Turning Whey into Alcohol
at Dubliner Cheese

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INTRODUCTION

Good morning ladies and Gentlemen.

I am going to talk to you about the Dairy industry.

The Dairy Industry is a large global industry estimated to be worth $296 Bn worldwide.

In the US alone there are between approximately

- 485 fluid milk production facilities and
- 481 cheese production facilities,
- 196 dry, condensed and evaporated dairy products sites,

and that doesn't include ice cream production.

It is an industry which uses large amounts of energy and large amounts of water. It is generally regarded as the single largest source of food processing wastewater in many countries.

I am going to outline, by way of a case study, how its possible to save money and actually create revenue streams through sustainable water and energy management and with a little bit of creative out thinking.

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But first of all by way of introduction, I work with O_2 Environmental we are a consultancy group which works with three main groups. We work with Emerging Emerging Water Technology Companies to provide Market Analysis and competitive benchmarking studies to help them commercialize their technologies.

We work investors and Corporations carrying out Technology Assessment to help them if assess new technologies and determine 'will this do what it says on the tin'.
And we carry out work for some of the larger water companies to provide advice on areas of market growth in the water sector and to help with merger and acquisition assessment.

We have a Technology Assessment Group, the **O_2 TAG**, which a global team of water experts, we have people based in Canada, the UK, Germany and Ireland. We also maintain what would arguably be the world's largest database of emerging water technologies, the **BlueTech Tracker™**.

This is supported by a series of Water Technology Webinars which profile different areas of the market and different technologies which we have pre-screened.

We have a Technology Assessment Group which a global team of water technology market experts. **BlueTech Tracker**

The Dairy Industry

As I mentioned, the Dairy industry is a large use of water and energy.

On average for every gallon of milk produced, it takes between 1.5 – 3 gallons of water. That represents potable water consumption and wastewater produced.

So in the US, the dairy sector produces about

- **80-160 Million Gallons** per day of potable water which is used and approximately the same volume of wastewater which is produced.

That is equivalent to a city of between 800,000 – 1.6 Million people. Because dairy wastewater is typically 10 times the strength of municipal wastewater, in real terms of loading, its equivalent to the loading of up to **16 Million people.**

Carbery Milk Products:

I am going to talk now about a Dairy site Ireland, which has done something very unique. They ferment whey into potable alcohol, and they were the first plant in the world to do this.

Many of you may say that it is no coincidence that it was a dairy in Ireland, that came up with the idea of trying to turn a milk product into a potable alcohol.

Carbery Milk Products is a major international food ingredients, flavours and cheese manufacturer headquartered in Cork, Ireland. They have operations in the US as well, and many of you may be familiar with their flag ship product, which is a cheddar cheese, called Dubliner Cheese.

The interesting thing is, about what Carbery did, in looking at what to with their whey, was they didn't do it for environmental reasons, there was an economic driver.

They needed to find something to do with their whey.

The story here starts with Whey.
When you make cheese you end up with these two ingredients, curds and whey. The curds make the cheese and the whey is a byproduct.

Now in the past, historically, many cheese producers kept pigs, because pigs love whey, and it was a fantastic way of getting rid of the whey and a perfect example of animal husbandry and a sustainable system.

Nowadays many of the larger dairies would take that whey and they would dry it, condense it, evaporate try and turn it into a product of some sort, food ingredient additive, a whey powder, and that is probably the best use for whey, as it’s an excellent food, it’s full of nutrients.

However, while the markets have been developing, there is still a surplus of whey produced above and beyond the market for whey products.

In 2006, there was 90.5 Billion pounds of whey produced; about 45% of this can be accounted for in whey products. But 65% is unaccounted for and much of that may be treated as a wastewater, but could be fermented into alcohol.

If this whey is treated as a wastewater, it is hugely energy intensive. Milk, and by association whey, is an excellent food.

Its nature’s best. After millennia of evolution, it’s what mammals came up with to ensure the survival of the next generation. To treat it as a purely a wastewater is crazy.

There are a lot of valuable components in there. The single biggest ingredient is lactose.

Lactose is a sugar, like glucose and sucrose, and can be fermented like sugars into ethanol. In face 1 pound of lactose will produce just over a half a pound of ethanol.

Therefore if you looked at the surplus whey in the US in 2006, there is the potential there to generate 203 million gallons of ethanol.

Now this process should never compete with the use of whey as a food ingredient market, but where you have exceeded market demand, it’s certainly a very good secondary use for it.

And you can still then recover other useful products such as Phosphorus, which I will talk about in a moment.

Carbery Milk products was the first dairy in the world to do this,
There are a few other facilities that have mirrored this.
The process was mirrored at two sites in the US, the Golden Cheese Facility in Corona, California, operated by Dairy Farmers of America Co-operative, and a plant in Melrose,

Minnesota operated by Land O Lakes. The Golden Cheese facility has actually since been shut down.

The flow sheet looks something like this:
They take the whey byproduct and they put it through MF & RO, the lactose is sent to a fermenter where it is fermented into beer which is 2-4% alcohol.

That then goes forward to a distillation system where they distill and produce a 96% ethanol product.

Now initially the goal at Carbery was to produce a potable alcohol which they would market as vodka. I think they were going to call it Brian Boru Vodka.

But they ran into one significant hitch with that plan.
Vodka by definition has to be made from a grain, barley. And apparently there are tests that can be done using carbon isotopes to determine the source of the feedstock.

But fortunately, another outlet presented itself in the form of the Bioethanol fuel market.

And now Carbery sells **660,000 gallons** of ethanol each year to the oil company Maxol for use in the oil company's E5 and E85 blends. And if you fuel up with bioethanol in Ireland it is coming from this one plant. In fact Ireland is the only ethanol-consuming country in Europe not using sugar cane based ethanol imported from Brazil.

But the story of energy and resource efficiency does not stop here.

So you have taken the sugars which were present and converted into ethanol.

The next step is there was steam which is used in the distillation process which comes off at 75 deg C and 92 dec C. recover and use that heat to pre-heat boiler water, heat water for CIP, to pasteurize and milk and cheese.

The plant also has its own on-site Combined Heat and Power facility which runs on natural gas. The use of the energy recovery from the steam distillation process, greatly reduces the energy required in the CHP plant, thereby saving money.

Now when you have finished the fermentation process, there is still a waste stream.

They put that waste stream in an Anaerobic Digester and produce methane, or Biogas.
That biogas is burned in an on-site boiler and used to produce more heat energy which they use to pasteurize milk, to pasteurize product and to provide hot water.

But, the story doesn't stop there……

There is a saying the Pork industry that the only part of the pig they don't use, ….is the **squeak**.

And Carbery is very like this, they take every last ounce of energy they can out of this system.

And this would be described as **Energy Cascading**, which is one of the tenets of good **industrial ecology**.

Where you are taking energy and each step of the way, you pull back what you can out of it.
(This happens in nature, and we can mirror this in industrial systems. For example in a city, this could be the co-location of an ice-rink with a school, the waste heat from the ice rink could be used to heat the school, that's energy cascading)

When the wastewater comes out of that Anaerobic Digester, its actually quite warm, its at 100 deg F, body temperature.

Now that's low grade heat, but its enough, if you run it through a heat exchanger, to pre-heat incoming milk, which is coming in chilled at from 4 deg C and bring it up to 16 deg C.

That also has a double effect.
As well as saving the energy required to heat the milk, it does another important thing.

This Dairy discharges its wastewater back into a local river, the River Bandon.
There is a temperature limit on what they can discharge, they are not allowed to increase the temperature of the river or it would have a detrimental effect on the ecology of the river.

So in running that through a heat exchanger, they are saving energy and meeting discharge consent, at the same time.

Now having tackled pretty much all you can do on the energy side of things, **what's next?**

The Phosphorus.

As I said, Milk is an excellent food, it contains a lot of Ca + P.
In fact , P is the currency for energy in all living cells and life depends on it.
And it's a big sustainability issue, because P is mined.

It's a non renewable resource. It is mined in just a few places worldwide, China, Florida, and Morocco.

You have heard of Peak oil, you may have heard of Peak water, but peak phosphorus is potentially even more worrying.

And there is a lot of talk now around the geo-political issues surrounding Phosphorus.

China, which has put a big export levy on Phosphorus as they realize the strategic importance of this resource.

Europe, has very little natural phosphorus reserves, and countries like Sweden are mandating P recovery.

Dairies have l**arge quantities** of Phosphorus.

And it's an issue for them, as they have to take it out before they discharge to rivers or lakes, as it would have a negative environmental impact.

Also it tends to precipitate and block pipes and cause operational issues in the plant.

In Carbery, they have an **extremely** tight limit on phosphorus, its 0.8mg/l.
And it's coming in at maybe 100mg/l +, so that's in a 99% removal.
They have remove 99% of the Phosphorus, which they do, in the WWT process, but they then recycle that Phosphorus back onto agricultural land.

And there are some interesting technologies being developed to refine that process and produce a higher value Phosphorus product. I will touch on these later.

If you go into any dairy anywhere in the world, the chances are the have problems with precipitation of phosphorus in pipes, forming deposits.

Water Re-Use
So having dealt the energy and recovered, the Phosphorus, you are left with a very high quality treated effluent.

And this is where my involvement with Carbery began.

O_2 Environmental was doing some work with a Californian based water tech company called APT Water. APT Water has an Advanced Oxidation Technology called HiPOx and recently received VC investment from Kleiner Perkins and a Canadian VC, XPV Capital.

And they were looking at different market applications for their Advanced Oxidation technology and wanted to look at water re-use in the dairy sector.

So we looked at it and we quantified, the number of dairies, the quantities of water that they produce, the market size, the market potential. We evaluated which dairies had on-site treatment, what they currently paid for water and what the drivers were for on-site water re-use. And then we wanted to some treatability tests to generate a cost model for water re-use.

And Carbery made an ideal case study due to the huge amount of efforts at the site on sustainability. Which had been used on the site to date.

So we took samples of wastewater and we shipped them up and sent them off 20 gallons of wastewater to California for testing.

And the **drivers** at this site for water re-use would be as follows:

- **Provide water required for Plant expansion**

Carbery is limited in how much additional water they can abstract from that river.
Essentially they can't extract any more water from river.

They can't use ground water, they did that before, and they drew down all of the wells in the area.

Now if they want to expand production at that site, which they do, water re-use represents a potential source for the water they would need to feed the process.

- **Reduce environmental impact of river discharges**

Secondly, from an environmental perspective, in the summer time, when the flow in the river is low, there is not that much dilution capacity available.

And if Carbery could re-use that water they would be reducing their impact on that river.

So the results of the benchscale tests were very positive.

We found that it was quite easy to take that water which was already high quality, and polish it up and go that extra yard to produce a re-use quality water.

From an economic perspective, its not that expensive, it's cheaper than buying potable water at regular rates.

The reason being, you only really have to look at the marginal capital and the marginal operational costs.

The WWTP is in place already and is required to meet discharge permit.
Its adding the additional bit of technology, is where the costs are.

So where would they re-use this water?

So then we looked at where you could use that water on-site.

And this would be applicable to any number of Dairies, and indeed right across the food industry.

The most obvious choice is **Boiler Feedwater.**
There are boilers on-site, before the water goes onto the boilers, it is demineralised using a Reverse Osmosis plant.

We could take water, treat it with Advanced Oxidation and feed it to the RO plant.

There are a number of advantages to this: it could

a) it could reduce fouling on the membrane, increase time between clean cycles and prolong the life of the membranes.
b) secondly its, an outlet which Is not coming into direct contact with Food Product. which reduces concerns about cross contamination.

So now you see a Dairy where we have integrated energy use, Phosphorus recovery, and the potential for water re-use.

How replicable is the Carbery scenario to other dairies?
Well it's very replicable.
Milk is milk and a dairy is largely a dairy.

It takes between 1.5 – 3 gallons of water to produce a gallon of milk no matter where you are.

So you have a $296Bn global industry which is energy and water intensive, but with the **potential,** with a bit of clever planning and technology integration, to greatly reduce energy use, recover phosphorus and re-use its water.