National Waste Prevention Programme 2014-2018

Final Report For Green Enterprise Programme (GEP) Phase 2

Improved Treatment of Distillery Wastes
Project Ref: 2013-ET-CP-47

Date: 28th September 2015

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Summary

The aims of this project were to provide increased visibility of energy use in co-product treatment for existing distilleries and to provide information for new distilleries to choose the most appropriate route for co-products.

There is at present no one ideal co-product treatment route for every distillery. There are several competing factors at play, including scale of operation and geography of the distillery's location.

Pot ale is the most challenging distillery co-product to deal with because of its high water content and high biological oxygen demand (BOD). For this reason, its uses and treatments were the focus of this study. Evaporators are commonly used to concentrate pot ale and the concentrate is then sold, in the form of syrup which is used for animal nutrition. This is the treatment method in place in all three Irish distilleries visited over the course of the study.

Available treatment routes were investigated from both economic and environmental perspectives. Environmental assessments were on the bases of the hierarchy of waste, the circular economy and calculated carbon emissions. For all environmental philosophies however it is preferable that the selected treatment route be as well-designed and efficient as possible.

The most economic and environmentally friendly option for smaller distilleries was found to be to sell (or give) all co-products untreated to local farmers for animal feed. For larger distilleries, a balance must be found between the co-product market and its location relative to the distillery.

For a large scale distillery an MVR evaporator is the most economic treatment route at present. This conclusion is highly sensitive to energy prices and carbon costs however. If carbon costs were to rise significantly from current levels this would greatly increase the feasibility of anaerobic digestion at medium size distilleries also.

Recommendations in the report are summarised as follows:

Existing distilleries
1. Energy monitoring/benchmarking of treatment systems
2. Take steps to minimise fouling of evaporator surfaces
3. Heat recovery
4. Increased evaporator area
5. Improved control of evaporator/treatment systems
6. Vacuum pump seal cooling

New distilleries
1. Calculate how much of each co-product is produced per annum.
2. Identify what users are available and costs/revenues associated
3. Estimate costs of each treatment and environmental impact
4. If production capacity is less than 1MLA it is likely that on site treatment is not economically feasible.

All distilleries
1. Consider co-operative ventures either with other distilleries or with other symbiotic industries to use valuable substances in co-products, waste heat and CO_2 produced.

Contents

1. Background

Treatment of wastes and co-products from the distillation process provides a significant challenge for distilleries and is often one of the largest energy users on distillery sites. For every bottle of whiskey produced, approximately 4 times the volume of pot ale is produced.

At present, the most common treatment method for pot ale and thin stillage in Ireland is evaporation. This reduces transport costs and also increases shelf life. While evaporators have become much more efficient in recent times, evaporation is still a very energy intensive process. With ever increasing energy prices and carbon commitments there is a strong impetus to reduce energy consumption for all distillers.

On average, the Irish distilling industry produces over 60 million of litres of alcohol (MLA) each year (Irish Spirits Association, 2014). There has recently been huge growth in the industry with 23 new distilleries of various sizes planned or in construction at the time of writing (see map of distilleries currently in operation and in development in Figure 1.1). Pernod Ricard has recently completed a large expansion project in Midleton, bringing the site’s capacity to 64MLA (Quinn, 2014).

The current landscape is in stark contrast to 10 years ago when there were just 3 distilleries in operation on the island (Midleton, Cooley and Bushmills).

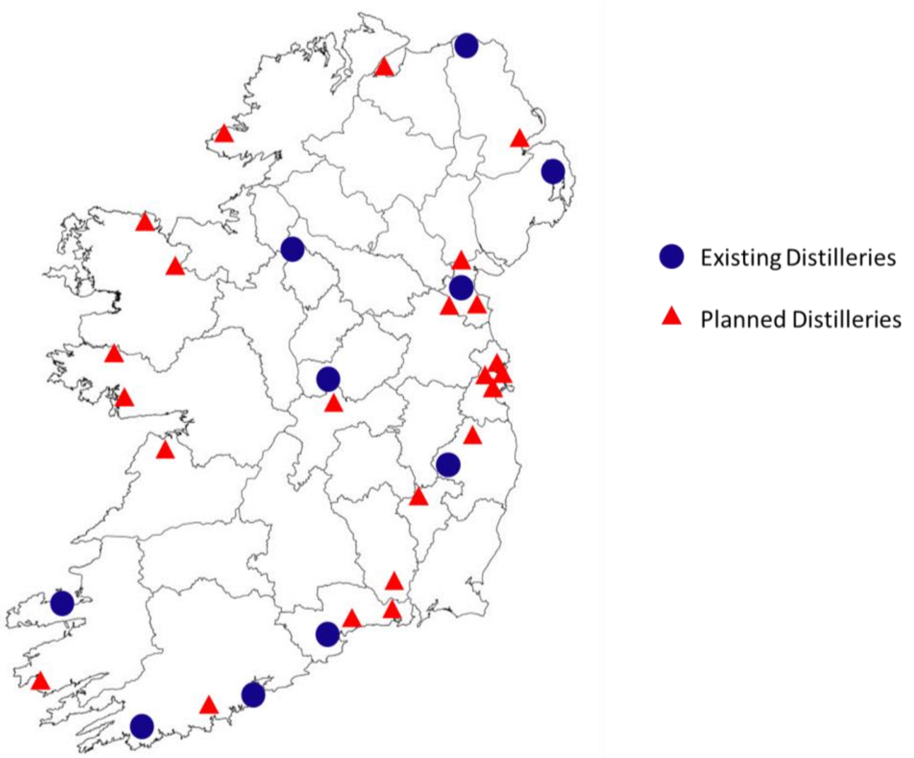

Figure 1.1 Distilleries in Ireland 2015

The situation with pot ale and thin stillage treatment seems analogous to that of whey in the cheese industry. Until recently, disposal of whey (a by-product of cheese production) was a significant issue for the dairy industry because it had a high biological oxygen demand (BOD), a short shelf-life and applications for it were limited. Whey protein however became a popular nutritional product in the

1980s causing whey to become a high value co-product. Pot ale is itself a high protein by-product. An economic high value application for pot ale has not yet been fully proven but there is significant research on-going in this area.

The challenge for each distillery is to identify a feasible route for co-products, with minimal cost and environmental impact. The use of draff for animal nutrition is well-established and not energy-intensive. Spent Lees contains little of nutritional value can generally be either discharged to drain without treatment or easily treated using conventional waste water treatments. The focus of this study is therefore pot ale because of its potential value as a co-product and because of the challenges it presents.

Key factors:

- Large volumes of high BOD liquid
- Shelf life of co-products, variable nutritional quality and uptake
- Environmental emissions
- Energy costs
- Market for co-products

1.1. Distilling in other industries/countries

Distilling is carried out throughout the spirits industry producing for example, brandy in France and rum in Jamaica. It is also carried out widely to produce ethanol for use as fuel e.g. in Brazil, using sugar cane as feedstock. The distilling industry most similar to Ireland in terms of products, climate and culture however is Scotland. Annual production in Scotland is much greater than Ireland and is in the region of 520MLA (SWA, 2014).

There are two significant differences between Ireland and Scotland which impact co-product treatment. The UK government provides a high rate of subsidy for renewable electricity and heat generation (the Irish government provides some support in this area but not at the same scale). The other significant difference is geography and the concentration of distilleries relative to the concentration of livestock. In Ireland, there is no strong concentration of distilleries in one area. The advantage of this from a co-product use perspective is that, because cattle and pig populations are spread over a lot of the country there is an easily accessible animal feed market. The disadvantage to the spread of distilleries in Ireland is that co-operative schemes like those that exist in Scotland are not feasible.

As the scale of distilleries in Scotland grew towards the end of the 19th and 20th century, coping with the ever increasing volumes of liquid co-products became more problematic. Co-operative ventures such as the "Combination of Rothes Distillers" (CoRDe) were set up to take advantage of the economies of scale for co-product treatment. CoRDe was originally set up to evaporate pot ale into pot ale syrup (PAS) for several local distilleries. The draff was added back to the PAS prior to final drying into "Distillers Dark Grains" (DDG), which was sold as an animal feedstuff. In the last few years, in order to take advantage of government incentives, a grain combustion based process producing PAS and supplying electricity to the mains has been installed at CoRDe.

1.2. Distillery co-products

Spirits are produced either by batch (or "pot") distillation processes or using continuous (or "column") distillation. Using pot distillation to produce whiskey is generally referred to as pot or malt distilling and using columns is usually referred to as grain distilling (also related to ingredients used in the respective processes). The terms used to describe the co-products vary by site. A glossary has been provided in Section 9.

1.2.1.1. Malt distilling

The co-products from malt distilling are Draff, Pot Ale and Spent Lees. A generic malt distillery mass balance for a distillery producing 1MLA of malt whiskey is shown in Figure 1.2 to indicate the scale of co-product production.

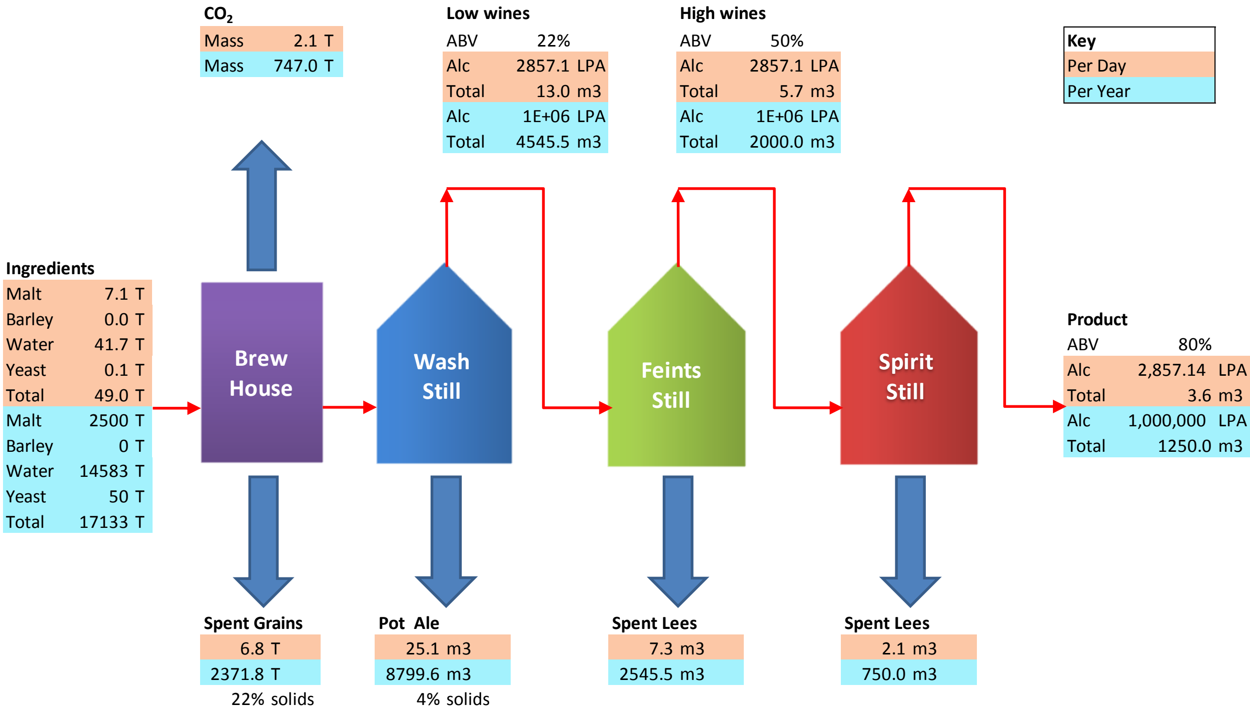

Figure 1.2 1MLA malt distillery mass balance

Draff consists of the grain solids left after starch and enzyme extraction in the brewhouse in the first stage of malt whiskey production. These are similar to spent grains produced in breweries. They are usually 20-25% solids and are 20% protein on a dry matter basis. Nutritionally, Draff is rich in digestible fibre and also contains concentrated protein and oil from the malted barley. It generally consists of 20% protein on a dry matter basis. It is moist, pale to mid brown in colour and palatable to all types of ruminant stock.

Pot ale is the residue after the first distilling stage. It is typically 4-5% solids and 40% protein on a dry matter basis. It is a golden brown liquid with a sweet malty aroma and comprises a rich blend of proteins, carbohydrates and yeast residues. Pot ale has been found to vary in exact composition not only from different distilleries but also within a single distillery (Graham et al, 2012).

Spent lees are the residue in the Spirit Still after the distillation of the foreshots, potable spirits, and feints. Spent lees have minimal nutritional value and tend to have a relatively high concentration of copper (approximately 40mg/L). They are usually combined with other effluent streams and sent to drain.

1.2.1.2. Grain distilling

The co-products from grain distilling are draff, thin stillage and spent lees. A generic mass balance for a 5MLA grain distillery is shown in Figure 1.3. Grain distilleries typically have much larger capacities than malt distilleries. Unlike in Scotland, it is quite common in Ireland for a given distillery to operate both types of process on site, producing both types of whiskey. Ingredients in grain distilling can include a variety of cereals such as wheat, maize and barley.

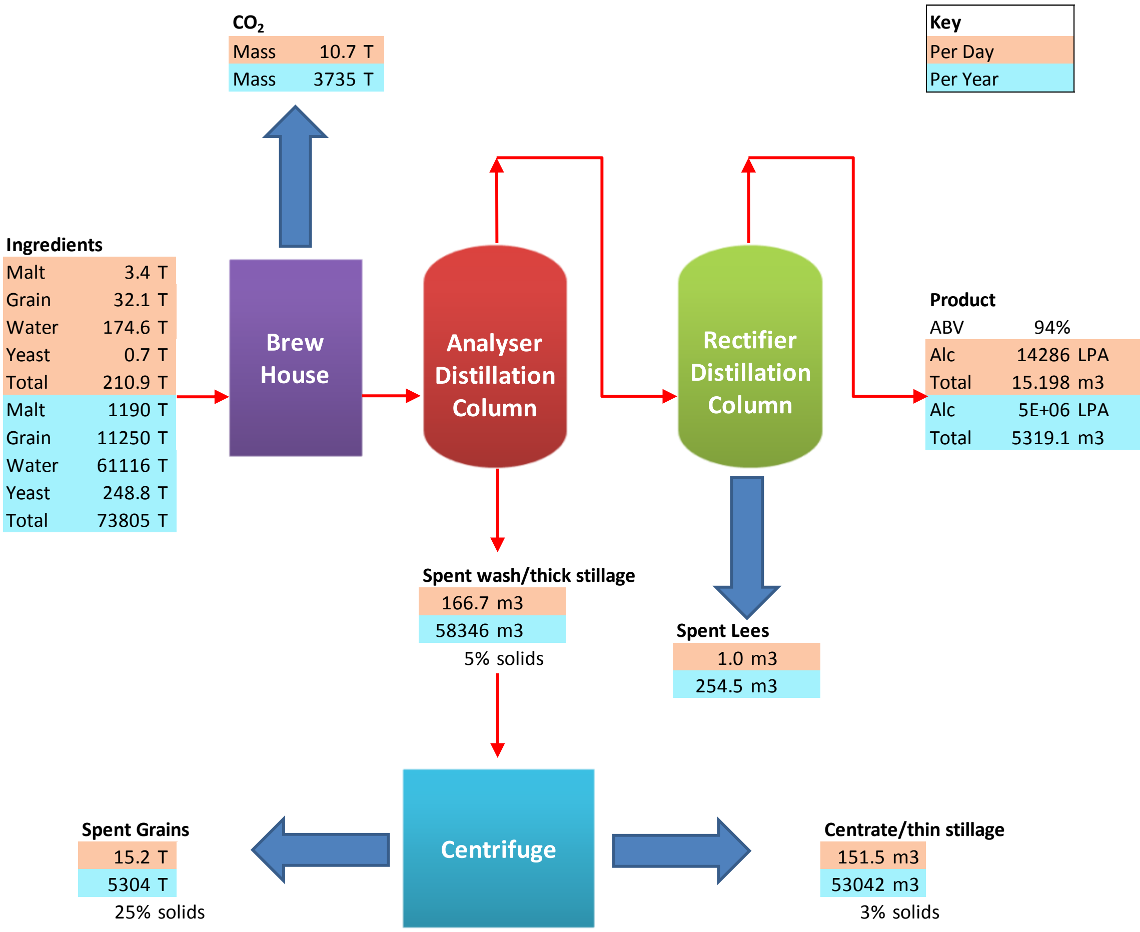

Figure 1.3 5MLA grain distillery mass balance

While grain distillery processes vary, "grains in" fermentation is common, meaning there is no separation process in the brewhouse producing draff. In this case, the liquid produced from the bottom of the analyser distillation column contains the grain solids as well as the materials which would be contained in pot ale in a malt distillery e.g. autolysed yeast cells.

Spent wash is approximately 5% solids and in most grain distilleries this is separated into two streams using a centrifuge or other mechanical de-watering device. The centrifuge cake is draff and the liquid thin stillage stream is similar to pot ale.

Although pot ale (from a pot still) and thin stillage (from a centrifuge, post distillation column) are not identical, they are similar and were treated as the same for calculation purposes in this study. Much of the autolysed yeast from the fermentation is removed from spent wash in the centrifuge, leaving the draff higher in protein than draff from a malt distillation and thin stillage with a slightly lower protein content than pot ale.

Spent lees is the residue from the Rectifier Column and is similar to spent lees produced in Malt Distilling.

1.2.1.3. Pot ale syrup (PAS)

PAS is pot ale or thin stillage which has been concentrated by evaporation to 25-50% solids. The higher the percentage solids, the more viscous and difficult to convey the syrup is. PAS is used for animal nutrition.

The benefits of syrup production are that the volume of co-product to transport is reduced and that the shelf life of the co-product is increased. Increased shelf life also increases the value of the final product.

The evaporated fraction produced when concentrating pot ale to make pot ale syrup is known as foul condensate and contains some of the volatile components of the pot ale such as trace ethanol and acetic acid. This is usually treated as per the site's emission limits and discharged to drain.

1.2.1.4. Distillers dark grains (DDGs)

Distillers dark grains are produced by drying draff and adding pot ale syrup. This mixture may or may not also undergo shaping processes e.g. pelletising. DDGs are high in undegraded protein and low in starch and are used for animal nutrition. This is a popular treatment route for large distilleries because of the increased shelf-life and thus value of the co-product.

1.2.2. Pricing of co-products

Approximate prices of distillery co-products used for animal nutrition are shown in Table 1.1. There are many factors which influence these prices e.g. the size of the distillery, the local agriculture market and the availability of competing feeds in the area.

Co-product	**Market price**
Draff (22% DM)	€20 per tonne
Pot ale syrup (35% DM)	€63 per tonne
DDGs (90% DM)	€250 per tonne

Table 1.1 Co-product pricing

There is no established market price for unconcentrated pot ale as it is not usually sold on a large scale in this format. The PAS price is equivalent to €180 per tonne DM. A price of €160 per tonne DM has been used for unconcentrated pot ale in calculations on the basis that pot ale and PAS are nutritionally equivalent but PAS has a longer shelf life and there are more established handling regimes in place.

1.2.3. Quality of effluent water

The allowable characteristics of effluent water from a distillery vary widely from site to site. Limits are dependent on several factors e.g. the capacity of local municipal treatment facilities, the proximity of a fast-moving sea outfall (and thus the dilution required), proximity to sensitive environments etc.

The main environmental parameters associated with pot ale and spent lees are shown in Table 1.2.

Parameter	Pot ale/spent wash	Spent Lees
Solids	4.5%	Negligible
Of which suspended	*1.8%*	
Of which dissolved	*2.7%*	
BOD	25,000mg/L	1,500mg/L
COD	55,000mg/L	2,500mg/L
Copper	7.5mg/L	40mg/L
Viscosity	<1cP	<1cP
pH	3.8	3.5

Table 1.2 Co-product environmental parameters

The IPPC limits for process effluent for licensed distillery sites in the Republic of Ireland are shown below in Table 1.3.

	Flow (day) m3/day	**Flow (hour)** m3/h	**pH**	**BOD** mg/L	**COD** mg/L	**SS** mg/L	**Copper** mg/L
Cooley Distillery	400	18.0	6 - 9	100	500	50	0.5
Midleton	5000	270	6.5 - 9	25	125	35	0.5
Tullamore DEW	720	-	4 - 9	800	1500	200	1
Great Northern Brewery[1]	2000	235	6 - 9	5690	10000	2500	n/a

Table 1.3 IPPC License limits for existing sites

Data for Bushmills was not readily available from UK system but the site does have a fast-moving sea outfall and license limits which would allow the site to discharge pot ale without treatment.

2. Project Description

The aim of this project is to give distilleries increased visibility on the energy consumed in production of Pot Ale Syrup and DDGs and also to investigate the most economic and environmentally friendly co-product routes. This will enable existing distilleries to optimise their processes so that they are as efficient as possible. It will also allow distilleries which are still at the planning stage, to incorporate best practices into their design and procurement, reducing the purchase of unnecessary, high cost equipment with associated high lifecycle energy cost.

The scope of the research includes well-established treatment routes, innovative methods and potential solutions that are well proven in other industries but as yet not widely used in the distillation industry. Using data gathered from existing

[1] Great Northern Brewery license information for reference only. IPPC license will be superseded by the Great Northern Distillery license (at the same site) when it is granted.

distilleries and literature, energy models for evaporator systems and other treatment routes have been generated. Each method has been costed and rated on a running cost per unit production basis for each of four distillery sizes (including grain distilling) to allow comparison. Each solution has also been assessed with respect to practicality and ease of implementation.

3. Project Management

FDT is a 100% Irish-owned, independent process engineering consultancy, based in Dublin, serving clients in Ireland, the UK, Europe and Africa. Formed in 1991, the company has a highly skilled team of engineering consultants with professional qualifications and strong technical experience that provide in-depth knowledge of process, utilities & packaging plant.

FDT serve a range of sectors, such as Brewing, Food and Dairy, Pharmaceutical, Healthcare and Chemical industries, with a variety of process engineering solutions and consulting services. FDT provide a range of Sustainability and Resource Efficiency services which help to reduce our client's operating costs and help them meet their compliance obligations.

As part of this, FDT has taken part in Cleaner Greener Production Programme Phases 1, 2, 4 and 5. These include:

- Pilot Plant for Recovery of Caustic from Spent CIP Solutions
- Diageo Dundalk Industrial Scale Spent Caustic Recovery Plant
- Galco Spent Pickle Acid Recovery and Reuse
- Galco Continuous Flux Treatment System.
- Feasibility of recovery and reuse of CO2 and water from industrial waste streams

This project was run by Aoife Hamill and Michael Clancy with support from Paul Kavanagh, John Regan, Philip Michalski, Colm Carey, Andrew Lynam, and Alan Wolstenholme (Caledonian Solutions). Aoife co-ordinated site visits and research and Michael had responsibility for liaising with the EPA, resourcing and financial reporting.

A series of project meetings were held throughout the life of the project in order to ensure that all parties were aware of progress and any new developments. These meetings took place at each major stage of the process and progress was tracked against the Gantt chart in the initial project submissions.

4. Project Methodologies

Site visits to the Bushmills, Cooley and Midleton distilleries were carried out to examine current practices. On the basis of these visits and discussions with experts, a list of recommendations with respect to efficient evaporator operation was generated.

A detailed literature search was completed with the following focus areas:

- Current co-product treatment practices in distilling worldwide
- Efficiency in evaporation processes
- Alternative de-watering methods

- Alternative uses for pot ale

The factors which impact a distillery's decision with respect to co-product treatment/handling were examined. Because of the variety of treatment routes, scales of distilleries and effluent requirements, it was challenging to effectively compare all the options available.

In order to evaluate the routes available it is necessary to establish a feasible baseline scenario for dealing with co-products from the distillery. For an existing distillery naturally the baseline scenario is current operation. For any distillery it is beneficial to gather the following information:

- How much of each co-product is produced per annum?
- Can liquid co-products be discharged to drain?
- What potential customers are available?
- How far away are the customers?
- Will customers purchase the product on a regular basis i.e. is there any seasonality?
- How much will customers pay for untreated liquid co-products?
- How much does it cost to transport the pot ale to the customer? Total cost/revenue per annum on this basis?
- How much will customers pay for treated liquid co-products? Total cost/revenue per annum on this basis?
- Practicality/ease of implementation?
- Running and capital costs associated with treatment options

Capital costs and energy requirements of available treatment routes at various scales of operation were obtained from suppliers. In order to assess the advantages and disadvantages of each treatment route, four case studies were generated for distilleries of varying sizes, activities and locations and the available routes for co-products were assessed.

5. Project Results

5.1. Review of existing distilleries

Site visits to Cooley Distillery, Old Bushmills Distillery and Midleton Distillery were completed during the project.

5.1.1. Cooley Distillery

Energy use of co-product treatments was reviewed on 17th of April 2014. Annual production is approximately 3 MLA (25% malt, 75% grain). A general outline of waste/co-product routes on site is shown below.

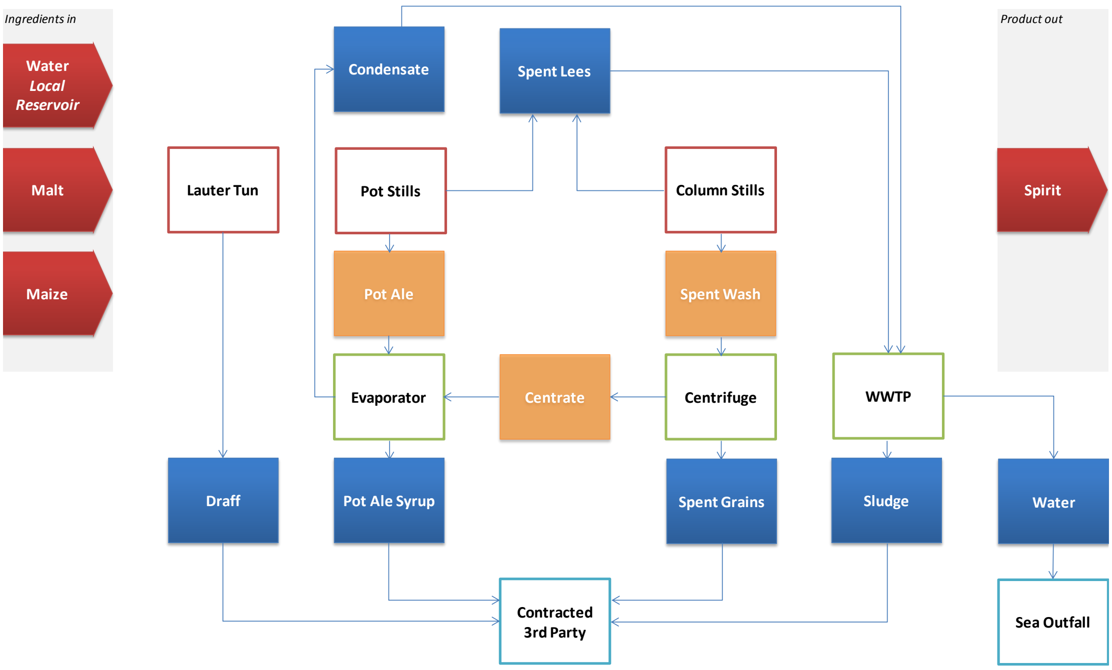

Figure 5.1 Cooley Distillery co-product treatment

5.1.2. Old Bushmills Distillery

A similar review was carried out at Bushmills on the 18th of June 2014. Annual production is approximately 5 MLA (100% malt). A general outline of waste/co-product routes on site is shown below.

Although Bushmills has access to a fast-moving sea outfall, an MVR evaporator is operated on site producing pot ale syrup.

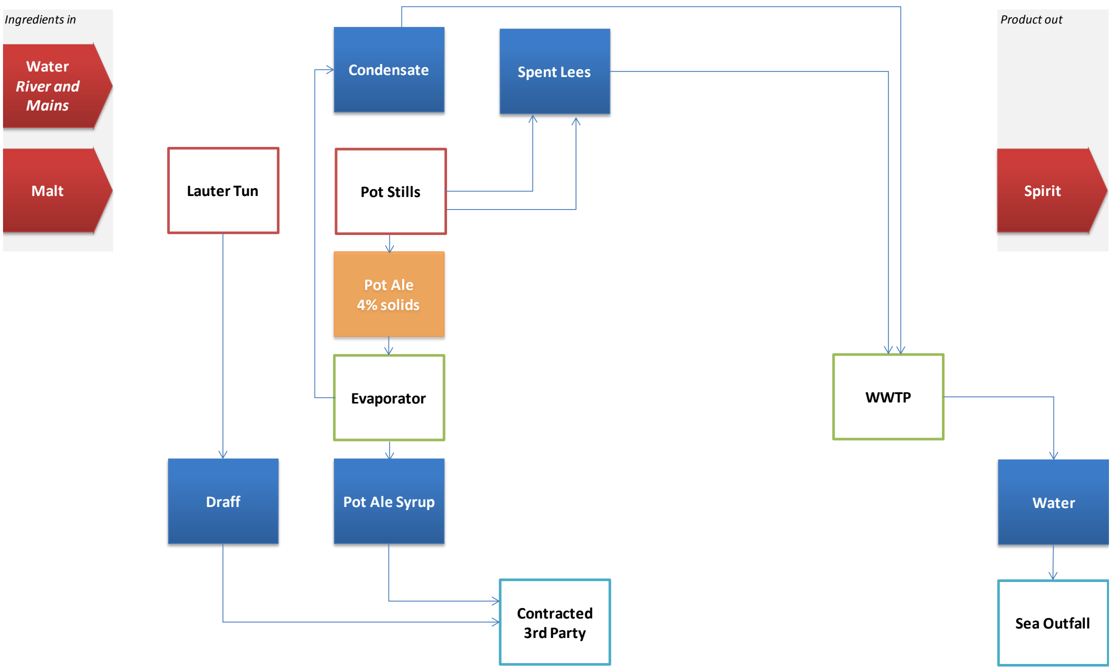

Figure 5.2 Old Bushmills Distillery co-product treatment

5.1.3. Midleton Distillery

A review was carried out at Midleton Distillery to review the operation of the evaporator on the 7th of July, 2014.

Pernod Ricard completed a large expansion project in Midleton, bringing the site's capacity to 64MLA installing new pot and column stills. Site production was in the process of ramping up at the time of the site visit. The site operates 24/7 with shutdowns in the summer and at Christmas.

The distillery has two main process streams, a batch process to produce variations of malt whiskey and a continuous process to produce variations of grain whiskey.

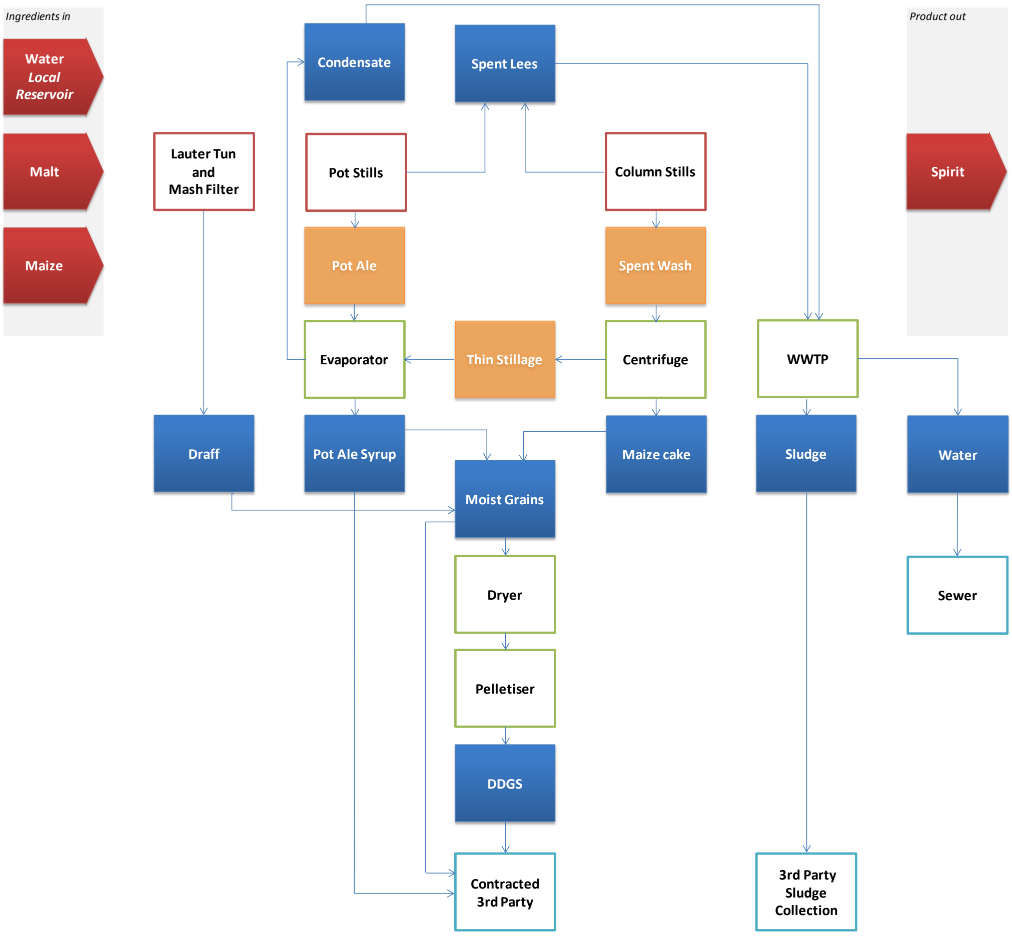

Figure 5.3 Midleton Distillery co-product treatment

5.1.4. Discussion

All three plants evaporates pot ale/thin stillage to produce pot ale syrup using MVR evaporator systems. Midleton also has DDGS plant and produces moist grains and DDGS as well as pot ale syrup. Pot ale syrup concentrations varied from 25% to 35% DM between the sites.

Metering levels vary by site. Electrical and thermal energy per tonne evaporation are not tracked as KPIs at every site.

The MVR fan is the biggest drive on each site so its usage and maintenance is monitored. As a result, it was possible to estimate electricity use per tonne evaporation for each site (ranging from 16kWh/tonne to 28kWh/tonne). Steam use was more difficult to quantify.

Reasons for varying calculated efficiencies include the following:

- High levels of fouling in the evaporator tubes
- Faulty instrumentation leading to errors in model
- Larger syrup output than estimated
- Higher % solids in syrup

All three sites reported much greater evaporation efficiency following a deep clean of the evaporator. Each site performs a caustic clean on a routine basis and completes a deep clean of the evaporator during shutdowns. This is consistent with FDT's findings from working with evaporators in related industries.

5.2. Key Consideration: Environmental Impact

5.2.1. Hierarchy of Waste

The hierarchy of waste management is an established method of prioritising waste management options and is central to EU policy in this area (Figure 5.4). This hierarchy gives substance to the obligations set out in Article 3 of the Waste Framework Directive. It prioritises the prevention and reduction of waste, then its reuse and recycling and lastly the optimisation of its final disposal.

This is the basis of identifying Best Available Techniques (BAT) for the purpose of waste management and IPC licenses with the EPA. Treatment methods for pot ale should thus be considered in this context.

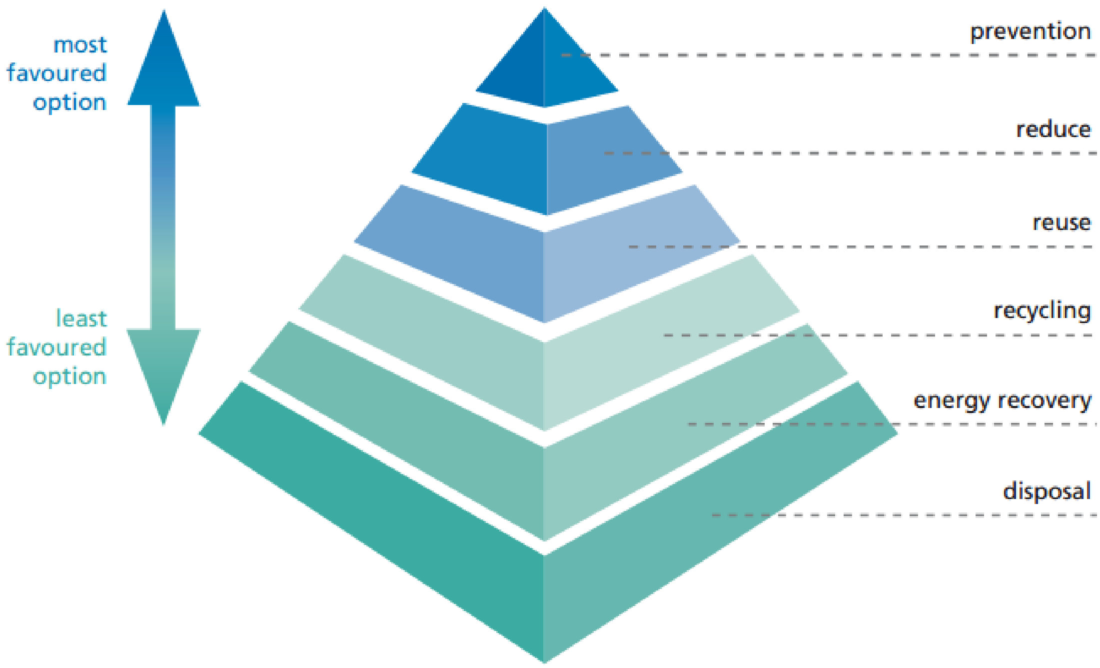

Figure 5.4 EU Waste Hierarchy

5.2.2. Circular economy

A circular economy is one which re-uses, repairs, refurbishes and recycles existing materials and products. This is in contrast to the traditional "take-make-consume and dispose" model which assumes that resources are abundant, available and cheap to dispose of.

In this model, what used to be regarded as 'waste' can be turned into a resource. The aim is to look beyond waste and to close the loop of the circular economy. All resources need to be managed more efficiently throughout their life cycle.

Moving towards a circular economy is at the heart of the resource efficiency agenda established under the Europe 2020 Strategy for growth.

5.3. Key Consideration: Impact of transport

As discussed in Section 4, geography and proximity to a market for co-products are significant drivers in treatment route selection. A transport model was developed in order to assess where the cut off lies with respect to purchase and operation of various de-watering equipment.

Two surveys of haulage companies were completed during the project where rates were procured for transporting a tanker of non-hazardous food waste to and from various locations. These costs were averaged to calculate a cost per Tkm i.e. to transport one tonne of liquid one kilometre.

The first haulier survey was in September 2014 when and the second in January 2015. An average cost per Tkm of €0.14 was calculated from both surveys. This is quite a blunt instrument to calculate the impact of transporting liquid but it does give a good approximation. In reality there are certain costs that are incurred for every journey irrespective of distance e.g. if cleaning of the tanker is required so short journeys may have a higher Tkm cost. On the other hand there may be savings available if the volumes are significant so larger distilleries may be able to negotiate with the haulier resulting in a lower Tkm cost.

The average price of diesel in Ireland has dropped 15% over this time period (€1.459/L in September, €1.240 in January, AA) but the rates quoted were the same. While it is clear that large variations in fuel prices will have an impact, this does highlight that other factors such as wages, vehicle costs, diesel rebates and regulatory instruments are also significant and the impact of varying fuel costs is not simple to quantify.

A summary table is shown in Table 5.1 including the costs and carbon emission implications for each of the sample sites of tankering all of their pot ale/thin stillage to a user untreated. These costs provide a baseline scenario for evaluating various treatment routes.

Description	**Amount of liquid T**	**Distance km**	**Cost of transport €**	**CO_2 T**
1T of liquid transported 1km	1	1	€0.14	0.0001
25T of liquid (approx 1 tanker)	25	1	€3.50	0.0019
Distillery A	968	10	€1,355	0.7365
Distillery B	4840	20	€13,551	7.4
Distillery C	62721	50	€439,048	239
Distillery D	434405	100	€6,081,663	3305

Table 5.1 Cost of tankering liquid co-products

The same € per Tkm figure was used for each distillery although realistically, this may cost smaller operations more due to the impact of part loads and lower levels of bargaining power. It should also be noted that most distilleries engage with an animal feeds merchant who will generally take charge of transport. The costs and emissions will still be incurred but not directly by the distillery in most cases i.e. the costs will be included in whatever financial arrangement is agreed between the distillery and the animal feeds merchant.

5.4. Key Consideration: Animal nutrition

The current standard route for distillery co-products such as draff, pot ale, PAS and DDGs is as an addition to animal feed rations. All sites using this route must comply with feed law and commercial assurance schemes such as the Feed Materials Assurance Scheme (FEMAS).

The feasibility of using distillery co-products for animal feeds is based on the nutritional value, the farm gate price and the local animal population. Agriculture in Ireland is quite well dispersed so there is a readily available animal feed market throughout most of the country.

According to the Irish Grain and Feed Association (IGFA) which operates in the cattle, sheep and pig sectors, the Irish feeds market was just under 2.3 million tonnes in 2008. Sheep are sensitive to copper so cattle and pigs are the main sectors to which distillery co-products are sold currently. Aquaculture is a promising sector which has been examined in some detail.

5.4.1. Comparison of co-products to other feeds

The key factors from a farmer's perspective are the dry matter content, protein content and cost.

Pot ale has the same nutritional value as PAS (on a DM basis). An animal nutrition expert advised that a similar farm gate value can be taken for pot ale syrup. The additional water does not have a negative impact from the farmer's perspective because water is also a necessary part of the animal's diet.

Table 5.2 compares the nutritional components of draff, pot ale, DDGs and common feedstuffs. All parameters (apart from dry matter) are on a dry matter basis. Thus pot ale values also apply to PAS.

Component (g/kg)	Draff	Pot Ale	DDGS	Barley	Rape meal	Soya meal
Dry matter	258	40	875	860	900	890
Crude Protein	198	350	287	115	400	530
Phosphorus	3.7	22	8.3			
Magnesium	1.4	6.6	3.3			
Copper (mg/kg DM)	10	133	83			
Metabolisable energy (MJ/kg)	10.8	14.2	24	13.2	12	13.3
Degradability of Protein	0.8	0.95	0.8			
Zinc (mg/kg)	-	18	8.5			

Table 5.2 Nutritional data for distillery co-products

The high content of crude protein in pot ale is a positive factor with respect to its use for animal feed. Its crude protein and metabolisable energy figures are also comparable with the common commercial feeds.

There is some discussion of the impact of heat treatment on the availability of amino acids in the literature (Crawshaw, 2001). This would give untreated pot ale a nutritional advantage over pot ale syrup although the uptake of MVR systems means that the evaporation process takes place at much lower temperatures.

Soya and cereals are the most popular protein sources for animal nutrition and the price of DDGs tends to track with cereal prices. Approximately 30% of the protein used for animal feeds is imported into the EU, with soya meal being the most common form (Scheiby, 2012). Soya meal prices have increased over the last few years (€427 per tonne in December 2014 (CSO) compared to €211 for barley and €277 per tonne of maize meal). In Scotland, much of the soya meal has been imported for use in aquaculture.

5.4.2. Cows

As a result of the abolition of dairy quotas and an upsurge in the global meat market, the number of cattle in Ireland has increased over the last few years leading to an increased demand for feeds. Beef processing in Ireland is expected to grow further with the news that Irish beef has been approved to return to the US and Chinese markets in 2015.

As of December 2014 there were 6.2 million cattle in Ireland (18% dairy cows). At a requirement of 9kg per head per day through a 200 day winter, Ireland's dairy herd alone has capacity to consume draff from distilling capacity of 847MLA. This is far in excess of the planned distilling capacity in Ireland. When beef cattle are taken into account (although they have lower nutritional requirements) it is clear that there is plenty of capacity for use of draff from distilleries.

Cattle can digest untreated pot ale e.g. virtually all of the crude protein can be digested in the rumen (Crawshaw, 2011). Cattle are tolerant of high levels of copper so this does not pose an obstacle to pot ale being used in their feeds. Cattle do not usually consume pot ale in its untreated liquid form; the large volumes do not generally suit their diet. The do often consume pot ale when it is processed in the form of DDGs however. Pot ale syrup can also be fed to cattle in several ways including:

- Poured onto coarse roughages e.g. hay or straw
- Self-fed through ball and lick feeders
- Blended with molasses and condensed molasses solubles

The maximum recommended portion of dietary dry matter for ruminants to come from pot ale is 10% (Crawshaw, 2001).

5.4.3. Pigs

In 2014 there were 1,550,000 pigs in Ireland located in just over 330 pig farms throughout the country; this is an increase of 8.8% on figures for 2013. The total pig population has been slowly increasing over the last few years. Almost 50% of the total pig production can be found in just three counties; Cavan, Cork and Tipperary (in decreasing order of production). Figure 5.5 shows the distribution of pigs by county.

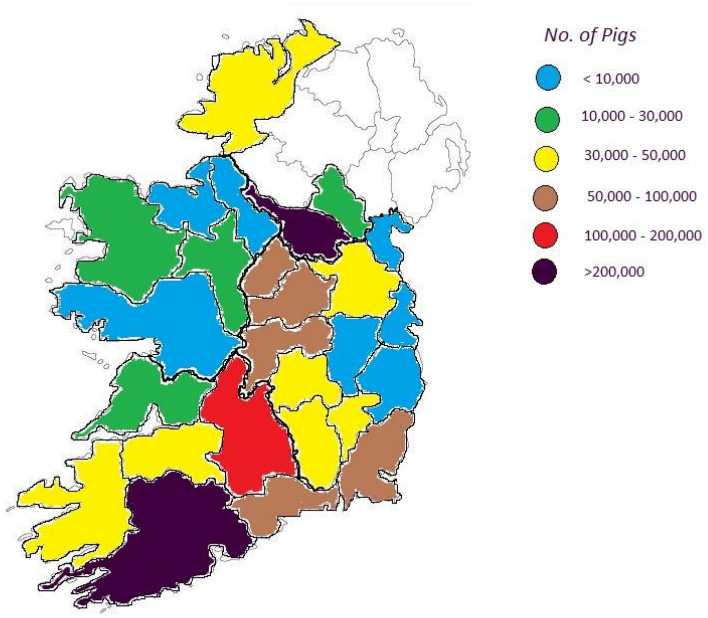

Figure 5.5 Distribution of pig population (Dept of Agriculture, 2013)

It is also useful to note that 33% of the country's pig population resides in just 2% of the farms which contain over 10,000 pigs each.

There are different nutritional requirements for growing pigs (0.5 to 3.075kg feed per day, based on size of animal, at 90% dry matter feed) and gestating/lactating sows (1.88/5.35kg feed per day respectively). A figure of 2.575kg/day which is advised for a pig in the range 50-80kg has been used to estimate the capacity for pot ale in the pig feed market. All figures are as advised by the US National Academy of Sciences (1998).

The maximum recommended portion of dietary dry matter for growing pigs to come from pot ale is 30% (Crawshaw, 2001). On this basis the maximum consumption of pot ale by one pig per annum is 1.75T (based on the pot ale containing 4% dry matter). This figure has been extrapolated to demonstrate the capacity of pig farms for pot ale and the country overall. The results are shown in Table 5.3.

	Pigs	Pot ale/y	MLA equivalent
1 pig	1	1.7	0.00018
Average farm	845	1469	0.15
Big farm	10000	17381	1.80
Ireland	1425000	2476828	255.88

Table 5.3 Capacity for use of pot ale as pig feed

As the pigs can consume the pot ale in its original form or in a dewatered state, the driving factor in deciding if de-watering is necessary is the distance from the distillery to the farm. The pairing of a distillery with an appropriately sized pig farm is thus an attractive choice if geography allows.

5.4.4. Aquaculture

Aquaculture is the farming of aquatic organisms. In contrast to the animals previously discussed, the use of distillery co-products for fish nutrition is not well established.

There are approximately 29 fish farms in the Republic of Ireland with another 15 in Northern Ireland. Several types of fish are farmed in Ireland and the most common are Salmon, Oysters and Mussels.

There is a high level of demand for Irish fish. Wild catch is restricted by quotas so the fish farming sector is growing to make up the shortfall (Bord Iascaigh Mhara (BIM), the Irish Sea Fisheries Board, 2014). As of January 2015 there were 600 applications for fish farm licences under consideration by the Minister for the Marine (Irish Times).

5.4.4.1. Pot ale for nutrition of aquatic organisms

It was found in a project carried out at Heriot-Watt University in Edinburgh that pot ale has a similar amino acid profile to existing commercial salmon feeds. A consortium from the university has formed a spin-out company, Horizons Protein. The core technology is the extraction of the yeast and barley proteins from pot ale for use in salmon nutrition. Academic literature on the project indicates that the process involves enzymatic treatment, incubation and separation by centrifuge. The resulting feed is then freeze-dried for transport to fish farms. This is a higher level of processing than is performed in production of pot ale syrup and the resulting co-product has a higher value.

As it has been shown that pot ale has a similar profile to salmon feeds it begs the question, can untreated pot ale be fed directly to fish? At present, much of the feed used in aquaculture is imported so the introduction of a locally produced option has the added environmental benefit of reducing the feed transport required. Pot ale itself does not contain sufficient lipids to provide 100% of fish nutrition so it would need to be used in conjunction with another feed (common practice at present).

According to BIM, liquid feeds are unusual and are generally not used as the primary feeds in fish farms. This is due to the majority of fish farming being carried out on open waters. The fish are contained inside nets and it is likely that the liquid would disperse too quickly for the fish to consume the nutrients.

Liquid feeds are however used in the larva / hatchery stages of fish development. When fish are in this early stage, they are stored inside closed vessels. The market for pot ale for this application is limited because of the limited nutrition requirements of small fish at this stage of development but the fact that liquid feeds are used here is promising in general in terms of using pot ale as a liquid fish feed in an enclosed environment.

The possibility of using distillery co-products for nutrition of algae was also mooted by Geoffrey Robinson of BIM. Algae are a large group of plants that grow in water. The most commonly cultivated algae are seaweeds. Uses for algae include as a feedstock for biofuel/biorefinery applications, nutrition and also pollution control.

Algae are very simple to grow. At present, all Irish farms obtain their seaweed from naturally occurring batches found around the coast of Ireland so nutrition of algae does not incur any cost for the business. This model limits the economic use of distillery co-products for nutrition of algae. Cultivation of algae is a growth area however so as the market develops the use of distillery co-products should be considered.

Nutrition of microalgae is also a potential application for distillery co-products. Microalgae can be used to produce biofuels and also high-value products, such as cosmetic ingredients and nutritional supplements. In addition, they can be used to clean nutrient-rich waste water or capture CO2 from power producers.

At the moment, most of the world's algal biofuel production remains at the demonstration scale and there is very little commercial activity. There is no large scale cultivation in Ireland but a significant level of research is on-going.

A demonstrator has been installed at the Glenturret Distillery in Perthshire (Scotland) by Scottish Bioenergy Ventures (Aylott, 2010). The aim of the project is to capture CO_2 produced by the boilers and to clean waste water from the site (spent lees), producing microalgae which will initially be sold as protein-rich food for fisheries. In the future, it is planned to use the algae to produce other high value products and to feed the residues to an anaerobic digester. Each tonne of microalgae absorbs two tonnes of CO_2 so this area has strong potential from an environmental perspective.

5.4.4.2. Golden Fish Project

One example of a distillery becoming involved in aquaculture is the Midas Distillery located in Tamilnadu, India. The distillery (now owned by MBDL) developed the "Golden Fish Project" in order to deal with its co-products and effluent streams in conjunction with an anaerobic digestion system.

The distillery has a capacity of approximately 12MLA and its fish farm produces 100 tonnes of fish per annum.

5.4.4.3. Economics

Some common fish feeds and their prices per tonne in 2014 are shown in the table below.

Fish feed	Price per tonne
Fish meal	€1,600
Soya bean meal	€427
Aller Gold	€1,250

Table 5.4 Fish feed prices

Each of these feeds is approximately 90% dry matter so the costs equate to a range of €470 to €1,775 per tonne DM. Pot ale in contrast is sold at approximately €180 per tonne DM.

It is predicted that when the new tranche of fish farms are commissioned 15,000 tonnes of farmed salmon will be produced in Ireland per annum. The average weight conversion for fish is 1kg of weight gain for every 1.2 kg of protein. Thus the amount of feed needed per year is 18,000 tonnes on a protein basis.

On the basis of the salmon feed consumption figures and the nutritional figures in Section 5.4.1, the salmon industry in the Republic of Ireland could utilise pot ale from production of 142MLA of spirits. If fish farms were to be enclosed in some way (e.g. fish in tanks) this could increase the viability of using pot ale as feed.

Clearly management of this type of scheme would need to be closely regulated to ensure that the pot ale was being consumed by the fish and not discharged to the marine environment. Different types of fish feed in different ways and recognise different substances as food; this would need to be taken into account.

80% of Irish salmon is organic and organic salmon feed is one of the most expensive feeds in the world according to BIM. If it were possible to certify pot ale as organic this would add substantial value to the co-product. If however it is not possible, this limits the market for use of pot ale for fish nutrition. Sustainability is a significant driver in the fish industry however so this is a point in favour of pot ale. It is also positive from this perspective that all cereals used in the EU are GM free and fully traceable.

5.5. Treatment routes

5.5.1. Minimal treatment

With no on site treatment, the potential routes for pot ale are as follows:

- Discharge to sea
- Animal feed
- Land spreading
- Discharge to sewer

Clearly, minimal on site treatment is the most economic option from a capital investment perspective. All that is required is sufficient storage capacity. It is also attractive from an energy/running costs perspective. The main barrier here is the existence of a suitable pot ale customer or outfall option.

5.5.1.1. Discharge to sea outfall

Distillery waste can have both positive and negative impacts on aquatic life. Negative effects include a lowering of the PH (acidification), an increase in COD and BOD which may be harmful to life in the area, a depletion of the oxygen content as a result of this, the water may become discoloured or may smell bad which may impact both aquatic life and the tourism industry.

The key factor is the availability of a suitable outfall to the distillery. Suitability depends upon the following key factors

- local tidal conditions
- current profiles
- depth of the sea floor
- volume of pot ale for discharge

If the current is sufficiently fast-moving, the pot ale will disperse quickly and have no harmful effects. Several distilleries located on the island of Islay in Scotland discharge their pot ale to sea outfall because the local currents are sufficient to allow this. Few locations in Ireland are suitable from this perspective. As is demonstrated in Figure 5.6, the highest velocities in Irish waters occur off the coasts of northern Donegal, Derry and Antrim and eastern Wicklow and Wexford.

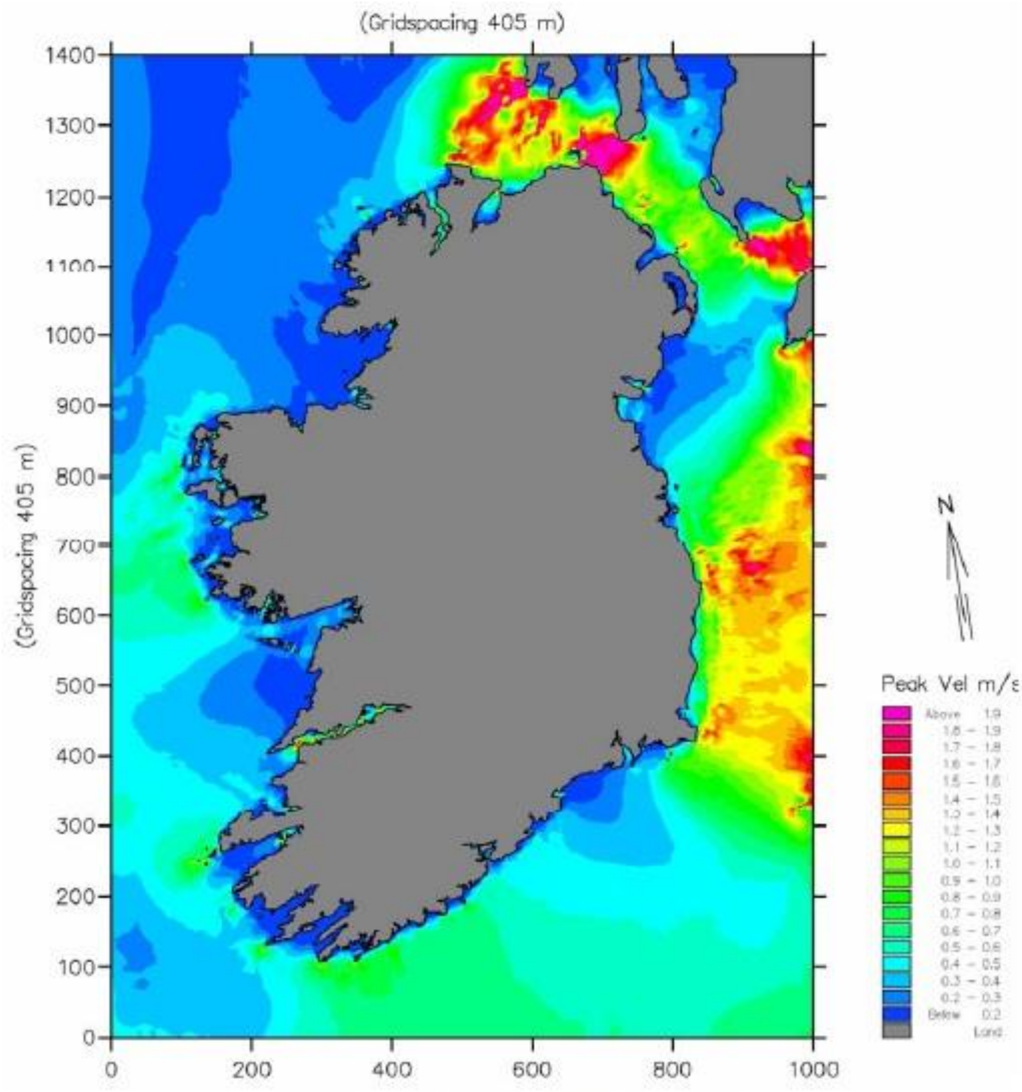

Figure 5.6 Depth averaged peak spring tidal currents (SEAI[2])

Discharge to sea can be a cost-neutral option. The material is arguably returned to the food chain with minimal energy expenditure so it is an environmentally positive option (assuming sufficient dispersion occurs) but no revenue is gained by the distillery.

5.5.1.2. Land spreading

Land spreading of pot ale is commonly practised in Scotland. Pot ale and thin stillage contain nutrients which are essential to plant growth: nitrogen, phosphorus, potassium, magnesium, calcium, sulphur, sodium. Also present are cations, free amino nitrogen, glucans, carbohydrates, unused sugars, amino acid peptides and polyphenols.

The Food Safety Authority of Ireland (2004) conducted a study on land-spread organic industrial waste in Ireland to find that the brewing/distilling industry accounted for 28,487 Tonnes (5.75%).

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[2]Tidal Current Energy Resources in Ireland Report, SEAI

According to the Irish EPA (2004), land spreading should coincide with the growing season so that the nutrients applied will be utilised by the growing crop and should be avoided when soil conditions prevent infiltration or when heavy rain is forecast within 48 hours.

The main advantages and disadvantages of the use of these co-products as fertilisers are listed below.

Advantages	Disadvantages
• Recycling of a potential waste product • Increases phosphorus and Nitrogen content in soil • Significant improvement in physical properties of the soil: Mean weight diameter, saturated hydraulic conductivity, water retention, available water content. • **Has been found to suppress heather growth.**	• Salts and heavy metals present: Ni, Cd, Pb, Zn, Cu, Cr • Ammonia, methane, CO2, Nitrous Oxide • Pathogens: Bacteria, Virus, Protozoa. High BOD and COD • Odour nuisance • pH adjustment required • Run-off can be difficult to control

5.5.1.3. Discharge to sewer

Few distilleries can put liquid co-products to drain un-treated because of their high oxygen demand. The cost of discharge to sewer varies widely from site to site depending on the distillery's contract with the local council.

5.5.2. Mechanical de-watering

With a mechanical dewatering process, the underlying advantage is that the water is removed in the liquid state. The lack of a phase change renders the process less energy-intensive and in some instances may improve the end-product quality.

Various established de-watering methods were investigated using literature data and discussion with suppliers. Trials are advised for individual sites to prove feasibility prior to capital investment.

Most mechanical de-watering methods have minimal impact on dissolved solids. The finer the filtration required the greater the capital and running costs. This must be balanced against the value of the concentrated product or the value of recovered water.

5.5.2.1. Centrifuge

The technology of centrifuges is well established and they are popular for many applications in the food industry. They are very effective at removing suspended solids but have much less of an impact on dissolved solids. Centrifuges are very commonly used in grain distilleries to separate draff from spent wash.

Centrifuges can remove suspended solids from streams with 4 to 20% dry solids and usually produce a centrifuge cake of 24 to 26% dry solids.

Energy usage will vary by manufacturer and model. An average electricity usage of 3.5kWh per m3 of water removed from the stream has been used for calculations in this study based on quotations received.

Centrifuges have typically lower footprints than some other mechanical de-watering methods such as belt presses for instance. Another advantage is that they require minimal operator intervention and cleaning compared to some other methods.

A supplier advised that one Scottish distillery is using a centrifuge on pot ale prior to feeding to an anaerobic digestion plant. The supplier also noted that in trials carried out by the company that "the separation was challenging" and that it was necessary to oversize the equipment. Final solids contents of approximately 25% were found to be achievable but larger centrifuges were required than for a similar volumetric flow with a higher solids content.

5.5.2.2. Mechanical press

There are several types of mechanical press available e.g. belt press, screw press, filter press. All of these technologies are well-established and have been used in the treatment of draff/spent wash. Of the three, belt presses would be slightly less robust.

Filter presses in particular are suitable for a wide range of feed moisture contents and can increase cake dry matter concentration from 5 to35%.

5.5.2.3. Membrane filtration

While some sites do use forms of membrane filtration for their pot ale, there was little confidence from suppliers contacted that this was a viable option without significant pre-treatment. One supplier communicated that while several confidential studies have been carried out on membrane systems to process pot ale, a successful solution has not been identified. Reasons outlined were as follows:

- Membrane blockages from starch, fibre and contaminants
- Very large membrane areas were required with large single use CIP volumes so there was no benefit from an environmental perspective.
- The membrane process was not a good alternative to the thermal process as the source product was too unreliable leading to high operating costs.

A complete process line solution was tested 6 years ago by another supplier. Several membrane process steps were put in series to be used as a complete new waste water solution. It was found that the operating costs (cleaning and energy costs) made the project unviable.

Ceramic membranes are used in the brewing industry for purposes such as beer recovery from yeast. They are more robust than traditional organic membranes and one supplier offered a proposal where through a sequential process with reducing pore size, pot ale or thin stillage would have its dry solids content reduced from 4.5% to 0.04%.

An advantage to membrane treatment is that dissolved solids can be removed and that a low COD effluent can be produced (413mg/L estimated by supplier). The disadvantage to this kind of system is that it is quite capital intensive and the "high solids" fraction tends to be quite dilute (approximately 10% on average) i.e. the amount of low COD effluent is low relative to some other treatment routes and the distillery must still deal with a relatively large high COD fraction.

It is possible to add substances to improve water recovery from membrane separation processes e.g. if a basic material is added, acidic materials are converted to water and salts which come out of solution. The downside with this type of action is that it may render the retentate unsuitable for consumption by animals.

The average cost of water for business in Ireland is €2.38 per metre cubed (the combined (water and waste water) charge per cubic meter of water across Irish Local Authorities). Wicklow is the most expensive location for water services at €3.04 compared to just €1.59 in neighbouring Kildare[3].

In a 2011 EPA CGPP study it was concluded that the low cost of water in Ireland does not encourage companies to proceed with water recycling projects, particularly for water recycling involving membrane filtration, which is an expensive technology[4]. Water rates have not increased sufficiently in the intervening time period to justify large investment in water recovery.

5.5.3. Thermal de-watering

5.5.3.1. Evaporation

Evaporation is the most common treatment method in use (in conjunction with mechanical dewatering). While it is relatively energy intensive, it is sometimes a practical choice based on the scale of the distillery and the geography of its location.

Evaporators are usually utilised to bring the solids concentration of the pot ale from around 3.5 – 6% up to 30 – 50%. There are several evaporation technologies available, each with different operating limits.

The most efficient method for evaporation for medium to large scale processes is Mechanical Vapour Recompression (MVR). This system works by compressing the vapour using a mechanical device and using the resulting higher pressure vapour to evaporate the incoming feed. This technique requires only enough energy to compress the vapour because the latent heat energy is always re-used. Once the system is running, in theory no further steam is required.

Falling Film Evaporation in conjunction with MVR is the most popular evaporation option at present. Falling Film Evaporation can bring solids to approximately 35% economically. If a higher concentration is required Forced Circulation Evaporation can be used to increase it to between 40 – 50% solids matter.

Forced circulation evaporators tend to be more economic for higher viscosity liquids and have the further advantage of reducing residence time of the liquid in the tubes. With less viscous liquids, the extra pumping cost associated with forced circulation does not add sufficient benefit.

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[3] National Competitiveness Council, Costs of Doing Business in Ireland 2014

[4] Murray et al (2011) EPA CGPP Recovery & Reuse of Water and Carbon Dioxide from Industrial Waste Streams

For a distillery using an evaporator to produce pot ale syrup, the final concentration should depend on an economic balance of the energy input required versus the transport costs. Energy efficient operation of evaporators is discussed in detail in Section 8.

Evaporator condensate is usually sent to drain (via treatment depending on site limits). It is a good source for heat recovery and a possible source for water recovery e.g. by membrane treatment as discussed in Section 5.5.2.3.

5.5.3.2. Dryers

Drying is a very energy intensive process, using approximately 16 times more energy than removing water using an evaporator (IBD, 2009). For this reason it is preferable to maximise water removal by other methods and to only use dryers when very high dry matter concentrations are required i.e. in the production of DDGs.

While dryers are energy intensive, it is possible in some cases to recover heat and use this in conjunction with the evaporation process. Similarly to evaporation, drying produces a condensate stream which could provide a water recovery source.

5.5.4. High-value/alternative co-products

A search of patents and other activities in the area of distillery co-product use was performed in order to identify any innovative treatments or high value products which can be recovered from co-products.

5.5.4.1. Bioethanol (2nd generation)

Feedstock for ethanol generation and further biorefinery products is a promising area. In a study at the University of Abertay a yield of 7.7g ethanol per 100g of spent grains treated was calculated (Yohannen et al, 2012).

Bioethanol may be used as a chemical or as a biofuel. The final use will determine the production process selected e.g. on the basis of purity required.

Production of bioethanol from lignocellulosic co-products is known as 2nd generation bioethanol. The feedstock is first broken down to constituent sugars by hydrolysis with the use of heat, acid, or enzymes and then fermented.

Environmentally, 2nd generation biofuels of this type are beneficial because they use crop residues or by-products from other processes rather than using wheat for example which could otherwise be used for food. As a result there is significant funding support available and this is an active area of research and development with plants such as the Beta Renewables facility at Crescentino in Italy being constructed. The challenge in this area is to bridge the gap between the cost of the energy/material input and the energy in the product.

In a feasibility study for Balmenach Distillery in Scotland in 2010 it was noted that the gross energy recovered from production of bioethanol from draff is a fraction of the energy input. For this reason, the use of co-products for feedstocks for higher value products may be more feasible e.g. lactic acid as discussed in Section 5.5.4.

5.5.4.2. Biobutanol

Similar to bioethanol, biobutanol may be produced by hydrolysis and fermentation of distillery co-products and may be used as a chemical or as a biofuel. Celtic Renewables in Scotland were in the process of commissioning a pilot plant to produce butanol and acetone at the time of writing.

5.5.4.3. Lactic acid

Using a similar pre-treatment process, spent grains and pot ale can be used to produce lactic acid. Cellulac, an Irish company, are constructing a plant in Dundalk to produce lactic acid from second generation feedstocks including draff and pot ale.

5.5.4.4. Succinic acid

Succinic acid is used as a supplement in the food and beverage industry, primarily as an acidity regulator. It is also used in the production of some specialized polyesters.

Similarly to other biorefinery products discussed, succinic acid can be produced in fermentation. Several patents have been filed on the subject of producing succinic acid by fermentation of spent wash as there is a demand to produce it in a more sustainable manner.

5.5.4.5. Protein products/yeast extracts

Pot ale is high in protein so recovery of this for other uses is a promising area.

In one example, Glenfiddich Distillery installed a plant in the 1960s to grow single cell protein (SCP) using distillery co-products as feedstock. SCP typically refers to sources of mixed protein extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria (grown on agricultural wastes) used as a substitute for protein-rich foods, in human and animal feeds. This plant is no longer in use having failed to achieve reliable economic operation.

Protein recovery for use in fish nutrition was discussed in Section 5.4.4.1. Another area in which protein extracts could be useful is in yeast nutrition products (e.g. Fermaid). Spent wash has historically been used for yeast nutrition at distilleries in Scotland in conjunction with urea and ammonium salts.

A project at Teagasc Food Research Centre (Moorepark) has developed a hydrolysed yeast extract flavour ingredient called Carbelac YE using whey protein. Pot ale protein could similarly be used as feedstock.

A study is on-going in the UK to recover yeast protein from bioethanol spent wash. The goal of the project is to produce a high protein supplement that can be used in diets for pigs and poultry and to reduce the UK's reliance on imported proteins such as Soya Bean Meal.

5.5.4.6. Polyphenols

Polyphenols are naturally occurring compounds which are present in plant material and are known to have a range of useful properties

The main raw material in producing whiskey or other grain spirits, barley, is a relatively rich and consistent source of these polyphenols which have a range of antioxidant and other positive effects. Polyphenols give fruit, vegetables and grains their distinctive colour and contribute significantly to their health promoting properties.

Evidence of their role in the prevention of degenerative diseases such as cancer, neurological and cardiovascular diseases is emerging and this is an area of much research and innovation. They are used in a range of industries, including healthcare and food processing. The global market for polyphenols is expected to reach €824 million by 2020, according to a recent study (Grand View Research, 2014).

FDT Consulting Engineers has secured European Commission funding for a €1.6 million CIP Eco-Innovation project, PUReOPE, (Process for Upgrade and Recovery of Polyphenol Extracts). This project aims to develop a business that uses new methodologies to extract high-value polyphenol compounds from waste in brewing, malting and cereals production.

The PUReOPE process offers an environmental benefit to the distillery through the reduction in wastewater emissions and treatment requirements. This is because polyphenols, due to their anti-bacterial, anti-viral, antifungal and antioxidant nature, can inhibit conventional wastewater treatment processes.

The project (running from 2014-2017) will include an industrial-scale demonstrator, which will be built and tested on a handful of brewing and distilling sites across Ireland to produce a polyphenol extract fit for human consumption.

5.5.4.7. Food ingredients

There are several patents on the subject of recycling distillery co-products for use as food for human consumption e.g. using draff as an ingredient in production of wheat bread, rye bread, sausages and sauces[5], nutraceuticals, breads, milk beverages, textured soft drinks, non-alcoholic beverages[6] and flavours[7].

Palatability can be an issue with some co-product foods. Pot ale for instance has been reported to have a "burnt" flavour.

Irish Craft Brewery N17 in Tuam have produced biscuits for both dogs and humans using brewing spent grains and have looked at a number of alternative uses for their co-products.

5.5.4.8. Cement adjunct

The use of distillery spent wash as an adjunct in cement production has been investigated by several parties. It is unclear in some cases if the main aim is to find a way to dispose of the spent wash or to use spent wash because its properties are beneficial. Properties of spent wash which are beneficial for this application are that it is acidic and can be used to neutralise lime which is alkaline and one patent[8] for eco-friendly cement cites that melanoidin present in the spent wash can act as a binder in the manufacturing process

[5] Use of stillage from alcohol production as functional ingredients in food, 2003, EP 1358807 A2

[6] Food Products, 1999, WO 1999008547 A1

[7] Product and process of making a product flavoured using a by-product of alcohol production, 1992, US 5316782 A1

[8] Green cement for sustainable construction, 2010, WO 2012010936 A1

5.5.4.9. Commentary

Bioethanol and biobutanol for instance can be used as biofuels. Energy recovery is near the bottom of the waste hierarchy pyramid so this is an unattractive option from an environmental perspective. While there is much activity in the area of second generation biofuels, the production of higher value biochemicals is more economically feasible.

The high value/alternative co-product routes listed are not well established but some are promising. A combination of sequential recovery processes in the form of a biorefinery, with energy recovery from residual waste streams may provide the most attractive route for co-product treatment. Water recovery could also be a possibility in this case. Prices for energy, water and biorefinery products all impact the feasibility of such a project.

5.5.5. Energy recovery

Energy recovery can be achieved through several treatment methods:

- Anaerobic digestion, producing methane for combustion
- Combustion of dried co-products
- Use of co-products as feedstock for biofuel production (see discussion on bioethanol and biobutanol in Section 5.5.4).

5.5.5.1. Combustion

Combustion of co-products is popular in the UK. There are a number of reasons for this but chief among them is an incentive structure which encourages renewable energy, including biomass combustion.

In order to efficiently combust biomass, the higher the dry matter content the better (at least 45%) so that the latent heat required to vapourise the water is minimised. The biomass must also be dried in as efficient way as possible to make the whole process economically viable. Combustion of biomass can be challenging technically particularly where there is variation in feedstock consistency.

The attraction of combustion, if successful, is that the distillery insulates itself from exposure to energy price fluctuations as it affects both spirit and co-products. There are also benefits from using low carbon energy. While combustion to produce electricity certainly has lower carbon emissions than alternative routes which use fossil fuel energy (e.g. evaporation using grid electricity), it is energy recovery rather than recycling and is thus lower down the waste hierarchy (Figure 5.4).

The "food for fuel" debate is also a factor in this instance. Is it ethical and/or sustainable to incinerate substance rich in protein and other potentially valuable by-products which could feasibly be returned to the food chain or have a medical use?

Below are some examples of plants combusting distillery co-products:

- Diageo Cameronbridge Grain Distillery (110MLA) in Scotland: A large biomass CHP plant and water recovery system was also installed

- Diageo Roseisle Distillery and Maltings (10.8MLA) in Scotland: A mix of spent grains, pot ale solids and maltings waste are dried using a steam drier and the biomass is then combusted using a moving grate burner

(Jappy, 2012).

- Helius CoRDe biomass plant, Rothes, Scotland: Cooperative venture which takes in 115,000 tonnes of wet draff per annum from local distilleries in Speyside. The draff is mechanically de-watered and combusted along with woodchips to provide 7.2MW of electricity to the grid. The plant also contains a 66.5T/h evaporation plant.

- Glenlossie bioenergy plant, Scotland: Two distilleries (Glenlossie and Mannochmore) share this plant outside Elgin. Draff is taken in from various distilleries, reslurried, put through a filter press and then co-combusted with 10% woodchips to produce steam for the distilleries and dark grains plant.

5.5.5.2. Anaerobic digestion

Anaerobic digestion is the breakdown of organic materials in the absence of oxygen producing biogas, sludge and waste water (which usually requires aerobic treatment prior to discharge). The biogas can be used to produce electricity, steam or hot water (or a combination thereof) depending on site requirements or can in some cases be fed directly to the grid. Anaerobic digestion usually reduces liquid COD by approximately 90%. It depends on specific site conditions whether this is suitable for discharge. It may also possible to recover this water for re-use e.g. using membrane filtration.

The major advantage of anaerobic digestion versus combustion is that it is suitable for wet biomass i.e. there is no efficiency loss associated with drying or otherwise removing water from co-products. Anaerobic digestion operates at a relatively low temperature (approximately 38°C) so there tends to be no heat input required by the distillery. The co-products are warm as a result of the process and as previously noted, distilleries usually have an excess of low grade heat available.

It is possible to anaerobically digest both liquid and solid co-products and produce biogas but the residence times required for draff are extremely long (60 days relative to 3 days for liquids). This increases the volume required (and thus capital expenditure) significantly.

Anaerobic digesters tend to have quite a large footprint and require significant capital investment. This means that it is not generally feasible for small distilleries. The level of capital investment required is quite high. One supplier indicated that at current government incentive levels, the lowest capacity distillery which would be feasible for on site anaerobic digestion in Ireland would be 3 to 4MLA. In contrast to this, they advised that 1.5MLA is the smallest feasible capacity in the UK.

The main advantages and disadvantages associated with this treatment option are summarised in Table 5.5.

Advantages of AD	Disadvantages of AD
• Insulates the distillery from increases in energy prices and renewable/carbon incentives.	• Large footprint requirements • High capital cost • From an environmental standpoint energy recovery is less preferable than use of the co-product for animal nutrition.

Table 5.5 Advantages and disadvantages of anaerobic digestion

Some examples of existing anaerobic digestion plants using distillery co-products as feedstock:

- Roseisle Distillery (Diageo), Scotland: Plant produces biogas which contributes to the site's energy load and warm recovered water for use in its adjacent maltings. The water is treated using membrane filtration post anaerobic digestion.

- Revico treatment plant, Cognac, France: Cooperative venture treating vinasse from approximately 140 distilleries. The plant produces 20Gwh of biogas per annum and injects into the grid.

- Bacardi, Puerto Rico: Produce biogas from vinasse from rum production and fires in boilers on site. Apart from the energy savings, it is beneficial to the plant to reduce the amount of oil and gas which must be imported to the island.

- Girvan Distillery (William Grant & Sons), Ayrshire, Scotland: Plant produces 25MWh of heat and 60MWh of electricity per day.

- Dailuaine Distillery (Diageo), Speyside, Scotland: Spent lees and washing water from the distillery are digested as well as liquid co-products from other local distilleries. Electricity is fed back to the grid and heat generated is used in the distillery.

- North British Distillery, Edinburgh: Plant has capacity to produce 3.4MW electricity and also produces steam for use on site. A portion of the waste water stream post digester is recycled.

5.5.5.3. Government subsidies for renewable energy in Ireland

The REFIT scheme was announced in Ireland in 2006. The aim of the scheme is to promote renewable energy and make it cheaper to bring to market. The Scheme does this by offering a feed in tariff to producers of renewable energies for each unit of electricity that they feed to the grid. The level of money given to the producers depends on the technology they are using. Unlike similar schemes in the UK for instance, should the renewably energy be used by the producer, no remuneration will be provided i.e. subsidies are by way of feed in tariffs only.

In order to qualify for the REFIT schemes there has to be planning permission for the type of technology to be built. Each REFIT project requires its own meter in order for feed in tariffs to be calculated off units of electricity exported to the grid.

These feed in tariffs are linked with the consumer price index. The maximum amount of time that a project can benefit from the REFIT scheme is 15 years.

Technology	2014 Tariff €/MWh
Large Wind >5MW	69.581
Small Wind <=5MW	72.023
Hydro	87.892
Biomass Landfill Gas	85.451
Biomass Combustion	89.136
Biomass Combustion - Energy Crops	99.623
Large Biomass CHP >1.5MW	125.839
Small Biomass CHP <= 1.5 MW	146.812
Large AD Non CHP >0.5MW	104.866
Small AD No CHP <=0.5MW	115.353
Large AD CHP >0.5MW	136.326
Small AD CHP <=0.5MW	157.299

Table 5.6 REFIT tariffs

Average industrial energy prices for varying levels of usage (SEAI, October 2014) are shown in Table 5.7 (information for higher band users is available). Whether or not it is in the distillery's best interest to use all power generated on site or to feed it to the grid is dependent upon the relationship between the REFIT figure and the site's electricity rates.

Electricity		Natural gas	
Band	**€/MWh**	**Band**	**€/MWh**
Band IA	208.3	Band I1	60
Band IB	178.3	Band I2	50.2
Band IC	150	Band I3	45.2
Band ID	127.8	Band I4	35.2

Table 5.7 Average industrial energy prices

5.6. Comparison of treatment methods

Quotes and energy usage data were obtained for each type of conventional treatment. In order to compare these, the following ratio was calculated for each:

1. Capital cost per m3 feed

2. Thermal energy consumption per m3 water removal

3. Electrical energy consumption per m3 water removal

This provides a useful method of comparison for treatment methods in order to estimate the scale of investment required. Specific capital costs for various methods are shown in Figure 5.7.

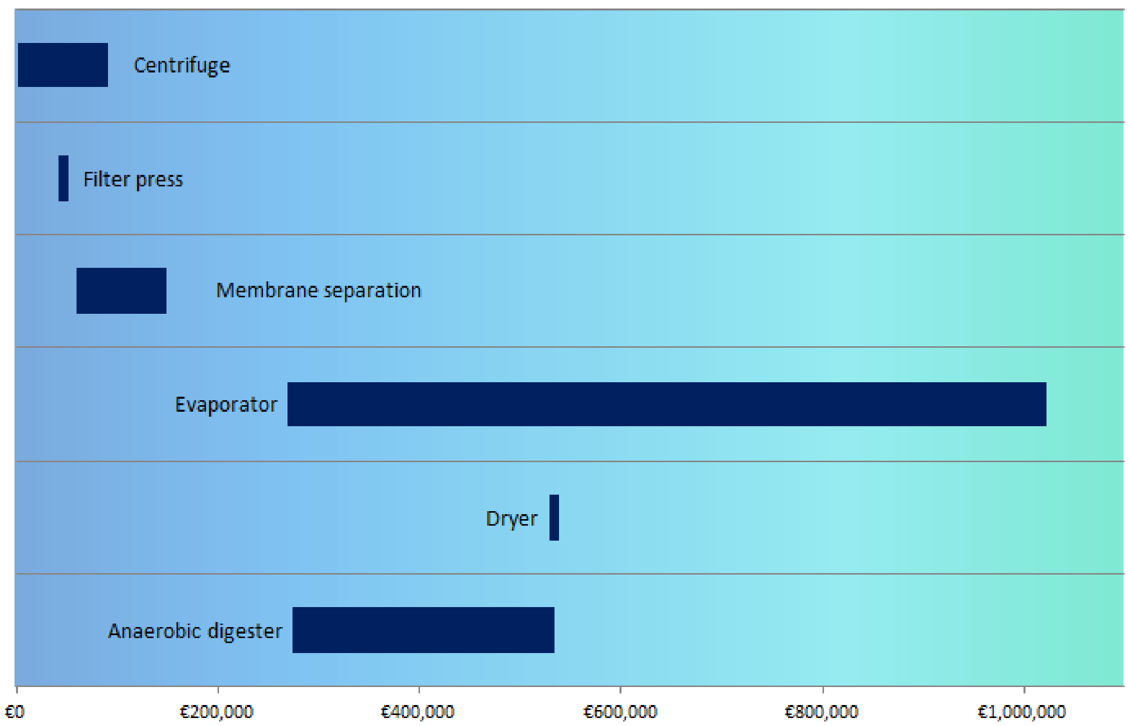

Figure 5.7 Capital costs per m3/h feed

Unsurprisingly, the economy of scale is a significant factor with equipment such as evaporators and anaerobic digesters. Variations in evaporator pricing also occur because of the different types of evaporator available and varying assumed feed temperatures. In general it was found that evaporation was a cheaper route than anaerobic digestion from a capital cost perspective.

It was also the case that some quotes had a greater scope of supply e.g. some included for all associated equipment, pipework, instrumentation and control whereas others quoted for the evaporator itself only.

The specific energy consumption range calculated for each treatment method is shown in Figure 5.8. It should be noted that figures well in excess of 900kWh/T evaporation were quoted for some dryers but in order to make the graph easily readable the axis was capped at 900.

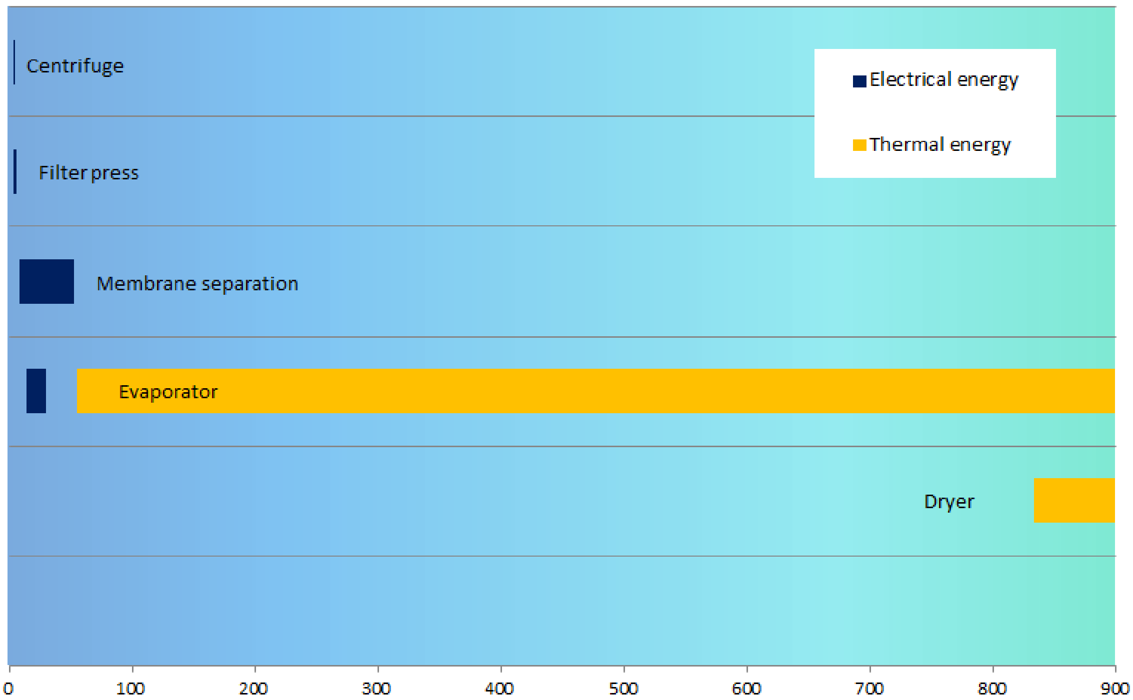

Figure 5.8 Specific energy consumption of de-watering processes, kWh per T water removed

It is clear from this graph that separation processes driven by electrical energy have a far lower gross energy input. Anaerobic digestion was not included here as it has quite a low energy input and is also a net energy generator.

It is important to note that for each technology the energy input is a range so the most efficient version will be at the lowest end of the range. It should also be noted that the most efficient evaporators have only a very small thermal load (i.e. MVR evaporators) but that there is a wide range of efficiencies available.

These figures are useful to weigh up the options available. Variables such as scale of operation and parameters such as the required dry matter of the treated co-product will have a significant impact.

In order to assess the advantages and disadvantages of each treatment route, four case studies were generated for distilleries of varying sizes, activities and locations. A summary of the co-product outputs is shown in Table 5.8

Distillery	**Site activities**		**Per annum**			**Per hour**
	Malt	Grain	Draff	Pot Ale/Stillage	Spent Lees	Pot ale/stillage
A	0.1 MLA	0.0 MLA	237 T	968 T	330 T	0.5 T
B	0.5 MLA	0.0 MLA	1211 T	4840 T	1648 T	2.4 T
C	1.0 MLA	5.0 MLA	7726 T	62721 T	10049 T	7.5T
D	12.0 MLA	30.0 MLA	60886 T	434405 T	75564 T	51.7 T

Table 5.8 Approximate co-product production per annum

While these are representative of typical distilleries being planned in Ireland at present, they are not based on any specific distillery. The locations assigned to each distillery are shown in Figure 5.9.

Figure 5.9 Locations of case study distilleries

Treatment routes under the headings outlined in Table 5.9 were evaluated for each case study.

	Category	Types
1	Minimal treatment	Discharge to sea Animal feed Land spreading Discharge to sewer
2	Mechanical de-watering	Centrifuge Filter press Membranes
3	Thermal de-watering	Evaporation Drying
4	High-value co-products	Ethanol Protein Polyphenols
5	Energy recovery	Anaerobic digestion Combustion
6	WWTP	Discharge to sewer

Table 5.9 Overview of main co-product routes

Assumptions:

- Boiler efficiency: 80%
- All distilleries using natural gas to raise steam.
- Energy rates as per SEAI guidance, October 2014 (outlined in Section 5.5.5.3).

In the case studies, only routes which are currently established and available have been examined. It should be noted that costs and energy consumptions outlined are indicative only and a detailed quote for a specific distillery will be required to provide robust capital and running costs.

If it is assumed that a use for untreated pot ale can be found at a certain distance from the distillery then the baseline energy usage and cost can be calculated. This can be weighed up against other treatment options to assess their advantages and disadvantages from economic and environmental standpoints. It has been assumed that none of the sample distilleries have access to a fast-moving sea outfall because these are rare in the Republic of Ireland.

Staffing costs have not been included in running costs because some operator intervention is required for every option.

5.6.1. Case Study: Distillery A

Distillery A is a craft distillery operating five days a week and producing 0.1MLA of malt whiskey located in Drogheda, Co. Louth.

The annual and daily production of each co-product is shown below in Figure 5.10.

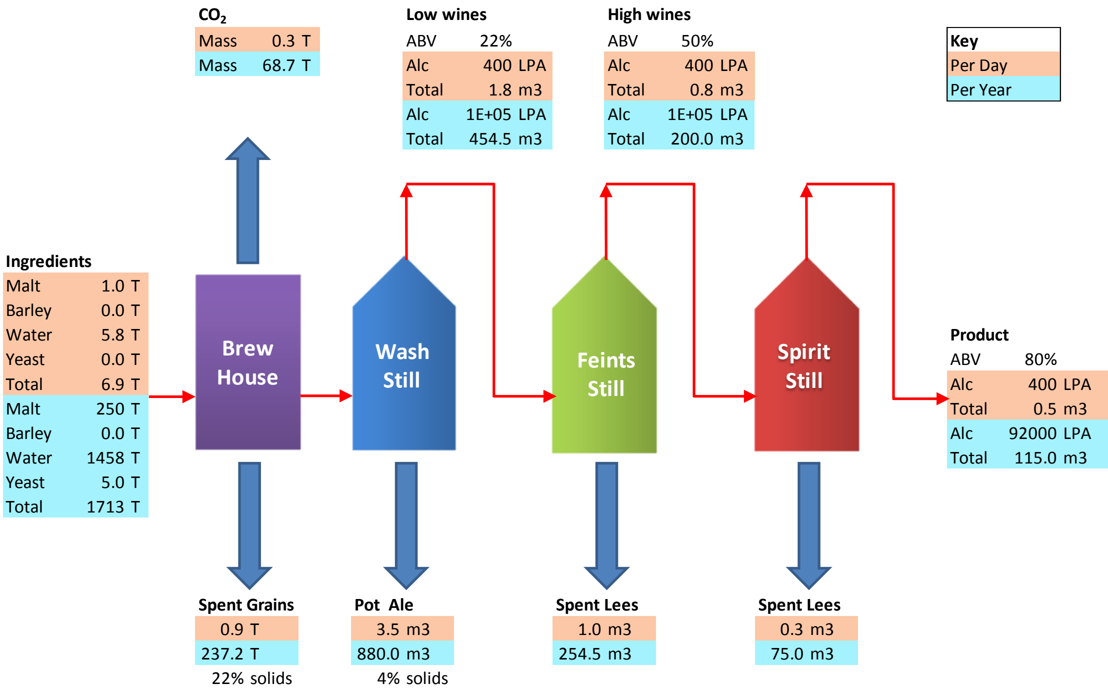

Figure 5.10 High level mass balance Distillery A

Just under 1T of Draff, 3.5m^3 of Pot Ale and 1.3m^3 of Spent Lees are generated each day.

For this size of distillery, there is a good chance of developing a relationship with a local farmer who will pick up the pot ale every few days and use for animal feed in winter and as fertiliser during summer.

It is reasonable to assume that 1.3m^3 of Spent Lees can be discharged to drain each day. If there is any local sensitivity the liquid could be released at a slow rate.

At this scale, it is unlikely to be feasible to do any on site treatment but costs are discussed below for reference.

5.6.1.1. Baseline scenario

A pig farmer 10km from the distillery will pay €140 per TDM for pot ale at the farm gate.

In this scenario, the distillery must deliver pot ale to the pig farmer twice a week (to avoid souring). A €/Tkm cost of 0.14 was discussed in Section 5.3. Clearly however, to transport a load of 9T of pot ale 10km will cost more than €12.60.

The revenue from 1 year's worth of pot ale is €5,421. Transport costs for the year are €5,200. All in all, in the baseline scenario the distiller is €221 in profit.

5.6.1.2. Dewatering

If the pot ale were to be concentrated to 35% using an evaporator, transport costs would be reduced. It is likely however that they would only be reduced by 50% because syrup would still have to be transported off site on a regular basis. Transport costs would then be reduced to €2600.

In order to achieve this saving, a capital investment on the scale of €200,000 would have to be made and €72,800 per annum spent on energy.

Similarly to evaporation, the saving from concentration by centrifuge would not be substantial in this case. A centrifuge at this scale would cost in the region of €45,000 and would allow concentration to approximately 25% solids.

5.6.1.3. Alternative treatment routes

There is no fast-moving sea outfall available near the site. Unless there was an anaerobic digester nearby, or some other process which would use pot ale as feedstock, animal nutrition is the best choice.

5.6.1.4. Discussion

It is clear that on this scale, it is preferably to avoid capital investment in treatment and also that it is possible to avoid it. No matter the distance to a suitable user, investment in on site evaporation or other concentration equipment cannot be justified at this scale.

5.6.2. Case Study: Distillery B

Distillery B is a distillery operating five days a week and producing 0.5MLA of malt whiskey located in Clonakilty, Co. Cork.

The annual and daily production of each co-product is shown below in Figure 5.11.

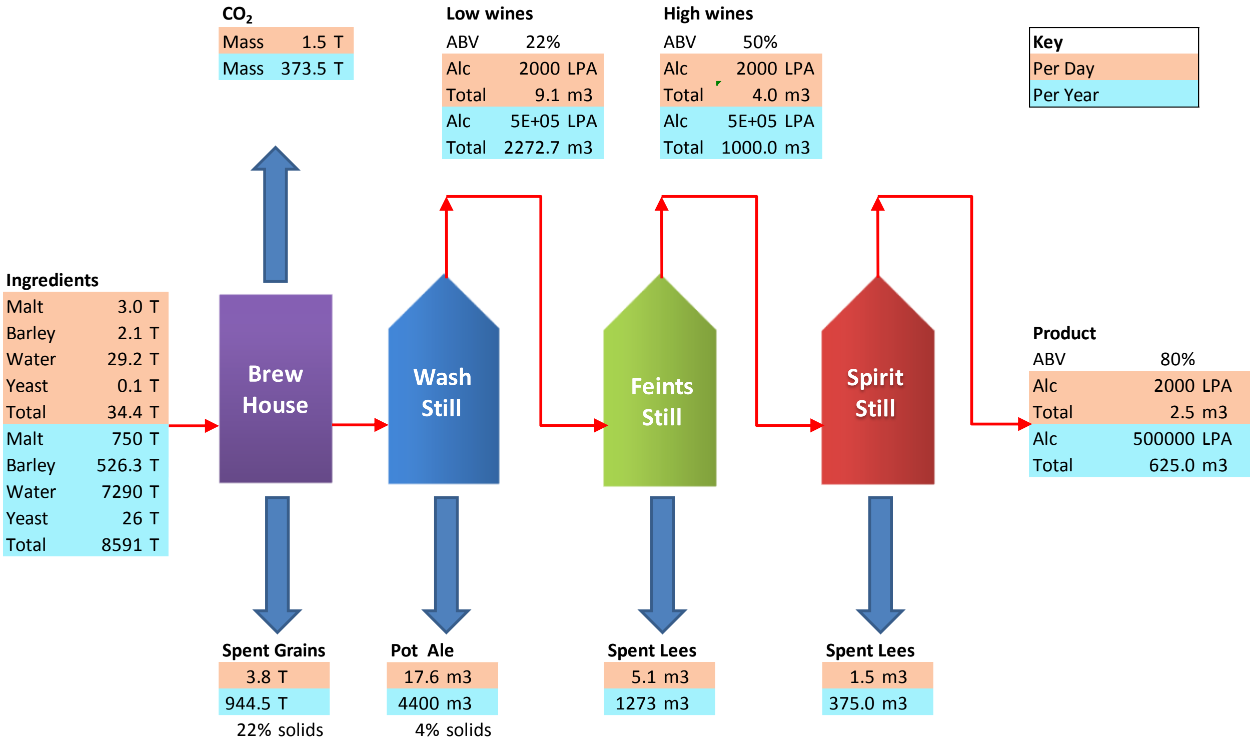

Figure 5.11 High level mass balance Distillery B

5.6.2.1. Baseline scenario

Similarly to Distillery A, a pig farmer 20km from the distillery will pay €140 per TDM for pot ale at the farm gate. To put this into context, this quantity of pot ale would be suitable for a herd of 2,800 pigs (on basis outlined in Section 5.4.3). This is a reasonable hypothesis given the number of pig farms in Cork.

On the basis of the daily mass balance a tanker would be required 3-4 times a week. Based on a transport cost of €0.14/Tkm, transport costs for the year are €13,551.

The revenue from 1 year's worth of pot ale is €27,103. All in all, in the baseline scenario the distiller is €13,552 in profit.

5.6.2.2. De-watering

If the pot ale were to be concentrated to 35% solids using an evaporator, transport costs would be reduced to approximately €1,550.

An evaporator for the site would be sized for a feed of 2.5m3/h and would cost in the region of €600,000. Annual energy costs would be €90,000.

Even if evaporation increased the value of the co-product to a large extent, there is no payback to justify this investment. For a distillery at this scale, the customer would need to be more than 140km away in order to break even between the annual energy costs and the associated transport savings. This calculation used a value of €180/TDM for the pot ale syrup.

A similar argument can be made for any other de-watering methods.

5.6.2.3. *Alternative treatment routes*

Similarly to Distillery A, there is no fast-moving sea outfall available near the site. Unless there was an anaerobic digester nearby, or some other process which would use pot ale as feedstock, animal nutrition is the best choice.

An anaerobic digestion system for the site would be sized to take approximately 0.6m3/h (sized for continuous operation) and would cost in the region of €1.8 million. The system would produce approximately 68,000m3 of methane per annum which would amount to a €33,500 energy saving to the site before running costs are taken into account. When running costs such as energy, consumables and staffing are taken into account the investment cannot be justified.

5.6.2.4. *Discussion*

The best option for Distillery B is to use all co-products for animal nutrition. Even if the farmer was a greater distance away or the price paid for the liquid co-products was drastically reduced this would still be a preferable option than investing in on site treatment equipment.

5.6.3. *Case Study: Distillery C*

Distillery C is a distillery operating 24 hours, 7 days a week and producing 1MLA of malt whiskey and 5MLA of grain whiskey, located in Kilkenny.

The annual and daily production of each co-product is shown below in Figure 5.12 and Figure 5.13.

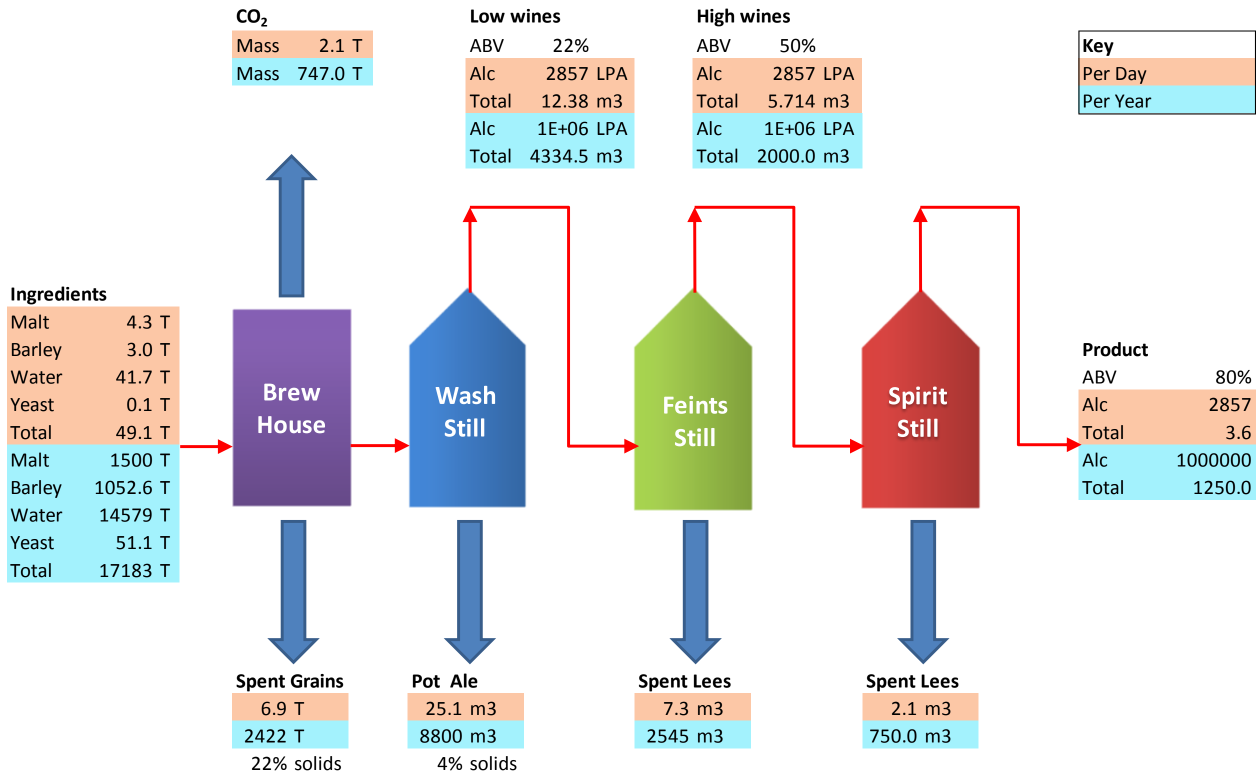

Figure 5.12 High level mass balance Distillery C malt distillation process

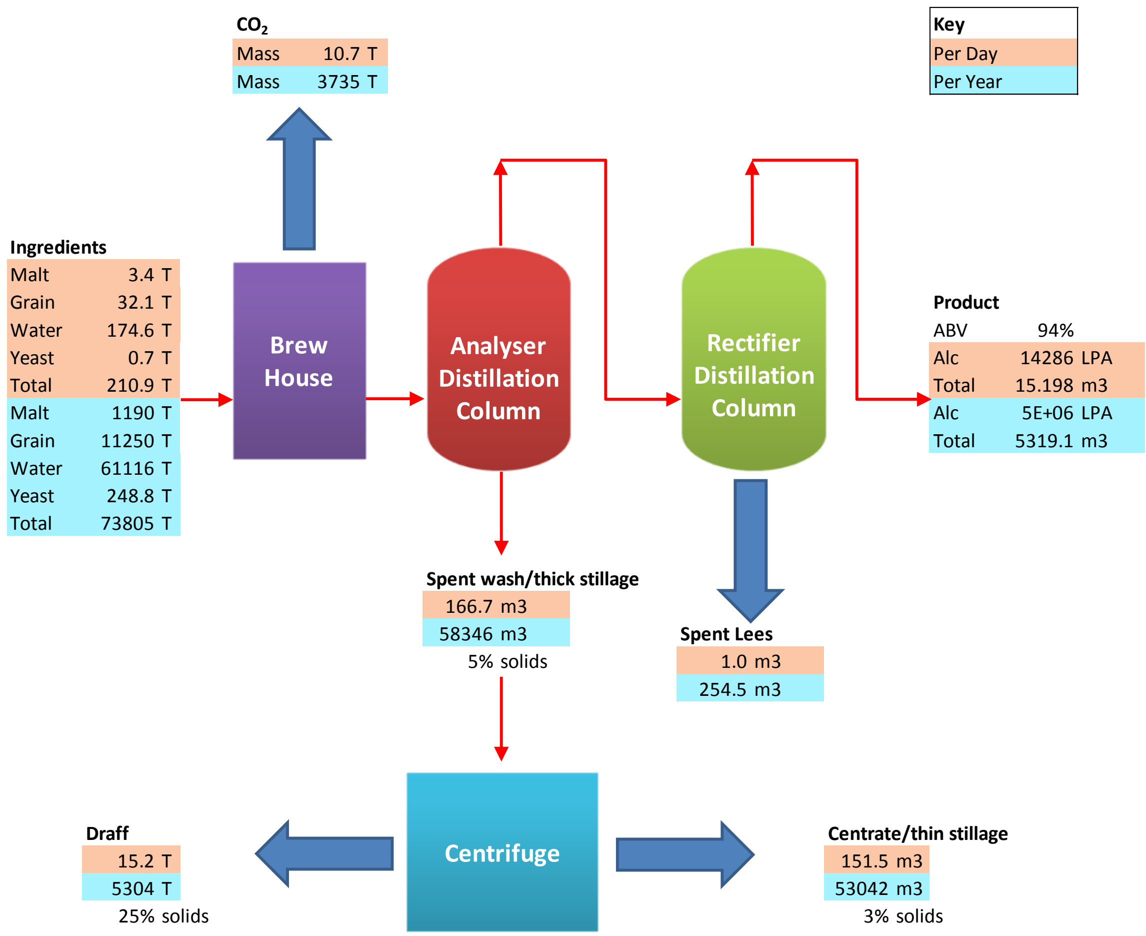

Figure 5.13 High level mass balance Distillery C grain distillation process

5.6.3.1. Baseline scenario

A pig farmer 50km from the distillery will pay €140 per TDM for pot ale at the farm gate. To put this into context, this quantity of pot ale would be suitable for a herd of 33,400 pigs (on basis outlined in Section 5.4.3). This would be an unusually large pig farm and realistically at this scale it is likely that the distillery would engage with an intermediate feed supplier. Using this situation as a baseline does however provide useful information as to the cost of transporting this amount of liquid-co-product to a user.

Based on a transport cost of €0.14/Tkm, transport costs for the year are €439,048. Transport would involve approximately 50 tankers of pot ale and thin stillage leaving the site per week.

The revenue from 1 year's worth of pot ale and thin stillage is €351,239. All in all, the baseline scenario costs the distiller €87,810 per annum.

5.6.3.2. Evaporation

If the pot ale were to be concentrated to 35% solids using an evaporator, transport costs would be reduced to approximately €50,180.

An MVR evaporator for the site would be sized for a feed of 7.5m3/h and would cost in the region of €1 million. Annual energy costs would be €360,000. If a value of €180/TDM is taken for pot ale syrup, total savings per annum of €128,900 could be achieved by the distillery relative to the baseline scenario (based on selling to the same customer 50km away). On this basis the payback for the evaporator would be approximately 8 years.

5.6.3.3. Alternative treatment routes

Discharge to sea outfall is not an option given the distillery's inland location.

An anaerobic digestion system for the site would be sized to take approximately 7.5m3/h (or higher depending on discharge requirement for spent lees) and would cost in the region of €6 million. The system would produce approximately 575,000m3 of methane per annum (full system including aerobic section so that water is suitable for discharge). This biogas can be used to direct fire boilers or alternatively in a generator or CHP engine (producing electricity and high and low grade heat). The plant would have a footprint of 40m by 40m.

Methane combusted to produce steam in the distillery

This would provide a €204,000 energy saving to the site before running costs are taken into account (approximately 15% of the site's annual thermal energy). Annual running costs would be approximately €80,000 (no heat input required, electrical load 60kW). Staffing costs have been neglected as an operator would be required for all on site treatment routes. Similarly it has been assumed that the existing on site boilers may be used. On this basis, the payback for an anaerobic digester would be approximately 26 years compared to the baseline scenario.

Methane combusted to produce electricity

Distillery C pays €150/MWh of electricity compared to €45.2/MWh for gas. Given that electrical energy is at present 3 times more costly than thermal energy, electricity generation should be considered. The REFIT tariffs for AD are shown in Table 5.10.

Technology	Tariff €/MWh
Large AD Non CHP >0.5MW	104.866
Small AD Non CHP <=0.5MW	115.353
Large AD CHP >0.5MW	136.326
Small AD CHP <=0.5MW	157.299

Table 5.10 REFIT tariffs

At a generator efficiency of 75%, this would provide 480kW of electricity. The site demand is estimated to be 350kW. On the basis of providing 350kW to the site and 130kW to the grid, an annual saving of €602,700 was calculated. The payback on this basis (with an additional estimated €1 million to take into account generator and connection charges) would be 11.6 years. Further savings would be possible in the form of carbon credits. A total of 2260T of CO2 would be saved per annum (on the basis of 535g CO2 emitted per kWh, Electric Ireland, 2015). Whether or not this has a financial impact depends if the site is signed up to the EU Emissions Trading Scheme and also on the cost of carbon credits (€5 per tonne in 2014). If this is taken into account, the payback is reduced to 11.4 years.

If there is a CHP unit on site, on the basis of the site energy costs and the REFIT tariffs, the distillery should feed all of the power generated to the grid.

Feeding the methane to a CHP engine is more efficient (approximately 90%) as heat is recovered in the process. However, even if the heat is fully utilised, the rate of savings per kWh of heat are much lower than per kWh of electricity fed to the grid. This extends the calculated payback to 14.2 years.

5.6.3.4. Discussion

The various options discussed are summarised in Table 5.11.

	Option	CAPEX	Revenue	Payback	CO_2 emitted
1	No treatment. Transport 50km	€0	-€87,810	n/a	239T
2	Evaporator	€1,000,000	€128,900	8	1346T
3	AD – boiler	€6,000,000	€226,000	26.5	-924T
4	AD – generator	€7,000,000	€602,700	11.6	-2260T
5	AD – CHP	€7,000,000	€491,200	14.2	-1784T

Table 5.11 Distillery C options

Option 2 is the least environmentally friendly course of action from an emissions perspective but the evaporator is most attractive from a payback perspective. The next most feasible option is an anaerobic digestion system used to generate mains electricity. The capital costs are prohibitive however.

If carbon costs (or other statutory incentives) were to increase substantially anaerobic digestion options should be reviewed. A value of €100 per T of CO2 for instance would reduce the payback of Option 4 to 8.4 years and also wipe out the savings associated with the evaporator.

5.6.4. Case Study: Distillery D

Distillery D is a large distillery operating 24 hours, 7 days a week and producing 12MLA of malt whiskey and 30MLA of grain whiskey located in Castlebar, Co. Mayo.

The annual and daily production of each co-product is shown below in Figure 5.14 and Figure 5.15.

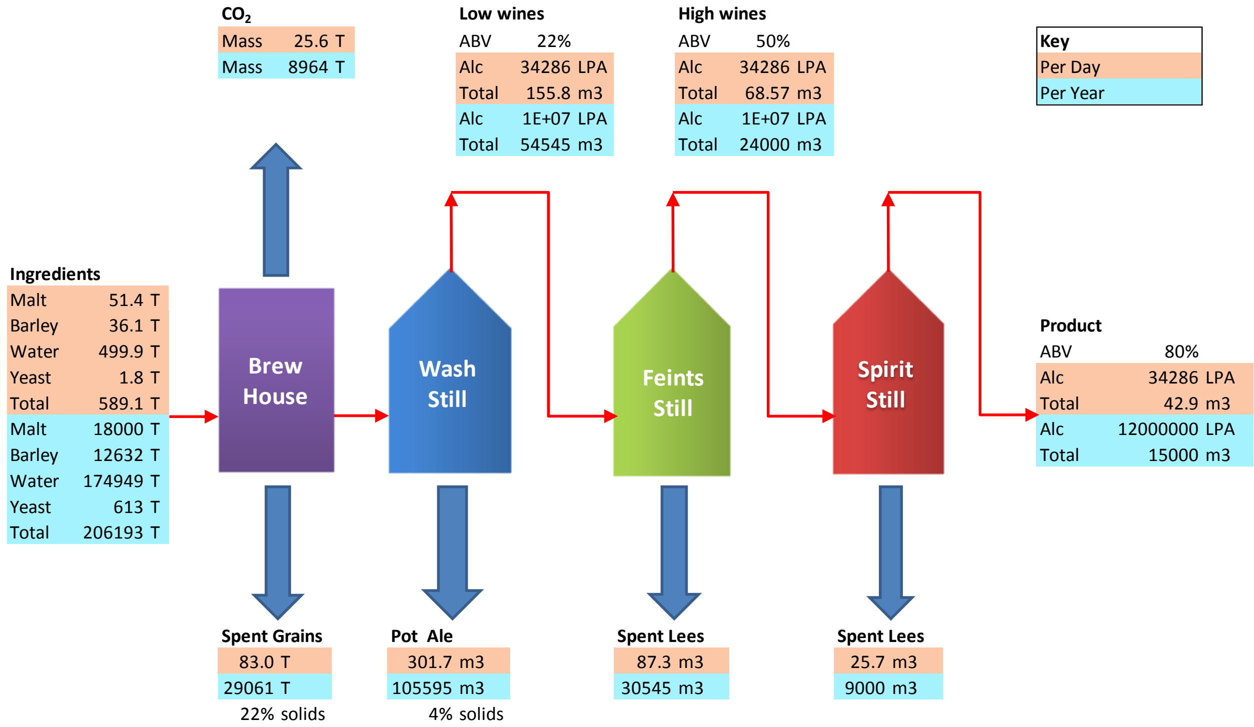

Figure 5.14 High level mass balance Distillery D malt distillation process

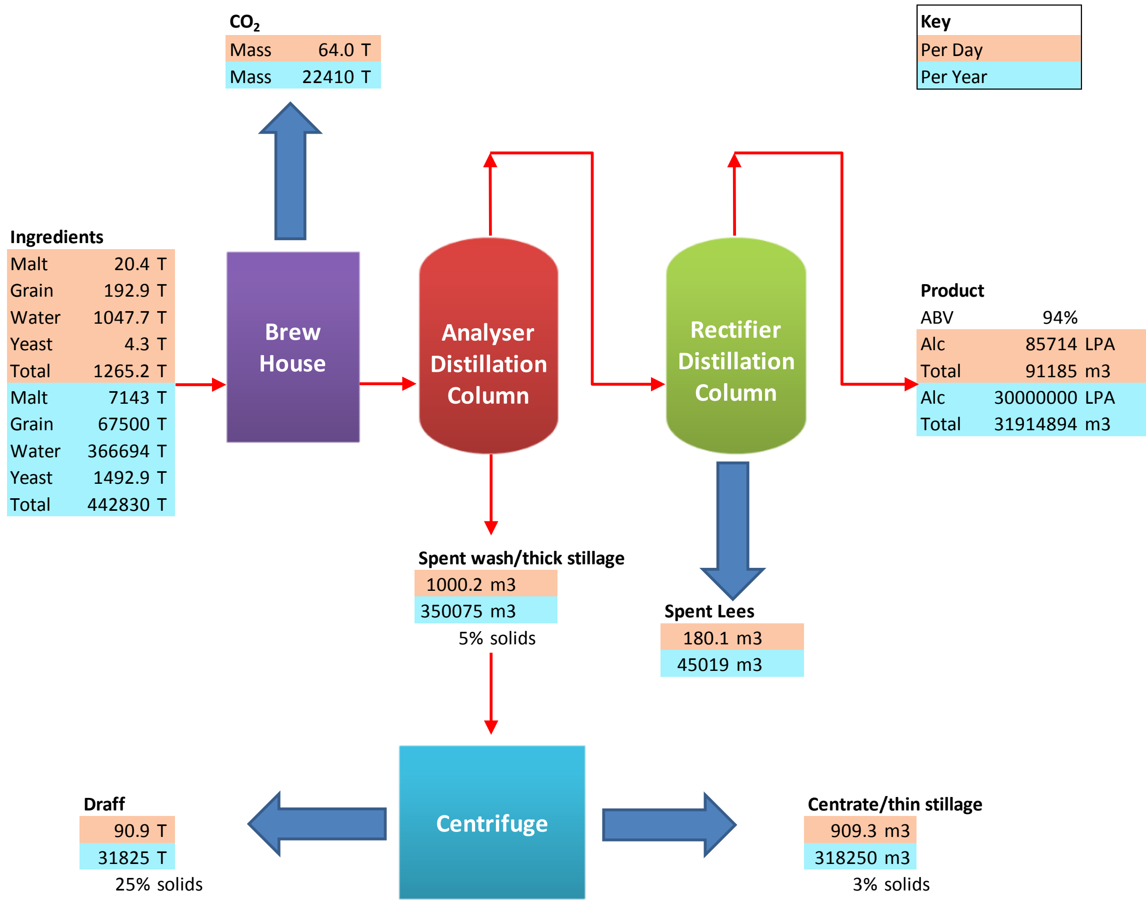

Figure 5.15 High level mass balance Distillery D grain distillation process

5.6.4.1. Baseline scenario

A pig farmer 100km from the distillery will pay €140 per TDM for pot ale at the farm gate. To put this into context, this quantity of pot ale would be suitable for a herd of 234,000 pigs (on basis outlined in Section 5.4.3). This would be an unusually large pig farm (16% of Ireland's herd). It is however possible that a sufficient population of pigs could live in this radius of the distillery. As for Distillery C, it is likely that the distillery would engage with an intermediate feed supplier.

Based on a transport cost of €0.14/Tkm, transport costs for the year are €6.1 million. Transport would involve approximately 50 tankers of pot ale and thin stillage leaving the site per day.

The revenue from 1 year's worth of pot ale and thin stillage is €2.4 million. All in all, the baseline scenario costs the distiller €3.6 million per annum.

5.6.4.2. Evaporation

If the pot ale were to be concentrated to 35% solids using an evaporator, transport costs would be reduced to approximately €695,000.

An MVR evaporator for the site would be sized for a feed of 52m3/h and would cost in the region of €4 million. Annual energy costs would be €2.1 million. If a value of €180/TDM is taken for pot ale syrup, total savings per annum of €4 million could be achieved by the distillery relative to the baseline scenario (based on selling to the same customer 100km away) so the payback for the evaporator would be 1 year.

5.6.4.3. Alternative treatment routes

Distillery D is quite close to the coast. Discharge to sea outfall is not an option because of the slow current in the area. A large fish farm is planned for Galway Bay. Co-operation between the distillery and the fish farm could be considered. As this route is not well established, the specifics cannot be quantified at this time.

An anaerobic digestion system for the site would be sized to take approximately 52m3/h (or higher depending on discharge requirement for spent lees) and would cost in the region of €15 million. The system would produce approximately 4,265,000m3 of methane per annum (full system including aerobic section so that water is suitable for discharge). This biogas can be used to direct fire boilers or alternatively in a generator or CHP engine (producing electricity and high and low grade heat). The plant would have a footprint of 80m by 80m.

Methane combusted to produce steam in the distillery

This would provide a €1.25 million energy saving to the site before running costs are taken into account (approximately 18.5% of the site's annual thermal energy use). Annual running costs would be approximately €223,300 (no heat input required, electrical load 200kW). Staffing costs have been neglected as an operator would be required for all on site treatment routes. Similarly it has been assumed that the existing on site boilers may be used. On this basis, the payback for an anaerobic digester would be approximately 3.2 years compared to the baseline scenario.

Methane combusted to produce electricity

Distillery D pays €127.8/MWh of electricity and €35.2/MWh for gas. Given that electrical energy is at present 3 times more costly than thermal energy, electricity generation should be considered. REFIT tariffs for AD are shown in Table 5.10.

At a generator efficiency of 75%, this would provide 3.6MW of electricity. The site demand is estimated to be 2.5MW. On the basis of providing 2.5MW to the site and 1MW to the grid, an annual saving of €6.3 million was calculated. The payback on this basis (with an additional estimated €2.5 million to take into account generator and connection charges) would be 3 years.

As discussed for Distillery C, further savings would be possible in the form of carbon credits. A total of 16,780T of CO_2 would be saved per annum (on the basis of 535g CO_2 emitted per kWh, Electric Ireland, 2015). A site of this size would be obliged to participate in the EU Emissions Trading Scheme. The impact of this depends on the cost of carbon credits (€5 per tonne in 2014). If this is taken into account, the payback is reduced to 2.75 years.

Similarly to Distillery C, if there is a CHP unit on site, on the basis of the site energy costs and the REFIT tariffs, the distillery should feed all of the power generated to the grid.

Feeding the methane to a CHP engine is more efficient (approximately 90%) as heat is recovered in the process. However, even if the heat is fully utilised, the rate of savings per kWh of heat are much lower than per kWh of electricity fed to the grid. This brings the calculated payback to 2.9 years.

5.6.4.4. Discussion

The various options discussed are summarised in Table 5.12

	Option	CAPEX	Revenue	Payback	CO_2 emitted
1	No treatment. Transport 100km	€0	-€3,648,998	n/a	3,305T
2	Evaporator	€4,000,000	€3,987,176	1.00	9,323T
3	AD – boiler	€15,000,000	€4,677,587	3.74	-6,862T
4	AD – generator	€17,500,000	€6,269,442	2.95	-16,789T
5	AD – CHP	€17,500,000	€6,443,710	2.87	-13,243T

Table 5.12 Distillery D options

From the calculations it is clear that the baseline scenario identified is costly and justifies investment in an evaporator. However at this scale, the installation of an AD plant should also be considered. Capital costs are high but annual profits in excess of €6 million bring the payback to less than 3 years. As was also discussed for Distillery C, anaerobic digestion has the advantage of insulating the distillery from increases in energy prices and renewable incentives. Disadvantages of anaerobic digestion include large footprint requirements as well as a high capital cost. While carbon emissions are prevented, from an environmental standpoint energy recovery is less preferable than use of the co-product for animal nutrition.

For Distillery D, Option 4 and 5 are financially similar. The reason for this is the higher efficiency of the CHP engine relative to the generator. It should be noted here that distilleries usually operate with a surplus of low grade heat so it may not be possible to utilise 100% of the available heat from the CHP. This would impact the payback of this option. Clearly further analysis would be required if the distillery was considering an AD plant.

The scale of this distillery means that co-product treatment is an important logistical issue but it also means that if an alternative high value product recovery process can be identified that it is easier to justify the capital investment.

6. Discussion

6.1. De-watering efficiency

Evaporation using an MVR is currently the most efficient single treatment method of de-watering pot ale to a significant extent. While other methods of de-watering are available (such as centrifuge and filter press) which have a lower specific energy consumption, the operating limits are such that they must be used in conjunction with an evaporator or other treatment if a high concentration of solids is required.

Drying is an energy intensive process (much more than evaporation). Drying to produce a DDGs type product can be justified if the co-product increases significantly in value or if demand from customers for draff/moist grains is variable (DDGs has a longer shelf life).

6.2. Combustion of co-products

Given that Ireland has a large population of cattle (and thus a substantial market for draff and pot ale syrup) and that the energy costs and capital investment required are high it is unlikely that combustion of draff will become feasible without subsidy. Combustion is clearly a less environmentally beneficial option than using the co-products for nutrition. Any subsidies promoting burning of these co-products must be based on a proper assessment of the impact of such practice on the environment. If energy recovery is to be promoted, it should be noted that anaerobic digestion offers much more efficient energy recovery from pot ale and spent lees.

6.3. Heat recovery

Distilleries traditionally operate with a surplus of low grade waste heat (from the condensing process). Many different applications to utilise this heat have been tried at distilleries over the years including eel farming at one Scottish distillery. Aquaculture and horticulture projects certainly have the potential to form a symbiotic relationship with distilleries where they buy heat, nutrients (in the form of pot ale) and also potentially CO_2 from boiler flues from the site.

The efficiency of existing treatment processes can also be increased by the use of heat recovery. It has been noted in the body of the report the technologies/treatments where efficiencies can be increased if recovered heat is utilised e.g. in evaporation or drying.

6.4. Case studies

The baseline scenarios utilised for each case study are summarised in Table 6.1.

	Distance to customer	Transport costs	Revenue	Total cost to distiller
Distillery A	10 km	€ 1,355	€ 5,421	-€ 4,065
Distillery B	20 km	€ 13,551	€ 27,103	-€ 13,551
Distillery C	50 km	€ 439,048	€ 351,239	€ 87,810
Distillery D	100 km	€ 6,081,663	€ 2,432,665	€ 3,648,998

Table 6.1 Baseline for each case study

Based on the size of the cattle and pig herds in Ireland these estimates seem quite reasonable. Most distilleries will engage with an animal feed merchant who will take care of logistics so the costs of co-product disposal may not be presented to the distillery in this form but rather in a cost or revenue per tonne of pot ale depending upon the commercial arrangement. The cost of transport will be used by the feeds merchant as a parameter in their business model.

Analysis of the case studies indicated that for the smaller distilleries (Distillery A and Distillery B, producing 0.1MLA and 0.5MLA respectively) there is little to be gained from on site treatment. Because of the scale of each operation, this outcome is much less sensitive to variables such as energy and carbon costs. Use of the co-products for animal nutrition is the most economic and environmentally friendly option. In the event that there was an anaerobic digester nearby this could be considered from an economic standpoint, animal nutrition is the preferably application from an environmental perspective however.

The best course of action for Distillery C (producing 6MLA) is less clear. The baseline scenario costs the distillery approximately €90,000 per annum. Installation of an evaporator has a payback of 8 years and the payback for anaerobic digestion is in excess of 11 years. The economic balance for each option is highly sensitive to energy and carbon prices. In the baseline scenario, it is assumed that the pot ale must be transported 50km. If a distillery of this size can find a user of untreated pot ale at a shorter distance (e.g. 25km), the annual costs to the distiller would be halved and the feasibility of on site treatment options would be much reduced. In many distilleries of this size, the best option is an evaporator. However, if alternative uses (such as pig nutrition or municipal/shared anaerobic digestion) are available locally, they would be preferable from both economic and environmental perspectives. The frequency of truck movements at the site is also an issue at this scale and would feed into the decision making process.

For distilleries with production volumes between Distillery B and C (i.e. between 0.5MLA and 6MLA), a similar decision making process must occur. At the lower end of the scale it is very unlikely that on site treatment could be justified, at the higher end of the scale the decision becomes dependent upon the proximity of potential pot ale consumers and any specific site requirements e.g. traffic restrictions, availability of space on site.

For Distillery D (42MLA), the annual costs associated with the baseline scenario clearly justify investment in on site co-product treatment. Both an evaporator and anaerobic digester are feasible at this scale. At present, the evaporator is preferable from an economic perspective. The feasibility of anaerobic digestion could be increased in the event of increasing energy or carbon prices or if the distillery (or its customers) were to put a premium upon carbon emissions. While, from a waste hierarchy perspective evaporation is preferable environmentally, anaerobic digestion does offer reduced carbon emissions and the potential for positive "green" publicity. Should low carbon electricity become available (e.g. by increased utilisation of wind energy in Ireland), this would negate the carbon benefit of anaerobic digestion.

6.5. Potential risks to animal nutrition market

Biofuel plants also produce distillery co-products which can be used for feed. These plants tend to operate on a very large scale so if plants like this were to enter the Irish market they could flood the animal feed market, making alternative applications more competitive. For example, two bioethanol plants in northern England, Ensus near Middlesbrough and Vivergo in Hull have the potential to produce around 750,000 tonnes of feed by-products on a dry matter basis which greatly exceeds the output of the distilling sector in Scotland (SAC, 2012).

Similarly, the greater the production of distilled spirits in Ireland, the more co-products will be produced, reducing the demand for co-product feeds. While the size of the distilling sector is rapidly increasing at present, it is still small relative to the meat and dairy industries.

A downturn in Ireland's food export business would also have a large impact on the animal feed market over time as a large portion of the meat produced is exported.

A lowering of the price of feeds increases the attraction of energy recovery from co-products.

6.6. Co-operative ventures

It may not be feasible for individual Irish distilleries to install an anaerobic digester (or evaporator) but it may be worthwhile for several distilleries to form a co-operative venture in conjunction with a third party who would be responsible for operating and possibly financing the facility. This type of co-operative venture is common in Scotland. It allows the distillery to benefit from the economies of scale and reduced running costs of a large treatment system while reducing the capital investment required. This would only be feasible for distilleries located quite close to each other.

7. Conclusions

There is at present no one ideal co-product treatment route for every distillery. There are several competing factors at play, including scale of operation and geography of location. See diagram shown in Figure 7.1.

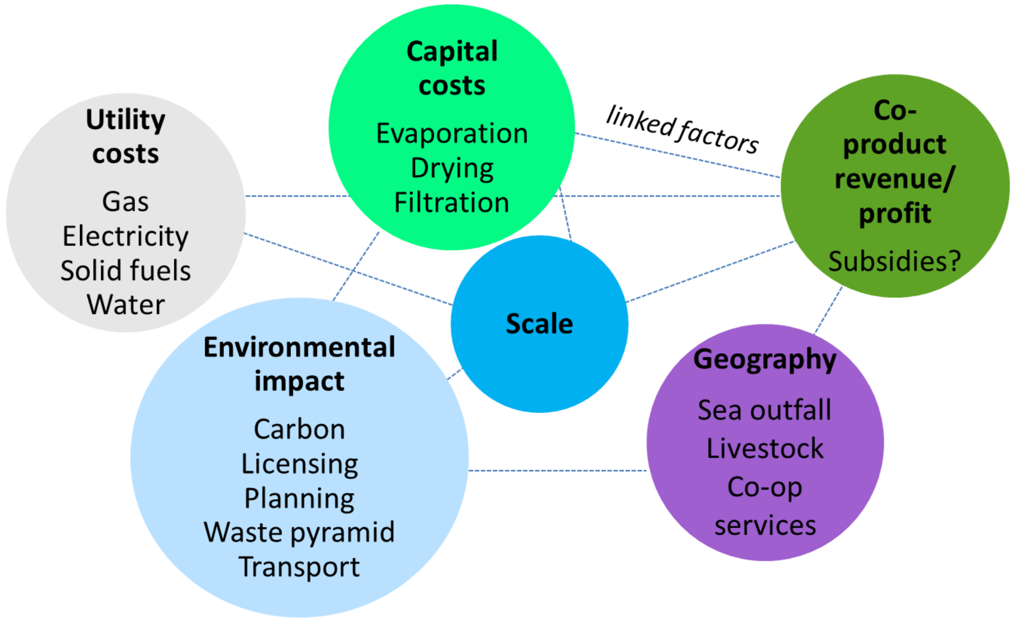

Figure 7.1 Factors in evaluation of treatment routes

Animal nutrition is the most common use of co-products. Research is on-going to identify alternative high value applications for co-products but none have been commercially proven as yet. Of the established uses for co-products, animal nutrition is the most preferable from an environmental perspective (based on the waste hierarchy).

Pot ale is the most challenging distillery co-product to deal with because of its high water content and high BOD. Pot ale is a valuable nutritional co-product (high protein) and can be consumed by pigs in its untreated form but the high water content means that transport can be expensive. At present most pot ale is evaporated to produce pot ale syrup, the greatly reduced volume decreases transport costs.

The most economic and environmentally friendly option for smaller distilleries (e.g. Case Study Distilleries A and B) is to sell (or give) all co-products untreated to local farmers for animal feed or land-spreading.

For larger distilleries, a balance must be found between the co-product market and its location relative to the distillery. Each of the three distilleries visited in Ireland operates an MVR evaporator for pot ale treatment.

The case study analyses illustrate that for a large scale distillery an MVR evaporator is the most economic treatment route at present. This conclusion is highly sensitive to energy prices and carbon costs however. Certainly if carbon costs were to rise significantly from current levels this would greatly increase the feasibility of anaerobic digestion at medium size distilleries also.

Membrane separation was found to not be feasible for pot ale de-watering, thus water recovery by this method is not feasible. If an application was found for concentrated pot ale which was particularly heat sensitive (i.e. negatively affected by the evaporation process) this could increase its viability.

Variables which influence the economics of each treatment route are as follows:

1. Energy costs
2. Animal population
3. Government instruments e.g. carbon prices
4. Cost of installation of technology
5. Availability of renewable electricity.
6. Number of distilleries/production volumes

The environmental benefits of each treatment route depend upon which philosophy is in place. From waste hierarchy and circular economy perspectives it is preferable that co-products be recycled in some way e.g. for animal nutrition. From a carbon perspective, anaerobic digestion is preferable. For all environmental philosophies however it is preferable that the selected treatment route be as well-designed and efficient as possible.

8. Recommendations

8.1. Existing distilleries

On the basis of site visits completed, literature review and communication with suppliers the following opportunities were identified to increase the efficiency of existing evaporator systems in operation at distilleries.

1. Energy monitoring/benchmarking

In general, increased metering and monitoring allows identification and verification of energy-saving projects. It is advisable to measure the following parameters to ensure efficient operation.

- Incoming temperature, flow rate and solids content
- Steam flowrate to system
- Fan electricity usage
- Condensate flow rate
- Cooling water feed and return temperature and flow rate
- Syrup flow rate, temperature and solids content

The economy of any dewatering method can be expressed in terms of the energy required to remove 1 tonne of water. The specific energy consumption for an efficient MVR is generally in the range of 12-18kWh/tonne evaporation (Scheiby, 2012). This KPI should be tracked.

It is advisable that a distillery maintains a model indicating the impact of key variables e.g.

- If the price of gas increases for the site but diesel/transport costs remain static, should the set point for the evaporation system be adjusted?

- If carbon tariffs increase, should the pot ale be disposed of by other means?

2. Take steps to minimise fouling of evaporator surfaces

As fouling levels increase the overall heat transfer coefficient decreases and an increased quantity of energy is required to achieve the same level of evaporation. Most distilleries clean on a time basis but condition monitoring to prompt cleans should be considered. The value of this action can be evaluated by measuring plant performance directly before and after a deep clean. The fan motor on a mechanical vapour recompression (MVR) evaporator is frequently the largest drive on site and runs continuously. This provides a good payback for any improvements.

Another action which can help to minimise fouling is to operate the evaporator at as low a temperature as possible. Operating temperatures below 80°C can be achieved with modern evaporators, reducing the Maillard effect (a form of nonenzymatic browning) on the product.

Fouling can also be minimised by maintaining high flow rates though the evaporator. The addition of enzymes (e.g. beta-glucanase) to thin stillage reduces the viscosity of the liquid and can facilitate higher flow rates.

3. Heat recovery

The higher the feed temperature the better so that all the energy being supplied to the evaporator is used for evaporation rather than heating the fluid to its boiling point. It is thus worthwhile for a distillery to ensure that pot ale/thin stillage is fed to the evaporator as quickly as possible with as minimal heat loss (i.e. in a well-insulated system) and with no cooling processes (i.e. do not recover heat from pot ale pre-evaporation).

Both the condensate and syrup streams from the evaporator are good candidates for heat recovery. Evaporator condensate in particular given the larger volumes is a good source of high grade heat for recovery. The evaporator's long run hours also increase the justification for investment in this area.

The vapour from the evaporator is usually condensed using a cooling tower. It is possible to recover the latent heat from this vapour stream if a suitable heat sink is available.

Heat recovery from driers is also a good opportunity e.g. in Starlaw Distillery, vapour from the drier is used to boil the first effect in the evaporator.

Thermal vapour recompression (TVR) should also be considered, particularly in evaporator set ups which have a high usage of steam.

4. Increased evaporator area

In general, the greater the area of the evaporator, the less energy input required to achieve the same level of evaporation. An economic balance must be found between increased capital costs and reduced running costs.

An increase in evaporator area (or initial oversizing) also increases efficiency.

Forced circulation evaporators are more efficient at high target concentrations so a forced circulation finished should be considered if PAS of 35% solids or higher is required. They can be driven with recovered energy depending on the evaporator arrangement.

5. Improved control

Steady state operation is most efficient for an evaporator i.e. operating at constant feed and syrup draw off rate. Balanced operation has the further benefit of making it much easier to recycle streams/heat.

6. Vacuum pump seal cooling

MVR systems utilise a vacuum pump. Vacuum pumps usually have water cooled seals. It is advisable from a water consumption perspective that a closed system with temperature switch be used for this purpose. When the water temperature rises above the set point the water is dumped and refilled fresh. Without such a system the pump seal can be a large user of water.

8.2. New distilleries

In order to evaluate the routes available it is necessary to establish a feasible baseline scenario for dealing with co-products from the distillery. It is beneficial to gather the following information:

- How much of each co-product is produced per annum?
- Can liquid co-products be discharged to drain?

- What potential customers are available?
- How far away are the customers?
- Will customers purchase the product on a regular basis i.e. is there any seasonality?
- How much will customers pay for untreated liquid co-products?
- How much does it cost to transport the pot ale to the customer?
- Total cost/revenue per annum on this basis?
- How much will customers pay for treated liquid co-products?
- Total cost/revenue per annum on this basis?
- Practicality/ease of implementation of treatment options?

This methodology for assessment of the options available is summarised in Figure 8.1.

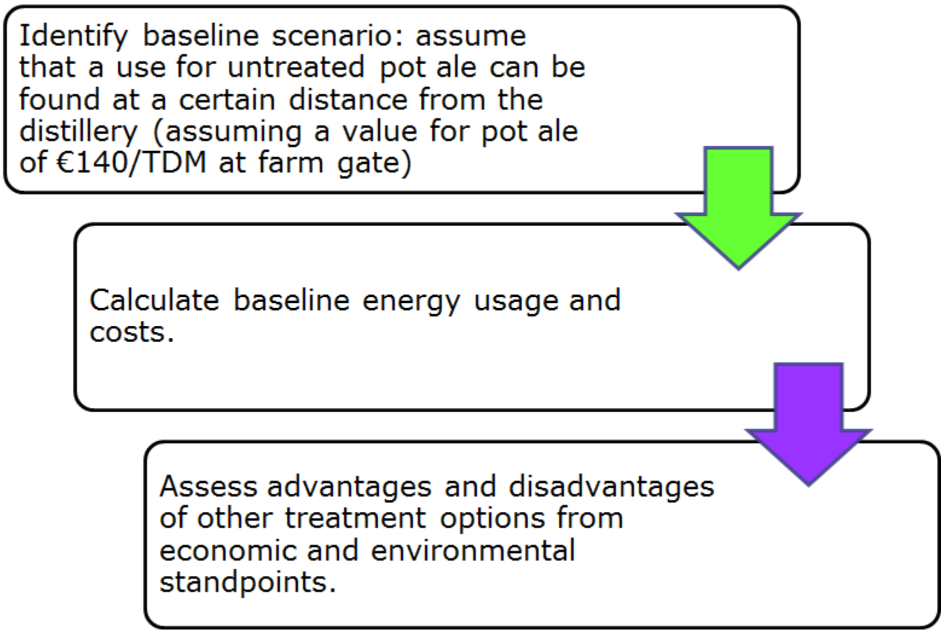

Figure 8.1 Methodology for new distilleries to select co-product treatment route

For distilleries up to 1MLA capacity it is generally preferable from an economic perspective to identify a co-product route which does not involve on site treatment.

8.3. All distilleries

Consider co-operative ventures either with other distilleries or with other symbiotic industries e.g.

- Fish farm (to use pot ale for nutrition and possibly low grade heat)
- Pig farm (to use pot ale)
- Anaerobic digestion plant (using pot ale and spent lees to produce heat and/or electricity)
- Greenhouse (to use pot ale for fertiliser, low grade heat, CO_2)
- Swimming pool (to use low grade heat)
- District heating (to use low grade heat)

9. Glossary

Centrate	Liquid fraction from centrifuge separation
DDGs	Distillers dark grains. Dried draff and pot ale syrup
DM	Dry matter
Draff	Grain solid residues
Lutter water	Synonym for spent lees (generally from distillation column)
LPA	Litre of pure alcohol
MLA	Millions of litres of alcohol produced per annum
PAS	Pot ale syrup
Pot ale	Residue from 1st distilling stage
Pot ale syrup	Pot ale concentrated by evaporation
Spent lees	Residue from 2nd (and later) distilling stages
Spent grains	Synonym for draff
Spent Wash	Residue from first column in grain distilling
Thick Stillage	Synonym for Spent Wash
Thin Stillage	Liquid fraction of Spent Wash after separation

10. Acknowledgements

Aidan Curran, Pernod Ricard Midleton

Anthony Styles, SPX

Claire Doyle and Michael O'Connell, GEA

Colum Egan and Roy Goodlad, Bushmills Distillery

David Scheiby, GEA Wiegand

Geoffrey Robinson, BIM

Mike Hogg and Richard Gueterbock, Clearfleau

Morag Garden and Julie Hesketh-Laird, Scotch Whisky Association

Noel Sweeney, Padraic Clear and Gabriel O'Loughlin, Cooley Distillery

Peter Latham, Latham International

Dr. Thomas Fahrenwaldt and Dr. John Tuohy, Inopor

Ultan Keady, Cargill

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