Investigation into the production of Sea Salt at North Yell, Shetland

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1. Introduction

The North Yell Development Council (NYDC) is currently developing a wind farm project in North Yell, Shetland with a rated capacity of 4.5 MW. Due to network and demand constraints it is likely that the wind farm could be subject to a curtailment of up to 30%.

The wind farm has two mechanisms to generate income, firstly Renewable Obligation Certificates (ROCs) are payable for each MWh of electricity produced, and secondly the NYDC is paid for each MWh delivered onto the grid.

Under normal circumstances both these quantities are the same i.e. all the energy produced is sold onto the grid. In this situation, during times of low demand or network saturation the wind farm (or individual turbines) will effectively be turned off, even though they have potential to continue generating. During these times the wind farm is prohibited from generating income from both the mechanisms above.

There is an opportunity however to utilise this available energy on a private network, which would allow the wind farm to receive income from ROCs.

This paper will investigate the potential to utilise some, or all, of this available energy in the production of sea-salt.

2. Methodology

The generally accepted approach to establishing the feasibility of any business venture is to estimate the market demand for a product or service and work backwards through the supply process to establish what is sensible and/or indeed practicable.

Here we take the reverse methodology to establish how much raw material we have (energy), investigate how much product (sea salt) we can produce, and only then determine if there is a market for the product.

Although it is arguable that any such investigation is iterative, the emphasis here is to utilise all the available energy and not necessarily generate the maximum amount of end product.

3. Available Energy

The quantity of energy available corresponds to the level of curtailment experienced by the wind farm. The level of curtailment is in turn dependent upon the energy generated (supply) and the demand on the local grid.

Both energy generation and demand fluctuate seasonally, the generation due to increased winds during winter and demand largely due to increased heating requirements during winter.

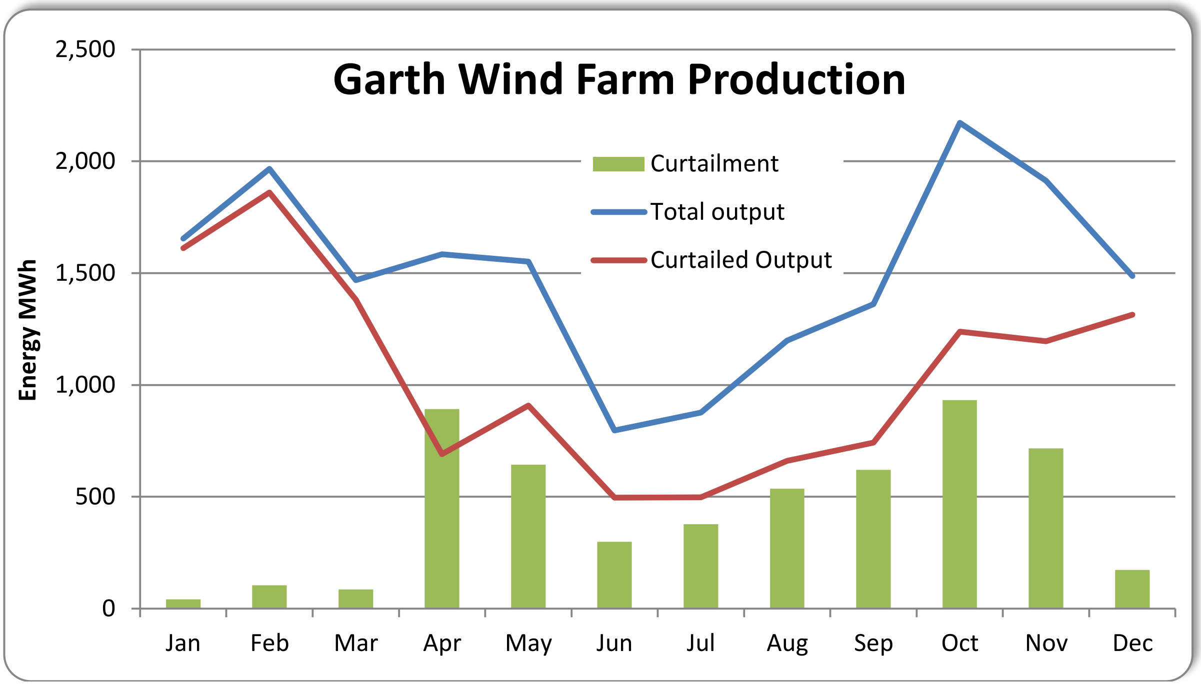

Figure 3-1: Garth Wind Farm Production

Unfortunately the variations in generation and demand do not fully match, so there are relatively sharp changes in curtailment throughout the year.

From Figure 3-1 we can see that the first three months of the year, the curtailment is minimal and for our purposes here we will assume that the energy available is insufficient for production of sea salt. We will therefore proceed on the basis that the plant will be shut down during these months.

During the remaining months the energy available varies between 173 MWh to 933 MWh. Such a large variation is unlikely to be practical for the efficient use of a single boiler, so splitting the load between two boilers is the sensible option.

The IS52 Electric Steam Boiler from Collins-Walker is a suitable appliance, and the breakdown of loading is given in Figure 3-2.

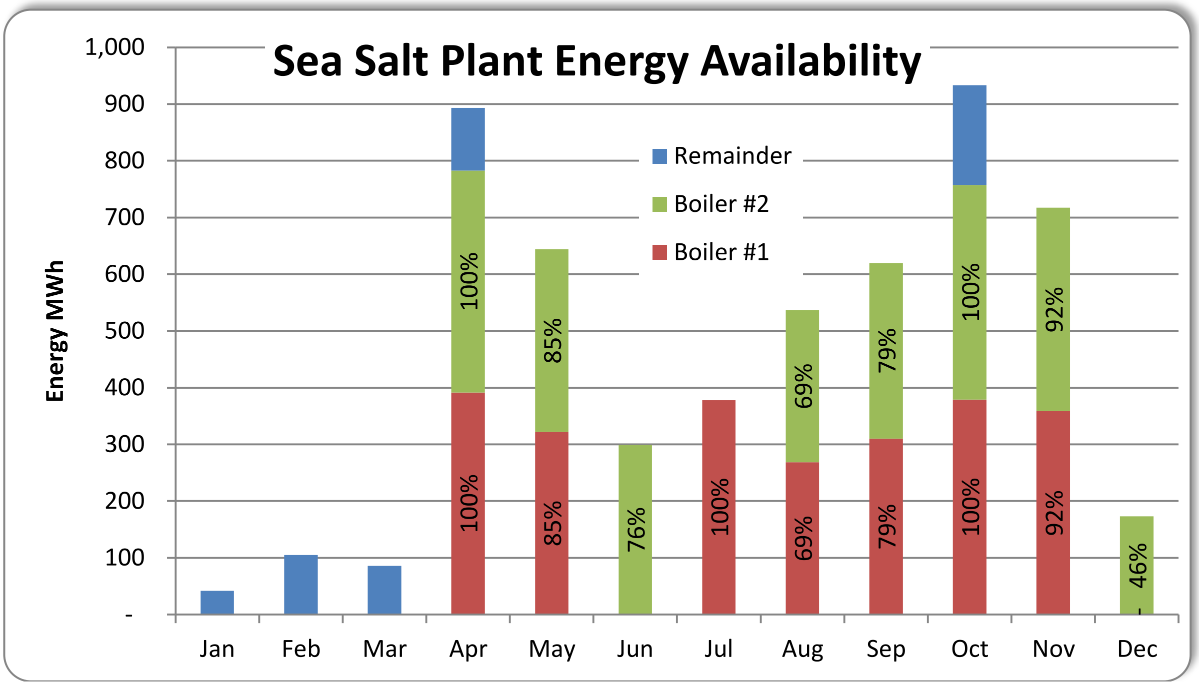

Figure 3-2: Salt Plant Energy Usage

This configuration allows for the utilisation of 90% of the curtailed energy.

4. The Science of Sea Salt Production

4.1. Chemistry

The sea water around Shetland has a salinity of 35 which means it has a total salt content of 35g per 1000g of seawater.

The first step in the process is to heat the seawater to boiling point to evaporate off 47% of the water, at this point some of the crystals begin to form.

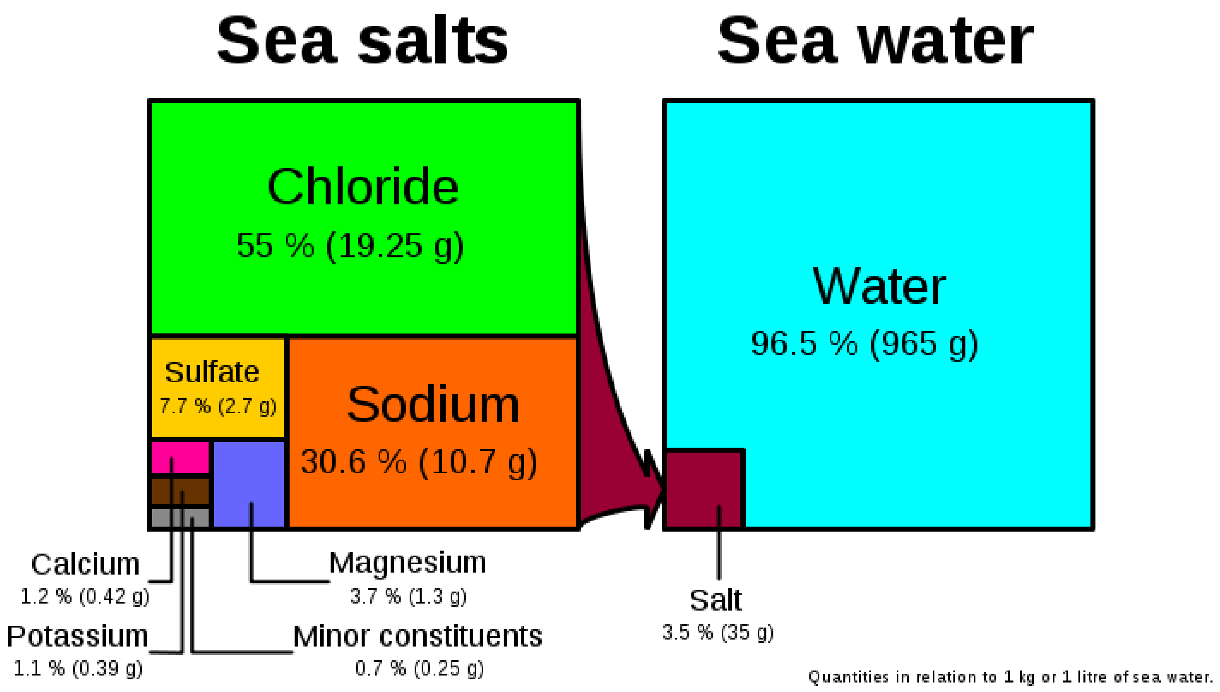

Figure 4-1: Composition of Sea water.

Sea water is a mixture of many different particles (called ions) dissolved in water. As the water is removed, by evaporation, these ions combine into pairs and precipitate out. This precipitation occurs at different rates for each ion pair (or salt).

The first crystals are composed of Calcium Carbonate and Calcium Sulphate. Both these are edible but undesirable in the final product so they are removed as they are formed. The water is further reduced to 89.8% of its original volume.

At this stage the crystals formed are made of Sodium Chloride (Common or Table salt) , this is the main product.

The evaporation is halted before the water is completely removed as the remaining liquid contains Magnesium and Potassium which have a very bitter taste.

4.2. Physics

The amount of energy required to evaporate water is considerable, and far more than to do any other part of the process. To illustrate this in simple steps, consider processing 1 tonne of seawater per minute:

0.49 kW required to pump the seawater into the building
6.62 kW required to heat the seawater to 100°C
37,667 kW required to evaporate it.

Therefore for simplicity we will only consider the energy required to evaporate the water.

5. Production processes

There are various techniques used for the production of sea salt but all ultimately rely on the evaporation of water from seawater or the by-product of a desalination plant.

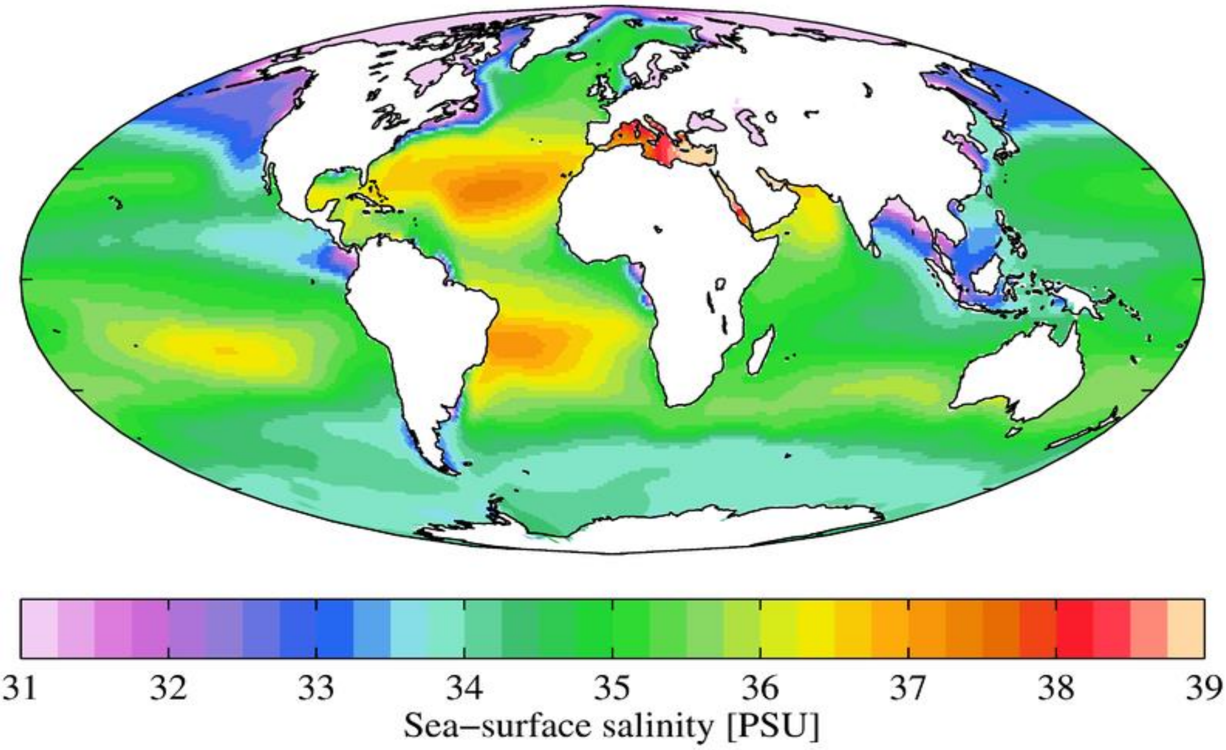

Figure 5-1: Sea water salinity

Typically sea salt production is situated in areas where the seawater is high in salinity and temperature. Therefore the Mediterranean and Middle East areas are key producers of sea salt. These countries also tend to suffer from a scarcity of fresh water and are therefore home to numerous desalination plants. These plant by their nature produce and abundance of concentrated sea-water which can be used as a cheap feedstock for sea salt production.

However these waters are also heavily polluted[1] and without careful processing these pollutants can be concentrated in the sea salt.

5.1. Industrial process

Using all the advanced techniques of a modern chemical plant, an efficient process can be employed to produce sea salt. The process involves the evaporation of the water under vacuum, the recondensing of the generated steam and heat recovery.

Despite being highly efficient, this process has two inherent problems. Firstly the process is a continuous one i.e. the raw material (seawater) flows in continuously while the products (salt) and by-products (fresh water) flows out continuously. While this may not appear to be an issue at first

[1]World Wildlife Fund : http://mediterranean.panda.org/threats/

glance problems arise when starting and stopping the process. For example in normal operation the hot steam from the boiler would be cooled by the incoming seawater. This in turn would pre-heat the incoming seawater before reaching the boiler. Stopping this process suddenly would mean there was nothing to cooled the steam with, and similarly during start up the boiler would take a long time to get up to temperature without seawater pre-heating.

The other problem is that the process favour fast evaporation and therefore small grains of salt. There is a perception of the larger the grain/flake size the greater the quality.

5.2. Traditional saltpan process

For centuries salt has been made in Britain essentially by boiling up a large vessel or salt pan. As the saltwater condenses crystals begin to form on the surface. These crystals continue to grow as the water evaporates until they have become too large to float and sink to the bottom of the vessel.

When water has almost disappeared, the salt is raked up and shovelled into trays for drying an oven.

With some modifications this is the basic process used to produce Maldon Salt[2], Halen Môn[3] and Cornish Sea Salt[4] which are the only sea salt producers in Britain.

Figure 5-2: Salt pan in operation at Maldon Crystal Salt Company

[2] Maldon Crystal Salt Company: www.maldonsalt.co.uk
[3] The Anglesey Sea Salt Company: www.halenmon.com
[4] Cornish Sea Salt Company: www.cornishseasalt.co.uk

5.3. Proposed process

Given our constraints here in not being able to guarantee a continuous supply of electricity the 'Industrial Process' described above is not practical and is unlikely to achieve the efficiencies which are the key advantage of this method.

Therefore the process based on the 'Traditional process' has been developed as follows:

1. The seawater is pumped from the tidal stream in Bluemull Sound, to ensure that it is free from any land outfalls.
2. The seawater will then pass through a filter to remove any series of filters to remove plankton and other marine life.
3. The first stage boiling will reduce the water to 47% of its original volume and create deposits of calcium sulphate, calcium carbonate and a froth of organic material.
4. The brine will then flow via gravity feed into the salt pans 2m below. These pans will be operated manually to ensure that the salt flakes are to the highest standard.
5. The harvested salt is then loaded onto trays and baked in an oven to remove any excess moisture.
6. The dried salt is then loaded into the packaging machine which forms pre-printed packets and fills them with 250g of premium Shetland salt.

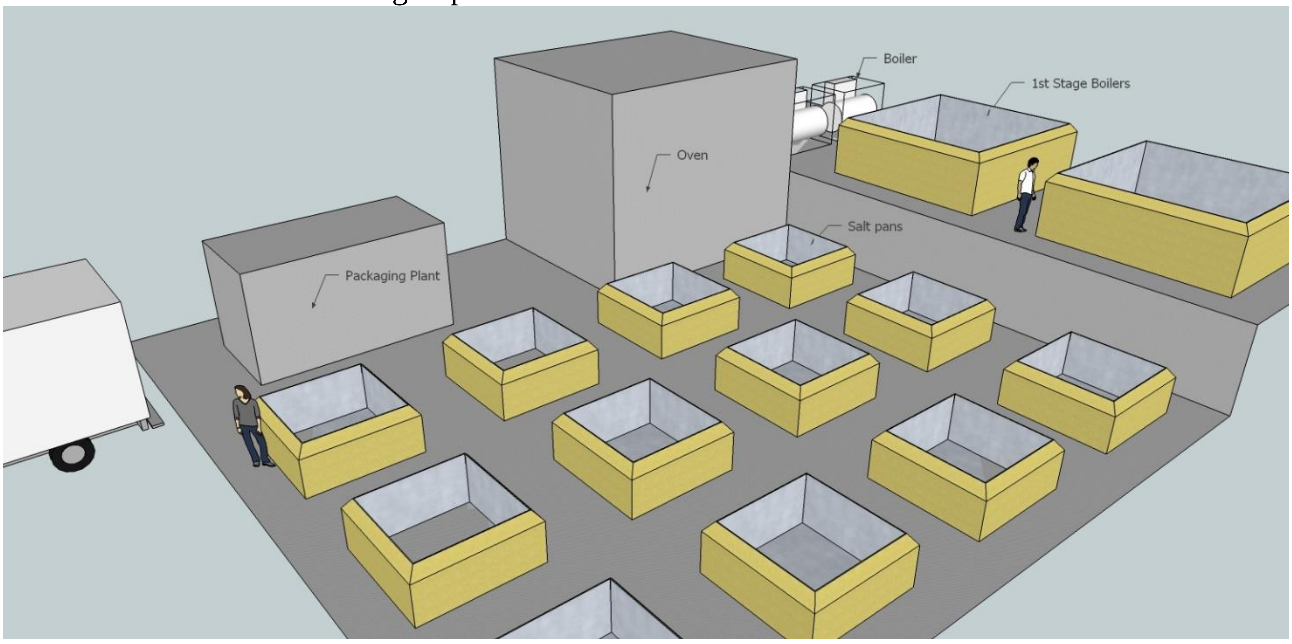

Figure 5-3: Production plant layout

5.4. Design considerations

Careful consideration is required at every stage to ensure that the plant operates safely when the power fails which may happen frequently.

It is also important that as soon as power becomes available that the plant becomes operational as quickly as possible, and can function on a variable load.

Given that the majority of the power consumption from the boilers, it is crucial to size these appropriately to maximise their productivity. By having two smaller boilers instead of just one, means that under low power supply (i.e. low curtailment on the wind farm) one of the boilers can be energised and gain operational pressure much faster than one large one. The boilers have also been specified to operate on variable loads.

Following the process downstream from the boilers, the plant has been split into two 'trains' to allow operation at half capacity when required. Therefore there are two primary boiling tanks which each feed six secondary pans.

The evaporation of water from an open tank is usually assisted by forced ventilation i.e. extractor fans. Although this is certainly possible here when the power is on, we have to allow the evaporation to continue after the power is shut off. Therefore the large number of pans and large surface area are required to compensate for reduced ventilation.

The primary tanks are raised above the level of the secondary pans to allow a gravity feed from the former to the latter. This means that if the first stage is almost complete at the time of a power shut down, then the brine can be fed into the salt pans without the need for pumping. The hot brine will reduce naturally as it cools, depositing salt as it does.

The primary tanks are also sized to accommodate all the calcium carbonate and sulphate deposits accumulated over 5 months of operation, this means that the tanks are always available when required. Thorough cleaning will be required during January, February, March and either June or July.

5.5. Production

	Curtailment MWh	Boiler #1 MWh	Boiler #2 MWh	Water evaporated Tonnes	Salt produced tonnes
Jan	42	-	-	-	-
Feb	105	-	-	-	-
Mar	86	-	-	-	-
Apr	893	391	391	1,241	35
May	644	379	265	1,021	28
Jun	299	299	-	474	13
Jul	378	-	378	599	17
Aug	537	269	269	852	24
Sep	620	391	229	983	27
Oct	933	379	379	1,201	33
Nov	717	391	326	1,137	32
Dec	173	173	-	274	8
Totals	**5,427**	**2,672**	**2,236**	**7,784**	**217**

6. Market

There is an established and apparently growing market for sea salt with new producers appearing in the marketplace.

Brand	Since	Location	Products	Retail Price (per kg)
Maldon	1882	Essex, England	Sea Salt	£ 6.60
			Smoked Sea Salt	£ 15.60
Cornish Sea Salt	2004	Cornwall, England	Sea Salt	£ 7.52
			Smoked Sea Salt	£ 29.20
			Chilli Sea Salt	2.39
			Sea Salt and Luxury Pepper	2.50
			Garlic Sea Salt	2.29
			Onion Sea Salt	2.29
Halen Môn	1996	Anglesey, Wales	Sea Salt	£ 20.00
			Smoked Sea Salt	£ 38.75
			Spiced Sea Salt	£ 26.00
			Vanilla Sea Salt	£ 38.75
			Celery Sea Salt	£ 26.00
			Finer Flake Sea Salt	
Irish Atlantic	2010	Cork, Ireland	Sea Salt	€ 19.96
Saxa		France	Sea Salt	£ 1.72
Geo Organics		Portugal	Sea Salt	£ 4.36

7. Appendix A: Case Study - Maldon Crystal Salt Company Ltd

The Maldon Crystal Salt Company is run by the 4th generation of the Osbourne family in Essex. Although it has undergone some modernisation over the years it is still operating on the same traditional used on the site since 1882.

	2011	2010
Turnover	9,442,816	9,249,808
Cost of Sales	1,876,842	1,819,823
Gross Profit	**7,565,974**	**7,429,985**
Gross Profit %	**80%**	**80%**
Distribution Costs	434,222	356,086
Administration Expenses	1,055,799	3,157,106
Interest charges	(3,010)	2,263
Profit before taxation	**6,078,983**	**3,914,530**
Net Profit	**64%**	**42%**