Investigation of Dehydration Technology to Reduce Waste and Add Value to Fish Processing Residuals and By-Catch

Overview

This report was conducted to investigate the use of dehydration or drying systems to add value to fish processing residuals and unwanted and unavoidable catch (UCC). The results concluded that the process does add value to the waste products. However, the process does entail significant additional capital and operational costs.

Introduction

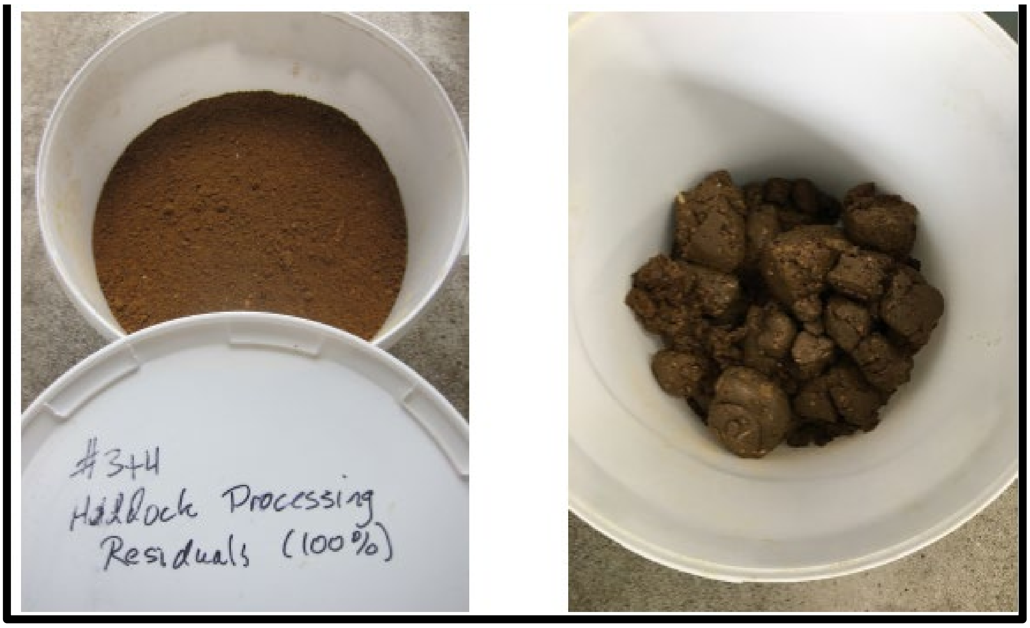
In Ireland, it is estimated that there are…

- 67,437 tonnes per year of Unwanted & Unavoidable Catch
- 77,416 tonnes per year of fish processing residuals generated

At the moment, both the UUC and fish processing residuals are considered waste products. There are some markets that will accept the residuals and by-catch. However, all of these markets are considered low-value like fishing bait, composting and land spreading of fish processing sludges.

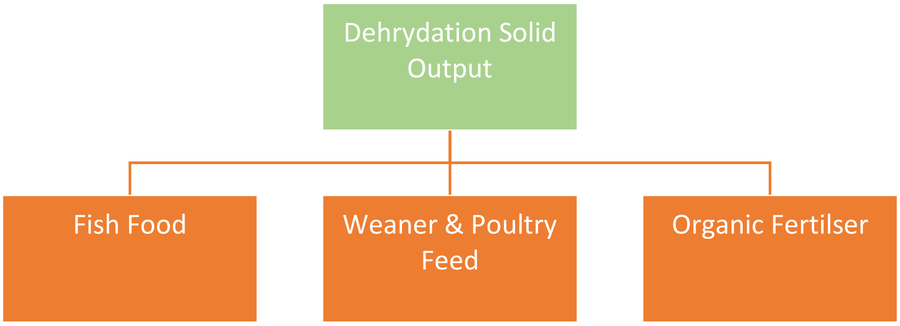
Dehydration & Drying Systems

Dehydrators use a mechanical- thermal approach to dry food materials with a 70-90% water content to 1-20% moisture. A trail was conducted in Howth using A Gobi G100 from Tidy Planet UK. The dehydration machine trialled produced two output products: a solid material and a liquid condensate.



During a trail, 16 batches of haddock and whiting were run through the machine as whole fish, fish processing residuals and a combination of both. Of the 16 batches, all but 2 produced a dry powder like material (as shown above to the left); 2 batches of whiting processing residuals produced a more solid like product (as shown above to the right) due to its higher oil content.

From the dehydration and drying process, this new powder like material has more commercial value than the unprocessed fish processing residuals. Below is a summary of some of the commercial markets available from the dry solid output from the dehydration process.



<u>Figures</u>

As this process would be considered an investment, below is the breakdown of the figures. There are different machinery and equipment available based on the amount of residue processed per day. As seen below, higher daily volumes requires higher capital cost.

System (tonne/day)	Indicative Capital Cost (€)
0.1	20,540
50	77,160-136,527
100	2 million

In addition to this, energy seems to be the highest operational cost between €11-80/tonne of input.

Although this is a large investment, there could be a decent payback depending on the markets developed for the solid output material. For the best returns, organic fertilisers to horticulture growers, landscapers and home gardeners were identified as the best market. Wholesale and retail pricing are estimated at €125-2,333 and €499-9,333 respectfully. Other markets include fish bait or feed for aquaculture or poultry operations, and weaner pig production.

Conclusion

Preliminary economic analysis for the pilot project shows that the feasibility of the project would be very challenging at a small scale and not very cost-effective because, for example, fish processing facilities are currently getting rid of their processing residuals for free to mink farms on the East coast or are selling them to the fish meal plant in Killybegs in the Northwest. However, Ireland is currently in a 'phase out' status regarding the mink fur farms in operation, following suit with many other EU countries. The equipment becomes more feasible if a fisherman or fish processing operation is required to recycle the material at a biogas plant or composting facility with costs between €60-160/tonne.

For more information on this report or pilot please contact Bord Iascaigh Mhara's Green Program at jeanne.gallagher@bim.ie *or 01 2144 124. This report was funded by Bord Iascaigh Mhara. The research and pilot project conducted to produce the feasibility report was carried out by Craig H. Benton of Benton Ecological Solutions & Technology; craig@bentonecosolutions.com or by mobile phone at ++353 86 387 1548.*

Economic Feasibility of Using Anaerobic Digestion Technology to Manage Fish Processing Waste in Ireland
August 2020

Study Funded by:

BIM Ireland's Seafood Development Agency

Benton Ecological Systems & Technology

Study Produced by:

Contents **Page**

This report was funded by BIM and supervised byBIM Green Programme Co-ordinator and Food Safety Specialist. The report was researched and produced by Craig Benton of Benton Ecological Solutions & Technology in Dublin. For questions or more information contact the BIM Green Seafood Programme at jeanne.gallagher@bim.ie or Craig at craig@bentonecosoultions.com

A. Introduction

In late 2017 and early 2018, Demetra, Ltd., conducted a pilot project at Island Seafoods, Ltd, near Killybegs, County Donegal to test an innovative anaerobic digestion technology developed in Italy. A final report was produced by Demetra in 2019 to document the results of the pilot project which is attached as an appendix to this report. In summary, the pilot project proved that fish processing residuals combined with sludge produced from Island Seafood's waste water treatment plant could be used as primary feedstocks to produce biogas. In other words, it is technically feasible to use anaerobic digestion technology to process solid and liquid wastes from a seafood processor to generate biogas and produce a stable slurry like "digestate" suitable as an organic fertilizer for application to agricultural land.

The purpose of this report, therefore, is to determine the economic feasibility of installing a full-scale anaerobic digestion system at Island Seafoods based on the results of the pilot project. To undertake this analysis, the consultant for this project, Benton Ecological Solutions & Technology (BEST) of Dublin, met with staff from Demetra to understand the specifications, performance and capital costs of a larger scale system as well as meeting with the owner of Island Seafoods to understand how a larger scale project could be integrated into the existing seafood processing facility and how much it would cost to operate the biogas system.

Another purpose of this report is to understand and explore the feasibility of using anaerobic digestion technology to handle liquid and solid wastes from the fish processing industry here in Ireland. For this, a well established anaerobic digestion company from Germany, Weltec BioPower, was contacted and asked to model and cost a more traditional biogas system for use within the industry. For both biogas systems, an Excel spreadsheet model was used to evaluate the economic feasibility of deploying these systems for Island Seafood specifically and in general for the seafood industry within Ireland.

This report contains a summary of Island Seafoods including its size and amount of waste generated; a conceptual description of the larger scale biogas systems that could be installed on site; a general description of the Excel spreadsheet model used; the assumptions, capital expenditures and operating costs inputed into the model; the results of the spreadsheet modeling; and conclusions and recommendations for both Island Seafoods and the Irish seafood industry as a whole.

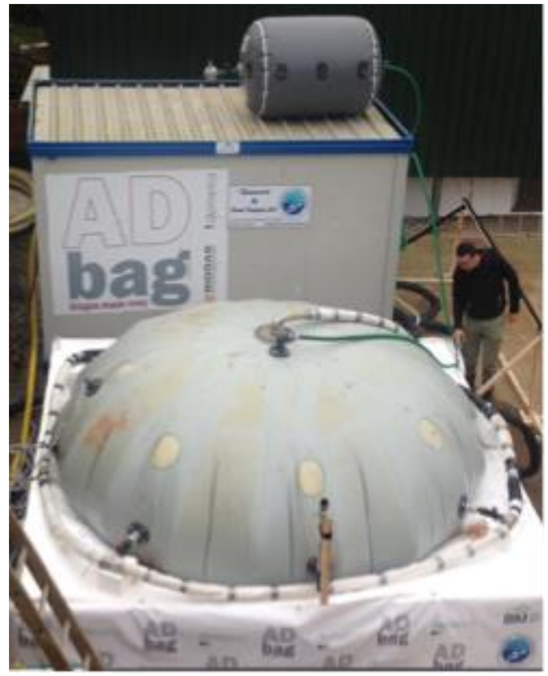
B. Background to Island Seafoods

1. Introduction to Island Seafoods

Established in 1986, Island Seafoods, Ltd., is a family owned seafood business that specialises in the processing of pelagic fish including mackerel, herring, sprat, horse mackerel, boarfish and blue whiting. The facility produces whole rounds as well as gutted and headed, butterflied filleted and single filleted fish products, most of which are individually or jumble packed for quick blast freezing. The company also produces a mince fish meat product that is frozen in blocks. The company prides itself as being one the greenest seafood processors in the country, explaining on its website:

> *"Inspired by green ethics, Island Seafoods, Ltd. has a squeaky clean carbon footprint. We operate our own hydro-electric plant which saves over 350 tonnes of greenhouse gases a year, ensuring the sustainability of our operations. We have been MSC certified which recognizes and rewards sustainable fishing and promotes the environmental choice in seafood. We are constantly looking at our carbon emissions and how they can be reduced. The company is multi-award winning and has many certifications including MSC, Bio Suisse, Naturland, Origin Green, IOFGA Organic Standard and EU Organic Standard. Working with each customer individually, we help discover, through innovation, products which are developed in-house and delivered to the highest standards.*

2. Summary of AD Bag Pilot Project



In the autumn of 2017 and winter and spring of 2018, Bord Iascaigh Mhara (BIM) funded a pilot project to install and operate a micro AD Bag anaerobic digestion system developed by the Demetra Group, srl of Italy at Island Seafoods, Ltd., as shown to the right. The purpose of the project was to determine the technical feasibility of using anaerobic digestion technology to process waste from a seafood processing facility. The new technology uses a plasticised fabric bag instead of a stainless steel tank or covered circular concrete structure. The AD Bag is placed within an insulated pit below the soil surface as opposed to an above ground insulated stainless steel or concrete tank. Fish processing waste (heads, bones, skin, guts) are shredded and then mixed with sludge from the facility's waste water treatment plant to create a slurry like material with 10-12% solids.

After mixing in a designated mixing tank, the combined feedstock material is added to the digester. Circulation and mixing of materials within the digester is accomplished by drawing materials from the bottom of the AD Bag and pumping them into a series of inlet jets along the sides of the AD bag to create a circular flow within the digester. Biogas is collected and extracted from the top of the AD Bag and can be used to fuel a boiler or run a combined heat and power (CHP) system to generate electricity and low grade heat. With a 21-22 day cycle time, about 5% of the digester contents are removed each day and refilled with fresh feedstock material. The removed material is then stored in a digestate tank until it can be spread and used as an organic fertiliser on nearby farmland.

At first, the 3 meter in diameter digester processed a mix of fish processing residuals (34% solids), sludge from the company's onsite waste water treatment plant (7% solids) and bread crumbs to balance the high protein mix at a ratio of 1 part bread crumbs, 1 part processing residuals to 10 parts sludge. However, at the end of the trial, the bread crumbs were phased out and the system performed well without them, generating slightly less biogas per tonne of input fed into the system. It seems that the fish oil of the pelagic fish provided a sufficient amount of carbohydrates necessary to sustain a robust anaerobic digestion process.

Here is a summary of the results from the pilot project which were used in modeling a larger scale system:

- Average biogas production = 27.3 cubic meters of biogas per tonne of input (biogas production ranged from 25 to 46 cubic meters per tonne during the trial depending on the type and solid content of the input materials)

- Purity of the biogas ranged from 66-75% methane (a minimum of 60% is required to run a CHP system)
- Biogas production varied during the pilot project and can be attributed by the variation in dry matter or volatile solids in both the sludge and the fish processing residuals.
- Ammonia levels within the digester were a third lower than levels that may inhibit the digestion process. The worry was that high protein feedstocks can generate excessive ammonia when digested anaerobically.

3. Fish Processing Waste Management at Island Seafoods

Island Seafoods generates two stream of waste from its operation: solid wastes from the processing of fish that consists of heads, bones, skins and guts (17-36% solids), and a sludge from an on-site waste water treatment plant (4-7% solids).

The quantity of these two waste streams vary during the year and is dependent on the quantity and type of seafood processed. On average, the owner of Island Seafood estimates that 25 tonnes per week of sludge is generated by the company's on-site waste water treatment plant. On the other hand, 7.5 tonnes per week of fish processing residual are generated by the seafood facility (1.5 tonnes per day on a five day work week).

Normally, the fish processing residuals are sold to Pelagia Feed Limited in Killybegs for €185 per tonne where it is converted into a fish meal product. When the fish meal plant is not operating, the material can be sent to Enviro Grind Limited in Pettigo for composting at a cost of €58/tonne (€44/tonne tipping fee plus €14/tonne for transport). The sludge produced by Island Seafoods from its on-site waste water treatment plant is currently sent to a new biogas plant at Ballybofey, County Donegal for digestion at a cost of €14/tonne. There is no tipping fee at this large scale anaerobic digestion facility but the transportation cost is €350 per 25 tonne tanker truck load.

4. Existing Infrastructure at Island Seafoods

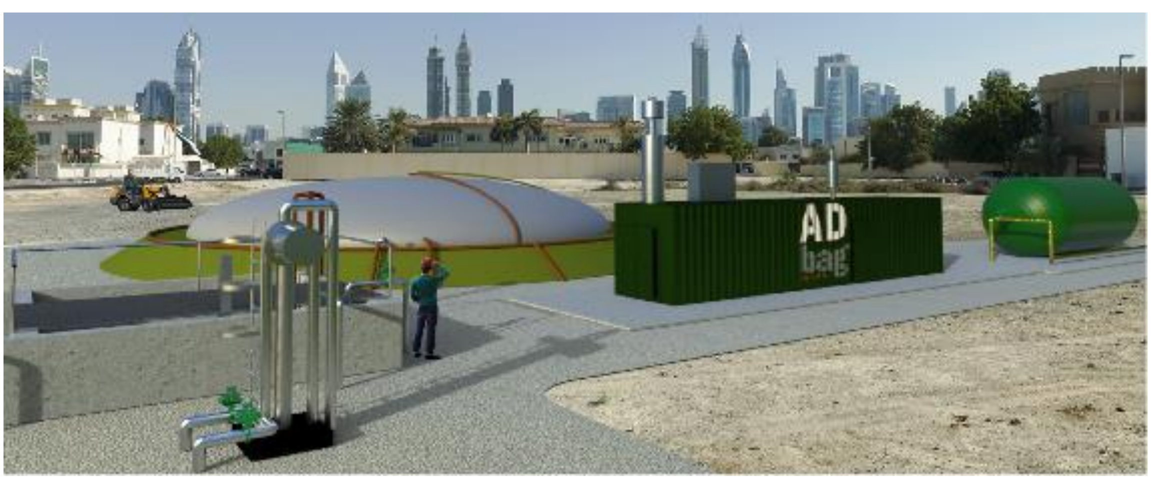
The Island Seafoods processing and storage facility is located in Bungosteen, just over 5 kilometers north of Killybegs in County Donegal. The facility is cut in half by a county road that runs parallel to the R263 coming north out of Killybegs and the N56 that runs up to Rinmore. The main processing facility, office and freezer storage areas are located on the west side of the road while the waste water treatment plant is located on the east side of the road. On average, about 30,000 liters of waste water per day from the fish processing facility travels by gravity flow to the waste water treatment plant on the other side of the county road. The industrial style waste water treatment plant uses a dissolved air flotation (DAF) system for separating the solids from the liquid fraction. In addition to the waste water treatment system, Island Seafoods has two storage tanks on site: one is a 32,000 liter tanker trailer and the other is a 180,000 liter input storage tank.

Between the waste water treatment plant and the county road is a large relatively flat piece of property where a full-scale biogas plant could be installed. Here, the biogas plant wold be next to the waste water treatment plant making it easy to move sludge to the digestion facility. Processing residuals from the seafood processing facility could then be placed in fork liftable plastic containers and easily transported to the biogas plant for processing.

Although electric lines run along the county road, they do not have the capacity to accept electricity from the biogas plant unless they are upgraded at a cost of about €197,000 (€77,000 for a line upgrade and €120,000 for a transmission substation upgrade). The owner of Island Seafoods has already researched this for a proposed wind energy system he would like to install on his property to make the company energy self-reliant. The biggest issue now is the lack of incentives for generating green energy. Currently, Island Seafoods is paid 9.5 cents per kilowatt hour for hydro energy it generates on site versus the average of 15 cents per kilowatt hour it pays for electricity from the grid to run its facility and freezer storage areas. Needless to say, there needs to be a feed in tariff that encourages small generators to install renewable energy systems in Ireland that would pay a fair price for renewable energy, like so many other countries in Europe have.

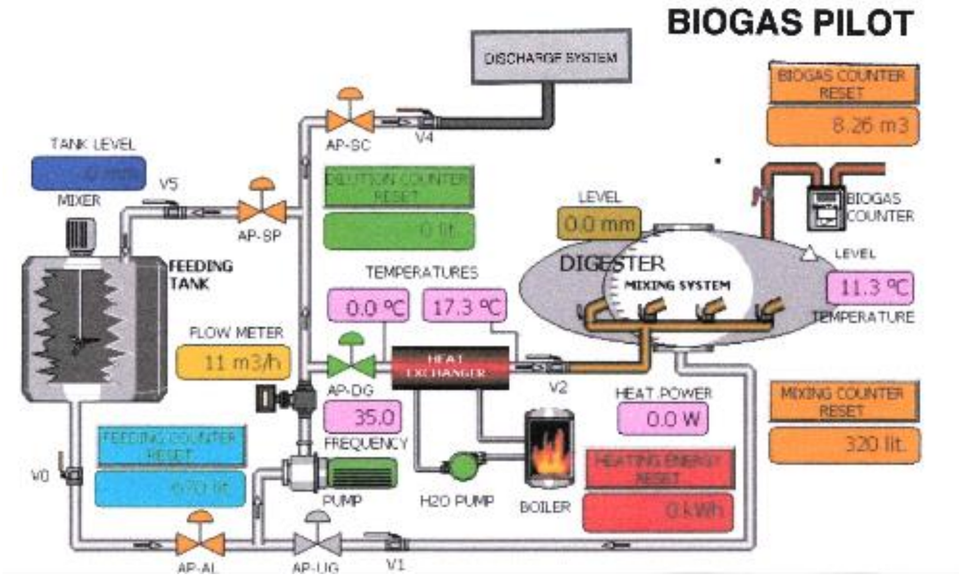
C. Proposed Anaerobic Digestion Technology

This section describes the technology and components of the two types of anaerobic digestion systems that could be deployed at Island Seafoods or other locations within Ireland to create energy from fish processing residuals: an innovative and less expensive ADBag system from Italy and a more traditional biogas system from Weltec BioPower Gmbh in Germany.



1. ADBag System from Demetra Group srl

The ADBag system, as pictured above, utilises a partially buried plasticised fabric bag to contain the digestion process. Feedstocks are shredded and mixed prior to being pumped into the ADBag digester. A chopping pump is used to draw materials from the bottom of the digester and push them through a heater before they are injected back into the sides of the digester using a series of jets all aligned in the same direction to create a circular flow within the digester. The engineering schematic below shows how the digester is



configured and operated.

The attached fact sheet from Demetra provides an idea of how the plant is laid out and provides some extra specifications. The capacity of the 18m diameter ADBag system is 817 cubic meters and holds 782 cubic meters of digestible materials leaving room at the top of the bag to collect biogas. With a 22 day retention time, 28 tonnes per day of feedstock can be added to and removed from the digester (seven days a week). Based on the results of the pilot project, Demetra estimated that the larger 18m system would generate 278,787 cubic meters of biogas per year. The ADBag system can be operated with a 80kw CHP to produce electricity from the biogas produced with an estimated 514,000 kilowatt hours of electric power generated per year.

The specific components included for the conceptual design of the 18m ADBag system for Island Seafoods would consist of the following elements:

- 30,000 liter feedstock storage tank for waste water treatment plant sludge (4-7% solids)
- 650w shredder to reduce fish processing waste solids to a 5-10mm size
- Feeding tank with mixer (as shown in above diagram)
- 18m in diameter ADBag digester
- Chopping pump and piping
- Boiler and heat exchange system to keep digester up to temperature
- Process monitoring and control system
- 80kw CHP combined heat and power system
- Pasteurisation tank (70° C for 1 hour)
- 3,300 cubic meter digestate storage tank (4 months of storage)

The 18m AD Bag system has been specified by Demetra to handle the following quantities and types of feedstocks for the Island Seafood project:

- 3,650 tonnes per year of fish processing wastes (17-36% solids)
- 6,570 tonnes per year of waste water treatment plant sludge (4-7% solids)

This will provide 10,220 tonnes per year of combined feedstock materials with range of 8.6 to 17.4% solids or an average of 13% solids.

For more information about the Demetra Group ADBag system, please see https://www.demetragroupsrl.it/en/

2. Weltec BioPower Gmbh Biogas System

Formed in 2001, Weltec BioPower Gmbh is a well established anaerobic digestion system supplier from Germany that has designed, built and supports over 330 individual plants worldwide. They have installed over 20 biogas facilities in the UK and Ireland operating a UK based subsidiary called Weltec BioPower Limited.

The Weltec BioPower system is similar to many coming out of Germany where over 7,000 biogas plants have been installed, mostly on farms, generating more electricity than the country's nuclear power plants. The difference between Weltec BioPower and their competitors is that the digester is made with insulated stainless steel instead of concrete. This allows facilities to be built in less than 60 days at a lower cost.

Like many biogas plants, the Weltec BioPower system uses a dedicated chopping mixer to blend feedstocks together prior to being added to the digester. Within the 1,543 cubic meter digester (twice as large as the ADBag digester) are mixing propellers that constantly operate to prevent stratification within the digester or crusting on top of materials preventing biogas release. The cycle time within the digester is 50 days to maximise biogas production and is the main reason why the Weltec BioPower system is capable of producing 2-3x more biogas than the ADBag system. According to the attached technical yield estimation based on the same types and quantities of materials from Island Seafoods, the biogas production per year would be 723,923 cubic meters (as opposed to 278,787 cubic meters from the AD Bag system). With this increased biogas volume, a 250kw CHP can be used to generate over two million kilowatt hours of electricity per year (as opposed to the 514,000 kWh/year from the ADBag system). Similar to the ADBag system, the CHP would produce sufficient low grade heat to keep the digester warm to optimise biogas production and supply the heat necessary to pasteurise the digestate coming out of the digester each day at 70°C for one hour to comply with Ireland's Animal By-Products regulations.

The components of the Weltec BioPower system would consist of the following elements:

- 50,000 liter feedstock storage tank (heated and mixed)
- Feed hopper with remote control lid (12m3)
- MULTIMIX pre-feed system (see attached specification flyer).
- Insulated stainless steel digester (1,543m3: 17.66m diameter, 6.3m wall height)
- Pumps, actuated valves and associated piping
- Process monitoring and control unit, in container
- CHP, containerised and including all necessary accessories
- Flare
- Biogas analysis unit
- Pasteurisation unit, EU ABPR complaint, with buffer tanks, control system, heat exchangers and macerator.
- 3,300 cubic meter digestate storage tank (4 months of storage)

For more information about the Weltec BioPower system, please see the attached flyers and the company's website on the following link: https://www.weltec-biopower.com

D. Excel Spreadsheet Model Used

BEST has developed and uses an Excel spreadsheet model to help evaluate the feasibility and profitability of composting facilities which has been used to model dozens of similar facilities, including anaerobic digestion plants, in Ireland and the UK over the last 15 years. This interactive spreadsheet allows the input of assumptions and variables about costs and revenues so that an accurate forecast of profitability can be determined. The model also allows for the manipulation of variables to see what happens to the bottom line when different scenarios are modeled. In other words, the model allows for sensitivity analysis of all variables that can be inputed into the model. A summary of the variables that can be inputed into the first three tabs of the model are provided below, including:

1. Assumptions

- tonnes processed per day
- operating days per week
- fuel use per hour for every piece of equipment
- hours of operation per day for every piece of equipment
- cost of fuel per liter
- electric power rating for every piece of equipment in kilowatts
- hours of electricity used per day for every piece of equipment
- building and site electricity use per day in kilowatt hours
- cost of electricity on a per kilowatt hour basis

These assumptions calculate fuel and electricity use and cost per day and per month. These then feed automatically into the annual income statement (see section 3 below)

2. Capital Costs

- core processing equipment cost
- process control system cost
- storage tank costs
- ancillary equipment costs per item
- site or land purchase cost
- site improvement and development costs by category, for example planning and permits, site preparation costs (clearing and grading), fencing and gates, access roads, buildings, office, utilities, electrical and plumbing, engineering, contingency, etc.
- other capital costs
- mortgage or loan calculations for five categories of capital expenditure: core equipment, ancillary equipment, land purchase costs, site development costs and other capital costs where the subtotals of capital costs allow for various interest rates and length of loans in years to be entered for each category.

3. Annual Income Statement

Revenues:

- tipping fee received or savings from tipping fees
- tipping fee escalator per year
- revenue from sale of electricity
- sales escalator per year

Total revenue per month

Operating Costs:

- labour costs by employee category (6 categories available in model)
- benefit rate for staff
- payroll escalator rate per year
- laboratory testing expenses
- maintenance and repair expenses
- water, sewer and non energy utility expenses
- other miscellaneous expenses
- travel and transport costs
- rent
- insurance expenses
- electricity and fuel energy costs carried over from assumptions page

Total operating expenses per month

Capital Expenses:

- Capital monthly payments carried over from capital costs page for the five capital cost categories

Total monthly capital loan repayment costs

The total monthly revenue, operating expense and capital repayment expense figures from above allow for the calculation of monthly net income or loss, and with the model extending for 5 years, a cumulative monthly cash flow figure is calculated for each of the following 60 months in this five-year income statement. Then monthly revenue, expenses and profit are shown for each of the 60 months, and finally monthly capital cost per input tonne, operating costs per tonne and profit per tonne are shown.

4. Annual 5-Year Income Statement

From the previous three tabs, an annual 5 year income summary is produced by the model for the facility and presented in the fourth tab of the spreadsheet. Looked at in another way, the last or forth tab of the spreadsheet summarises the 60 month income statement into an annual five-year income statement (pre tax, including VAT, and with no depreciation) showing:

- input tonnes per day
- total annual input tonnes
- total annual revenue
- total annual operating costs
- revenue per tonne
- operating expenses per tonne
- profit per input tonne

This spreadsheet model provides an opportunity to fine tune both capital expenditure budgets and annual operating costs so that an accurate forecast of profitability can be made. The assumption typically employed when working with the spreadsheet model is to overestimate costs and underestimate revenues so that a more realistic picture can be painted or we can see what a worst case scenario might look like financially speaking.

E. Assumptions and Inputs into the Spreadsheet Modeling

Nine spreadsheet models were created and run to analyze the economic feasibility of using the two biogas technologies identified above for deployment at Island Seafoods. Three spreadsheet models will evaluate a status quo scenario for Island Seafoods reflecting the current economic reality of their situation, namely that waste water treatment sludge is transported to a nearby biogas plant €14/tonne and that Pelagia Feed Limited pays them €185/tonne for their fish processing residuals. One model looks at the 18m diameter ADBag system, another examines the 250kw Weltec BioPower system and the third evaluates a 500kw Weltec BioPower system. The reason for including the larger Weltec system is that by doubling the capacity of the system, capital costs only increase by 25-30% while revenue doubles from the sale of electricity. Here, economies of scale may increase the return on investment in this worst case scenario (when Island Seafoods is being paid for fish processing waste).

Another three spreadsheet models evaluate a scenario where the Pelagia Feed plant ceases operation or cannot accept fish processing residuals from Island Seafoods and therefore cannot pay Island Seafoods for their fish processing waste. This scenario may be more reflective of other seafood processing facilities in Ireland that are too far away from Killybegs to transport their fish processing residuals at a reasonable cost. In these three scenarios, it is assumed that the sludge and fish processing waste is sent to the Ballybofey or another nearby anaerobic digestion facility at a cost of €14/tonne. In this scenario, the 18m ADBag system, the 250kw Weltec BioPower system and the 500kw Weltec BioPower system are modeled.

The last three spreadsheet models evaluate a scenario where the Pelagia Feed plant ceases operation or cannot accept fish processing residuals from Island Seafoods and therefore cannot pay Island Seafoods for their fish processing waste. This scenario may be more reflective of other seafood processing facilities in Ireland that are too far away from Killybegs to transport their fish processing waste at a reasonable cost. In these three scenarios, it is assumed that the sludge and fish processing waste is sent to Enviro Grind or another nearby composting facility at a cost of €58/tonne. In this scenario, the 18m ADBag system, the 250kw Weltec BioPower system and the 500kw Weltec BioPower system are modeled.

What follows are the assumptions used and how variables were calculated or determined for input into the model as outlined in the previous section.

1. Spreadsheet Model Assumptions

a. Tonnes processed per day = 28 tonnes per day
3,650 tonnes per year of fish processing wastes (17-36% solids)
6,570 tonnes per year of waste water treatment plant sludge (4-7% solids)
This will provide 10,220 tonnes per year of combined feedstock materials with range of 8.6 to 17.4% solids or an average of 13% solids. 10,220 tonnes per year divided by 365 days per year equals 28 tonnes per day (seven days a week) for both the ADBag system and the 250kw Weltec BioPower ssytems. It is assumed that 56 tonnes per day are needed for the larger 500kw Weltec BioPower system

b. Operating days per week = 7 days

c. Fuel use = 4-8 liters of diesel per day
Fuel would be used to operate the fork lift to move fish processing residuals from the fish plant to the biogas facility. As the fork lift at Island Seafoods in run on natural gas, a diesel equivalent has been used to estimate costs. For the two smaller plants, 18m ADBag system and the 250kw Weltec system, it is assumed that the fork life consumes 4 litters per hour and that it is used one hour a day to move 9 tonnes of fish processing waste solids per day. For the larger 500kw Weltec system it is assumed that it would take two hours a day to move the solids to the facility.

d. Off-road diesel cost in County Donegal = €0.75/litre

e. Electricity use is variable
For the 18m ADBag system, the following assumptions were made:

One 2kw mixer is used to prepare input feedstocks 4 hours per day
One 2kw pump is used to circulate materials within the digester 24 hours a day
Two 2kw pumps are used to feed and empty the digester for 4 hours each day
0.5kw is used by the process control system 24 hours a day
1kw is used 12 hours a day for site electricity (lighting, office, etc)

For the Weltec BioPower Systems
Electricity used by the biogas system (pumps, mixers, grinder, process control) is powered by the CHP before the excess electricity is sent to the grid. For the 250kw system, the attached technical yield estimation calculates total electric use per year by the biogas system to be 203,722 kilowatt hours. For the 500kw system, approximately 400,000 kilowatt hours per year are needed to run the biogas plant. Electricity expenses, or purchase of electricity from the grid is avoided, and therefore are not entered as an expense into the spreadsheet models for these systems. Only the net amount of electricity exported to the grid is included as a revenue (total electricity produced by the CHP minus the electricity used by the system equals the net amount exported to the grid).

f. Cost of electricity = €0.15/kilowatt hour
Different rates of electricity are charged during different times of the day. The owner of Island Seafoods estimates that an average of 15 cents per kilowatt hours would be a

good figure to use in the spreadsheet analysis. With this per unit cost, the estimated cost of electricity to run the ADBag system, would be €438 per month.

For the Weltec BioPower system, the cost of electricity from the grid would be €2,546/month for the smaller system and about €5,000/month for the larger system at 15 cents per kilowatt hour. As the feed in rate for renewable energy is 9.5 cents per kilowatt hour, the loss in revenue would be €1,612/month for the smaller system and €3,167/month for the larger system.

2. Capital Costs

Equipment costs were obtained from ADBag Group and Weltec BioPower Limited for the core biogas system components and ancillary equipment costs. Storage tank costs were sought from three vendors with the lowest cost used in the model (Weltec BioPower, Irish Industrial Tank and Stortec in the UK). Site improvement costs were estimated with information obtained from the biogas system suppliers and from conversations with the owner of Island Seafoods. Financing costs (term and interest rate) were based on a loan sought by Island Seafoods for the installation of a wind turbine on the Island Seafoods property last year that approximated the capital cost of the smaller biogas systems.

a. Core system equipment costs, including process control system, installation and commissioning are:
18m ADBag System = €580,000
250kw Weltec BioPower system = €1,264,000 (quoted)
500kw Weltec BioPower system = €1,750,000 (estimated)

b. Ancillary equipment costs
For the AD Bag system, the feedstock grinder and pasteurisation unit was not included in the core system cost.
Grinder = €10,000
Pasteuriser = €9,000
For the Weltec BioPower systems, the grinder, mixer and pasteuriser are included in the core system cost.

c. Storage tank costs
30,000 liter feedstock storage tank with concrete base and cover for odour control = €62,000 from Irish Industrial Tank (extra for ADBag system but included in core equipment offered by Weltec BioPower)
3,300,000 liter digestate storage tank with roof and concrete base = €212,900 (Weltec)

d. Site or land purchase cost = 0
The AD Bag or Weltec BioPower systems would be installed on existing land already owned by Island Seafoods. For other seafood processors, the assumption would be that there would be land available for installation of the biogas system.

e. Site improvement and development costs = €530,000-655,000

Site improvement and development costs include those costs that are not covered in the core system technology and ancillary equipment costs and include such things as site grading and hard core, access roads, concrete working areas, office construction, utility hook ups and consultant fees for civil engineering, planning permission, waste permitting and licensing, and animal by-products approval and verification.

For the ADBag and the 250kw Weltec BioPower systems, the following site improvement and development costs have been estimated to be:
€50,000 for civil engineers, planning, waste permitting and ABP approvals
€30,000 for site preparation: grading and hard core
€50,000 for concrete areas and access roads
€400,000 for utilities, drainage, grid connection, office and contingency

For the 500kw Weltec BioPower systems, the following site improvement and development costs have been estimated to be:
€50,000 for civil engineers, planning, waste permitting and ABP approvals
€40,000 for site preparation: grading and hard core
€65,000 for concrete areas and access roads
€500,000 for utilities, drainage and grid connection, office and contingency

f. Financing terms = 5% interest over 10-15 years

The interest rate for capital equipment and site development is estimated to be 5%. Loan term for equipment is assumed to be 10 years and on site improvements 15 years.

3. Annual Income Statement

a. Revenues or savings

Savings from transporting waste water treatment sludge in the three status quo models would be €14/tonne for 6,570 tonnes of sludge per year for ADBag and 250kw Weltec BioPower systems or €91,980/year or €7,665/month. For the 500kw Weltec BioPower system, the savings would be €14/tonne for 13,140 tonnes per year or €183,960/year or €15,330/month

Savings from transporting sludge and fish processing residuals to the Ballybofey anaerobic digestion facility would be €14/tonne for 10,220 tonnes/year for the ADBag and 250kw Weltec BioPower systems or €143,080/year or €11,923/month. For the 500kw Weltec BioPower system, the savings would be €14/tonne for 20,440 tonnes/year or €286,160/year or €23,847/month.

Savings from transporting sludge and fish processing residuals to the Enviro Grind composting facility would be €58/tonne for 10,220 tonnes/year for the ADBag and 250kw Weltec BioPower systems or €592,760/year or €49,397/month. For the 500kw

Weltec BioPower system, the savings would be €58/tonne for 20,440 tonnes/year or €1,185,520/year or €98,793/month.

Revenue from the sale of electricity would be at a rate of 9.5 cents per kilowatt hour:
ADBag system producing 514,000 kwhr/year = €48,830/year
250kw Weltec BioPower system producing 1,830,214 kwhr/year = €173,870/year
500kw Weltec BioPower ssytem producing 3,660,428 kwhr/year = €347,741/year

No increases in tipping fees at either the merchant anaerobic digester or composting facility or increases in the per kilowatt price paid for renewable energy were assumed.

b. Operating costs

Labour costs for the ADBag and 250kw Weltec BioPower systems include:
half time operator at €14/hour
one-fifth time site manager at €25/hour
one-fifth time administrative staff at €16/hour

Labour costs for the 500kw Weltec BioPower system includes:
full time operator at €14/hour
one-third time site manager at €25/hour
half time administrative staff at €16/hour

Annual pay increase = 2%

Laboratory testing expenses = €6,000/year or €500/month

Maintenance is estimated to be = €24,000/year for ADBag system, €48,000/year for the 250kw Weltec BioPower system and €72,000 for the 500kw Weltec BioPower system (about 4% of core system costs)

Utility costs other than electricity = €2,400/year (phone and internet)

Insurance is estimated to be €6,000/year for the ADBag system, €12,000 for the 250kw Weltec BioPower system and €18,000 for the 500kw Weltec BioPower system

Loss of revenue from selling or the purchasing of 3,650 tonnes/year of fish processing residuals = €675,250/year for the ADBag and 250kw Weltec BioPower systems and €1,350,500 for the 500kw Weltec BioPower system.

It is being assumed that nearby farmers will come to the site and collect digestate for spreading on their own fields with no transportation costs charged to Island Seafoods and no revenue from the sale of the digestate fertilizer paid by farmers. In other words, the distribution of digestate to local farmers would be a revenue and cost neutral proposition.

F. Conclusions

The table on the following page summarises the five-year income statement for each of the 9 scenarios run: 3 status quo configurations (status quo in table), 3 configurations where both sludge and fish processing residuals are being taken to a nearby biogas plant at €14/tonne (biogas in table), and 3 where both sludge and fish processing residuals are being taken to a nearby composting facility at €58/tonne (compost in table).

The conclusion from the spreadsheet analysis is that given the status quo at Island Seafoods where they are being paid €185/tonne for their fish processing residuals, the biogas plant is extremely unprofitable and not economically feasible. In fact, the cost to run the plant would be from €60.40/tonne for the larger 500kw Weltec BioPower plant to €74.39/tonne for the ADBag system. In other words, it would cost between €760,236/year to run the ADBag system and €1,243,671/year to operate the larger 500kw Weltec BioPower facility.

For those seafood processing facilities that are too far away from Killybegs to take advantage of the revenue gained from selling their fish processing residuals to Pelagia Feed Ltd., the economics improve significantly. With the savings from avoiding the transportation and tipping of sludge and fish processing residuals at a nearby biogas facility at a cost of €14/tonne and the revenue from the sale of green power to the grid at 9.5 cents per kilowatt hour, the cost per tonne to operate an on-site anaerobic digestion facility would be from a loss of €3.32/tonne for the AD Bag system to a profit of €8.89/tonne for the 500kw Weltec BioPower facility. In other words, an annual loss of €33,884 would be incurred from operating the ADBag system and a profit of €181,673/year would be gained from operating the larger 500kw Weltec BioPower facility.

If seafood processing facilities were required to use a nearby composting facility instead of a merchant biogas plant to dispose of their sludges and fish processing residuals, at an average cost of €58/tonne, the savings would be quite significant for all three systems assessed. The per tonne savings from avoiding the composting of wastes and revenue from the sale of electricity would be between €36.58/tonne for the ADBag system to €48.89 for the larger 500kw Wetltec BioPower facility. The spreadsheets show an annual profit of €373,848 for the ADBag system and €999,272/year for the 500kw Weltec BioPower facility.

The spreadsheets were also used to determine the breakeven scenario for each of the systems assessed. For the ADBag system, avoiding a transportation and tipping fee of

€17.50/tonne for fish processing wastes created a cost and revenue neutral proposition for installing an on-site biogas system. For the 250kw Weltec BioPower system, the breakeven point was €15.20/tonne. For the 500kw Weltec BioPower system, the breakeven point was lower at €5.22/tonne. This means that any tip fee that is higher than these figures would allow for profitable operation of that particular system.

Table 1: Summary of Spreadsheet Analyses

Scenario	Annual Revenue/ Savings	Annual Costs	One Year Profit or (Loss)	Five Year Profit or (Loss)	Revenue/ Tonne	Total Costs/ Tonne	Operating Costs/ Tonne	Capital Costs/ Tonne	Profit or (Loss)/ Tonne
Status Quo ADBag	140,816	901,052	(760,236)	(3,808,548)	13.78	88.17	74	15	(74.39)
Status Quo Weltec 250kw	265,868	984,365	(718,497)	(3,610,275)	26.01	96.32	74	22	(70.30)
Status Quo Weltec 500kw	531,736	1,766,408	(1,243,671)	(6,208,901)	26.01	88.42	72	14	(60.40)
Biogas ADBag	191,916	225,800	(33,884)	(174,788)	18.78	22.09	8	15	(3.32)
Biogas Weltec 250kw	316,968	327,293	(10,325)	(69,415)	31.01	32.01	10	22	(1.01)
Biogas Weltec 500kw	633,936	452,264	181,673	872,819	31.01	22.13	8	14	8.89
Compost ADBag	599,648	225,800	373,848	1,132,300	62.67	22.09	8	15	40.58
Compost Weltec 250kw	725,768	332,549	393,219	1,948,305	75.01	32.54	10	22	42.48
Compost Weltec 500kw	1,451,536	452,264	999,272	4,960,819	75.01	22.13	8	14	52.89

Lastly, the spreadsheets were used to see what effect a feed in tariff would have on the bottom line. In other countries within Europe, the price paid for renewable energy is subsidised to create an incentive for the generation of clean electricity. Right now, ESB pays renewable energy generators 9.5 cents per kilowatt hour while charging customers an average of 15 cents per kilowatt hour to use or consume energy from the grid. Incentives can vary by country, but in some cases as much as 22 cents per kilowatt hour is paid. These incentives vary by type of technology used and the size of the system in terms of energy produced. A scenario of paying Irish suppliers of renewable energy 15 cents a kilowatt hour was run in the biogas spreadsheets for each system. For the ADBag system, the additional revenue from increasing the kilowatt hour price paid for green electricity added €2.27/tonne processed. For the 250kw Weltec BioPower system, revenue increased by €9.84/tonne and for the 500kw Weltec BioPower system, revenue jumped to €9.90/tonne. These then affect the breakeven scenarios for each of these system. For the ADBag system, the breakeven point was reduced to €14.73/tonne, for the 250kw Weltec BioPower system, the breakeven point came down to €5.36/tonne, and finally for the 500kw Weltec BioPower system, the breakeven was (€4.68/tonne). This means that for the larger Weltec BioPower system, the facility could be operate at a profit of €4.68/tonne without any savings from tipping fees.

In summary, anaerobic digestion facilities have a potential to be used to cost-effectively manage liquid and solid wastes generated by Ireland's fish processing industry. The analysis from this report shows that biogas plants can be run profitably for the sector if they are paying to dispose or recycle their wastes at a cost of between €5.22/tonne to €17.50/tonne or higher. If a feed in tariff is created to encourage generation of green energy, these tipping fee breakeven thresholds can be reduced and in the case of the larger 500kw Weltec BioPower system, the facility can be operated at a profit without any savings from avoided transportation costs and tipping fees. In other words, there are economies of scale; by doubling the size of the Weltec BioPower system from 250kw to 500kw, profitability increases by €10/tonne of input material. Conversely, if fish processors are paid for their solid fish processing wastes, anaerobic digestion would not be financially viable.

G. Recommendations

Clearly the recommendation for Island Seafood is to not proceed with installing an anaerobic digestion system for its seafood processing residuals or waste water treatment sludge as long as it is getting paid by Pelagia for its fish processing residuals. If the Pelagia plant ceases operation and Island Seafoods is forced to send materials to a merchant biogas or composting facility and pay to recycling them, then an on-site anaerobic digester would make sense economically.

For BIM and the Irish seafood industry, if processors on the east and southern coasts of Ireland are too far from Killybegs to take advantage of selling their fish processing residuals to create fish meal and are spending money to manage liquid sludges or solid fish processing residuals, then anaerobic digestion may be an appropriate solution to investigate further. If mink farming is phased out, many fish processors on the east coast would lose the ability to shift fish processing residuals to this outlet at no charge. Economics for a biogas plant installation and operation for the seafood industry improves when:

- Electricity produced by the biogas plant is used to expand freezer storage space so producers can sell products in the off season to maximize revenue. So instead of paying 15 cents a kilowatt hour for electricity from the grid, the processors use cheaper electricity from the anaerobic digestion facility at a feed in rate of 9.5 cents a kilowatt hour instead;
- Excess heat from the CHP unit can be used for facility or district heating purposes, offsetting fossil fuels costs and taking advantage of the renewable heat incentive offered by the Irish government;
- A group of processors can join together to feed a large scale biogas plant, improving economies of scale and the economic feasibility and profitability of such a venture; and
- The digestate can be processed into a dry fertilizer product. Excess heat from the CHP could be used to dehydrate some of the digestate helping to concentrate nutrients, reduce volume (by 80-90%) and increase the shelf life of the organic fertilizer product making it cheaper to transport as well as easier to apply and use. The drier product could be sold as a stand alone fertiliser or be used as an ingredient in more balanced organic fertiliser blend instead of giving it away to farmers who are willing to pick it up from the facility free of charge.

There are many ways to improve the economic feasibility of using anaerobic digestion technology within the Irish seafood industry, however, many advantages would be site and project specific. BIM could follow up on this study by surveying all fish processors in Ireland to find out how much waste is being generated by each operation, how individual processing plants are managing this waste and at what cost. Aggregating this data would provide an industry wide snapshot on how much liquid and solid wastes are being generated by fish processors and how much it costs the industry as a whole. Most importantly, this industry wide survey would help identify individual operators or group of processors that are currently paying to manage their wastes. As ocean dumping of sludge becomes more limited, as it has in Killybegs, mink farms cease operation, and paid or free outlets for fish processing residuals become limited or dry up, biogas facilities would be one of several viable options to consider for adding value, reducing costs and generating revenue for the Irish fishing industry.