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Executive Summary

One way for the dairy processing industry to achieve significant CO₂ reductions is to improve energy efficiency in sector-specific manufacturing processes. The Carbon Trust has been working with a number of industry sectors, as part of its Industrial Energy Efficiency Accelerator (IEEA), to identify where savings can be made in each one. This novel approach aims to deliver substantial reductions in industrial process emissions by accelerating innovation in process control, considering changes in product strategy and encouraging the uptake of low carbon technologies; all based on substantive monitoring and process investigations.

The UK dairy processing industry processes over 13 billion litres of milk and emits around 860,000 tonnes of CO₂ every year from over 100 sites that produce a variety of dairy products, from powered whey protein supplements to liquid milk for supermarket shelves. The processes involved vary considerably from one product to the next but most share the first, initial steps of raw milk processing – separation, standardisation, pasteurisation, homogenisation (for the liquid milk industry) as well as supporting processes such as refrigeration, steam generation and Clean-in-Place (CIP) systems. CIP is the method of cleaning the interior surfaces of pipes, vessels, process equipment, filters and associated fittings, without disassembly, which can consume large quantities of energy and water.

The milk industry’s competitive nature, energy-intensive operations, environmental targets and pressure from the supermarkets has resulted in a proactive approach to energy efficiency and cost reduction and it has been steadily reducing the specific energy per m³ of milk through a range of different energy saving measures.

As part of this IEEA Stage 1 project, we have identified core processes that apply to a wide segment of the industry: raw milk pasteurisation; separation; homogenisation; and CIP. Detailed data on the performance of these processes was collected through a non-invasive metering campaign at three representative sites and supplemented with information extracted from site SCADA systems. The data was analysed to gain a better understanding of how key process parameters affect energy performance and hence carbon emissions.

These results were then used to quantify the potential benefits of a range of alternative technologies applicable to each of the core processes investigated. The opportunities which offer the greatest potential for significant energy and carbon savings in the sector, but which face institutional, technical and cost barriers to implementation fall into three areas:

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

Within these three areas there are opportunities at a stage of technical development appropriate for on-site demonstration or pilot projects, but the associated costs and potential regulatory barriers mean that such projects are unlikely without financial or other support. As such, projects in these areas are candidates for support under Stage 2 of the IEEA programme.

Aside from these opportunity areas appropriate for IEEA Stage 2 support, there are a number of other potentially cost-effective improvements available to the dairy industry, including scope for further process optimisation, and the implementation of heat pumps to recover energy from refrigeration units. These opportunities can be taken up without the need for financial support.

This report sets out the background to the dairy sector, the data collected and analysis carried out, presents a range of opportunities for energy efficiency and carbon reduction in the sector, and sets out the high level business cases to justify investment in these opportunities.
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1 Sector background and carbon emissions

1.1 Background

The UK dairy industry processes 13.3 billion litres of raw milk per year\(^1\) and is made up of over 100 processing sites. However, the sector is dominated by seven large milk companies which account for 40 major processing sites. The outputs of the dairy sector 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). The breakdown of production, in terms of percentage of raw milk consumed, is shown in Figure 1.

Of this milk processed, the majority goes through an initial raw milk processing stage prior to processing into the final product. The breakdown of carbon dioxide emissions by dairy type is shown in Figure 2.

![Figure 1 - Raw milk volume by end use](image1.png)

![Figure 2 - Carbon emissions by type of dairy](image2.png)

The industry is represented by Dairy UK which has an environmental steering group that meets quarterly. The process descriptions in the following sections are sourced from members of Dairy UK.

The total carbon footprint for the UK dairy sector including emissions from dairy farms, as well as transport and distribution is estimated by Defra to be 15.5 million tCO\(_2\)e\(^2\) per annum.

The actual emissions that fall under the control of the dairy processing industry are estimated to be 5% of the total lifetime emissions of the milk products\(^3\) with the majority of the emissions (84%) being embodied at the farm. Figure 3 shows the breakdown of end-to-end emissions for one kilogramme of UK raw milk\(^4\).

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\(^1\) DEFRA 21st July 2009

\(^2\) DEFRA the Environmental, Social and Economic Impacts Associated with Liquid Milk Consumption in the UK and its Production

December 2007

\(^3\) DEFRA the Environmental, Social and Economic Impacts Associated with Liquid Milk Consumption in the UK and its Production

December 2007

\(^4\) DEFRA the Environmental, Social and Economic Impacts Associated with Liquid Milk Consumption in the UK and its Production

December 2007
The focus of this project is on the 5% which relates to liquid milk processing. For the data analysis in this report we have used validated historical data from the dairy sector Climate Change Agreement report for 2007/08, which states sector-wide carbon emissions of almost 860,000 tonnes CO$_2$ per year for liquid milk processing. This total accounts for all but the smallest dairy companies, who may not be part of the industry’s CCA. The figure will be used as the basis for estimating the potential industry carbon savings resulting from the opportunities investigated in this report.

1.2 Processing facilities and emissions

The processing segment of the dairy sector can be divided into three distinct facility types. The three processes are characterised by their final products, namely:

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

It can be seen from Figure 4 that there is a substantial spread in performance in terms of energy. This wide variance can be explained in part by the fact that a small number of sites carry out evaporation and spray drying which is very energy intensive. However for the purposes of CCA reporting these activities are not separated out. Other reasons for the wide variance can be accounted for through technology solutions and good practice measures that are either not fully applied, or are not applicable, across the full range of dairy processors. The good practice questionnaire results detailed in Appendix 2 highlight some specific areas of difference.
The carbon emissions relating to raw milk processing are monitored and reported as part of the Climate Change Agreement (CCA) for the dairy processing industry (see Section 1.5 for an overview of the CCA). The breakdown of emissions covered by the industry’s CCA is shown in Figure 5 (on a specific basis, i.e., kgCO$_2$ per m$^3$ of raw milk processed).
1.3 Specific performance benchmarking

Using a Camco historical data set (weekly energy, water and production for 2008) from 23 dairy sites across the UK it was also possible to benchmark the specific energy and water performance. The analysis below concludes that the sites with good water ratio also have a good energy ratio. This is because much of the energy consumed at a dairy becomes embodied in hot water, which is usually subsequently lost to drain or as low grade heat.

![Water Efficiency vs. Energy Ratio](image)

Figure 6 - Water Efficiency vs. Energy Ratio

The following data shown in Figure 7 only includes sites sub-250 kWh/m$^3$ (typically liquid milk sites) and shows three performance zones, Zone 3 being the target zone (beyond current good practice).
Figure 7 - Performance Zones: Water Efficiency vs. Energy Ratio

In addition to the energy balance and the high-level benchmarking, the validated data set was used to understand how energy is consumed on a weekly basis compared to facility production. Observing correlations using the standard ‘monitoring and targeting’ regression analysis we can conclude some overall relationships as shown in Figure 8.

Specifically for the dairy data analysed, the baseline value for both electric and fuel across many sites was very high indicating significant standing losses. Understanding what causes the base load is very important when selecting the improvement technologies. High base load strongly indicates that process optimisation still has a large part to play for sites wanting to enter the higher performance zones.
1.4 Key processes

The Carbon Trust uses the accepted term “black box process” to define industrial processes where the inputs and outputs are known but where what goes on inside is not clearly understood. The IEEA approach is to identify and investigate black box processes within each target sector and identify opportunities that could help achieve a step change improvement in the energy performance of those processes.

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

**Figure 8 - Energy versus Production Relationships**

![Energy vs Production Relationships Diagram]

- **Base load = 70% to 90%**
- **Base load = 40% to 60%**
• **Raw milk processing**: raw milk is brought in to the processing facility from the farm in tankers, separated, pasteurised (and sometimes homogenised);

• **Secondary processing and packaging**: it is either then packaged and transported to the supermarkets and other retail outlets or goes on to further processing to be made into other products such as cheese, cream, yogurts, butter, condensed and powdered milks, etc.

• **Support processes**: Clean-in- Place (CIP), heating and cooling systems.

Figure 9 below shows a simplified representation of the main heat, chill and electrical demands in a typical dairy: the raw (liquid) milk process followed by an example cheese process.

Figure 9 - Simplified energy demands in milk and cheese production

From the base data set and data collected from the target sites a picture of the estimated relative energy intensity of the raw milk processes and CIP was produced as demonstrated in Figure 10. As can be seen, pasteurisation and CIP are by far the greatest carbon emitting process stages.
Raw milk processing
The first, raw milk stage is common to virtually all of the industry and is made up of a few simple procedures:

- **Separation**: after reception and holding at in storage tanks at the processing site, raw milk is heated to separation temperature and sent to a centrifugal separator where the cream fraction is removed. The skim is then usually inline blended back together with the cream at predefined ratios to make the desired fat content end product. Excess cream is cooled and stored for shipping or for further processing.

- **Pasteurisation**: this process involves killing the majority of bacteria within the raw milk to increase its shelf life. This is done through heating the milk above 72°C and then cooling it 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.

As the milk has to be heated and cooled within a few seconds the intensity of the heating and cooling supplied results in this process being one of the largest emissions sources within the industry, even though a large fraction of the heat is regenerated and re-used in the pasteuriser.

- **Homogenisation**: this is a treatment which principally applies to liquid milk processors and prevents a cream layer from separating out of the finished milk. The milk is pumped at high pressures through very narrow tubes, breaking up the fat globules into small particles which do not recombine so that the resultant, homogenised milk has a consistent texture and taste. Electricity is used to drive the pumps which create the pressure drop across the homogeniser tubes.

The main electricity driven emissions from the raw milk processing stage is from the homogeniser and separator machines as well as cooling loads from pasteurisation and intake chilling. The refrigeration plant and equipment have large electrical motors that can have a power of several hundred kilowatts which run non-stop during milk production.

Secondary processing and packaging
The other side of the dairy industry is what happens to the milk after this initial processing stage. The processes involved vary between sub-industries but the most energy intense processes are associated with the drying of liquids (milk and whey) into powders. The supply and demand for milk are in close equilibrium, which means that any surplus milk in the supply
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 the minority of sites which produce powders.

The other common procedures involved with treating dairy products after initial pasteurisation is the mechanical process of making cheese. This can be a whey separation drying technique for the harder cheeses or a texture process for the softer varieties.

Support processes

Clean-In-Place (CIP) is a method of cleaning process equipment, tanks and pipework and is common throughout the entire industry, as the processing facilities must constantly be cleaned to inhibit the growth of bacteria and remove fouling/scaling. The process is typically constituted of an initial rinse of recovered water to remove heavy soiling, followed by a hot detergent wash of caustic or acid solution, a final rinse of clean potable water, and then sometimes a high temperature sterilisation or use of a terminal disinfectant. The 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 lost to drain. CIP is a large consumer of water so there is a cost incentive to reduce CIP water usage as well as heat.

1.5 Regulatory drivers

Climate Change Agreement

The UK dairy sector is covered by a Climate Change Agreement, under which its members receive an 80% discount on the Climate Change Levy, which is a surcharge on energy bills. The CCA requires companies to reduce their carbon emissions according to an agreed series of milestone targets or risk losing the discount. The scheme provides an incentive to improve energy efficiency: if the milestone reduction target is not achieved, the CCL discount is lost on all energy and fuels purchased. As a consequence, the dairy sector has performed well, reducing energy consumption by 16% since the start of the scheme in 2001.

The CCA originally was due to expire to the end of 2012 but has been extended to 2017, albeit with a reduced CCL discount of 65%. A consultation is currently under way on the details of the extended scheme, but there are no proposals to make any changes to the eligibility criteria for Climate Change Agreements.

Dairy UK is currently in consultation on behalf of the industry to agree new baseline and target levels, which currently look set to be much more stringent than current requirement. As most dairy sites fall under the terms of the CCA there will be little if any participation in the Carbon Reduction Commitment, a new UK emissions reduction scheme which is aimed at medium intensity energy users.

EU Emissions Trading Scheme

The 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 plant above a certain size threshold (20MW). If a site meets one of these criteria then it must join the EU ETS, even if it is also covered by a CCA. Sites in the EU ETS are assigned an emissions “cap” and they must buy emissions permits to hit the cap if they are not able to reduce their emissions internally. 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.
F-Gas Regulations
HFC refrigerants are affected by EU Regulation 842/2006 which covers certain fluorinated greenhouse gases (F-Gases) commonly used in refrigeration equipment. HFCs are potent greenhouse gases, with global warming potential of around 2,000 times that of CO₂. In the past refrigeration and air-conditioning systems have leaked badly which has been extremely bad for the environment. Many dairy sites use separate refrigeration plants with HFC’s for areas such as cold stores. The F-Gas regulations require operators of air-conditioning and refrigeration plant to prevent refrigerant leakage and carry out regular leak tests; recover HFC refrigerants during maintenance and plant decommissioning; maintain accurate records and ensure that equipment is appropriately labelled and operated and maintained by suitably trained personnel.

Ozone depleting substance regulations (R22 phase out)
The phase out of HCFCs for maintenance of existing refrigeration and air-conditioning systems began at the end of 2009, as required by EU Regulation 2037/2000 on ozone depleting substances. The regulation banned the use of virgin HCFCs for maintenance from the end of 2009 and recycled fluid from the end of 2014. This is of crucial importance for many companies and means that all users of R22 and other HCFC systems, if they have not already, need to consider alternative refrigerants or the purchase of new equipment. Other clauses in the regulation also affect the use of existing HCFC systems.

It is important that R22 users have plans in place for the phase out of HCFCs as it is not recommended to rely on the 2014 recycled fluid phase-out date, as this date could be brought forward as part of the review process. The amount of fluid being recycled has in fact turned out to be very small to date, so there is no guarantee that sufficient supplies of recycled R22 will be available between 2010 and 2014.

An alternative in some refrigeration plant is to use drop in replacement gases, but in nearly all cases these have a degrading effect on refrigeration plant energy efficiency.

IPPC
Integrated Pollution Prevention and Control (IPPC) has been in place since 2005 and is a regulatory system that employs an integrated approach to control the environmental impacts of certain industrial activities. It involves determining the appropriate controls for industry to protect the environment through a single permitting process. This UK Guidance for delivering the PPC (IPPC) Regulations in this sector is based on the Best Available Techniques (BAT) reference document BREF produced by the European Commission. For the dairy industry the key environmental issues managed by the permitting system are:

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

The system covers operators who are treating and processing more than 200 tonnes per day of milk. To gain a permit, operators have to demonstrate that the techniques they are using or are proposing to use, are on the BAT list.

Food safety
The amount of energy consumed by the dairy industry is also influenced by legislation that demands pasteurisation is carried out to specific standards. The requirements for regular drinking milk to be pasteurised at 72°C for a minimum of 25 seconds (cheese making can

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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/
involve a lower temperature for a longer holding period), and for milk always to be stored below 6°C, puts constraints on the way that the pasteuriser is configured and how much energy is required to heat the milk and then cool it down to regulated levels.

If an alternative method for pasteurisation is found, which can bring about the same level of microbial destruction but at lower temperatures, then the Food Standards Agency will still need to be engaged to create a revised definition of pasteurisation in its regulatory requirements before any such method can be deployed commercially. This is a key barrier to change.

1.6 Other business drivers

Dairy processing is quite energy and water intensive and the introduction of carbon-related costs means there is ongoing strong pressure to reduce utility costs. This is compounded by the squeeze on product sales prices applied by the major customers – supermarkets – who are in a position to dominate the supply chain and who often require their suppliers to take the pain of product discounts and promotions in the stores. The demand by supermarkets for products such as regional and organic milk also complicate manufacturing processes. Cost minimisation is a powerful driver.

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

1.7 Industry progress on energy saving

Raw milk processing into drinking milk and other dairy products is complex and energy intensive. The internal and external pressures on the industry to reduce costs have led to the dairy sector being progressive in terms of energy efficiency. This in turn means that good practice in energy management is already quite widespread (although there is still potential for improvement, as described in Section 4), and that many of the cost-effective technology opportunities for reducing energy consumption – such as improved controls, or more efficient motors and drives - have already been implemented at some sites. The best practice survey shows that there is still significant opportunity available, and maybe the best way to address this is to raise awareness of what is possible at a site level.
2 Methodology

2.1 What metering/data gathering was done and why

The metering design and associated data gathering was focused on the processing of raw milk. The objective of the metering process was to deploy additional meters to supplement the information that could be collected from the existing site SCADA systems to build up a more detailed understanding of the following process energy consumptions:

- Pasteurisation
- Clean-in-Place
- Homogenisation

Since pasteurisation and CIP are common to all dairy processing sites and homogenisation to liquid milk sites the opportunities identified in these areas will have the widest possible potential for replication across the UK dairy industry.

2.2 Raw milk process focus

Through taking the processes that were most common across the dairy industry the study aimed to focus on specific areas that would have the most impact to the sector if savings were identified. The raw milk process involves taking raw milk in from tankers and then processing it to a stage where it can either be sold as finished milk or sent on for further processing to be used for a secondary dairy product.

The milk is initially heated in the regeneration zone of the pasteuriser (extracting the heat from the milk leaving the process), the milk (now hot) is standardised and homogenised to obtain the desired final fat content. Separation involves physical separation of the fat and skim in a centrifugal ‘separator’. The surplus hot cream is usually processed in a separate pasteuriser set ready for bulk storage and transportation to a cream packing plant.

The resulting standardised milk at the desired fat content is homogenised and further heated to the pasteurisation temperature. The pasteurisation zone is usually a simple a holding tube that ensures the pasteurisation temperature is held for the correct time in seconds (e.g. 72°C for 25 seconds) to deliver the required bacterial destruction. The hot milk is now passed through the regeneration zone giving up its heat to the incoming cold milk. Finally, chilled water is used to control the milk exit temperature from the pasteuriser at approximately 2°C.

It is this initial, raw milk process that was metered as pasteurisation, separation and homogenisation (liquid industry) is common across the sector leading to opportunities being replicable in most sites. The other area of interest is CIP. This is also common to the entire dairy sector and so opportunities identified can be replicated across the industry.

There are other processes such as spray drying that account for much larger amounts of energy consumption but the relatively small number of sites in which this process is carried does not warrant its inclusion within this programme, which is aimed at identifying opportunities with the potential for industry-wide replication.
2.3 Engagement with the sector

During the study there was continual engagement with the sector laying out what was the progress with the report and the direction that we were intending to follow. This was initially done through agreement with the three companies providing sites for metering, about which site would be the most suitable, and then through regular update emails, project steering group meetings and a final workshop, in which a wider industry group (including technology companies, equipment suppliers and academics) participated in a discussion on the benefits and barriers relating to the opportunities identified. Appendix 1 describes the site selection process.

2.4 Host site selection

The rationale for this choice was:

- The identified processes have common attributes at most dairy sites; therefore a small sample size should be sufficiently representative;
- The processes are carried out in a similar manner or encompass the same principles whether the site is big or small; and
- Monitoring at this number of sites will be cost effective.

Three sites were selected for metering and data collection based on the following criteria:

- Their process types and methodologies are representative of the wider industry;
- There is some metering infrastructure already in place that can be taken advantage of, to help manage the monitoring costs; and
- Conveniently located to make repeat visits both time and cost effective.
<table>
<thead>
<tr>
<th>Site</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
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<td>Annual raw milk throughput (m³)</td>
<td>374,162</td>
<td>209,000</td>
<td>468,000</td>
</tr>
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<td>Water ratio (m³/m³)</td>
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<td>1.38</td>
<td>0.41</td>
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<tr>
<td>Fuel ratio (kWh/m³)</td>
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<td>83</td>
<td>23</td>
</tr>
<tr>
<td>Type of dairy</td>
<td>Liquid</td>
<td>Liquid</td>
<td>Liquid</td>
</tr>
</tbody>
</table>

2.5 Data gathering

Data on process energy performance was gathered in the following ways:

- Historical data from large sites within the UK dairy industry
- Meetings with site engineers over the course of the metering programme
- Data collected during the metering programme itself; and
- An energy good practice check list that was sent out to industry members.

2.6 Metering approach

Having focused the metering strategy on raw milk processing and CIP a metering plan was devised to collect process performance data whilst minimising disruption to the day-to-day running of the site. The approach involved looking at the individual processes that needed to be understood in more detail and highlighting the data needed to build this picture.

The first step was to assess the range of information already being recorded on the site’s SCADA system and, where there were gaps in the data required, to specify the incremental data collection hardware to be installed in order to build up the complete set of data. The appropriate metering technology was then installed and all of the data streams were then combined after the monitoring period for analysis.

Non-invasive metering

The dairy processing industry runs year round and shut-down periods on site are usually to deal with the most pressing problems affecting production, leaving little opportunity to disrupt operations in order to install permanent meters and cut open pipes.

A non-invasive approach was taken where all of the data that was to be recorded was taken through surface-mounted devices or from existing probes already built into the plant and used within the site’s SCADA system. This did limit the information that could be gathered over the metering programme but the industrial partners of the study agreed that this was the most viable approach.

Ease of metering

Collecting three identical data sets from the target sites was problematic as the data that could be extracted from the SCADA systems varied from site to site, depending on the age and installation of the systems. Older SCADA systems have limited memory and so the number of variables that were monitored was limited, reducing the amount of data that could be combined with our metering for analysis.

Through using a non-invasive monitoring system the majority of the data was collected but the process was much more difficult than collecting data from a semi-permanent, more invasive system. There were also some limitations to the non-invasive monitoring equipment capability;
including having to account for temperature drop when monitoring based on pipe surface temperature, and inability to measure steam or gas flows effectively with non-invasive monitoring equipment.

**Pasteurisation, CIP and homogenisation metering devices used at the three sites:**

- Ultrasonic flow meters
- Radio temperature loggers
- Micro temperature loggers
- Radio current transformers
- Exported information from SCADA systems

The metering devices were installed in mid-April and removed at the end of May 2010. Data was therefore collected over a six-week period. This is a more than adequate length of time, since dairy operations normally run 24/7 with little variation.

![Figure 12: Photos of installed non-invasive meters on site](image)

Through data collected from all of these sources models could be compiled that would allow review of energy consumption during the monitoring period and the identification of any irregularities during process runs.

### 2.7 Good practice checklist

During the monitoring period a survey of energy good practice was sent to industry members. The aim of this survey was to gain an understanding of how widespread the take-up of good practice was across the industry, and also to raise awareness of energy issues and the IEEA programme itself. The survey comprised a checklist of 150 questions, divided into the following sections:

- Compressed air
- Building and lighting
- Cooling and refrigeration
- Boilers and steam distribution
- Vacuum
- Waste water treatment
- Process energy
- Energy management practices
- CIP practices
3  Key findings

This section first describes the findings from the good best practice check list that was sent out to industry members and the implication of the collated responses. Following this the analysis of the data collected at the three monitored sites will be discussed, leading onto the opportunities that correspond to both of these findings.

3.1  Feedback from the good practice survey

The pie chart below illustrates how, for the 10 sites that responded to the survey, nearly a third of the 150 measures classed as ‘good practice’ have not yet been carried out but could be implemented. Therefore there could be good potential for energy savings within the industry simply based on the implementation of further low, or no-cost measures. Whilst this is not the focus of the IEEA programme, energy managers within the industry should make sure that they have not overlooked any of these measures that may apply to their sites.

The full analysis of survey responses in shown in Appendix 2.

![Figure 13: Summary of responses from the good practice survey](image)

From the collated responses there were several opportunities that over half of the respondent sites thought were possible, and were either easy to implement or could lead to substantial savings:

- Use high efficiency jet nozzles in blowing application to reduce compressed air use
- Use high frequency lighting fitting with optical mirrors to reduce electrical costs
- Reduce cooling loads by 0.5 °C on chilling applications
- Fit a VSD 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
3.2 Monitoring results: pasteurisation

3.2.1 Data to demonstrate the point

There are two methods to measure the energy consumption of a pasteuriser: measure the steam and coolant flows into the heating and cooling sections respectively; or measure the temperature change across these sections combined with the flow rates of the milk.

Measuring the steam flow rate using a non-invasive approach was not possible as the reliability of ultrasonic flow meters with steam is low. Therefore the temperature difference, milk flow rate method was used in the monitoring programme carried out as part of this project.

The diagram of Figure 14 shows one of the sites as an example with a combination of internal and external temperature probes and flow probes connected to the site’s SCADA system. The data collected from these sensors allows the specific energy used to heat, and cool, the volume of milk that passes through the pasteuriser to be calculated.

Figure 14: Pasteuriser map showing temperature and flow sensors

- Yellow sensors are SCADA information (ie, owned by the site)
- Blue sensors are external temperature sensors (ie, installed as part of this IEEA project)
- 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

This analysis was carried out on the other two sites in a similar fashion. Figure 15 shows a temperature plot of the above probes over a one week period.
3.2.2 Data analysis

Temperature trends

- From the three sites that were monitored, trends were sought to connect specific temperature points of pasteurisation against the overall ideal specific carbon that was calculated from the measurements taken at each site.
- The regeneration of a pasteuriser based on the heat added is compared to the overall temperature rise that the milk goes through. The graph of Figure 16 shows that a higher regeneration rate leads to a lower specific CO$_2$.
- The relationship that has been charted in Figure 16 is only valid in the region investigated and cannot be used to extrapolate, as the three points are not enough to get a clear picture of the full relationship of regeneration against specific CO$_2$ outside the metered area.
- Another way of showing how temperature affects pasteurisation efficiency is through the heating approach compared to the specific CO$_2$/m$^3$. The diagram of Figure 17 demonstrates how the smaller the approach temperature of the heat exchanger (the red section of the bar), the higher the regeneration and the lower the specific carbon emissions of the process.
Figure 16: Regeneration against specific CO$_2$/m$^3$ milk

Figure 17: Average pasteuriser temperatures - demonstrating link of heating approach temperature to specific CO$_2$/m$^3$ of milk processed

Circulation of pasteurisers

- The time that a pasteuriser spends in circulation has been shown below in Figure 18 for two of the three sites that were monitored. The time spent in circulation can be associated with wasted resources as it does not aid production. For the third site it was not possible to determine the circulation time split due to lack of data available from its SCADA system.
• This analysis showed that the energy used for circulation increased the specific pasteurisation CO$_2$ per unit of milk by between 16% and 18%.

![Figure 18: Pasteuriser time split for two sites measured](image)

• The time split of one pasteuriser in terms of production, circulation or neither (CIP or off) over a one week period is illustrated in Figure 19. The periods of circulation are not regular or linked to periods of production but are random, mostly occurring for long periods of time at either the end or beginning of production, showing that they can be potentially avoided through improvements in operations practice and scheduling.
Production and circulation over a one week period

- 5 hrs 49 mins of circulation
- 2 hrs 07 mins of circulation

Figure 19 - Site 1 Production and circulation over a week

For sites with pasteuriser profiles that include long periods of time spent in circulation, installing a hibernation system could help avoid unnecessary energy use. This concept is explained in detail below.

3.2.3 Key results

- **Specific carbon**: 2.53 to 3.55 kgCO$_2$/m$^3$ raw milk (heating/cooling – excludes pumping)

  The range in energy used per pasteuriser is influenced by the following:
  - Raw, finish 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 was found to be associated with how the pasteuriser was set up and not simply the number of sections)

- **Applicability**: 100% of milk processed is pasteurised. All milk that goes through the dairy industry is currently pasteurised but the holding temperature and time will vary depending on what the milk is being used for as an end product (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 tCO$_2$ per annum from the milk pasteurisation process (thermal energy input), equivalent to 4.9% of sector emissions (excluding cream, pasteuriser pumping).

- **Additional carbon emissions**: The pumping energy used for circulation increases the specific pasteurisation CO$_2$ per unit of milk by between 16% and 18%.

- **Relationship of efficiency to carbon emissions**: From the three sites metered a correlation can be seen between the specific CO$_2$ per m$^3$ of milk processed and the level of regeneration measured in terms of heat supplied out of total temperature rise.
Through using the gradient on Figure 16 we can deduce 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$^3$).

3.2.4 What this might mean in terms of opportunities

The significant 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. This is opportunity that will be discussed in the Section 4.

- **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 18). During hibernation the cooling section is turned off and the heating is reduced by about 90% (some heat losses through circulation). The heating and cooling load will therefore be reduced be 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 (eg, high pressure pasteurisation).

3.3 Monitoring results: homogenisation

3.3.1 Data to demonstrate the point

Homogenisation has a large variance in the specific amount of carbon dioxide generated per m$^3$ of milk processed. The data collected in this study shows that this is down to two reasons: the degree to which a site partially homogenises its milk rather than homogenising the entire flow; and the amount of time that a site runs its homogenisers during non-production periods such as CIP.

3.3.2 Analysis

Figure 20 illustrates the electrical power that homogenisers use at each site during production and CIP. Between 45% - 63% of the production power is drawn by the homogeniser when not in production during CIP cycles. This is because the CIP liquid must be pumped through the homogeniser, which has a high pressure drop and hence pumping load.
The same set of data was depicted in a different manner below in Figure 21 to show the difference in energy consumption that partial homogenisation makes when compared to full stream homogenisation.

When the entire data set was analysed the specific CO₂ per m³ of milk was averaged over all production periods and the amount of energy associated with CIP and non-production related times was calculated, as shown in Table 2.

Table 2 - Homogenisation figures across three sites

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

- **Specific Energy**: 0.7kgCO₂/m³ (partial homogenisation) to 2.2kgCO₂/m³ (standard full stream homogenisation) for raw milk production.

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

- **Applicability**: Liquid milk products only: 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 as this is the share of liquid milk in the annual raw milk input. For liquid milk sites 18% of the milk is skim (UK milk figures) 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 3,800tCO₂ 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 12,000tCO₂ per annum. These figures 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 (see Section 4), said that they still ran full stream homogenisers and if this was representative of the industry as a whole (i.e. 30% of all sites still operating a full stream homogenisation process), the associated sector carbon emissions associated with homogenisation would be approximately 6,300tCO₂ per annum.

In order to fully estimate the potential savings associated to switching the whole industry over to partial homogenisation a clearer understanding needs to be achieved of the number of sites that still run full stream homogenisation and the level to which sites are running partial homogenisation (the technology has been continuously improving over the last 20 years).

3.3.4 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**: 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. Whilst 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 350,000m³ 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 0.48kgCO₂/m³ of milk).

For calculating the savings associated with partial homogenisation we took the initial findings from our best practice survey of 3 in 10 sites being able to move to partial homogenisation from full stream homogenisation. The savings from moving all of these over to the most up-to-date partial homogenisers that can process a fat content of 18% would equate to 5,500 tCO₂ or 0.6% of the entire sectors’ emissions.

- **Reducing head pressure**: the energy needed to drive a conventional homogeniser is proportional to the pressure at which the system needs to run 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:

  Effective kW = Flow rate of homogeniser x homogenisation pressure in bar / 30,600
Discussions with manufacturers suggest that upgrading the head to the most efficient design, could reduce electrical consumption by up to one third (180bar down to 120bar). This will vary depending from the equipment installed at each site. For a site running full stream homogenisation, this would result in an annual saving of £27,000 or for a site that is running a partial homogenisation system £8,600.

- **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 hence energy consumption. Further study to determine when the homogeniser is clean during the CIP process needs to be carried out so that fluid can be bypassed once this point has been achieved.

### 3.4 Monitoring results: Clean-In-Place

In dairy sites there are a number of CIP systems and for this programme there were insufficient resources to meter all CIP systems on site. The most cost effective strategy was to focus on Raw Milk and Finish Milk CIP as they are usually situated near by each other.

Through the verified data set we were able to see that the water used in Raw and Finish CIP was approximately half the water used for the entire CIP of the sites investigated. Our data set discussed in Section 1.3 suggests that there is strong relationship between the specific energy and water consumption of a site, because much of the water consumed at a site is heated during CIP and then is lost to drain.

From four comparable CIP systems on different sites, where CIP water meters were present we were also able to plot a graph of water versus energy usage. Figure 22 shows that there is a degree of proportionality. The sample data also showed that Raw and Finish Milk CIP account for approximately half of the water consumed in CIP. Therefore to estimate the total CIP heating energy used on-site, the figures for Raw and Finish Milk CIP were doubled.

![Graph showing CIP Energy use versus water consumption](image)

**Figure 22 - CIP Energy use versus water consumption**

### 3.4.1 Data to demonstrate the point

The heat energy that was added to the system was calculated on the basis that energy is proportional to the mass flow rate multiplied by the temperature difference across a heat exchanger.
The diagrams below show a sample set of data collected at each site. When the tank temperature drops below a set point (from either gradual heat loss through the tank walls or through the introduction of a colder fluid, such as recovered caustic or fresh water and caustic concentrate to top up the tank), steam is sent to the heat exchanger and the tank temperature rises to the upper set point. The three temperature profiles show how the energy is added into the systems across the three sites.

**Figure 23 - Energy input into caustic tank on Finish CIP on Site 1**

**Figure 24 - Energy input into caustic tank on Finish CIP on Site 2**
Tank and recirculation temperature

![Graph showing tank temperature and post-heating temperature](image)

**Figure 25 - Energy input into caustic tank on Finish CIP on Site 3**

The rate at which the steam valves at Site 3 opened and closed during periods of heating was very rapid and did not follow a smooth heat profile as was the case at Sites 1 and 2. This was identified as a fault with the system during the metering process but the site was not able to remedy the situation before the end of the metering process.

Note, that the lack of a smooth heating load will result in spot loads to the steam system and could decrease efficiency through causing additional boiler firing to satisfy the demand.

### 3.4.2 Analysis

**CIP heat loss bridge**

From the monitoring and analysis carried out we were able to break down the heat balance for the CIP plants monitored. The total energy input was derived from the metered data, whilst tank standing losses and tank dumps to drain were based on calculation, and the energy lost to drain during CIP was calculated from the amount of raw detergent addition to the system (replacing losses at a given concentration). The following four figures show the results. The top bar shows the total energy added to the system over the monitoring period and the subsequent bars show the balance of the heat lost.
Figure 26 - Site 1 Raw Milk CIP Loss Bridge

Figure 27 - Site 1 Finished Milk CIP Loss Bridge
The key points to note are:

- Tank standing losses are from the radiation and convection of heat away from the surface of the CIP tanks and in general are small.

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

- Figure 28 shows Site 3 Raw Milk CIP. This has notably less detergent losses to drain than the other plants investigated. This was the only CIP plant solely dedicated to use acid detergent; however it was not clear that this should have a particular influence on the losses.
to drain. Through discussion with the site it is more likely that the high efficiency is 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 hence carbon emissions.

- Heating up infrastructure includes heating up pipe work, tanks, valves and other conducting materials that the CIP solution comes into contact with 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) with ambient temperature at 20°C, 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 done with caustic at 80°C then for every 10°C reduction in CIP temperature, there would be on average a reduction of 0.4 kgCO₂/m³ of milk processed on site, or an annual saving of £19,000 on a typical site processing 350,000m³ of milk. Multiplying out across the sector would result in a sector-wide reduction of 5,300 tCO₂ for every 10°C the CIP temperature could be reduced.

The makeup of individual CIP systems varies from site to site with some sites operating 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 would give an idea of the possible savings but further investigation into the specific design of a site’s CIP set up would be needed before savings associated with reducing temperature could be calculated.

### 3.4.3 Key results

The energy and carbon intensities measured across the three sites show a wide range in performance that cannot be readily explained through any simple metric. The energy consumption of a CIP system is highly dependent on the design of the plant and how the CIP system was initially commissioned.

- **Specific carbon:** Raw and Finished Milk CIP is 0.7 to 1.73kgCO₂/m³ raw milk (heating only – excludes pumping):
  - Raw Milk CIP: 0.46 - 0.92 kgCO₂/m³
  - Finished Milk CIP: 0.24 - 0.81 kgCO₂/m³

- **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 of within the scope of this study, such as pumping and effluent treatment. These will relate to the volumes used and would be subsequently reduced if the amount of CIP solution used can be reduced.
3.4.4 What this might mean in terms of opportunities

The opportunities associated with CIP can be classified into two areas: opportunities that involve optimisation of the current process, and opportunities that require fundamental redesign with a new system.

Through the CIP loss bridges we have shown that the two largest areas of heat use are hot detergent lost to drain and heat absorbed through infrastructure in order to get the system up to temperature. Where detergent is lost to drain there are opportunities for optimisation of the CIP system, but in order to reduce the costs associated with heating up infrastructure, a system that does not use heat as a fundamental component of cleaning could be considered.

Optimisation of CIP

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

- When cleaning valves and vents, hot detergent solution is pushed out of seals and openings and this is lost to drain.
- 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 caustic used to clean these items is not reused and simply goes to drain.
- When some systems are cleaned the amount of material that the detergent solution picks up results in the detergent being thrown to drain as it would contaminate the central detergent supply.
- Insufficient caustic tank size means that if a single system is performing multiple cleans at once, the caustic tank level may fall below the minimum point and will be filled with fresh cold caustic and water which then needs to be heated up. When the existing caustic solution comes back from the items it has cleaned there is not enough space in the tank and so the hot solution is either sent to drain or to the pre-rinse tank and then to drain.
- User alteration: over time, minor adjustments or ‘tweaking’ of the system to the CIP recipes 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.

If a low temperature CIP system was implemented then the cost of heating caustic and fresh water to replace the solution lost to drain would be mitigated. However before a new CIP system is installed we would recommend that a CIP engineer visit the site in question and check through all of the items mentioned above with the aim of achieving some quick wins and reducing the heat, water and chemical demand of the CIP system.

Other CIP Optimisation Opportunities

- **Reduction of CIP water volume and/or temperature** would reduce the energy consumption of CIP systems. It will not be possible to predict how much impact this would have across the sector as each site benchmarks their CIP systems differently and has a different set up of caustic and acid systems. The regulated aspects of CIP are the microbial levels within the pipes and not the temperature of the working fluid. Volume reduction can generally be achieved through incremental monitoring, adjusting and testing. Often this is best achieved with the assistance of a commissioning engineer.
- **Reduction in the number of CIPs:** Typically CIP cycles are instigated through either timers, product change and also through 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 utilisation of the
plant whilst 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 utilisation, proportionally the less CIP carried out per unit output.

- **Understanding what is clean** through a better understanding of “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 the calculation of 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 associated with CIP. 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 thin membranes** would reduce the amount of hot solution that is currently lost to drain after becoming too contaminated to return to the main tanks. The cost savings would be associated with the amount of solution lost through tank dumps and solution not currently 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.

**3.5 Key findings summary**

Figure 30 below summarises the results of the measured data analysis from the three reference sites, focussing on the main areas monitored. For pasteurisation and CIP this is limited to heating and cooling only.

![Measured process intensity](image)

**Figure 30 - Measured process intensity**
Figure 31 shows average specific carbon dioxide emissions for each process, multiplied by the sector applicability of each process to show percentage of total sector emissions accounted for by each process.

![Figure 31 - Processes in terms of % sector emissions](image-url)
4 Opportunities

4.1 Overview

The approach taken during this IEEA Stage 1 was to categorise opportunities in terms of “waves”, dependent on their level of commercial and technical maturity, and associated cost-effectiveness of implementation. This is shown diagrammatically in Figure 32 below.

<table>
<thead>
<tr>
<th>Wave 1</th>
<th>Good practice</th>
<th>Immediate action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Proven application within the dairy industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No / low barriers to implementation within the dairy industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Take-up limited by awareness or site/process specific constraints</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wave 2</th>
<th>On the horizon</th>
<th>Controlled progress</th>
<th>Pilot projects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Medium capex / payback</td>
<td>• Minor barriers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pre-commercial technologies</td>
<td>• Few/no sector-specific example projects</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wave 3</th>
<th>Blue sky: the future</th>
<th>Further assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Early stage R&amp;D; further trials/tests needed before site-based demonstration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High initial capex, but with potential or cost-effectiveness one in production</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High barriers: may require changes to process design and/or regulatory change</td>
<td></td>
</tr>
</tbody>
</table>

Figure 32 - Categorising energy saving opportunities in terms of commercial and technical readiness

The so-called “Wave 1” opportunities include both low/no cost energy good practice measures (such as effective energy management and maintenance), as well as proven energy and carbon saving technologies for which there is a solid business case without any need for external grant support (and therefore no need for grant support under Stage 2 of the IEEA programme). Examples in this latter category include VSDs, improved controls, and partial homogenisation.

To the extent that these cost-effective opportunities have not yet been implemented within the dairy sector, the requirement is one of awareness raising across companies and sites so that they can be taken up to their fullest extent, allowing for the fact that some sites may have insurmountable, site-specific constraints to implementation.

The “Wave 2 and 3” opportunities are those which will be the main focus of the IEEA Stage 2 programme, and therefore the focus of this project. These opportunities can be classed as either ready to be piloted at a demonstration scale at a dairy site or to be the subject of further tests and/or development to generate the additional data needed to quantify their energy saving benefits in more detail, as well as to provide evidence in support of any required regulatory approval (for example, such approval will be needed in the case of opportunities relating to low temperature pasteurisation).
The barriers here relate to high costs (since they are not yet in production and so must be built as “one-offs”), or to regulation (for example, pasteurisation is currently defined as a thermal process, so alternative techniques must be tested and approved by regulators), or to production risk (potential process interruption and/or impacts on quality). Hence these issues must be addressed as a part of any IEEA Stage 2 project.

4.2  Good practice opportunities

The following good practice opportunities have been extracted from the collated survey responses, selecting the measures that were still possible (ie, not yet implemented, but could be), at most sites, but which also have the potential to achieve effective emissions reduction. The full summary of responses to the check list survey can be found in Appendix 2.

Based on the ten survey respondents, the following list summarises the measures which had the most potential for implementation (ie, had not yet been implemented, but could be):

- **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; and
- **Compressed air**: Heat recovery from air compressors for space heating or hot water.

Partial homogenisation could be added to this list. Even though only 3 out of 10 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.

However, these good practice initiatives are outside of the scope of the IEEA programme and will not be discussed further in this report. Appendix 2 provides the full list of survey questions (the good practice “check list”) as well as tabulated summary of responses.

4.3  Innovative opportunities

Table 3 below summarises the more innovative opportunities investigated as a part of this project. The full descriptions of the opportunities, as well as the performance and cost data (where available) needed to form an initial business case for each one, are provided in Appendix 3 to this report.
### Table 3: Summary of opportunities

<table>
<thead>
<tr>
<th>No.</th>
<th>Wave</th>
<th>Opportunity summary</th>
<th>Cost of implementation on a typical site</th>
<th>Payback (years)</th>
<th>Sector saving (tCO$_2$/yr)</th>
<th>Readiness level</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td><strong>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>All opportunities have been implemented elsewhere in the sector</td>
<td>Awareness, culture, finance and resource availability.</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td><strong>Partial homogenisation</strong> allows the fat content that modern homogenisers can take to 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>3</td>
<td>1</td>
<td>A new range of <strong>direct drive separators</strong> have been developed that 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>4</td>
<td>1</td>
<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>5</td>
<td>1</td>
<td>By Upgrading the <strong>Homogeniser head</strong> the energy demand of a homogeniser can be reduced 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 rational for moving to the most up to date equipment depends on which level of technology is already installed</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td><strong>Increasing the efficiency of the pasteuriser</strong> can be done through enlarging the heat exchanger with 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>7</td>
<td>2</td>
<td>A high temperature hot water <strong>heat pump</strong> is a mechanism for the recovery of waste heat from existing centralised site refrigeration systems to generate hot water which can subsequently be used to heat dairy processes including 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, dependent on layout of refrigeration and heating systems, and more cost-effective when carried out as part of wider site refurbishments or a new process line.</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td><strong>Anaerobic Digestions</strong> is the process of breaking down waste products in the absence of oxygen to biogas which can then used on site for heat or power with CHP</td>
<td>1,200 - 2,000 £/kWh</td>
<td>Dependent on site and feed stock</td>
<td>Depends on feed stock</td>
<td>Commercial product, skid-mounted modular systems available</td>
<td>Wastes in dairy effluent often too dilute to make AD viable unless the COD can be increased by mixing with other wastes or by increasing effluent COD by reducing CIP water.</td>
</tr>
</tbody>
</table>
### Table 3: Summary of opportunities

<table>
<thead>
<tr>
<th>No.</th>
<th>Wave</th>
<th>Opportunity summary</th>
<th>Cost of implementation on a typical site</th>
<th>Payback (years)</th>
<th>Sector saving (tCO$_2$/yr)</th>
<th>Readiness level</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>3</td>
<td>Ultrasonic homogenisation involves using a sonotrode to agitate milk in order to reduce the particle size of the fat globules in the milk.</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 sector</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>10</td>
<td>3</td>
<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>11</td>
<td>3</td>
<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>12</td>
<td>3</td>
<td>Ultrasonic cleaning is the process where ultrasonic actuators create cavitation within tanks and other solid structures, removing dirt 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>13</td>
<td>3</td>
<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>14</td>
<td>3</td>
<td>Cleaning verification is a university research programme that has been working with industrial partners to determine what level of cleanliness is 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>

* A typical plant is 350,000m$^3$/annum of raw milk input, having three raw milk production lines with each one have a pasteuriser, homogeniser and separator.
5 Next steps and recommendations

5.1 Next steps for the dairy sector

The level of awareness of the need for energy saving in the dairy industry is good and the cost constrained nature of the sector means 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.

5.1.1 Implement good practice

More robust implementation of good practice opportunities at all sites in the sector is recommended. Operational staff should be made more aware of the level of opportunity that is still available as indicated by the best practice survey.

5.1.2 Optimise and upgrade process equipment

Working more closely with suppliers, companies should optimise and upgrade process equipment, including:

- Increasing pasteuriser efficiency through upgrades of heat exchangers and set-up optimisation
- Installing hibernation controls on pasteurisers to reduce the impact of non-production related recirculation.
- Routinely replace separators with the most up to date gearless, direct drive systems;
- Improve the level of, or implement partial homogenisation
- Work with the University of Birmingham to develop and implement sector wide standards for CIP requirements
- Work with plant suppliers to review & optimise the set up of existing CIP plants

5.1.3 Install hot water heat pumps

The use of high temperature hot water heat pumps on refrigeration plants may soon be a proven application available commercially. If successful, companies should begin to investigate site specific feasibility, as a step towards understanding whether heat pump technology can be retrofitted, or included as part of new process line installations. Whilst the heat pump technology can be cost-effective at appropriate sites, greater awareness of the opportunity within the dairy sector could be encouraged by the dissemination of case studies and other evidence of the technology’s potential benefits.

5.1.4 Engage in IEEA pilot projects

Companies should take advantage of Carbon Trust support within the IEEA programme and participate in research and pilot projects to develop the market readiness of newer technologies as part of IEEA Stage 2:

- Low temperature pasteurisation
- 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 relatively high cost of innovative equipment not yet in commercial manufacture, any such projects should be structured so that they are sufficiently large in scale to provide a realistic evidence base relating to energy performance, process integration and production impacts needed to demonstrate the technology’s applicability and potential cost-effectiveness to the dairy sector in more detail, yet not so large as to be unacceptably costly to implement as part of IEEA Stage 2.

5.2 Next steps for the Carbon Trust: IEEA Stage 2

5.2.1 Low temperature pasteurisation

Low temperature pasteurisation technologies have the potential to create a step change in dairy sector emissions but legislation governing the processing of milk and credible case studies are current barriers to implementation. The analysis carried out as part of this project has shown that thermal energy equivalent to 42,000tCO\(_2\) per annum across the UK dairy industry is consumed by milk pasteurisation processes, 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, the regulatory definition of pasteurisation as a purely thermal process 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 in any IEEA Stage 2 project, in order to enable the development of an alternative definition based on non-thermal process(es), supported by the required evidence base. Working in partnership with such regulatory bodies, the Carbon Trust could have significant impact on commercialisation in this area. Technologies that could be considered under the scope of this work stream include UV pasteurisation or pulsed electric field pasteurisation.

5.2.2 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 but is down to the site. Usually it will be determined at the installation of the equipment in conjunction with choosing detergent levels and times for each CIP. The analysis carried out as part of this project has resulted in a sector-wide emissions estimate of 19,000 – 46,000tCO\(_2\) per annum (2.2 – 5.4 % of the sector total), for CIP activities. Taking the middle of this range as typical, for each 10°C reduction in CIP temperature, or 15% reduction in CIP water usage, a sector-wide emissions reduction of 5,300 tCO\(_2\) per annum would result.

Most of the alternative CIP technologies investigated during this project were at the university research, start-up level, or requiring a commercialisation/manufacturing partner. Carbon Trust support could help speed up the route to market as part of an IEEA Stage 2 project. Technologies that could be considered under the scope of this work stream 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 a novel concept of 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, reducing the load and amount of water and chemicals needed substantially.

- **Whirlwind pigging** – This technology can clean through pipe systems using a fraction of the energy of traditional CIP systems while still providing the disinfectant and sterilisation necessary to ensure product quality
- **Ultrasonic cleaning** – Ultrasonic cleaning can be used along side traditional CIP to reduce the demand on the hot detergent through removal of material from difficult to clean areas and inhibiting material from adhering to surfaces in the first place.

### 5.2.3 Alternative homogenisation techniques

Current homogeniser technology is energy intensive during both production and non-productive CIP activity. Alternative homogenisation technologies that have lower energy consumption during both CIP and production operations have the potential to generate a step-change in sector energy consumption relating to this process. The analysis carried out in this IEEA Stage 1 project suggests a sector-wide emissions relating to homogenisation of between 4,700tCO$_2$ and 15,000tCO$_2$ per annum, dependent on the degree to which processing sites operate a full stream or partial stream homogenisation process.

At the current time the sector-wide split between full and partial homogenisation is not known, but three out of the ten good practice survey respondents (see Appendix 2) indicated that they operated a full stream process. Assuming that this is representative of the wider industry, this suggests that around 7,800tCO$_2$ per annum is related to homogenisation.

This level of emissions could be reduced by around 3,100tCO$_2$ per annum 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 project for Stage 2 of the IEEA programme.
Appendix 1: Metering rationale

Capturing the following variables for each process shown in Table A1.2 will allow a detailed understanding to be developed and compare the information collected from the different sites.

<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>
<tr>
<td></td>
<td>• Process steps from SCADA</td>
<td></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>CIP</td>
<td>At a time interval of 1 minute</td>
<td>The parameters identified will allow a full energy consumption model to be built and understood for the process in a cost effective manner. Steam metering would be optimum but the non-invasive approach of the project meant that ultrasonic flow meters were used, which do not have much reliability when dealing with steam.</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>Homogenisation</td>
<td>At a time interval of 1 minute</td>
<td>Electricity is the only key parameter to monitor the homogenisation process. At each process step the pressure in the homogeniser will change and therefore the electricity consumed will change, making it straightforward 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>
Appendix 2: Good practice checklist

A2.1 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 had drop-down boxes where, if the measure had not been implemented, an option could be chosen as to why not. The options were:

- Pay back too long >12 months
- Pay back too long >24 months
- Pay back too long >36 months
- Impact on production downtime
- Lack of people skills
- Lack of available capital budget
- Lack of available revenue budget
- Saving not perceived large enough
- Saving not perceived large enough
- Not relevant to our specific processes / operation
- Other – please indicate to the right (in a comment box)

The good practice measures are listed in the following sections.

A2.2 Good practice measures, by utility area

Compressed air

- Reduce delivery pressure
- Sequence compressors to reduce unloaded hours
- Leak test regularly and reduce leakage
- High efficiency refrigerated dyers
- Check and service filters (reduced pressure drop)
- Shutting down the compressor outside of working time
- Use high efficiency jet nozzles in blowing applications
- Use blowers instead of compressed air
- Don’t use compressed air for cleaning
- Replacement of outdated pneumatic tools
• Schedule pressure reductions outside main production hours
• Connect specific applications of compressed air to separate compressed air facilities. No running of the entire compressed air system at high pressure to satisfy one user when a local booster could be used
• Heat recovery from compressor for space heating or hot water
• Ensure cold feed air
• Application of small weekend compressor
• Cooling the cooling water of the air compressors with cooling towers instead of using chilled water
• Install VSD compressors or retrofit VSD on existing compressors
• Engineer out use of compressed air; is there and alternative?
• Isolate unused areas e.g. at weekends
• Separated compressed-air networks (high and low pressure/quality) to minimise generating costs
• Use of receivers/ bufferage in air distribution system
• Correct dimensioning of compressed air pipe
• Correct relation between drying/filtering and quality requirements

Buildings / lighting
• Energy saving lamps
• Daylight dependent control
• Lighting on the workplace
• Presence sensors
• High frequent lighting containing fittings with an optical mirror system
• Installing several light switching groups

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

**Boiler and steam distribution**

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

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

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

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

**Other**
• Voltage reduction - fit tap down transformers
• Scheduling & Simulation (debottlenecking/buffer reduction)
• Use of cogged V-belts in stead 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

A2.3 Summary of responses

This section shows the results of the survey (for the ten sites which responded), by utility area.

Under the options for clarifying why each decision was chosen the quality of the responses deteriorated, with most sites simply choosing ‘other’ of ‘not relevant’.

To use this information in future the questionnaire must be re designed to make the process less time consuming, through focussing on specific areas or making the respondent aware of the time needed to complete the check list thoroughly.
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 pipes
- 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 and alternative?
- Separated compressed-air networks (high and low pressure/quality) to minimise 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 dryers
Buildings and lighting

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

Legend:
- possible
- not possible
- no selection
- implanted
Cooling and Refrigeration

- 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
- Use alternative heat sinks if available e.g. river or lake
- Electronic expansion valves on DX systems (ev)
- Common compressor suction and discharge piping
- Convert liquid injected oil cooling to external cooling
- Use controls to operate plant at optimum setpoints
- Prevent excess heat release in climate controlled spaces.
- Switch off evaporator fans with compressor
- Improve insulation
- Reduce parasitic loads e.g. unnecessary pumping
- Using a cooled hallway to reduce chill room heat ingress
- Smooth loads to stabilise plant loading
- Improve cold store door discipline
- Have large enough pipes to minimise pressure drop
- Adiabatic cooling on air cooled condensers
- Heat recovery from oil coolers
- Improving heat release of condenser to reduce scaling and water treatment
- High efficiency motor or double-speed motor for evaporator fans
- Automatic air bleed
- Optimising defrost cycle
- Reduce cold store door openings and heat ingress
- Have large enough diameter piping to minimise pumping pressure
- Floating head pressure control on condenser fans
- Fit VSDs to condenser and evaporator fans
- Heat recovery (de-superheat/oil heat recovery)
- Reduce condensing temperature
- Check pumping for appropriate sizing
- Fit VSDs to secondary pumping
- Improve part load performance by changing compressor sequencing or retrofitting a VSD
- Increase evaporating temperature / secondary coolant temperature
- Calculate and reduce your cooling loads e.g. intake chilling setpoint (can we increase by 0.5°C?)

[Bar chart showing possible, not possible, no selection, implemented options for each measure]
Boilers and steam Distribution

- Manage instantaneous loads or use a surplussing valve
- Fit VSDs to FD fan and feed pump
- Condensate flash steam injection e.g. into CIP detergent tank or High pressure condensate return
- Blowdown heat recovery
- Use fully modulating burner
- Replace old burners for ones with better efficiency & turn down ratio
- Sequence boilers to reduce low fire running
- 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
- Use automatic side and bottom blowdown controls
- Ensure steam pipe size is large enough to minimise pressure drop
- Increase Howell 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
- Measure and increase condensate return
- Identify and repair faulty steam traps
- To improve burner efficiency use oxygen trim through exhaust gas analysis
- Use of direct firing for hot water generation
- Reduce reliance on steam, then decentralise use of steam
- Ensure steam pipe size is large enough to minimise pressure drop
- 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
- 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

- possible
- not possible
- no selection
- implemented
Vacuum

- Valves at point of use: 50% possible, 30% not possible, 20% no selection, 100% implemented
- Central vacuum generation: 50% possible, 30% not possible, 20% no selection, 100% implemented
- Heat recovery from vacuum pumps: 50% possible, 30% not possible, 20% no selection, 100% implemented
- Switching off pump outside of working hours: 50% possible, 30% not possible, 20% no selection, 100% implemented
- Detect leakage: 50% possible, 30% not possible, 20% no selection, 100% implemented
- Regular maintenance: 50% possible, 30% not possible, 20% no selection, 100% implemented
- Optimising pressure measurement: 50% possible, 30% not possible, 20% no selection, 100% implemented
- Frequency control of pumps: 50% possible, 30% not possible, 20% no selection, 100% implemented
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

Possible: Green
Not possible: Orange
No selection: White
Implemented: Blue
**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

Colors: possible (green), not possible (orange), no selection (white), implemented (blue)
Scheduling & Simulation
(debottlenecking/buffer reduction)

Shutting off machines when they are not needed

Use of cogged V-belts in stead of standard V-belts to transfer mechanical power

Select pumps with a high efficiency

Voltage reduction - fit tap down transformers

Misc

- possible
- not possible
- no selection
- implemented
Monitoring and Targeting

- Regular collection of sub meter data: implemented
- Regular collection of main meter data: implemented
- Regular on site meetings to review energy use: implemented
- An assigned carbon/energy manager at site level: implemented
- Have a quantitative improvement target: not possible
- Capital procedure to take account of energy: implemented
- Extensive sub-metering on key processes: implemented
- Have a written energy policy: implemented
- Hedged budget for energy saving measures: implemented
- Good Operation/practice guides: implemented
- Active reporting systems for energy waste (e.g. steam leaks): implemented
- Regular analysis of consumption patterns (e.g. regression analysis): implemented
- Capital procedure to take account of carbon savings: implemented
- Predicative maintenance procedures on energy consuming plant equipment: implemented
- Utility mass balances: implemented
- Technical training for staff: implemented
- Energy awareness training for staff: implemented
- Carry out regular energy surveys: implemented
A3.1 UV Pasteurisation

What is the technology?
Non-thermal processes, such as ultraviolet (UV) light technology, have the potential to cut demand for energy currently used for thermal pasteurisation. While some countries have explored these technologies, there have been no commercial demonstrations of UV milk processing in the UK. Regulatory change is the primary hurdle. Current UK food safety regulations strictly mandate the use of pasteurisation by thermal means as the only recognised standard for destroying pathogens in raw milk. Therefore, game-changing technologies such as UV processing are longer-term projects that require further trials and demonstration, and subsequent regulatory approval.

UV pasteurisation is a process where milk is subjected to a certain wavelength of light that is just the right frequency to interact with DNA and stop its ability to reproduce.

Where is the technology currently used?
In South Africa the technology is used on its own to process raw milk on a limited scale where allowed by local authorities, but legislative hurdles here in the UK mean that it can only be used in conjunction with heat based pasteurisation. In the UK there are currently trials to extend the shelf life of milk through post-pasteurising UV treatment of milk where it has been shown abroad (USA) to increase shelf life by up to 30%.

The technology is currently used in the photo purification of wine, sugar syrups and fruit juices and is also used in large scale water treatment facilities as a last stage sterilisation process.

What is the advantage over current practice?
The energy needed to disable bacteria with UV light is dramatically lower that that of thermal pasteurisation. By using UV light the energy is focused in breaking down the DNA of the bacteria, whereas in the heat based method the whole of the milk is heated in order to break down the entire structure of the bacteria.

Used in conjunction with heat based pasteurisation the shelf life of milk can be increased without the need for ultra high heat treatment and the associated taste degradation.
Are there any limitations?
The dosage needed to treat milk depends on its absorptivity. This characteristic will change with different fat content of milk grades and so there will need to be a control system that can cater for changing the exposure with specific grades.

What is the development stage?
The UV photo-purification process is well understood and the effects on microbial levels within milk have been extensively researched and compared with heat based pasteurisation. Large scale equipment has been manufactured for other industries and incorporated into factories.
The technology is at a commercial stage and in South Africa where the laws regarding pasteurisation are less stringent than the UK and the US. In South Africa in some cases, where local legislation allows, UV sterilisation is used as the only microbial defence for raw milk.
The modification to plants in order to replace heat based pasteurisation would not be extensive as the only consumable needed is electricity and the pipe work can remain relatively unchanged. There are initial trials underway with one of the larger UK dairy companies into the use of UV as a purification technology for milk.

Barriers to overcome
The largest barriers will be in producing robust validation trials and prompting changes in the legislation regarding the processing of raw milk to give industry the confidence in the wholly new approach to pasteurisation.
Initial trials are already taking place on a decentralised level to incorporate this technology into the dairy process by having the technology running side by side with conventional pasteurisation. By using both technologies at the same time there are no legislative barriers to overcome and the shelf life of the product can be increased.
However, robust validation trials of the sole use of UV still need to be carried out if the technology is to be proven and progressed in the UK.
When sufficient trials have been accepted by the regulator the legislation can be altered to allow UV treatment as a form of bacterial control on milk. This would allow facilities to switch over entirely to a UV system.
At present the cost of implementing this system in a dairy would mean that for switching entirely to this system should be considered for new builds and replacing obsolete pasteurisation systems. The other option would be to gradually move over by having both systems running simultaneously, to increase the shelf life of the milk.

Who are the technology providers?
SurePure: A South African company and leader in turbid liquid photo purification
Steribeam: A German company that offers pulsed light, cold plasma and UV sterilisation
### Business case

#### Ultraviolet Pasteurisation

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity 2.53 - 3.55 kgCO₂/m³</td>
<td>Heating &amp; cooling load only</td>
</tr>
<tr>
<td>New process intensity 1.47 - 1.47 kgCO₂/m³</td>
<td>Surepure own calculations of a 20kl system plus additional milk chilling of 2C required</td>
</tr>
<tr>
<td>Carbon intensity saved 1.06 - 2.08 kgCO₂/m³</td>
<td></td>
</tr>
<tr>
<td>Sector applicability 95 %</td>
<td></td>
</tr>
<tr>
<td>Sector carbon dioxide saving (absolute) 13 - 26 ktCO₂ per annum</td>
<td></td>
</tr>
<tr>
<td>Sector % carbon dioxide saving 1.6 - 3.1 %</td>
<td></td>
</tr>
</tbody>
</table>

#### Site Financials

<table>
<thead>
<tr>
<th>Site Capex (350,000 m³/yr site) 1,084 £k</th>
<th>Cost Saving 81 - 99 £k per annum</th>
<th>Payback 13.3 - 11.0 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include Opex of £2000 for bulbs every year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Lifetime Savings

<table>
<thead>
<tr>
<th>Carbon Cost 30.8 - 15.7 £/tCO₂</th>
<th>Technology Life (persistence) 15 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifetime Carbon Cost 2.1 - 1.0 £/tCO₂</td>
<td></td>
</tr>
</tbody>
</table>
A3.2 Ice pigging

What is the technology?

Pigging is widely employed in the hydrocarbon industry where solid plugs or ‘pigs’ are used to clear and clean pipes. The technique is beginning to be adopted in the food and pharmaceutical industries and can be used for more than just cleaning as the technique is effective for both product recovery and separation. But conventional pigging is limited in the pipe geometries to which it can be applied.

Ice pigging is a novel and innovative new pigging technique that has significant advantages over conventional solid pigs. The ice pig plug is formed from thermodynamically stable ice slurry combined with a freezing point depressant which is capable of cleaning a product from ductwork and/or separating products in different phases of the production cycle. The unique non-Newtonian flow characteristics of the pig allow it to negotiate a wide variety of obstacles successfully (even plate pack heat exchangers), while maintaining the cleaning efficiency and in many cases a sharp product interface.

Where is the technology currently used?

The Ice Pig has been trialled and is now in use in the water industry where Bristol Water use a flat bed lorry mounted device to clean out mains water piping (pictured above). The technology has been successfully trialled on a small scale in the food sector and it is ready for licensing in other sectors.

What is the advantage over the current best practice?

Ice pigging allows for much higher product capture (product recovery) at the end of each run as the sharp interface of the ice acts as a solid plug, contaminating only the small volume abutting the pig face.

The ice pig also has superior cleaning abilities to fluid washes. The high shear forces within pig mean the ice crystals effectively dislodge material as they scrape past. The same cleaning effect can be achieved with a much reduced amount of water, reducing both water (and effluent costs) as well as the amount of heating and chemicals required.

The ice pig can also be used as a simple product separation device. This is particularly advantageous in situations where there is a need to separate one product from another, but there is no need to fully clean/sterilize between products (for example, for different milk batches).
Another advantage of ice pigging is that it reduces downtime; this is particularly important where lines are running at full capacity. The technology can be applied to existing plant plants with minimal engineering modifications or be introduced at the design stage of new plants.

The energy used to heat the entire pipework in current CIP systems would be removed/reduced and the amount of fluid passed around the system would also be reduced, saving on pumping costs. The amount of water used and sent to drain would be significantly lower than at present, saving on water and effluent costs.

Additives can be mixed with the pig to deliver a range of results. Abrasive materials can be added to scour the inside of the pipe. The pig can be made alkali (caustic) or acid and if the pig ever becomes lodged in a certain inaccessible location the solution is merely to wait for it to melt.

**Are there any limitations?**

Ice Piggling can not be used to clean tanks and so a separate system would have to be in place, working alongside Ice Piggling to clean the entire factory. There are some products (such as chocolate) that are difficult to treat with this technology.

**What is the development stage?**

Ice Piggling technology is at a stage where it can be effectively demonstrated at any site where the pipe topology is suitable. Bristol University are now at a stage where they are looking to license the technology to an international equipment provider who can provide the support necessary to make this a saleable product within the food and drinks industry. The technology is currently at a pre-commercial state having been proven with several prototypes currently in use in different industries including the food and drink sector.

**Barriers to overcome**

- **Equipment manufacturer acquiring licence:** a suitable equipment manufacturer would need to acquire the technology under license from the university to develop a commercial product. This would also provide a support network for the product which is not currently possible from Bristol University.

- **Technology commercialisation:** a control system would also have to be developed for integrating the technology into the CIP systems and processes that exist in most dairies. A robust set of dairy validation trials will also be required before this technology can be fully commercialised and used as a sole cleaning method.

- **Freezing Point Depressant:** the use of salt as a freezing point depressant within the ice pig may involve the need for a flush after each cleaning run to eliminate the salt from the system. Other temperature depressants are available and so the right one most suited to the dairy industry would have to be selected.

**Who are the technology providers?**

Bristol University - The technology has been developed by Prof Joe Quarini and team in the Department of Mechanical Engineering.
### Business case

#### Ice Pigging

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original process intensity</strong></td>
<td>1.39 - 3.46 kgCO₂/m³</td>
</tr>
<tr>
<td><strong>New process intensity</strong></td>
<td>0.08 - 0.08 kgCO₂/m³</td>
</tr>
<tr>
<td><strong>Carbon intensity saved</strong></td>
<td>1.31 - 3.38 kgCO₂/m³</td>
</tr>
<tr>
<td><strong>Sector applicability</strong></td>
<td>50 %</td>
</tr>
<tr>
<td><strong>Sector carbon dioxide saving (absolute)</strong></td>
<td>9 - 23 ktCO₂ per annum</td>
</tr>
<tr>
<td><strong>Sector % carbon dioxide saving</strong></td>
<td>1.0 - 2.6 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site Financials</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Capex (350,000 m³/yr site)</td>
<td>170 £k</td>
</tr>
<tr>
<td><strong>Cost Saving</strong></td>
<td>11 - 60 £k per annum</td>
</tr>
<tr>
<td><strong>Payback</strong></td>
<td>15.4 - 2.8 years</td>
</tr>
</tbody>
</table>

- Estimated costs from provider as there are no commercial example available
- 20k (conservative) running cost have been anticipated
- This payback only takes into account the energy cost of heating the CIP solution and creating the ice for pigging. It does not take into account product capture, reduced effluent and shorter CIP times which could increase the viability of the technology

<table>
<thead>
<tr>
<th>Lifetime Savings</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon Cost</strong></td>
<td>7.4 - 2.9 £/tCO₂</td>
</tr>
<tr>
<td><strong>Technology Life (persistence)</strong></td>
<td>15 years</td>
</tr>
<tr>
<td><strong>Lifetime Carbon Cost</strong></td>
<td>0.5 - 0.2 £/tCO₂</td>
</tr>
</tbody>
</table>
A3.3 Whirlwind pigging

What is the technology?
Whirlwind pigging is a process where a vortex (whirlwind) is generated in a pipe system which cleans the inner surfaces of the pipes through gaseous displacement and through adding cleaning additives to the ‘whirlwind’.
A laminar air stream is blown through the pipework, recovering 60 – 80% of the product. A whirlwind is generated within the airstream which clears the remaining product. This is done by a blower system and does not involve compressed air (which is very energy inefficient). This typically reduces the remaining product to less than 5%. At this point a small amount of water or cleaning agent (caustic or acid) can be introduced into the airflow, enhancing the cleaning effect from the turbulent flow. This generates an inner surface which is fully clean.
Heated air is introduced completely drying the pipework. By warming the whirlwind airflow any traces of water droplets on the inner surfaces are dried ready for production to restart in a short period of time.

Where is the technology currently used?
The whirlwind technology is currently used to recover product and clean with wine, spirits, juice drinks, drink additives, soups and sauces, perfumes and soaps as well as food pastes and spreads. It is particularly relevant to high-value products where the value of additional product recovery due to the whirlwind technology makes it commercially attractive.
The technology is currently being trialled in the construction and utilities sectors.

What are the advantages over current practice?

- **Product recovery**: The initial vortex that is formed can push the majority of the product out of the pipe system without having to use contaminants such as water or detergent. This product would normally not be recoverable and in the cases of more expensive products this can offer a valuable cost saving. This is more applicable to the cream and dairy industries that have valuable product that is normally lost at the end of each run with water pushing it through.

- **Heat, water and effluent reduction**: This system uses less heat and water for CIP and less chemical cleaning agents than conventional CIP.
Are there any limitations?
The technology cannot be used to clean plate pack heat exchangers or large tanks and silos. Separate cleaning systems would have to work side by side with the whirlwind pig. To date the only pipe diameters that have been successfully pigged are 0.5 inch to 4 inch pipes. Any pipe sizes outside of this level will require additional testing before they are deemed suitable.

What is the development stage?
The technology has been proven to work in the sectors identified above. The whirlwind system is a commercial product with a procurement process that starts as an initial assessment and carries through with after sales service.

Barriers to overcome
The whirlwind concept should prove very efficient at cleaning through pipework using less energy than is currently used with traditional CIP systems, but it will be unable to clean through plate pack heat exchangers tanks. Removing plate packs from pasteurisation would allow the technology to be utilised further and be more effective. Coupling this technology with UV pasteurisation would overcome the problems associated with navigation of the plate packs and reduce the number of separate systems needed to CIP.

There was a UK trial of the technology a few years ago with one of the larger dairy companies, but this was not a success. The company behind the whirlwind technology – Aeolus – claim that this was because it was unsuitable for cleaning systems with cream in the pipework, and it would perform much better with milk lines. Whilst this may well be the case, the technology may have to overcome some understandable scepticism in the dairy industry before it can be implemented on any scale.

Who are the technology providers?
Aeolus Technologies: A company formed specifically to commercialise and develop the whirlwind technology for use in industry.
## Business case

### Whirlwind Pigging

| Carbon Emissions                      | Notes                                                                 |
|---------------------------------------|                                                                      |
| Original process intensity             |                                                                        |
| 1.39 - 3.46 kgCO₂/m³                  |                                                                        |
| New process intensity                  | 1/5 of present CIP from conservative figures from Aeolus Technology  |
| 0.28 - 0.69 kgCO₂/m³                  |                                                                        |
| Carbon intensity saved                 |                                                                        |
| 1.112 - 2.768 kgCO₂/m³                |                                                                        |

| Sector applicability                   |                                                                        |
| 40 %                                   | Whirlwind pigging can not clean plate packs or tanks giving it a reduced sector applicability and also reducing the amount of savings available from each plant. |

| Sector carbon dioxide saving (absolute)|                                                                        |
| 6 - 15 ktCO₂ per annum                |                                                                        |

| Sector % carbon dioxide saving         |                                                                        |
| 0.7 - 1.7 %                           |                                                                        |

### Site Financials

<table>
<thead>
<tr>
<th>Site Capex (350,000 m³/yr site)</th>
<th>350 £k</th>
<th>£300k for the unit and £50k for installation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Saving</td>
<td>21 - 52 £k per annum</td>
<td>Opex has been taken into account through the 1/5 reduction in energy needed to clean through the pipe systems. Figures are supplied from technology provider.</td>
</tr>
<tr>
<td>Payback</td>
<td>16.6 - 6.7 years</td>
<td>This payback only takes into account the energy cost of heating the CIP solution against. It does not take into account product capture, reduced effluent and shorter CIP times which could increase the viability of the technology.</td>
</tr>
</tbody>
</table>

### Lifetime Savings

| Carbon Cost                            | 22.5 - 9.0 £/tCO₂            |                                                                        |
| Technology Life (persistence)          | 15 years                     |                                                                        |
| Lifetime Carbon Cost                   | 1.5 - 0.6 £/tCO₂             |                                                                        |
A3.4 Ultrasonic homogenisation

What is the technology?

Ultrasonic homogenisation involves using a “sonotrode” to agitate milk in order to reduce the particle size of the fat globules in the milk. The proposed system can homogenise milk inline through a modular system.

Where is the technology currently used?

The products are currently used in a very large range of industries: bio-diesel, biology, chemistry, nano materials, inks and paints, oil and gas, cement and concrete, food, drinks, and cosmetics.

The processes that ultrasonics are used for are also wide ranging but include dispersing, wet milling, emulsifying, disinfection and sieving.

In these sectors ultrasonics have been used to homogenise emulsions on a commercial scale and so providers have all the necessary equipment support to incorporate it into the dairy system.

What is the advantage over the current practice?

If the power needed to homogenise milk to approved standards is lower than that of current homogenisation then the technology will offer a cost and energy saving. This saving can not be quantified until tests have been carried out to determine the actual energy needed to break down the fat globules to the required size through this method. Note that this is also compatible with partial homogenisation. Ultrasonic induced cavitation has been used to clean surfaces and has also been found to destroy bacteria and other microbes. The extent to which this technology would further increase the shelf life of the milk through microbial reduction is not yet understood but it is a topic which should receive further attention.

Are there any limitations?

Initial testing will need to be done to determine what power is needed from the sonotrode effectively to homogenise the milk to the desired standard of the UK dairy market. If the systems are overpowered then the sonotrodes may experience minute damage, with the milk taking on a metallic taste. This will only happen if the machinery is set up incorrectly, and can also happen with piston-based homogenisers.

What is the development stage?

The product is a fully developed commercial system which has been incorporated in the industries mentioned above. It has been used in the dairy industry abroad and previous results with homogenising milk have proved successful and economically
viable. The floor space for the units would be less than that of existing piston driven devices and the electric supply can be wired into the same panels.

Barriers to overcome
A set of experiments need to be done to see what power is necessary to homogenise the milk. This can either be done on a company by company basis or from Dairy UK with an approved specification for fat particle size.

If the technology can perform at lower energy level to that of conventional piston homogenising, then taste tests must be carried out to determine if the ultrasonic process results in any changes to product quality.

Who are the technology providers?
Hielscher Ultrasonics: A major global supplier for innovative ultrasonic components.
Pro Scientific: Laboratory equipment and distributor based in Connecticut, USA (small scale equipment only)

Business case

**Ultrasonic Homogenisation**

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity</td>
<td></td>
</tr>
<tr>
<td>New process intensity</td>
<td></td>
</tr>
<tr>
<td>Carbon intensity saved</td>
<td></td>
</tr>
<tr>
<td>Sector applicability</td>
<td></td>
</tr>
<tr>
<td>Sector carbon dioxide saving (absolute)</td>
<td></td>
</tr>
<tr>
<td>Sector % carbon dioxide saving</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site Financials</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Capex (350,000 m3/yr site)</td>
<td>230 £k</td>
</tr>
<tr>
<td>Cost Saving</td>
<td>19 - 86 £k per annum</td>
</tr>
<tr>
<td>Payback</td>
<td>12.0 - 2.7 years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lifetime Savings</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Cost</td>
<td>30.7 - 6.9 £/tCO₂</td>
</tr>
<tr>
<td>Technology Life (persistence)</td>
<td>15 years</td>
</tr>
<tr>
<td>Lifetime Carbon Cost</td>
<td>2.0 - 0.5 £/tCO₂</td>
</tr>
</tbody>
</table>
A3.5 Anaerobic digestion

What is the technology?
Anaerobic digestion is a process which breaks down organic matter to simple chemical components in the absence of oxygen. In the case of the dairy industry effluent or by products are converted to bio gas which can then be burnt in a boiler or CHP plant to provide heat and power to the site.

The technology was first industrialised in 1859 in a sewage plant in Bombay and the technology has gradually improved to be a well known process that has applications ranging from fuelling rubbish trucks in Brazil to providing the power for many of the world’s sewage treatment plants.

Where is the technology currently used?
The process is currently used for providing a saleable fuel from waste water, sewage sludge, farm waste, municipal solid waste and green waste. Industries that treat their waste products with AD include food & drink, sugar, paper, pharmaceuticals and cosmetics.

What is the advantage over current practice?
AD produces energy which leads to a net reduction in greenhouse gas emissions: from the destruction of methane caused by anaerobic decomposition, as well as the displacement of fossil-generated energy (gas and/or electricity). The feedstock that it runs on is usually a waste product and would have to undergo waste treatment in order to make it safe to return it to the environment again. Turning the whey or waste skim streams into powder or concentrate as a saleable product is a very energy intensive process; whereas using AD creates a green source of energy.

Are there any limitations?
AD can only be a viable option if the strength (Chemical Oxygen Demand, COD) of the effluent stream is enough to justify purchasing the high capital cost equipment. The effluent stream must have a COD of between 2,000mg/l and 50,000mg/l which in most cases rules it out for general dairy effluent which is generally quite dilute.

What is the development stage?
The technology is a well-understood, commercial process that has been consistently refined for over 150 years.
Barriers to overcome

The viability of AD as marketable technology within the dairy industry is effected by the price of energy and the market rate for processing by products as a powder and liquid. There have been feed in tariffs introduced for creating electricity through biogas from AD but at present these are targeted at effluent with no alternative value. The by-products from the dairy industry vary depending on what process has been applied to the raw milk. Some whey can be used as a food supplement or additive and the market value of this product currently makes using it in AD economically unviable. Some whey (acid) is less valuable and is treated as effluent and therefore using it with AD is potentially feasible.

As energy and carbon prices rise the use of AD within the dairy industry will become more practical, ensuring further energy savings from the biogas created.

As dairy processing plants take steps to significantly reduce water consumption in the coming years, the strength of general effluent may rise to a level where AD becomes viable.

Who are the technology providers?

There are numerous providers of AD plant, including providers of skid-mounted modular systems which have the advantages of both ease of installation and ease of removal should the project for any reason become redundant after operation has started.

Business case

These are rough estimates based on a large plant. The economics for a site will depend on the variable discussed above and the following calculator can be used to give an initial feasibility study.

**CAPEX**

<table>
<thead>
<tr>
<th>Equipment:</th>
<th>£1,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation (10% estimates):</td>
<td>£100,000</td>
</tr>
</tbody>
</table>

**OPEX per year**

| Consumables: | £100,000 |
| Maintenance: | £10,000  |
| Running costs: | £40,000   |
A3.6 Pulsed electric field pasteurisation

What is the technology?
The pulsed electric field method is known as a cold sterilisation process where bacteria and spores are destroyed by polarizing and stretching them to destruction or through their electrical breakdown. The milk passes through a chamber between two electrodes and comes out sterilised with very little increase in temperature.

Where is the technology currently used?
The technology has been commercially available for the pasteurisation of fruit juices and has been successfully trialled with soups, eggs, and some initial lab scale work has been done on milk.

What is the advantage over current practice?
The field acts on the entire liquid, preventing any areas from not being treated while having a negligible effect on the temperature of the fluid. There are no distribution problems as the technology is situated around the flow. The optical problems associated with the absorptivity of milk are not a problem with this technology and the there are no taste altering side effects as with heat based methods which can be particularly important for the cheese making industry.

Are there any limitations?
For destroying some spores and viruses the method requires energy deposition in to a sterilized media of up to 41kWh/m$^3$, whereas for simple bacteria in water it can be as low as 1.16kWh/m$^3$, compared to the average 12kWh/m$^3$ that steam heated pasteurisation uses. Therefore the range of organisms that need to be destroyed will affect the energy efficiency of this product.

What is the development stage?
The technology was shown to work in demonstration over 10 years ago but remained undeveloped due to prohibitive costs. Return on investment has recently improved due to increased energy prices and now the technology has been taken up by some of the fruit juice producing industry.

Barriers to overcome
The largest barriers will be in producing robust validation trials and prompting changes in the legislation regarding the processing of milk to give industry the confidence in the wholly new approach to pasteurisation.
The amount of sterilization that is required is an important factor in the decision to implement this technology. If the kill rate is too high the energy needed will make this technology uneconomical. A trial should be taken to establish exactly how much energy is needed to kill the microbes that are present in raw milk.

At present the cost of implementing this system in a dairy indicate that switching entirely to this system should be considered for new builds and replacing obsolete pasteurisation systems. The other option would be to gradually move over by having both systems running simultaneously, to increase the shelf life of the milk.

Who are the technology providers?
Steribeam: Dr Alex Wekhof, who specialises in designing and manufacturing custom built pulsed UV and PEF sterilisation equipment.

| Business case |
|---------------|----------------|
| Pulsed Electric Field Pasteurisation |

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity</td>
<td>2.53 - 3.55 kgCO₂/m³</td>
</tr>
<tr>
<td>New process intensity</td>
<td>2.53 - 2.15 kgCO₂/m³</td>
</tr>
<tr>
<td>Carbon intensity saved</td>
<td>0 - 1.40 kgCO₂/m³</td>
</tr>
<tr>
<td>Sector applicability</td>
<td>95 %</td>
</tr>
<tr>
<td>Sector carbon dioxide saving (absolute)</td>
<td>0 - 18 ktCO₂ per annum</td>
</tr>
<tr>
<td>Sector % carbon dioxide saving</td>
<td>0.0 - 2.1 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site Financials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Capex (350,000 m³/yr site)</td>
</tr>
<tr>
<td>Cost Saving</td>
</tr>
<tr>
<td>Payback</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lifetime Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Cost</td>
</tr>
<tr>
<td>Technology Life (persistence)</td>
</tr>
<tr>
<td>Lifetime Carbon Cost</td>
</tr>
</tbody>
</table>
A3.7 Heat pump on refrigeration condenser

What is the technology?
A high temperature hot water heat pump is a mechanism for the recovery of waste heat from existing centralised site refrigeration systems to generate hot water which can subsequently be used to heat dairy processes including pasteurisers, CIP and bottle washers. It takes low grade heat from the hot pressurised refrigerant gas which would normally be discharged to atmosphere at around 30°C, and using a secondary high pressure compressor system, upgrades it to a condensing temperature which can heat up water via a heat exchanger to a maximum 82°C.

Using a buffer tank and pumps, the hot water is distributed around the factory, (in a similar fashion to that of a regular chilled water system – but hot) and is used as a heat source for processes.

Where is the product currently used?
All refrigeration plants are in fact a type of heat pump, but their primary purpose is to remove rather than deliver heat. With technology advancements and government led incentives, air and ground source heat pumps are now becoming more widely used in commercial buildings as energy efficient means to provide low temperature hot water for heating.

In the food and drink sector in the UK there are currently a handful of examples of hot water heat pumps but these are limited to food manufacturers that have a requirement for large volumes of 50°C – 60°C wash down water.

The first example of a heat pump using refrigeration condenser hear as a low temperature source in a dairy, is currently being installed in the North West of England.

What is the advantage over current practice?
Currently steam raised by firing a boiler is normally used as a heating medium in dairy processing plants and has an efficiency of 60% - 80% for useful output. A heat pump producing 80°C water has a COP of around 5; or in other words, an efficiency of around 500% heat output to electrical energy in.
When the relative costs of fuel and electricity are taken into account, as well as the different carbon intensities of the different energy sources, a significant saving in carbon emissions and costs is made over existing technology.

**Are there any limitations?**

If the generation of process waste heat and the requirement for heat are not synchronised, this could cause heat storage issues at the factory. A hot water heat pump is limited to generating water temperatures of just over 80°C, whereas temperatures far in excess of 100°C can be achieved using a conventional steam system, therefore flexibility is lower. However 80°C should be sufficient for thermal pasteurisation processes.

The higher the temperature of heat required, the lower the efficiency of the heat pump become, therefore water temperature has a direct impact on project economics.

**What is the development stage?**

To be considered useful for pasteurisation and CIP in a dairy, heat sources need to be in the region of 80-85°C. Until recently limitations in fridge plant technology have meant that the maximum temperature achievable using a heat pump was 65-70°C and at a low coefficient of performance (COP) or efficiency.

New design and technology developments have meant that a fully commercialised skid mounted capable of generating 82°C water is available. The first example of a dairy application of this technology is currently being installed in the North West of England and should be commissioned in the second half of 2010.

**Barriers to overcome**

A lack of industry case studies and technology acceptance could be barriers to take up of heat pump systems. The dairy industry is a heavily regulated industry with high quality standards and pasteurisation using steam as a heating medium is the accepted norm. Dairy companies may find it difficult to accept that the new technology will ensure product quality is maintained according to the standards.

Maintaining existing systems in tandem till the capability of new heat pump system is proved could be a solution for this. If the first UK dairy implementation later this year proves successful there will also be tangible results to be assessed and many of these concerns may be overcome.

Effective integration to existing process heating systems may also be complex as the application of a heat pump affects numerous systems including processing, steam and refrigeration.

**Who are the technology providers?**

- GEA Grenco: a refrigeration plant manufacturer who produce a skid-mounted high temperature heat pump
- Carbon Architecture: a newly formed UK based organisation specialising in the turn key implementation of heat pumping systems across the dairy and beverage sectors.
- Star Refrigeration: a UK based industrial refrigeration engineering company.
## Business case

### Heat pump on refrigeration condenser

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity</td>
<td>7-12% site carbon savings from previous dairy heat pump study of seven sites - saving dependent on site heat balance and fuel type</td>
</tr>
<tr>
<td>New process intensity</td>
<td></td>
</tr>
<tr>
<td>Carbon intensity saved</td>
<td></td>
</tr>
<tr>
<td>Sector applicability</td>
<td>May not be applicable due to heat balance and site layout</td>
</tr>
<tr>
<td>Sector carbon dioxide saving</td>
<td></td>
</tr>
<tr>
<td>Sector % carbon dioxide saving</td>
<td></td>
</tr>
</tbody>
</table>

### Site Financials

<table>
<thead>
<tr>
<th>Site Capex (350,000 m3/yr site)</th>
<th>Cost and savings are derived from alternative study into heat pumps within the dairy sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Saving</td>
<td></td>
</tr>
<tr>
<td>Payback</td>
<td></td>
</tr>
</tbody>
</table>

### Lifetime Savings

| Carbon Cost                           |                                                                                                                                       |
|---------------------------------------|                                                                                                                                       |
| Technology Life (persistence)         |                                                                                                                                       |
| Lifetime Carbon Cost                  |                                                                                                                                       |
A3.8 Real time cleaning verification

What is the technology?
Real time cleaning verification is a concept where a CIP system can be finely tuned so the amount of cleaning necessary is not exceeded. This is accomplished through a thorough understanding of what the term ‘clean’ encompasses for each site and then monitoring the contents of the cleaning fluid until it matches with the previously defined criteria.

Where is the technology currently used?
This concept is currently a research project at Birmingham University in collaboration with worldwide manufacturers.

What is the advantage over current practice?
At present CIP systems are set to run for timed amounts or volumes, or react to the conductivity of the flow. None of these systems uses a closed loop control that actually reacts to the amount of material that has been removed during the cleaning process or how much remains.

Are there any limitations to the product?
Designing a system that can guarantee the internal composition of a pipe system is virtually impossible and so with a finely tuned system comes an element of risk that some areas that are not measured would be still unclean after the cleaning process. This would need further detailed trials in a variety of environments to ascertain limitations and appropriate fail safes to be developed.

What is the development?
University collaborative research project.

Barriers to overcome?
If the results from the project are a success then this technology can be trialled at a volunteer site and compared against an established CIP system. The biggest barrier to overcome will be to prove robust, consistent, failsafe performance.
Who are the technology providers?

The University of Birmingham: they are working on a project to define what ‘clean’ is in the food and drink processing industry. They have been working with Cadbury and others on an EU-funded project called ZEAL and have managed to improve their CIP systems to great effect.

They are currently looking for future partners to take on the next ZEAL 2 and would be keen to work with a dairy industry partner to understand their CIP system and optimise it at the same time.

Business case

The predicted values are: reduction in cleaning time up to 70% and in water consumption up to 40% (depending on factory and process line considered). - Birmingham University quote.

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity</td>
<td></td>
</tr>
<tr>
<td>New process intensity</td>
<td></td>
</tr>
<tr>
<td>Carbon intensity saved</td>
<td></td>
</tr>
<tr>
<td>Sector applicability</td>
<td></td>
</tr>
<tr>
<td>Sector carbon dioxide saving (absolute)</td>
<td></td>
</tr>
<tr>
<td>Sector % carbon dioxide saving</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1.39</th>
<th>3.46</th>
<th>kgCO₂/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.39</td>
<td>0.00</td>
<td>1.73</td>
<td>kgCO₂/m³</td>
</tr>
<tr>
<td>0.695</td>
<td>9</td>
<td>23</td>
<td>ktCO₂ per annum</td>
</tr>
<tr>
<td>1.1</td>
<td>1.73</td>
<td>2.7</td>
<td>%</td>
</tr>
</tbody>
</table>

This is 50% of recorded energy from initial results of 70% water reduction and up to 40% on time of CIP in project ZEAL.
A3.9 Direct drive separation

What is the technology?
This is a new range of separators that run on a gearless direct drive system and offer a 30% reduction in energy consumption from previous designs.

Where is the technology currently used?
The technology has not officially been released but geared centrifugal separators are widely used in the dairy industry and the brewery industry.

What is the advantage over current practice?
The gearless system cuts down on transmission losses and makes the whole system more efficient.

Are there any limitations?
None in comparison to previous separators.

What is the development stage?
A commercial product that is about to be released into the market

Barriers to overcome
Cost of replacing geared separators not yet at the end of their useful lives.

Who are the technology providers?
TetraPak, AlfaLaval.
## Business case

### Direct Drive Separation

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity</td>
<td>0.40 - 0.45 kgCO₂/m³</td>
</tr>
<tr>
<td>New process intensity</td>
<td>0.28 - 0.31 kgCO₂/m³</td>
</tr>
<tr>
<td>Carbon intensity saved</td>
<td>0.12 - 0.13 kgCO₂/m³</td>
</tr>
<tr>
<td>Sector applicability</td>
<td>100 %</td>
</tr>
<tr>
<td>Sector carbon dioxide saving (absolute)</td>
<td>1.6 - 1.8 ktCO₂ per annum</td>
</tr>
<tr>
<td>Sector % carbon dioxide saving</td>
<td>0.19 - 0.21 %</td>
</tr>
</tbody>
</table>

### Site Financials

<table>
<thead>
<tr>
<th>Site Capex (350,000 m³/yr site)</th>
<th>No figures released yet</th>
<th>No figures released yet</th>
<th>£k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Saving</td>
<td>N/A</td>
<td>N/A</td>
<td>£k per annum</td>
</tr>
<tr>
<td>Payback</td>
<td>N/A</td>
<td>N/A</td>
<td>Years</td>
</tr>
</tbody>
</table>

### Lifetime Savings

<table>
<thead>
<tr>
<th>Carbon Cost</th>
<th>N/A - N/A £/tCO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Life (persistence)</td>
<td>N/A - N/A Years</td>
</tr>
<tr>
<td>Lifetime Carbon Cost</td>
<td>N/A - N/A £/tCO₂</td>
</tr>
</tbody>
</table>
A3.10 Partial homogenisation

What is the technology?
The fat content that modern homogenisers can take has increased to 18% meaning that the flow through the homogeniser can be decreased accordingly. Only the fat-enriched fraction from the separator is homogenised, then blended with the fat-free fraction to the desired fat content.

Where is the technology currently used?
The dairy industry.

What is the advantage over current practice?
Energy savings from not having to put the full milk flow through the homogeniser. Even though it takes more energy to homogenise the fat-enriched fraction, this is more than offset by the savings in only homogenising a partial flow.

Are there any limitations?
New pipework may have to be fitted in cases where no previous partial homogenisation was carried out.

What is the development stage?
A commercial product.

Barriers to overcome
Cost of replacing homogenisers and a new bypass pipework if not currently installed.

Who are the technology providers?
TetraPak
## Business case

### Partial Homogenisation

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity</td>
<td>- 2.15 kgCO₂/m³</td>
</tr>
<tr>
<td>New process intensity</td>
<td>- 0.48 kgCO₂/m³</td>
</tr>
<tr>
<td>Carbon intensity saved</td>
<td>- 1.67 kgCO₂/m³</td>
</tr>
<tr>
<td>Sector applicability</td>
<td>25 %</td>
</tr>
<tr>
<td>Sector carbon dioxide saving</td>
<td>5.49 ktCO₂ per annum</td>
</tr>
<tr>
<td>Sector % carbon dioxide saving</td>
<td>0.64 %</td>
</tr>
</tbody>
</table>

**Notes**
- Best already runs at 10% fat and new partial homogenisation is at 18% fat. Worst case runs at 4%.
- 3/10 sites responding from the check list saying this was possible (-17.88 % for skim milk as a national product)

### Site Financials

| Site Capex (350,000 m³/yr site)   | 150 £k                                                                  |
| Cost Saving                       | - 76 £k per annum                                                       |
| Payback                           | - 2.0 years                                                             |

### Lifetime Savings

| Carbon Cost                       | - 10.4 £/tCO₂                                                           |
| Technology Life (persistence)     | 15 years                                                               |
| Lifetime Carbon Cost              | - 0.7 £/tCO₂                                                           |
A3.11 Increasing pasteuriser efficiency

What is the technology?
Through adding more plates to the pasteuriser heat exchangers or enlarging its size the efficiency of the pasteuriser can be increased from around 90% to up to 94%.

Where is the technology currently used?
The food and drink industry.

What is the advantage over current practice?
The amount of energy needed to pasteurise the milk will decrease as the regeneration rate increases.

Are there any limitations?
The maximum regeneration rate that this can take a pasteuriser to is 94%. Above this a whole new pasteuriser will have to be commissioned and built with a very large heat exchanger.

What is the development stage?
A commercial product.

Barriers to overcome
Cost of downtime associated with upgrading pasteurisers

Who are the technology providers?
TetraPak, Alfa Laval
### Business case

#### Increasing Pasteuriser efficiency

<table>
<thead>
<tr>
<th>Carbon Emissions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original process intensity</td>
<td>3.13 kgCO₂/m³</td>
</tr>
<tr>
<td>New process intensity</td>
<td>1.878 kgCO₂/m³</td>
</tr>
<tr>
<td>Carbon intensity saved</td>
<td>1.252 kgCO₂/m³</td>
</tr>
<tr>
<td>Sector applicability</td>
<td>100 %</td>
</tr>
<tr>
<td>Sector carbon dioxide saving (absolute)</td>
<td>17 ktCO₂ per annum</td>
</tr>
<tr>
<td>Sector % carbon dioxide saving</td>
<td>1.9 %</td>
</tr>
</tbody>
</table>

#### Site Financials

<table>
<thead>
<tr>
<th>Site Capex (350,000 m³/yr site)</th>
<th>150 £k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Saving</td>
<td>101 £k per annum</td>
</tr>
<tr>
<td>Payback</td>
<td>1.5 years</td>
</tr>
</tbody>
</table>

#### Lifetime Savings

| Carbon Cost                      | 3.4 £/tCO₂ |
| Technology Life (persistence)    | 15 years |
| Lifetime Carbon Cost             | 0.2 £/tCO₂ |
A3.12 Ultrasonic cleaning

What is the technology?

Ultrasound has historically been used for to clean difficult to reach areas, or internal surfaces of components that would be difficult to reach. Components are placed in baths of cleaning solutions and then sonotrodes agitate the solution at an ultrasonic frequency with creates cavitation on the surface of the components, dislodging dirt and other contaminants. Cavitation is when the fluid pressure drops below the vapour point of the liquid and a bubble of gas is formed. This bubble then collapses and forces a high pressure jet onto the surface which aids in dislodging material.

The concept of using ultrasonics in the dairy industry is that this technology can be applied to pipework, tanks and solid metal objects, dislodging material from the inner surfaces and reducing the loads on CIP. By attaching ultrasonic actuators to either sections of pipework, solid metal components, or putting inside tanks a low ultrasonic source would stop the build up of material adhering to the inner surfaces.

This is not a substitute for standard CIP but a system that would work in tandem with it, reducing the load of the primary method.

Where is the technology currently used?

Ultrasounds are used in a number of industries (described in the ‘Ultrasonic Homogenising’ opportunity description). The use for ultrasonic transducers to be attached to pipes and metal work for internal cleaning is still a relatively new concept most work has been carried out at the experimentation level only. Attaching actuators to tube in shell heat exchangers has been shown to reduce the fouling within the chemical industry but has not yet been tested in the food and drinks sector within the UK.

An alternative approach is using tube actuators that resonate inside tanks and silos and reduce the fouling build up on the walls, further reducing the CIP loading.

What is the advantage over current practice?

Currently the only way in which pipe work and heat exchangers are cleaned in the dairy industry is through CIP. This involves pumping large amounts of hot caustic and acid solutions around the system to break up and dislodge any material that has adhered to the inner surfaces. The demand of these CIP runs is determined through the most difficult areas to clean, which usually have a complex topology where a low flow rate zone would result in a build up of solids. If the amount of solid deposits in these ‘problem spots’ could be reduced then the amount of water and energy used for CIP could be reduced.
There is also a potential that ultrasonics could be used during production to reduce the rate of fouling and therefore reduce the required frequency of CIP.

Ultrasonic cavitation not only dislodges material from solid surfaces but also kills bacteria and other microbes that are present on these surfaces, through the shock wave that is caused as the bubble collapses (there is no damage to solid surfaces).

Are there any limitations?
The ultrasonic transducers that clamp onto the outside of pipework and heat exchangers work best when the subject they are connected to is one solid body with minimal internal damping. Plate pack heat exchangers would not work well as they contain numerous rubber gaskets between the metallic plates that would damp out the ultrasonic vibration. The ideal heat exchangers would be the shell and tube type. However reduced heat transfer rates would be sacrificed for lower cleaning energy and water use. There are several other disadvantages from using a shell and tube exchanger that would only make this a possibility if the saving from CIP were deemed sufficient. The size of the exchanger would have to increase as would the space around it due the way that they are opened and extended to double their length. There would also be issues around the classification of shell and tube exchangers as pressure vessels which may lead to increased regulatory problems under the pressure system regulations.

If this system was used in conjunction with UV pasteurisation then the UV tubes could be cleaned using this system as they are comprised of solid state materials.

What is the development stage?
The technology is fully developed and available as a commercial product, but as of yet is new to the dairy industry and therefore new to the specific contaminants that need to be dislodged. This type of technology would involve bespoke design for each plant and so individual analysis of each pipe system would be necessary.

For cleaning tanks new technology has just become available in the shape of long round bars that resonate in all directions. These would be placed inside tanks and would keep the inner surfaces clean and bacteria free with occasional pulses of ultrasound. This is a new commercial product.

Barriers to overcome
Experimentation would have to be done to determine the transducers needed to act as an effective anti fouling method. The sector would have to change their primary heat exchangers to a solid state variety. If this was not practical then the technology would be limited to pipework and other solid body sections of the dairy system.

Trials would then have to take place in which the amount of liquid and energy (heat) used would be reduced in parallel with introducing a clamp on ultrasonic system and determining if the finished clean was similar enough to pass standards.
Who are the technology providers?

MPI Interconsulting: Offers products, R&D services and consultancy in high power ultrasonics, a range of top quality ultrasonic cleaning and sonochemistry equipment and special equipment development for new applications.

Bio Sonics: A new company that specialises in ultrasonic components for the cleaning of tanks and other components.

Business case
(Only for transducers for attaching to heat exchangers)

CAPEX
Equipment: €15,000 per heat exchanger
Installation (10% estimates): €1,500

OPEX per year
40W: £25 per heat exchanger per year

The savings for cleaning certain areas alone are not fully understood and so further research needs to be done when the products are more commercially available and have been proved in other industries.
A3.13 Microwave pasteurisation

What is the technology?

Microwave radiation has been used for heating food and drinks since 1945 and now the small scale household products that most people have in their homes can be scaled up to production lines where large amounts of product can be heated volumetrically on a continuous flow basis while being pumped through a pipe.

Where is the technology currently used?

Industrial microwaves are used through industry and can be found in most places where volumetric heating is needed. Microwaves can heat, dry, cure, cook, pasteurise and sterilise products.

What is the advantage over current practice?

Using a microwave system for most of the heating demands in a dairy removes the need for a large boiler system and the associated infrastructure to get the steam to specific areas around the site. The components of a microwave system are relatively simple and the megatron source can be easy changed if it wears out.

Are there any limitations?

Microwave pasteurisation still works on the principle of heating the milk to the current required temperature, holding it and then cooling the milk back down. This is an energy intensive process and as the microwave uses grid electricity the primary energy demand and carbon emissions will be more than that of the current steam system method of heating.

The effectiveness of a microwave system to evenly heat an entire volume of liquid is determined by the liquid's absorptivity. The high water content in milk would mean that only the outside layer of milk would be heated. Turbulators would have to be incorporated into the system to ensure that all of the fluid received enough microwave dosing to heat the milk sufficiently.

What is the development stage?

The technology is fully developed and available as a commercial product but is new to the dairy industry.

Barriers to overcome

Microwave pasteurisation is currently less economic and environmentally sound than steam based pasteurisation. If the carbon associated with electricity could be reduced then this system could become more viable.
Who are the technology providers?
IMS Industrial Microwave Systems

Business case
This technology runs using more energy and creating more carbon that the current system and so no business case has been included.

Savings (negative)
Cost: £127,000
Carbon: £995/tCO₂
Pay back: N/A