end user steam pressure to reduce flash losses
- Using closed loop dosing
- Measure and increase condensate return
- Identify and repair faulty steam traps
- To improve burner efficiency use oxygen trim through exhaust gas analysis
- Sequence boilers to reduce low fire running
- Reduce reliance on steam, then decentralise use of steam
- Use of direct firing for hot water generation
- RO treat make up water to reduce blowdown
- Improve lagging on valves, steam and condensate pipe
- Flue gas Economiser (preheats boiler feed water)
- Optimise generation and distribution pressure
- Replace old burners for ones with better efficiency & turn down ratio
- Use fully modulating burner
- Blowdown heat recovery
- Condensate flash steam injection e.g. into CIP detergent tank or High pressure condensate return
- Fit VSDs to FD fan and feed pump
- Manage instantaneous loads or use a surplussing valve

- Boiler tube cleaning
- Repair steam leaks
- Optimise generation and distribution pressure
- Flue gas Economiser (preheats boiler feed water)
- Use fully modulating burner

- possible
- not possible
- no selection
- implemented
Vacuum

- Valves at point of use
- Central vacuum generation
- Heat recovery from vacuum pumps
- Switching off pump outside of working hours
- Detect leakage
- Regular maintenance
- Optimising pressure measurement
- Frequency control of pumps

Waste water and effluent

- Connecting aeration to measurement of the oxygen level
- Intermittent aeration
- Maintenance on pumping-stations and pumps
- Maintenance on aeration systems
- Decreasing sludge content (amount of sludge per m3)
- Anaerobic (pre- or post-) treatment
- Mechanical sludge dewatering
- Full utilization of biogas
Process

- Reduce use of bactofuges / clarifiers
- Use sensors (conductivity) instead of timers for CIP runs
- Heat recovery for pre-heating / pre-cooling e.g. whey feed to evaporation, feed air
- Hot water system optimisation
- Validate CIP through
- Cat / fmt temps review
- Increase milk intake temperature
- Partial Homogenisation
- Waste water recovery & recycling e.g. dryer condensate, RO Permeate
- Turn off chilling on pasteuriser when on water circulation
- Pasteuriser holding Tube Insulation
- Pasteuriser heat profile review
- Reduced Pressure Homogeniser Head
- High efficiency lubrication on large gear boxes e.g. scraped surface HE
- Equipment efficiencies / baseloads

Misc

- Voltage reduction - fit tap down transformers
- Select pumps with a high efficiency
- Use of cogged V-belts in stead of standard V-belts to transfer mechanical power
- Shutting off machines when they are not needed
- Scheduling & Simulation (debottlenecking/buffer reduction)
Monitoring and Targeting

- Regular collection of sub meter data
- Regular collection of main meter data
- Regular on site meetings to review energy use
- An assigned carbon/energy manager at site level
- Have a quantitative improvement target
- Capital procedure to take account of energy
- Extensive sub-metering on key processes
- Have a written energy policy
- Hedged budget for energy saving measures
- Good Operation/practice guides
- Active reporting systems for energy waste (e.g. steam leaks)
- Regular analysis of consumption patterns (e.g. regression analysis)
- Capital procedure to take account of carbon savings
- Predicative maintenance procedures on energy consuming plant equipment
- Utility mass balances
- Technical training for staff
- Energy awareness training for staff
- Carry out regular energy surveys
The Carbon Trust is funded by the Department for Environment and Climate Change (DECC), The Department for Business, Enterprise and Regulatory Reform (BERR), the Scottish Government, the Welsh Assembly Government and Invest Northern Ireland.

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