BIM Ireland's Seafood Development Agency

A Study of the Viability of Heat Recovery in the Irish Seafood Processing Industry

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The economic value of each kWh of recovered energy will depend on what type of fuel is used. The installation cost will also be very different depending on the size of the processing plant and the layout of the refrigeration systems. In general, systems with larger refrigeration circuits connected to one shared condenser will be more financially viable than a system with multiple individual refrigeration circuits connected to separate smaller condensers. The reason for this is that each refrigeration circuit needs an auxiliary condenser, and each auxiliary condenser will have a similar amount of parts and labour associated with it. Therefore, the installation cost is influenced by the number of circuits that require intercepting. Since the value of the heat recovery system is based on the amount of recovered energy, while the installation cost is more related to the number of intersected refrigeration circuits, systems with a few larger circuits will generate more value than systems with multiple smaller circuits.

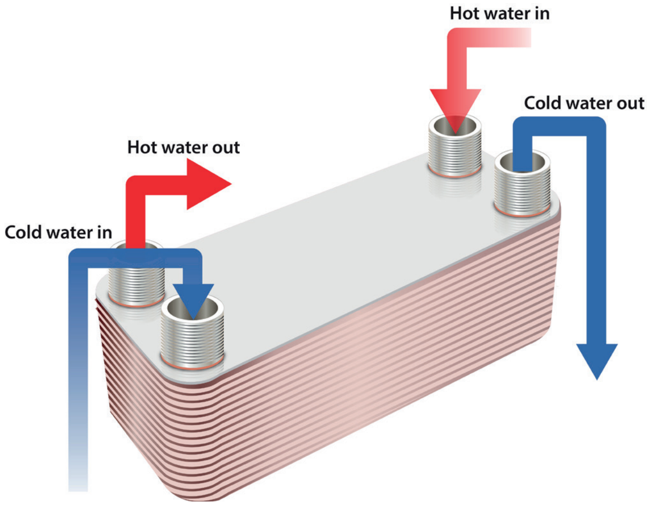
Contents

Executive Summary

As part of the Interreg funded Food Heroes project, BIM engaged Sea Box Energy to identify the possibility of recovering waste heat energy from existing processes in fish processing plants and using it in other applications.

As part of this work, four different fish processing facilities were visited to identify the availability of waste heat in the Irish fishing industry and to determine the feasibility of recovering it. During these visits, it became apparent that the industry's high reliance on refrigeration equipment in their facilities means that most sites generate significant amounts of waste heat. Of the four facilities visited during this work, only one had a waste heat recovery system already installed, though this system recovered only a small amount of the total waste heat energy. Through the observations from the site visits, it is clear that there is significant potential heat recovery in the industry, yet waste heat recovery is still relatively uncommon.

The project's key objective was to look for the best opportunities to retrofit waste heat recovery systems onto existing refrigeration systems. It was determined that the most suitable option would be to install an auxiliary condenser in series with the existing refrigeration systems condensers.



Recovering the heat directly from the refrigeration gas ensures maximum efficiency and leaving the original condensers upstream of the auxiliary condenser means that the system will still be capable of dissipating all heat, regardless of the performance of the new condenser. This configuration would make for a safe and efficient system with minimum interference to existing operations.

The type of auxiliary condenser to be used needs to be determined on a site-by-site basis as it depends on system type, piping system, usage of waste heat energy, and location of refrigeration circuits and buffer vessels.

The most common uses for such recovered energy is space heating and domestic hot water (DHW). It is possible to design an interlinked system that is capable of space heating, DHW generation and heating air for process drying. Such a system could also incorporate the existing heating system from the processing plants to work in tandem with the waste heat recovery system. Such interlinked system configurations are achievable without much complication by using central heating manifolds.

The financial viability of any waste heat recovery system will be very different from site to site.

1. Introduction

Understanding and evaluating the energy performance of manufacturing and refrigeration equipment and assessing other related factors is an essential step in the effective energy management of any food production plant. This report seeks to build on this process and provide information for fish processors on how to conserve and reuse existing energy through heat exchange, which will help toward meeting energy efficiency goals.

This report should be used to help company management and production staff respond to the challenges of rising fuel costs by taking more advantage of the energy already consumed through the recovery of 'free' heat. Through the use of real case studies, examples of the strategies companies could pursue to exploit readily available energy from the existing manufacturing processes with heat recovery technology are shown.

The information will assist companies in better understanding advances in heat recovery technology and become a competitive advantage. The improved competitive advantage is especially beneficial when the recovered energy is used to produce innovative fish products that can earn three to four times more money than selling fish waste. [1]. Using the otherwise wasted energy has many advantages, including:

- Creating a competitive advantage by offering companies new ways to outperform their rivals.
- It can spawn whole new businesses, often from within a company's existing operations.

2. Sources of Information

The data used within this report was gathered through a literature review and site visits to four Irish seafood processors. The literature review aimed to determine best practices for refrigeration heat recovery and energy usage. The site visits were used to gather real-world data on Irish fish processing plants.

While every effort has been made to ensure the information used reflects the situation on the ground, much of the data collected at the various sites were provided by non-technical personnel and may not be completely accurate. However, this report does not intend to provide a detailed energy analysis of each premise but to determine the viability of collecting waste heat energy based on a short site inspection. These inspections were used to gain a reasonable understanding of the quantity of waste energy and its potential availability for recovery.

3. Waste heat recovery

Waste Heat Recovery (WHR) is the process of capturing and reusing thermal energy that would otherwise be lost. This waste energy can come from a wide variety of industrial sources like heating, air conditioning, cooking and refrigeration, and it can, in many businesses, amount to considerable costs. Depending on the business, the recovered energy can be used to reduce the energy consumption of existing processes or to run a new process and increase the company's income. The reduction in energy consumption in existing processes grants two significant benefits: it reduces the business' current running costs; and reduces the CO_2 emissions if the energy comes from a non-renewable energy source.

Waste energy recovery is based on the physics principle that energy is never created or destroyed, only converted from one form into another. Waste energy can be recovered closed-loop (captured and fed back into the same process) or extended loop (captured and directed toward another process). If operating successfully, the recovered heat energy reduces the businesses' overall energy demand.

Not all waste energy emitted from a system is useable, and therefore the amount of useable waste energy that is emitted from a system is called exergy, which is most often in the form of heat. Exergy is always of lower quantity than the energy already within the system. Because of this, heat recovery must be performed efficiently to ensure there is an ample amount of useable energy for its desired purpose. If heat recovery systems were to be put in place in a business, a framework would have to be created in order to identify and categorise the type of waste energy that is being emitted and also a decision support tool would be needed so business/ plant managers could make informed decisions about what technologies to implement.

The main factors to be considered when analysing potential recoverable waste heat sources are as follows:

- Quantity of heat required (kJ)
- Quality of heat required (°C)
- Rate of heat required (kW)
- Time of day heat is required.

Practically speaking, the amount of useable heat recovered (exergy) must be large enough to pay back the investment costs and cover any other operational overheads. The quality and quantity of the waste heat should coincide with the demand for the energy needed

It can be very profitable to recover this thermal energy and use it for other areas of the business. The following options are feasible ideas where recovered heat can be used for:

- The reheating of dehumidified air (air conditioning)
- Heating of hot water
- For the operation of cold storage rooms
- Industrial processes like drying

3.1.Refrigeration waste heat recovery

When recouping waste heat from a chilling process, it not only conserves otherwise wasted fuels to provide needed heat but also, in some cases, it improves the efficiency of the initial cooling processes. The full amount of wasted energy is not entirely recoverable because of transmission losses and inefficiencies in the heat exchangers and other mechanical components.

4. Site Visits

A total of 4 fish processing plants were visited to identify energy recovery opportunities in the sector.

4.1 Processor 1

The primary source of waste heat energy identified was the refrigeration system. The air compressor in the plant also produced some heat, but not enough to be relevant for this project.

Site Summary

5 Refrigeration systems in place for

- 4 blast freezers (<-20°C)
- 1 cold room

4.1.1 Refrigeration System

The refrigeration system is divided into two categories that have very different operating criteria: blast freezers/ cold stores and a cold room. The blast freezers run at a very low (<-20°C) temperature and require more chilling power than the cold room. This results in a higher amount of waste heat energy and a higher refrigeration gas temperature. On the other hand, the cold room, operates at a higher temperature, which means that the waste heat energy is cooler than that of the blast freezers. The blast freezers operate for about 40% of the plant production time while the cold room is always in call mode, making it a more consistent source of energy.

All the refrigeration systems dispose of their waste heat energy through the use of outdoor condensers that emit the heat straight into the atmosphere with practically no heat recovery except for a minor amount of incidental heat gain through pipe insulation losses in the plant room. An air exhaust heat pump indirectly recovers that heat into the domestic hot water system.

There are a total of 5 refrigeration systems at the plant, one for each blast freezer and one for the cold room. We were told that the potential temperature of the refrigeration gas leaving the compressors is 80 °C for the blast freezers and 60 °C for the cold room. Table 1 below shows an overview of the refrigeration system.

Table 1: Refrigeration system at Processsor 1

System	Flow temp to heat dump	Power	On-time	Average Power
Blast Freezer 1	≈80 °C	52.0 kW	≈40 %	20.8 kW
Blast Freezer 2	≈80 °C	52.0 kW	≈40 %	20.8 kW
Blast Freezer 3	≈80 °C	74.5 kW	≈40 %	29.8 kW
Blast Freezer 4	≈80 °C	160.0 kW	≈40 %	64.0 kW
Cold Room	≈60 °C	52.0 kW	100%	52.0 kW

4.1.1.1 Blast Freezers 1 and 2

Blast Freezers 1 and 2 are identical systems, each run a pair of 35 horsepower compressors, equating to an energy load of 52kW per freezer. Each freezer has a separate refrigerant circuit, meaning that each of the two freezers requires one 52kW heat exchanger. When we adjust the compressor power for 40% 'on-time' (see Table 1), each freezer has an adjusted average power of 20.8kW.

4.1.1.2 Blast Freezer 3

Blast Freezer 3 has four x 25 horsepower compressors totalling to 74.5kW. When adjusted for 'on-time' 40% (see Table 1), the total average output is 29.8kW. Each compressor has its own refrigerant circuit, but they are all connected to a shared condenser. Therefore, each compressor requires a separate heat exchanger to recover heat (i.e. 4 heat exchangers are required to recover heat from blast freezer 3).

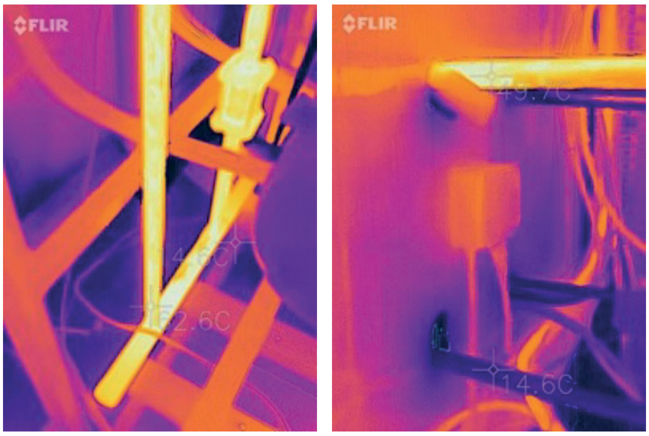
4.1.1.3 Blast Freezer 4

Blast Freezer 4 has a single 160kW compressor with one condenser. The average power for this system is 64 kW (see Table 1). As there is just 1 refrigeration circuit, only 1 heat recovery exchanger is required.

4.1.1.4. Cold Room

The cold room has a 70hp (52kW) compressor with one condenser. As the cold room operates at a higher temperature than the blast freezers, the refrigerant going to the condenser is colder than that of the refrigerant coming from the blast freezers (approximately 60°C) (see figure 1). Unlike the blast freezers, the cold room is always 'ON'; therefore, the average power equals the compressor power.

Figure 1: Pipework to and from the outdoor condenser. Flow is 49.7 °C and return is 14.6 °C.



4.1.2 Heat recovery opportunities

As there are multiple heat sources, there are many heat recovery opportunities. The number of refrigeration circuits requiring heat recovery determines the investment required for the heat recovery system. Therefore, we have to look at the power per circuit, which is the power per heat exchanger. Table 2 below shows the maximum power of each heat exchanger as well as the average power adjusted for on-time.

Table 2: Heat Exchanger information

System	Heat Exchanger	Power	Ontime	Average Power
Blast Freezer 1	BF 1	52.0 kW	40%	20.8 kW
Blast Freezer 2	BF 2	52.0 kW	40%	20.8 kW
Blast Freezer 3	≈80 °C	74.5 kW	≈40 %	29.8 kW
	≈80 °C	160.0 kW	≈40 %	64.0 kW
	≈60 °C	52.0 kW	100%	52.0 kW
	BF 3.1	18.6 kW	40%	7.5 kW
	BF 3.2	18.6 kW	40%	7.5 kW
	BF 3.3	18.6 kW	40%	7.5 kW
	BF 3.4	18.6 kW	40%	7.5 kW
Blast Freezer 4	BF 4	160.0 kW	40%	64.0 kW
Cold Room	CR 1	52.0 kW	100%	52.0 kW

Table 2 identifies that the heat exchanger in the cold room has the highest average output. Therefore, this is the heat exchanger that would provide the highest energy savings and the lowest payback time.

The blast freezers have great potential for waste heat recovery but cannot be relied on for consistent energy because of their irregular usage pattern. They could, however, be instrumental parts of an interlinked system that couples all of the viable heat exchangers together with a common manifold/buffer arrangement. A large buffer can counteract the effect of the intermittent output if the compressors are working without too long periods of downtime between each time they run. The manifold/buffer system could also include conventional heating boiler(s) or electrical power heat sources to overcome any shortfall in recovered waste heat energy availability.

4.2 Processor 2

At Processor 2, the primary source of waste heat energy was again identified to be the refrigeration system. This site already had a waste heat recovery system in place, recovering some of the waste heat from one of the refrigeration circuits.

Site Summary

3 Refrigeration systems in place for:

- 2 freezers (1 system each)
- 1 dual system serving 4 rooms at 6°C and 7 rooms at 0°C

4.2.1 Refrigeration system

The refrigeration system has three separate systems. The first two are independent, serving one freezer each, both maintained at -20°C. Each of these has its own condenser and refrigeration circuit. The third system (see Figure 2) is subdivided into two temperature ranges, one to maintain four separate rooms at 6 °C and another to maintain seven separate rooms at 0 °C. This double arrangement is served by one refrigeration circuit with one outdoor condenser. The actual power of each compressor was not determined, but with the cooling design criteria for each room available Table 3 below was compiled.

Table 3: Refrigeration system at Processor 2

System	Power	Flow temp to heat dump	On-time	Average Power
Freezer 1	BF 1	52.0 kW	40%	20.8 kW
Freezer 2	BF 2	52.0 kW	40%	20.8 kW
Dual System	18.28 kW	≈70 °C	≈100 %	18.28 kW
	18.28 kW	≈70 °C	≈100 %	18.28 kW
	91.16 kW	≈55 °C	≈100 %	91.16 kW
	BF 3.1	18.6 kW	40%	7.5 kW
	BF 3.2	18.6 kW	40%	7.5 kW
	BF 3.3	18.6 kW	40%	7.5 kW
	BF 3.4	18.6 kW	40%	7.5 kW
Blast Freezer 4	BF 4	160.0 kW	40%	64.0 kW
Cold Room	CR 1	52.0 kW	100%	52.0 kW

Figure 2: The compressors for the dual system; the two compressors on the left serve the higher temperature areas while the two on the right cools the colder rooms.

4.2.2 The existing heat recovery system

The dual system has an existing waste heat recovery plate heat exchanger installed (see Figure 3 below). In this system, the plate heat exchanger is the auxiliary condenser and is connected in series with the main condenser. The refrigerant has to pass through the plate heat exchanger before the main condenser can dissipate the excess energy outside. Pipework carries the heat absorbed in the auxiliary condenser (heat exchanger) to a coil inside the domestic hot water cylinder of the facility so that the waste heat energy is being used to heat the domestic hot water, which is used for hand washing.

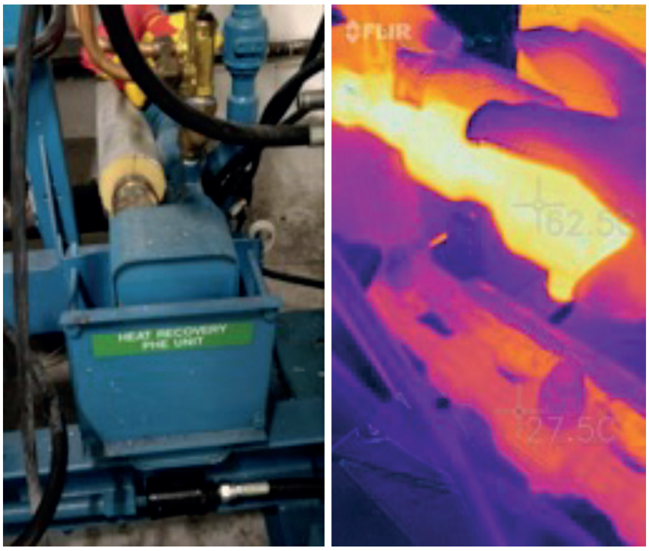
During the site visit, the existing heat recovery system was using all the heat from the dual system – though it was noted that only one out of four compressors was operating at a time. However, based on the pipe going from the auxiliary condenser to the DHW cylinder, the heat recovery system is only capable of taking a third of the maximum power generated by the system – in other words, it was undersized for using all of the available heat but probably sized sufficiently for the DHW needs.

4.2.3 Heat recovery opportunities

As can be seen in Table 3, there are three refrigeration systems with an opportunity for waste heat recovery. The larger dual system already has a heat recovery system installed, but it is unlikely that the current system can take away all the heat generated by the refrigeration process. Therefore further analysis should be done to determine the viability of extracting more waste heat from this system. The two freezer systems have a much lower power rating than the dual system, but they are still viable candidates. If the systems run at 18 kW for large parts of the year, it will amount to significant energy wastage, which could be recovered and utilised instead of being wasted. The economics of this potential capital investment would be determined by the space heating/hot water requirements of the specific site.

Figure 3: Existing heat recovery plate heat exchanger (auxiliary condenser).

- Right: Refrigerant flows from compressors to the plate heat exchanger (62.5°C).
- Left: Refrigerant flows from the plate heat exchanger to the main condenser outside (27.5°C).



4.3 Processor 3

After an inspection of the facilities, it was determined that the foremost opportunity for heat recovery is the refrigeration systems. It was also noted that there are some opportunities to save energy in the boiler plant room, but this is not within the scope of this report.

Site Summary

4 refrigeration systems in place:

- 1 ammonia system (3 compressors)
- 1 R404 system (3 compressors)
- 1 screw compresssor system
- 1 self-contained system

4.3.1 Refrigeration system

This refrigeration system can be divided into four systems: an ammonia system, a R404 system, a screw compressor system and a smaller self-contained system. The screw compressor is rarely used, and the self-contained system is too small and difficult to consider for heat recovery since all the components are mounted on one base with no room to intersect the pipework for heat recovery. Therefore the focus was put on the R404 and ammonia system.

4.3.1.1 Ammonia (NH3) System

The ammonia system consists of three compressors. Compressor 1 provides a cooling power of 80 kW, Compressor 2 is rated at 75 kW and lastly, Compressor 3 is a large backup compressor at 250 kW. They informed us that Compressor 1 runs from 08:00-17:00 on workdays while compressor 2 is always on during workdays. Table 4 below shows the cooling power of each compressor and the average power adjusted for on-time. The average power only applies to days the plant is active. We were informed that most processes were turned off during weekends.

Table 4: Ammonia System Parameters

Unit	Cooling Power	On-time (workdays)	Average power (workdays)
Compressor 1	80 kW	38%	30 kW
Compressor 2	75 kW	100%	75 kW
Compressor 3	250 kW	0%	0 kW

All the compressors for the ammonia system are connected to one large condenser (see Figure 4 below) through joint refrigeration pipework. This pipework means that only one heat exchanger is needed to recover all the waste heat from this system. The average power of this heat exchanger will be 105kW based on the numbers in Table 4, but it would need to be able to handle a peak load of over 250kW.

4.3.1.2 R404 System

The R404 system consists of three compressors, each rated at 25 kW. This system is always on, but only one or two compressors are running at any given time. Therefore, we can assume that the system's average output is 1.5 compressors or 37.5 kW. All three compressors are connected to a single condenser through joint pipework. Again, this means that only one heat exchanger is necessary to recover waste heat. This exchanger should be able to handle a full load of all three compressors, so it has to be rated at 75 kW.

Table 5: R404 System parameters

Unit	Cooling Power	On-time	Average power
Compressor 1	25 kW	50%	12.5 kW
Compressor 2	25 kW	50%	12.5 kW
Compressor 3	25 kW	50%	12.5 kW

4.3.2 Heat recovery opportunities

There are some excellent opportunities for heat recovery at Processor 3. As noted above, both the R404 and ammonia systems require only one heat exchanger each to recover the waste heat. This, combined with the fact that some parts of both systems are always running, at least during workdays, makes them excellent potential heat sources. Another benefit of this set up is that the two refrigeration systems most suitable for heat recovery are located in the same plant room. Both systems can feed into a shared buffer, saving labour and material costs by being in the same plant room. However, the greatest challenge with the systems at Processor 3 is that one of them uses ammonia as the refrigerant. Fewer installers work with ammonia, and it does complicate the job, but it should still be very possible.

Table 6: Heat exchanger information

Heat Exchanger	Power	On-time	Average Power
NH3	> 250 kW	Mixed	105 kW
R404	75 kW	50%	38 kW

Figure 4: Condenser for the ammonia system.

4.4 Processor 4

The primary sources of waste heat energy at processor 4 is the refrigeration systems and flue gases of a cooking machine that prepares breaded fish. Upon closer inspection with a thermal camera, it was determined that the waste heat coming from the cooking machine was not significant enough to study further for potential heat recovery.

Site Summary
11 self-contained systems are serving individual refrigerated areas and rooms.

4.4.1 Refrigeration system

The refrigeration system at processor 4 consists of multiple small self-contained systems serving individual refrigerated areas and rooms. The units are all located outside, and each of them has both the compressor and condenser combined. At the same time, there was also a large freezer, which was the largest waste heat source; due to accessibility issues it was not evaluated. In total, 11 separate refrigeration circuits were identified.

4.4.2 Heat recovery opportunities

There is waste heat being generated at this site but, due to the spread out nature of the refrigeration units, it would be difficult to recover the heat. Because there are many refrigeration circuits, each with relatively small power outputs, it will be costly to install enough heat recovery equipment to recover the heat sufficiently. The type of refrigeration equipment also makes heat recovery difficult because the self-contained systems are very compact, and this makes it difficult to install an auxiliary condenser on them.

The only viable option for heat recovery is the refrigeration circuit for the large freezer. This freezer is a large and reliable energy source since it generates a lot of waste heat energy, and it is always “on”.

5. Waste heat recovery recommendations

There are large quantities of waste heat energy generated in Irish fish processing plants, with the bulk of this waste heat coming from refrigeration equipment. At the same time, separate heating systems are used to heat office spaces, provide hot water for cleaning and in some instances hot water or steam for cooking. Heat exchange is an ideal energy efficiency action that matches wasted heat with the need for heat with the benefit of reduced costs and lower carbon emissions.

The maximum and average waste heat energy output varied greatly between sites visited as well as between the different systems within each site. A common characteristic between all systems is that they are all existing and therefore have sufficient condenser equipment to dissipate the current generated heat. For this reason, the waste heat recovery method where an auxiliary condenser is connected in series with the existing main condenser is recommend (see Figure 6 below). This 'in series' configuration makes it easy to intercept the existing pipework and, since all the refrigerant has to pass through the existing condensers after passing through the heat exchanger (or auxiliary condenser), the system has plenty of capacity to deal with the variable heat loads generated.

In many of the sites, some of the refrigeration systems were turned off for parts of the week and, even when they were on, the compressors would not be running all the time. When a system is "on", it means it monitors the temperature in the refrigerated rooms. The compressors turn on and off as needed to maintain the desired temperature. Due to the intermittent nature of heat supply from such heat sources, it is recommended that recovered waste heat is collected in a buffer storage system. The effect of using a buffer to collect waste heat energy is shown in Figure 7 below.

Figure 7: Illustration of the effects of a buffer vessel. The graph shows how the buffer enables the output to the drying process to stay constant even though the input from the waste heat recovery is absent at times.

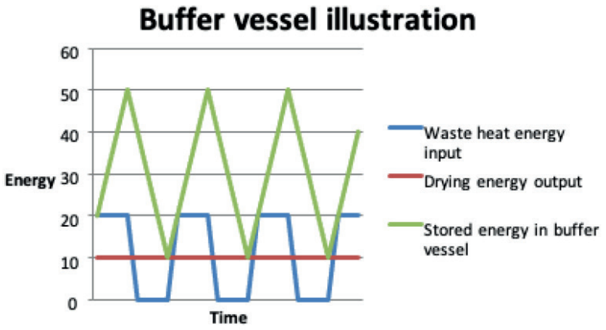
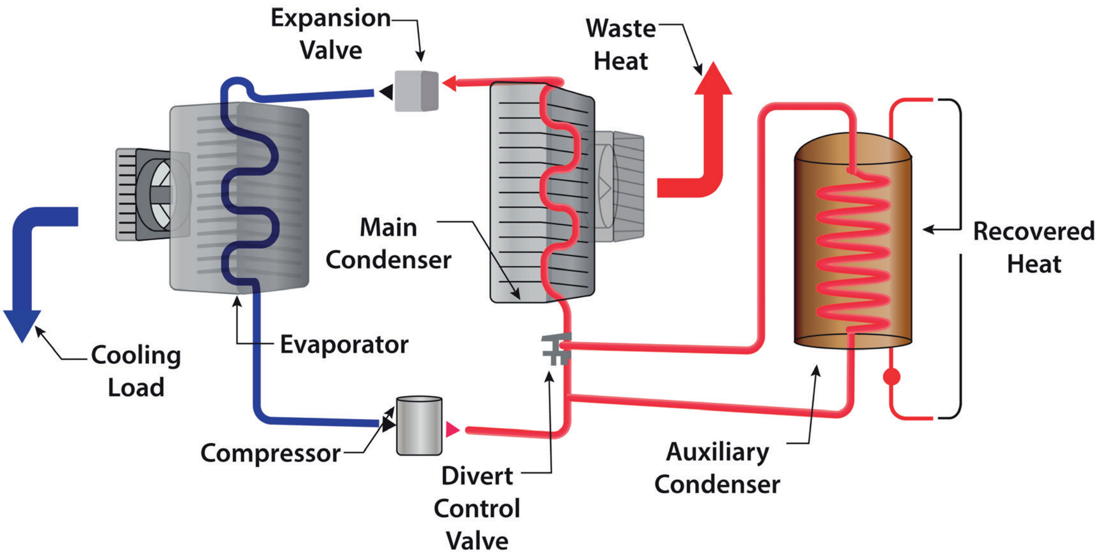


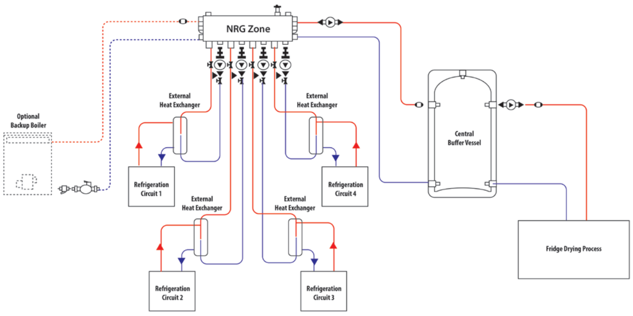
Figure 6: Illustration of waste heat recovered from a refrigeration circuit with the auxiliary condenser in series with the main condenser.



In this example, the input energy from the waste heat recovery system varies between 20 and zero units of energy per unit time. This supply is based on a compressor turning on and off. Meanwhile, the energy output to the drying process is constant at 10 units of energy per unit of time. The green line is the energy content of the buffer and it starts at 20 but fluctuates between 10 and 50. Any time the green line is decreasing is where the input energy is lower than the output energy, without a buffer; these are times when the drying process would not get any energy from the waste heat recovery. With a buffer, there is always available energy.

There are many options for the auxiliary condenser connected in series with the main condenser. The type of heat exchanger chosen depends on the system layout and waste energy usage. If the water in the buffer vessel is to be suitable as potable water, the heat exchangers have to comply with EN1717 (the protection of potable water supplies from pollution caused by back-flow) and EN12897 (Water supply. Specification for indirectly heated unvented (closed) storage water heaters); if not more conventional single-walled heat exchanger can be used.

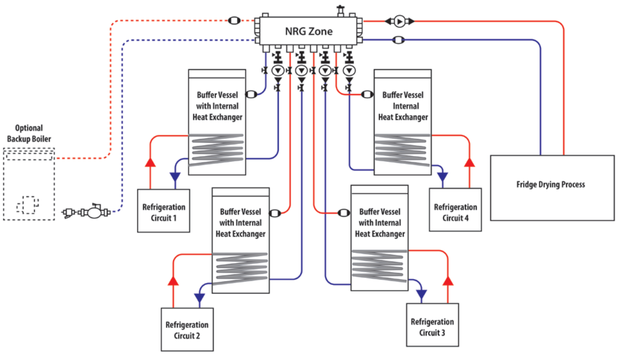
Figure 8: Waste heat recovery system with multiple buffer vessels with internal heat exchangers. The heat is collected by an NRG Zone manifold and then delivered to the fish drying process. There is also an optional boiler connected to the manifold for when there is not enough recovered waste heat to run the drying process.



When deciding on the exchanger, it is crucial to keep in mind the pressure drop across it, since this will affect the workload for the compressor. One also has to consider the fact that the refrigeration gas might condense in the auxiliary condenser and how that will affect system components further down the line. The selected heat exchanger can be mounted internally in the buffer vessel, or it can be external and piped into the buffer vessel. Especially larger refrigeration circuits might require external heat exchangers.

Another consideration when designing the heat recovery system is the buffer layout. Is it desired to have one large buffer vessel or multiple smaller ones? Depending on the heat exchanger design, multiple small buffers might be a good option when there are multiple refrigeration circuits spread throughout the processing plant, like in Processor 1 (Figure 8). A large central buffer might be more suitable if multiple systems are in a more central location like in Processor 3 (Figure 9). It is also easier to have one central buffer when using external heat exchangers since the heat exchange can happen at the source, and the heated water can be pumped through pipework to the central buffer. This pipework strategy will minimise the extra pipe length the refrigeration gas has to travel through, thereby reducing extra work for the existing compressors. However, there will be a cost associated with the circulation of the water on the secondary side of the exchangers.

Figure 9: Waste heat recovery system with multiple external heat exchangers. The heat is collected by an NRG Zone manifold and then delivered to a large central buffer vessel which supplies the fish drying process. There is also an optional boiler connected to the manifold for when there is not enough recovered waste heat to run the drying process.



6. Financial viability of waste heat recovery

Many factors need careful consideration when trying to assess the financial viability of a waste heat recovery system. The most crucial factor is the amount of waste heat recovered. The higher the amount of recovered waste heat, the higher the savings for the company.

Another factor is the energy price used to assess the value of the recovered waste heat. The value of the recovered waste heat equals the value of the energy that did not have to be bought to run the process in which the waste heat is being utilised. For example: when comparing the waste heat to heat generated by electricity, the heat is valued at 15.79 cents/kWh1. If the same waste heat is compared to the heat generated by a heat pump with a Seasonal Performance Factor (SPF) of 4, it is only valued at

3.95 cents/kWh. When compared to an 80% efficient oil boiler using light fuel oil, the value is 10.20 cents/ kWh [2]. Therefore, the cost of the current supply of energy that is to be replaced will have a significant impact on the payback period for the investment in a heat exchange.

The cost of installing the heat recovery system is another essential factor. The installation will require the procurement of new equipment, labour costs, and it might also require some downtime for parts of the fish processing plants. The total parts and labour are largely affected by the number of refrigeration circuits intercepted to recover the heat. Therefore, refrigeration circuits with high energy output will be more viable than circuits with low energy output.

It is difficult to accurately assess the financial viability of waste heat recovery in fish processing plants as most do not have any historical data on the energy generated by each refrigeration circuit. These, of course, can be estimated based on the maximum output of each circuit, but it is difficult to determine how close this value is to the real average value. When a refrigeration system is active, it does not necessarily mean that any or all of the compressors in it are running, it just means that the system is monitoring the temperature in the refrigerated room and turning on the compressors when needed. Therefore, when we are told that a system is always on, it does not necessarily mean that compressors are always running. When we visited the sites, we rarely saw more than 50 % of the compressors running in any active systems, and at times all compressors were entirely off even when the system was active. Without better data on energy generation, it is very difficult to give a proper estimate of the value of the recovered energy. However, as a rule of thumb (according to Herland et al.[3]), waste heat recovery can reduce the energy needed to dry fish by up to 50%.

1Assuming Band IC price from the SEAI Commercial Comparison of Energy Costs [2]

7. Potential uses for recovered waste heat

As established earlier, there is a lot of waste heat being generated in each fish processing facility, and it is possible to recover a large amount of this energy. One widespread usage of recovered waste heat is the generation of domestic hot water (DHW). DHW generation is usually a very energy-intensive process, especially if there is a high demand for hot water. Depending on the temperature of the recovered waste heat and the desired temperature of the DHW, the waste heat can either be used to bring the DHW to the desired temperature or can be used to preheat the DHW before the existing system takes over and brings it up to temperature. Either option will reduce the energy requirements of the DHW generation system. The financial benefit of these solutions will again depend on the price of the replaced energy and installation cost of the heat recovery system, as described in Chapter 6. When using the waste heat from the refrigeration gas to generate DHW, the heat exchangers must comply with EN1717 (the protection of potable water supplies from pollution caused by back-flow) and EN12897 (Water supply. Specification for indirectly heated unvented (closed) storage water heaters)

The recovered waste heat can also be used for space heating to reduce the processing facilities' heating costs. If the water heated by the waste heat recovery system is used solely for space heating, the heat exchanger does not have to comply with EN1717 and EN12897 as there will be no risk of contaminating potable water.

The recovered energy can be used for both DHW and space heating. We suggest interconnecting the waste heat recovery system with the existing heating system to provide both space heating and DHW generation. We would also recommend keeping the existing heat generation appliance to supplement the system if required. Keeping the existing appliance will ensure that there will not be any lack of heat or DHW. The easiest way to do this is through the use of a central heating manifold like the NRG Zone, as seen in Figure 10.

8. Conclusion

The site visits showed that there is a substantial amount of waste heat being generated in the Irish fish industry due to its reliance on refrigeration systems to prevent their products from spoiling. The limited sample of fish processing plants also indicated that waste heat recovery from refrigeration systems is uncommon in the industry.

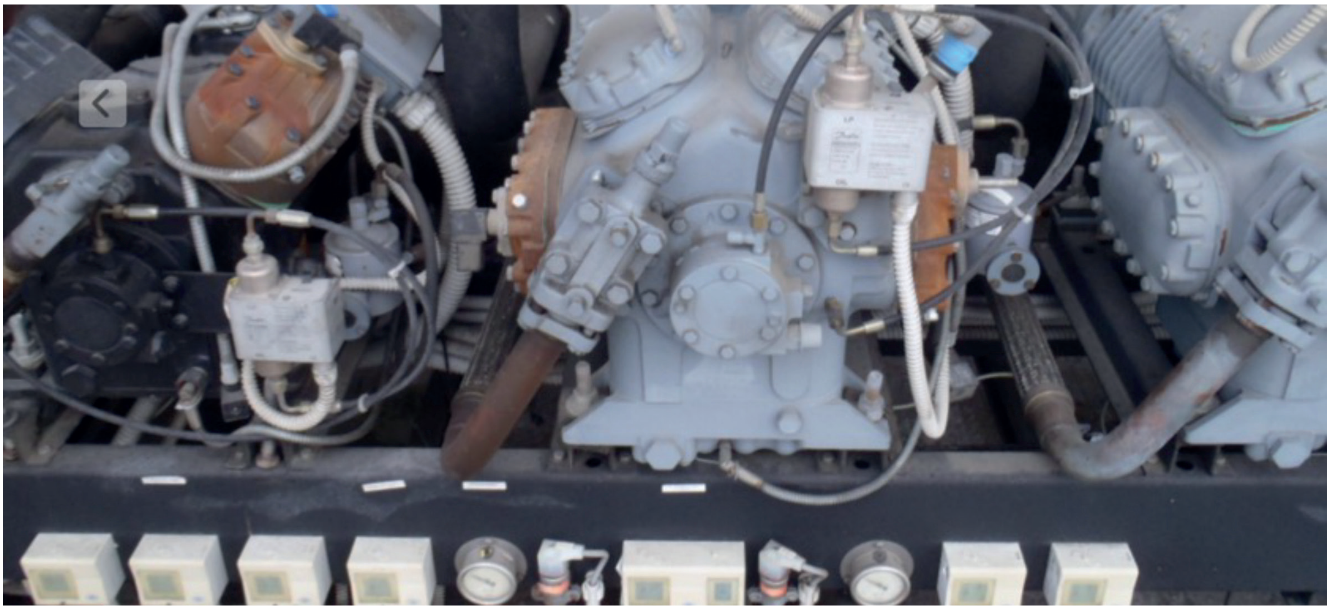
After a review of different waste heat recovery methods, recovering the heat directly from the refrigeration gas to achieve the highest possible efficiency is recommended. This can be achieved by connecting an auxiliary condenser in series before the existing condenser on each refrigeration circuit. Leaving the existing condenser downstream of the new auxiliary condenser will ensure that the system is still capable of dissipating all heat, regardless of the performance of the new auxiliary condenser, thereby securing the full functionality of the refrigeration system.

The cost of a waste heat recovery system is very dependent on the size and layout of the refrigeration circuits in the processing plants as well as the number of circuits. Therefore it is challenging to ascertain a general cost for this report. However, we can say that the amount of labour and parts is affected by the number of refrigeration circuits intercepted.

Using the recovered energy for space heating and DHW generation will reduce the overall running costs and carbon footprint of the processing plant. The interlinking of space heating, DHW generation and even the existing boiler room can be done simply with a central heating manifold like the NRG Zone.

The financial viability of the waste heat recovery system will mainly depend on the quantity of energy it produces, the cost of the replaced energy and the installation cost. The value of the recovered heat is the same as the value of the replaced energy. Therefore, the value of each kWh of recovered energy will depend on the current fuel price of each processing plant. The value of the system is tied to the amount of energy it produces and the value of that energy, while the installation cost is affected by the number of refrigeration circuits as well as their size. Therefore systems with a few circuits with a high waste heat generation will be more financially viable than systems with multiple smaller circuits.

Overall there is an excellent opportunity for the recovery of waste heat energy in the Irish fish processing industry for use in space heating and DHW generation. More widespread usage of waste heat recovery will reduce the industry’s operating costs and its carbon footprint.



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