Energy Audit Summary Report
CIT
Audit no. *58* – IRL02
Food Industry

July 2012

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AUDIT no. 58 – IRL02

1. Data of the auditor

1.1. Contact data of the auditor

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Chemical engineer and environmental consultant. 1st and 2nd visits to site, half-day duration each: Summer 2011; later visit onsite autumn 2011. Follow up with company via phone and e-mail on various occasions.

2. Introduction

2.1. Objectives

The company wishes to investigate options to reduce energy costs. In particular, there is a hot water waste stream, which the owner wished to investigate for potential reuse of the water and/or recovery of the heat.

3. Status Quo: processes, distribution, energy supply

3.1. General info on company

Seafood processor: cooking, vacuum packing, and pasteurising of shellfish and fish, primarily crab followed by lobster and mussels (just under 500 tpa). Peak season is August to December.

3.2. Flow sheet for the site

Flowsheet for the thermally relevant processes at the site is shown overleaf.

All product is cooked and sterilised. However, product received during the peak season is cooked and then either sterilised or frozen. Frozen cooked product is then thawed and sterilised later on during the off-peak season.

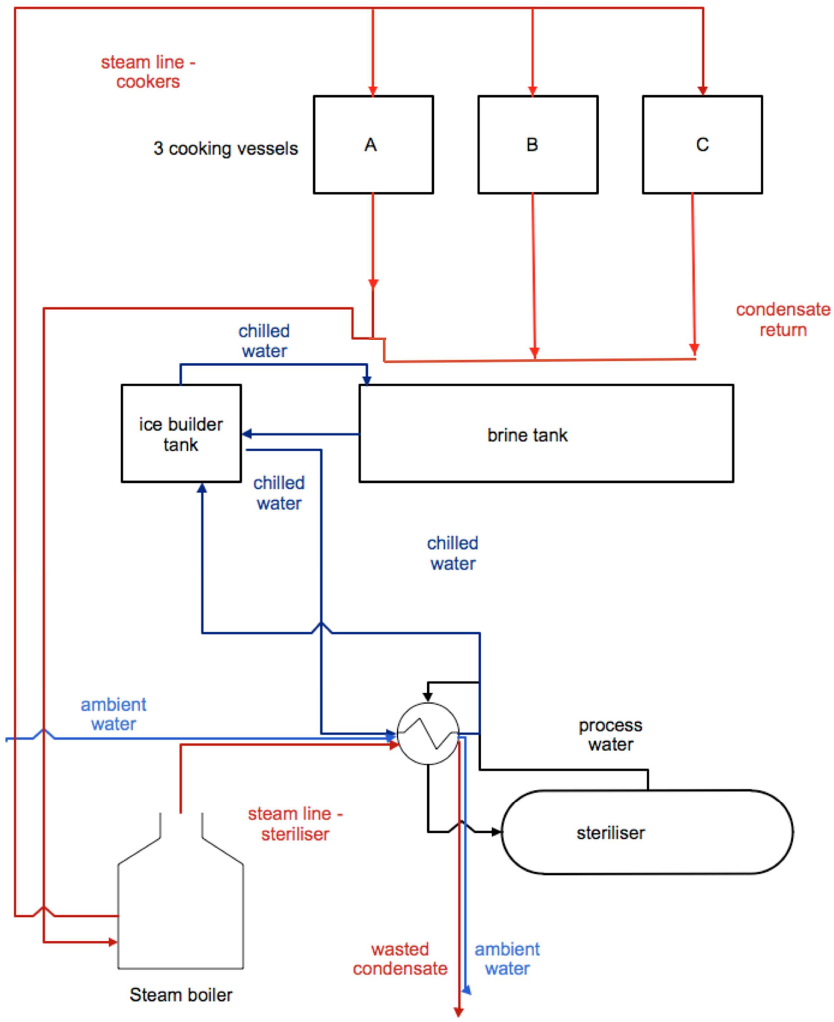


Fig: Flowsheet for the thermally relevant processes

Main energy consuming energy processes and buildings

The main energy consuming processes at the site:

- Pasteurisation retort (Steriflow).
- 3 shellfish cooking vessels.
- Ice builder tank for chilled water for cooling pasteuriser and a chilled brine solution for cooling cooked product.
- Refrigeration for storage of raw material and finished product.

There is also the following minor use:

- Hot water for use in cleaning equipment and in hand wash sinks in the production area and changing rooms - electrically heated in an immersion tank.

Shellfish Cooking Process

The shellfish cooking process takes place in 3 individual 0.69 m^3 vessels. Cooking water is prepared the evening before using ambient water. The following morning this is heated using steam, which is passed through the vessel jacket. The cooking liquor is kept and reused (stock) for up to 2 days – 1 day has been assumed on average. The assumed schedule based on information from the site is shown in Appendix 1.

The cooked product is removed from the vessel and chilled in the brine cooling tank, before being packaged and sterilised or stored.

Pasteurisation Process

The pasteurisation or sterilisation retort contains 5 baskets of vacuum packed product. The retort is heated using steam, which passes through an external heat exchanger. On the process side, the retort contains 1400 litres of process water. A certain portion of this water in the base of the retort can be retained for a number of batches.

As far as can be ascertained, the condensate is not returned to the boiler from the steriliser. Currently, this is discharged to 2 x 600 litre fish boxes located outside the plant. This was measured as 62 ^{o}C a short time after discharge, but it can be higher in temperature according to owner. It is sometimes used for washing fish boxes and vehicles, but in the main, goes to waste (both energy and water).

Cooling in the pasteuriser is in two phases – first ambient cooling water and then chilled water. The ambient cooling water is once through, and also goes to drain, while the chilled water is in a closed loop.

3.3. Description of the existing system

Energy Supply

Steam for the cooking and sterilisation processes are supplied by a 1450 kW steam boiler burning diesel (gas oil).

Cooling is provided by both ambient water and an ice builder tank, which generates chilled water.

Chillers for product & raw material storage rooms are serviced via a series of individual refrigeration circuits. These are not considered any further, with focus on process side cooling only.

Distribution system

There is one steam header supplying the two steam using processes at the site. The heat is transferred to the product cooking vessels via the outer steam jacket, while the heat is transferred to the steriliser or pasteuriser via a shell and tube heat exchanger. Condensate is returned from the crab cookers. However, as far as can be ascertained from the owner, and based on evidence observed, condensate is not returned from the steriliser.

The chilled water is used for cooling in the steriliser and it is also used to chill a brine tank, which is used for chilling both brine solution and cooked product. Containers of brine are submerged in this brine tank and cooled. Cooked product is then placed in the brine solution for cooling.

Media and temperatures

Steam is distributed at 6 bar(a), which corresponds to a temperature of 159 ^{o}C.

Chilled water supply is stated to be at approx. 1 ^{o}C, based on information from the owner. A return temperature of 3.5 ^{o}C is assumed based on typical temperatures in the tank noted by the owner at the end of the day.

Ambient water, which is sourced from a local group water scheme from a groundwater supply, is assumed to be 10 ^{o}C on average.

Energy Consumption – Present State

Annual data	**Present state**	
	MWh	€[1]
Primary energy consumption (PEC)*	1350	-
Primary energy consumption for thermal use (PET)*	1026	-
Final energy consumption (FEC) - diesel	271 (26,600 l)	€29,600
Final energy consumption (FEC) - electricity	481	€58,000
Final energy demand thermal (FET) - diesel	271	€29,600
Final energy demand thermal (FET) - electricity	337	€38,700
	MWh	
Useful supply heat (USH) – steam boiler	230	
Useful supply heat (USH) – immersion heater	8	
Useful supply cooling (USC) – chilled water tank	85	
Useful supply cooling (USC) – mains water	47	
Process heat demand (UPH) – total	170	
Process cooling demand (UPC) – total	90	

*NB: for electricity this includes energy consumed to produce the electricity at the point of generation.

[1] Based on diesel costs of €1.11 per litre (€0.109 per kWh) and average electricity costs of €0.115 per kWh (based on bills for the site).

The following figure shows the annual energy consumed by the different items of heating and cooling equipment; whether this is supplied by electricity, diesel or cooling water; and the associated annual cost.

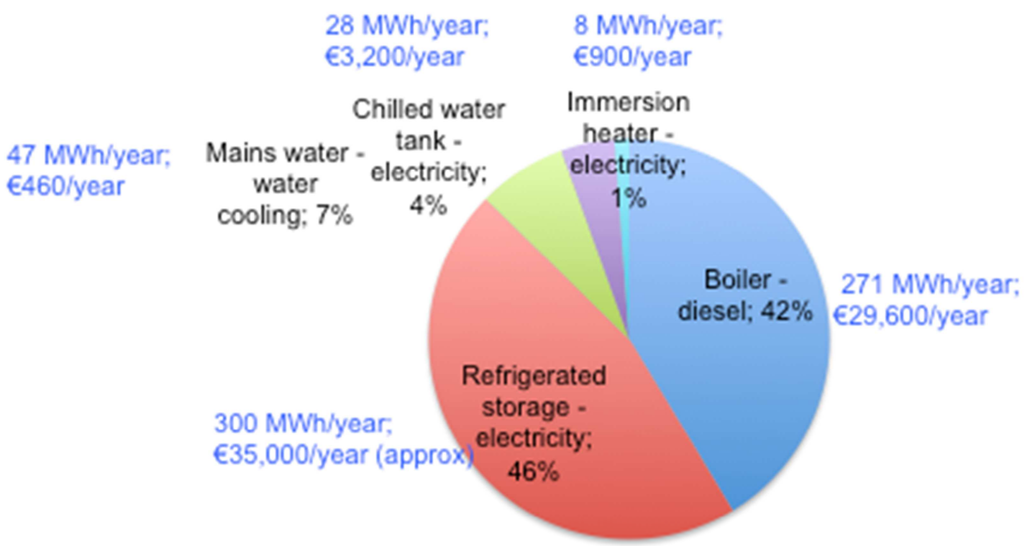
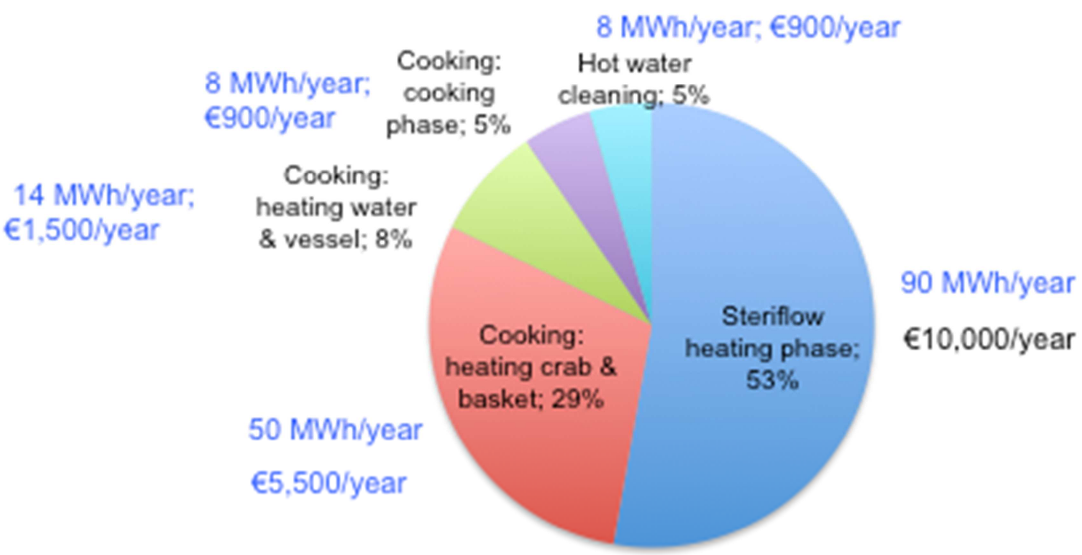


Fig: Final energy demand thermal (FET) – by equipment

The following figure shows the annual distribution of the heat demand and cost according to the different steps of the two main processes – sterilising and cooking.

Fig: Useful heat demand (UPH) – by process

The following figure shows the annual distribution of the cooling demand according



to the different steps of the two main processes – sterilising and cooking. The cooling demand for storage of product and raw material has been excluded.

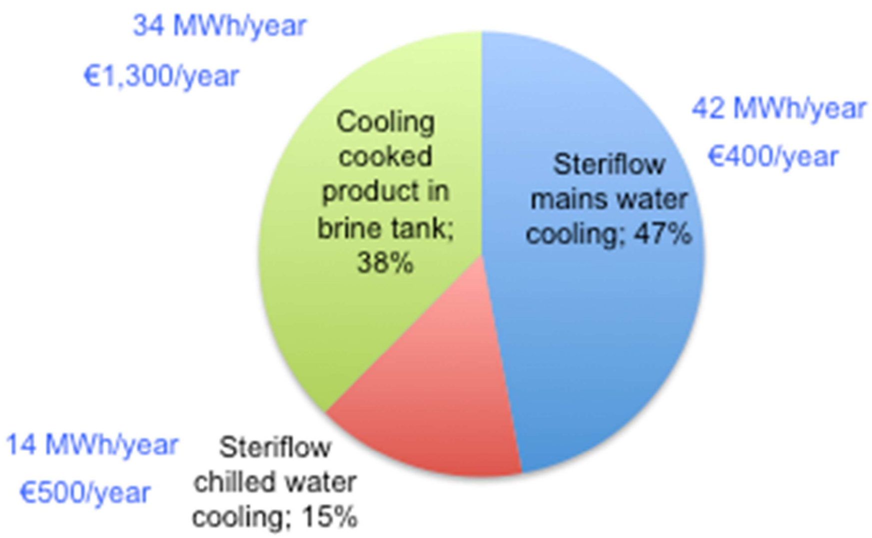


Fig: Useful cooling demand (UPC) – by process

3.4. Assumptions made and measurements performed

3.4.1 Assumptions by introduced by the auditor

A list of assumptions made by the auditor is provided in Appendix 2.

3.4.2 Measurements performed

The following measurements were performed by or on behalf of the auditor:

- Temperatures and approximate volumes were quantified for the rejected condensate.
- Water usage was monitored via an on-line water meter.
- Electrical energy usage by immersion tank over a 2 month period (used to quantify hot water used).
- Temperature of water from immersion tank was measured.

4. Comparative study of Proposed Aternatives

The company is interested in any possibilities for using the waste heat contained in the discharged steriliser condensate, as well as any opportunities for optimising the existing processes at the site.

The following options have been considered:

Option No.	Name	Potential Savings per year	Relevant data of likely equipment needed
1)	Return condensate from Steriflow to boiler	8 to 13 MWh €900 and €1,400	Return piping. Larger 'hot well' storage tank for feed to boiler; 1 m^3
2)	Reuse of Steriflow cooling water (heat and energy) as Steriflow process water	8 to 15 MWh €900 and €1,800	Storage tank of approx 5 m^3 (to be refined based on cooling flows) and piping.
3)	Ambient water cooling of cooked product prior to chilled brine tank	Monetary savings of approx. €400 per annum	Tank of ambient water for plunging product as an interim cooling step (~ 700 litres – similar to cooking vessel size)
4)	Reduce immersion tank temperature	1.3 MWh €150	Thermostat.
5)	Extend steriflow mains water cooling	€225	Re-programming steriflow only.
6)	Flue gas heat recovery	14 MWh and €1500	Flue gas heat exchanger and associated piping.
7)	Recovery of heat from the cooker water	3.5 MWh and €400	Heat exchanger, pump, and hot water storage tank.

4.1 Steriflow condensate reuse

At present, condensate is returned to the boiler from the 3 crab cooking vessels (~30% of heat load), but is not returned from the Steriflow (~70% of heat load). The company should return condensate from the Steriflow to the boiler feed tank. Return piping would be needed (~ 5 – 10 metres) and some storage in addition to the existing 'hot well' storage tank (existing volume < 400 litres) is also likely needed for the returning condensate, as existing tank is likely too small on its own to cope with the volume involved – typically 500 litres of condensate would be returning from the Steriflow per batch. There are potential savings of 8 to 13 MWh, corresponding to estimated fuel savings of between €900 and €1,400 per annum. (This is assuming a return condensate temperature of 80 °C; the lower estimate is peak season use only, the upper estimate is all year round, assuming all recovered condensate can be utilised).

4.2 Steriflow cooling water reuse

At present in the Steriflow process, mains water (assumed to be at an average temperature of 10 ^{o}C) is used on a once through basis to cool the Steriflow via a heat exchanger. Product is cooled from 85 ^{o}C to approx 50 ^{o}C. This cooling water is wasted to drain. During the peak season the product is usually taken out at this stage to allow for the next batch, while in the off-peak season chilled water cooling can be used to bring the product from 50 ^{o}C to approx 15 ^{o}C.

It is proposed that instead of being wasted to drain, cooling water is collected and stored and reused as process water for other uses. This could include as process water within the sterilisation retort as well as hot water for cleaning. This will save on water as well as energy. This water is only water which has passed through the utility side of the Steriflow heat exchanger. The only other fluids to pass through this utility side are steam and chilled water. Thus, it should be suitable for reuse.

At the moment it is assumed that the Steriflow cooling step with mains water takes 1 hour to complete and that there is a cooling water flowrate of 4 m^3/hour (based on observations of water meter readings; it may be lower than this). Based on this and the heat load removed, the average temperature of the cooling water will be 40 ^{o}C. Some more work is needed to work out the exact flowrates of cooling water and the temperatures reached.

Split recovery of cooling water would allow recovery of cooling water at separate higher and lower temperatures. For example, recovering a portion of the cooling water at a higher average temperature of 70 ^{o}C would increase the amount of usable heat that could be recovered.

The following table shows the availability of waste heat in the Steriflow cooling water as well as potential sinks for use of this waste heat.

Waste Heat available in Steriflow cooling water					
	m^3/batch	Batches per year	m^3/year	Heat content (MWh/year)	Cost
Steriflow cooling water	4	306	1,200	42	€4,600 (fuel) €400 (water)

Potential applications for Steriflow cooling water							
	m^3/ batch	Batches per year	m^3/ year	Cooling water recovered at 40 °C		Cooling water recovered at 70 °C	
				Heat content (MWh/yr)	Savings	Heat content (MWh/yr)	Savings
Steriliser process water	1.4	103*	144	5	€550 (fuel) €50 (water)	10	€1,100 (fuel) €50 (water)
Hot water cleaning	-	-	77	2.7	€300 (fuel) €25 (water)	5.3	€600 (fuel) €25 (water)
Total potential savings				**8**	**€900**	**15**	**€1,800**

* There are approx. 103 batches which occur during the peak period as "subsequent" batches on the same day, i.e. after a Steriflow batch has occurred earlier in the day.

In terms of utilisation of waste heat in the cooling water, this will really only occur during the peak season, where there is more than 1 Steriflow process per day. Thus, the above table only counts reuse in "subsequent" Steriflow batches on peak days of operation.

Split recovery of cooling water at separate higher and lower temperatures would also allow re-use of the cooler portion of the water for ambient applications like crab drowning, crab debyssing, and general cleaning with water (potential for a further 1000 m^3/year to be used; crab drowning uses approx 300 m^3/year, crab debyssing uses approx 150 m^3/year water; general cleaning with water is unquantified, but the remaining available cooling water is estimated to be of the order of 2 m^3/day). Net water savings (subtracting additional water use specified in other recommendations) of 600 m^3/year and €200 savings could be possible if cooling water is collected for reuse.

4.3 Introduction of an Ambient Cooling Step in Cooked Product Cooling

Introduction of an ambient cooling step (e.g. using ambient water) for the cooked crab cooling process could be considered, as the use of mains water for cooling is cheaper per unit of heat removed than the use of chilled water. At present, cooked product is removed from the cooking vessels and brought to the brine tank for cooling. Its estimated the product is at an average temperature of approx. 90 °C when entering the cooling tank, with the brine itself at an average temperature of 5.5 °C. There is scope for an intermediate cooling step of plunging in ambient mains water (or brine). While the cooling load remains the same, this cooling is performed by the ambient water instead of the chilled brine tank. This will help reduce the load on the chilled water tank, albeit there is an associated increase in water use. It is estimated that 14 MWh of cooling load could be transferred from the ice tank to ambient water, saving approx €500 per annum in electricity, while only costing an additional €100 – €130 in water (an extra 300 - 400 m^3 per annum, but additional savings outlined elsewhere in water can compensate for this increase). This ambient cooling water should be possible to reuse during the day, and be disposed of at the end of the day. During the peak it is likely it would be disposed of several times during the day.

Exact time and temperature achieved would have to be experimented with (savings above are assuming product gets down to an average of 60 °C). Considerations with regard to food safety, i.e. the length of time for cooling, would have to be considered as well as effect on product quality from this extra step.

4.4 Evaluation of optimum temperature for switching from ambient water to chilled water in pasteurisation cooling

At present, ambient water is used to cool the Steriflow down as far as 50 °C, during the off-peak season chilled water is then used to further cool the product. The product is usually removed at between 10 and 20 °C. It would be possible to use ambient water to cool down further than 50 °C.

It should also be noted that at peak time the product is sometimes removed at 50 °C (and presumably then put in the chill room) to free up the Steriflow for the next batch.

It is proposed to continue with the use of ambient cooling water beyond 50 °C before switching to chilled cooling water, when chilled cooling water is used (off-season). It does not save energy but utilises a cheaper form of cooling.

If ambient water is used for cooling down to 30 °C instead of chilled water in the off-season, it will save 2.6 MWh and €300 in electricity and use an additional 230 m^3 of water, costing €75, giving a net saving of €225.

4.5 Reduce immersion tank temperature

At present, there is no control on the electrical immersion tank temperature. The outlet on this tank was measured to be approx 70 °C. Installing a thermostat should save 1.3 MWh and €150 per annum, if set to 55 °C.

4.6 Flue gas heat recovery

At present there is no heat recovery associated with the flue gases from the boiler. Heat recovery could be considered for heating boiler feed water or to produce hot process water (e.g. for use as hot Steriflow process water and water for cleaning).

Heat losses in flue gases are estimated to be of the order of 25 MWh/year or €2,500. Thus, savings through heat recovery will be a percentage of this (approx. 14 MWh and €1500 if flue gases are cooled from an estimated 200 ^{o}C to 90 ^{o}C). However, recent investment cost at another site with a boiler 1.7 times the size of this site's boiler for a heat exchanger, new flue, storage tank and associated piping and controls was aprox. €30,000. Thus, even scaling for the smaller size, with potential savings of only €2,000 per year, payback is unlikely to be attractive.

However, there are standard flue gas heat recovery units available from the boiler manufacturer Certuss which could be priced and compared with potential savings.

4.7 Recovery of heat from the shellfish cooker water

A plate heat exchanger could be used to recover heat from the cooking liquor at the end of the production day.

There is 21 MWh or €2,300 of usable heat contained in the liquor per annum (if liquor is cooled to 30 ^{o}C). However, at this time of the day, the only demand for heat is in relation to hot water cleaning. The associated heat demand, which could be more than amply supplied by heat exchange with the cooking liquor, is only 3.5 MWh per year. Thus annual savings would be only of the order €400 per annum, making payback on any heat exchanger not worthwhile considering.

5 Selected alternative(s) and conclusions

5.1 Selected alternatives

The following table summarises the potential savings from implementation of the following selected options:

- Return condensate from Steriflow to boiler
- Reuse of Steriflow cooling water (heat and energy) as Steriflow process water
- Ambient water cooling of cooked product prior to chilled brine tank
- Reduce immersion tank temperature
- Extend steriflow mains water cooling.

'Flue gas heat recovery' and 'recovery of heat from the cooker water' have not been included since payback is unlikely to be favourable.

The following table summaries potential savings.

		Present state	**Alternative if options implemented**	**Saving**
Total primary energy consumption (1)				
- Total	[MWh]	1350	1303	47
- Diesel	[MWh]	271	243	28
- Electricity	[MWh]	1079	1060	19
CO_2 emissions	[t/a]	611	595	17
Final energy consumption				
- Total	[MWh]	752	716	36 (5%)
- Diesel	[MWh]	271		28 (10%)
- Electricity	[MWh]	481	473	8.4 (2%)
Annual energy system cost (2)	[€]	€87,600	€83,600	€4,000

(1) Including primary energy consumption for non-thermal uses

(2) Energy cost (fuel and electricity bills).

The return of condensate from the Steriflow should be carried out and is likely to be of a reasonable payback.

The reuse of cooling water could also be a feasible option, checking of the cooling water flowrate and temperature of the exiting water during cooling will more accurately determine the potential savings. Water quality checks would also ensure it can be reused.

5.2 Assumptions

A list of assumptions is provided in Appendix 2.

5.3 Constraints under which the results can be considered valid

The results are considered valid for the following:

- The production schedule detailed in Appendix 1.
- The process assumptions detailed in Appendix 2.
- Boiler diesel bills provided for August to December 2010 and an estimate for off-peak boiler diesel usage of 500 litres per week.

5.4 Areas where a more detailed analysis would be necessary

The following would improve the estimates:

- More accurate data on batch process times for steriliser in terms of time for heating up, time for ambient cooling and time for chilled water cooling – see assumed values in Appendix 1.
- Quantification of the ambient cooling water flowrate to the steriliser, and corresponding inlet and outlet temperatures. This would improve the estimate for the amounts of water available for reuse and the possible temperatures at which this cooling water is available.

5.5 Next steps with the company

CIT has been working with the company on some other areas such as water use and so will present the results to the company. Quantification of the ambient cooling water flowrate to the steriliser, and the outlet temperature if accessible, would aid in refining potential savings in relation to cooling water collection and reuse. Appropriate analysis of the cooling water to ensure it can be reused should also be carried out. The company will be directed to contact a number of engineering companies in order to price suggested measures.

Appendix 1 Production Schedule

The following schedules were assumed based on information from the site.

Cooking Process

Season	Months	Cooked batches per week (all shellfish)	Cooked batches in the period
Peak	Aug-Oct	202	2,370
Shoulder	Nov	134	519
	Dec	43	74
Off-peak	Jan-Mar	18	222
	Apr-Jul	4	227
		Total for the year	**3,412**

Sterilisation Process

Season	Months	Steriliser (batches per week)	Sterilised batches in the period
Peak	Aug-Oct	12	156
Shoulder	Nov	12	50
	Dec	3	10
Off-peak	Jan-Mar	3	38
	Apr-Jul	3	52
		Total for the year	**306**

Appendix 2 Assumptions

Cooking Process

- Assumed average temperature of cooked product has dropped from 100 °C to 90 °C before being plunged into cooling brine.
- Ignored evaporation from the cookers as vessel lid is closed at all times apart from removing/adding product.
- Vessels are not insulated. Assumed wall temperature to be 100 °C.

Sterilisation Process

- Information on the exact time for the heating up period has not been obtained. Heating curves for a similar model machine at another factory denoted 10 minutes for heating up time. However, this would have a steam demand greater than that possble with the site's boiler (3.4 t/hour versus max capacity of 2 t/hour). The heating up period was revised as 20 minutes to keep within boiler capacity.
- Ambient cooling – assumed a mains cooling water flowrate of 4 m^3 per hour (may be lower than this based on flowmeter flowrates) and mains water cooling time of 1 hour per batch.
- During the peak (August-November inclusive), it is assumed chilled water cooling is not used, just mains water cooling to 50 °C (based on information from company).
- Steriliser – used manufacturer value of 5% of heat load for losses as the value for maintenance heat losses.

Mains cooling water

- It is assumed that the mains cooling water heats up from 10 °C to an average of 40 °C. If the temperature increase is lower, the volumes of cooling water will be higher and the associated cost of cooling will be higher.