Nuffield Farming Scholarships Trust

A Trehane Trust Award

Energy from Agriculture

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Contents

1. Introduction

In January 2009, the Trehane Trust and the Nuffield Farming Scholarships Trust put their faith in me by awarding me a Nuffield Scholarship. It was a pivotal moment in my personal and business development. I hope I can inspire others to embrace the change and push the boundaries of achievement within British agriculture to new levels.

I milk 220 Holsteins at Hawick in the Scottish Borders. Since returning from college in 1998, I have worked together with my family to build the business which involved the installation of new parlour, cubicles and silage pits. However the most noticeable change is the production of cheese on farm which has been managed by my parents with all the cheese sold locally. Milk is sold on contract to Tesco. The 204 ha of arable land surrounding the farm is used predominantly for the stock rations with any surplus being sold into local feed markets.

Dairy farming however, is my ultimate passion. It provides me with the excitement to get me out of bed in the morning and needless to say, also provides me with the stress that sometimes keeps me up at night. It allows me to harness the new ideas I have and at the same time will always keep my feet on the ground. Having been fortunate enough to grow up in the Scottish Borders, my emotional connection to the land, the animals and the farming industry is as strong as ever and I'm sure will remain so.

My interest in energy was triggered as recently as 3 years ago when I investigated the prospect of installing an energy generating device to lower electrical consumption on farm. While I realised fairly quickly this was not economically viable on such a small scale, a passion had been ignited that was to grow and grow. I found that while there was little point trying to generate energy on a small scale; the potential to save energy was there and more importantly, the prospect of using my natural resources to create electricity and develop another income for the business was staring me square in the face. Throughout my Nuffield studies, I have become more and more fascinated with the concept of generating energy on farm.

Numerous people have expressed grave concerns to me over the moral dilemma that surrounds the usage of agricultural land for energy generation. However I see it as simply not a choice between food production and energy production. Many of the systems I have seen on my travels integrated both food and energy production side by side. While I would not underestimate the difficulty that the agricultural industry faces over the next 50 years to provide food for 9 billion people, the challenge stretches way beyond the demands that have been put on farmers in the past. The challenge for agriculture in the next 50 years in stark. Global agriculture must provide 100% of the world's food as well as 60% of the world's energy.

My Trehane Trust Nuffield Scholarship will explain my views as to why this is attainable, how it is attainable and why we as farmers are in a fantastic position to make a dramatic impact on energy supply that will shape the path of the 21st century and beyond.

Disclaimer

The views expressed in this report are entirely my own and do not necessarily represent the views of the Nuffield Farming Scholarships Trust, or my sponsor, or any other sponsoring body.

2. Acknowledgements

To my Father for "acting" manager when I was away and my Mother for convincing him to do it.

To my girlfriend Kerry, who has never been on a break with me that didn't involve cows or wind turbines.

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3. Objectives

My initial Scholarship objectives included

- Looking at potential to increase biogas production through improved feed stocks and improved plant breeding technology.
- To increase my knowledge of not only the technical developments in the Anaerobic Digestion(AD), but to also look more broadly at the implementation of AD and the best forms of utilising Biogas.
- To appraise the benefits that renewables can have not only on farm businesses but on surrounding communities
- To look at the benefits of farmer to farmer co-operation when investing in and implementing renewable projects.
- To gain knowledge on the future of renewable energy, particularly hydrogen production and utilisation may have on agricultural businesses and how that fits into existing renewable techniques and markets.
- To realise the potential of cutting edge technology to reduce dairy energy bills through the likes of milk cooling, heat recovery and variable speed vacuum pumps.

Although my Scholarship may have veered somewhat from my initial intention of chiselling away at the dairy energy bill, my focus still remains very much on the saving and generation of energy from agriculture.

In this paper I have outlined the potential that I believe there is for renewable devices to integrate not only with existing agricultural businesses but also how collaboration between agri-businesses as well as integration with local communities can all benefit incomes and society in a positive way. I feel it is necessary to highlight the driving motives of those people involved in the renewable sector as well as the history and political background that influence the decisions of individuals and governments in the countries that I visited.

During the autumn of 2009, I travelled to Sweden, Denmark and Germany while in the spring of 2010, I visited America taking in the States of Illinois, Wisconsin, Minnesota and Iowa. While my European travels were to be focused on Biogas, Wind and Hydro, the passion that had grown inside me to learn more about the future methods of renewable energy utilisation through fuel cells and NH3 production was fed by the innovation and creativity that I was to see in the States.

My report focuses on the financial gains for existing agricultural businesses with particular attention being drawn to Wind and Biogas, the 2 most potent ways to generate additional income streams on UK farms. Also I will set out my Scholarship recommendations to farmers and government as well as how my learning journey has influenced my own business and where I see my future.

4. The importance of energy and the present energy options on the table

Everything we touch is energy: from the books we read to the clock on the wall to the food on the table. Energy is the very foundation of every economy in the world. It is the cheapest commodity of which all other materials are based and will always remain so. Energy is where politics, history, war, mother nature and economics come together, a mixing pot that can produce horrific consequences. To add to this, the finite supplies we have fought over during the last century are becoming tighter and tighter. Two thirds of the energy supply we rely on at present has been used up or to put it another way, the easy stuff's all gone. We have no option but to change and we stand here at the beginning of the 21st century with a consensus among the people that we need to enter a new era.

While people of developing countries often had no option but to pursue a policy of energy independence, G8 governments are now seeing the need to invest in home grown energy. In the early 21st century we have seen politicians from the more affluent industrialised governments now investing in renewable energy. The result of this will ultimately make the gap between rich and poor countries all the greater as, when oil reaches levels that remain consistently over $200/barrel, those countries who have had the foresight to subsidise renewable energy will not be left to the mercy of OPEC. Be in no doubt, every penny of investment in renewable energy at this stage will pay itself back tenfold over the next 20-30 years as the "have-nots" fight over the last remaining drops of oil.

However, renewable energy is not without its opponents. Many concerns over the production of clean energy are peddled in pubs and bars that bear little resemblance to truth and reason. If we as food producers are to play a prominent role in energy generation, we must be aware of the factors that make us best placed to deliver. No one source of energy generation represents the "silver bullet". While I wouldn't advocate anything other than a shared blend of sources, renewable generation comes as close as any to ticking all the boxes when compared to the alternatives. Listed below is a snapshot of the pros and cons of the energy sources available.

4.1 Nuclear generation

Before I embarked on my Scholarship, I was very much pro nuclear. After having gained a greater understanding of the sector, I have formed a quite different opinion for the following reasons.

- **Cost**. It is predicted that each kw of nuclear electricity costs in the region of between 2-3p/kw. This is not the real cost. The real cost of nuclear power must include research and development, insurance and decommissioning. All of these are so high, it is not feasible for private enterprise to fund so governments are left to carry the burden of these costs. While no-one can put a figure on these costs, it is estimated to take the cost per kw of energy to near 20p/kw. It makes the ROC at 3.6p/kw look like a bargain.

- **Supply profile**. There are many who see the Achilles heel to renewable generation (especially wind) as its ability to produce power when required. However nuclear generation has greater problems. Nuclear power plants provide a flat base level of generation. This level cannot be turned up and cannot be turned down. The station is either on or off. This produces two problems. Firstly, the national peak energy demand in winter cannot be catered for. This is painfully exposed in France where farmers, on average, must supply 26 days worth of their own electricity during the winter because of the high level of nuclear dependency within the country (over 80%). Secondly, having a high level of nuclear production effectively puts a glass ceiling on the development of more modern, cleaner and growing energy markets.

- **Waste**. 10,000 years is a long time. It is also the period during which nuclear waste must be stored to make it safe. To put this in context, we cannot pinpoint the exact birthplace of Christ which took place just over 2000 years ago so 10,000 years could
- prove quite a challenge.

- **Sustainability**. Uranium 235 is not infinite. It will run out in just over 70 years time and all that we'll have left is WMD. In 300 years time, we will realise that the splitting of the atom was not the greatest legacy for those in the 20th century to have left.

- Centralised plants mean that losses through the national grid can be problematic.

4.2 Coal

Pros

- **Plentiful in supply**. Unlikely to run out in the near future and available here in the UK.

- **Clean coal technology** has a major role to play in low carbon energy generation.

Cons

- **Pollution.** The obvious point of pollution is the greenhouse gasses coal emits when burned. The less obvious problem is the sludge by product formed. In many cases in America, communities have been left to pick up the pieces of polluted rivers and ecosystems due to the excess sludge having not been dealt with effectively.

- **Supply**. In previous decades, the mining of coal was left in the hands of those with little or no respect for the national interest. In today's political climate, such problems are never likely to rear their heads again but the action of trade unionists in the 70's and 80's will still leave the public with a psychological barrier to overcome before we can rely on coal to the same extent that we did back then.

4.3 Crude Oil

Pros

- Cheap, economical and infrastructure is in place for utilisation.

Cons

- Rising in price which reflects the level of supply left in the world.
- The most damning factor in the supply of oil is the stability of the states that control the supply. Countless Western lives have been lost in a bid to secure supply and countless more will be lost unless we end the addiction to middle eastern oil.
- Greenhouse gas emissions are also at an unacceptable level to governments who seek a reduction in this area.

4.4 Natural Gas

Pros.

- The cleanest of the fossil fuels.
- New finds mean that the UK will be secure in it's supply well into the 21st century.

Cons

- A higher number of states are now depending on Russia for their supply of natural gas. Russia has not been slow to flex its muscles regarding supply whenever the political landscape dictates.
- Transportation losses. It is estimated up to 30% of the calorific value of natural gas can be lost through transportation.

4.5 Renewable energy

Pros.

- Low Greenhouse emissions. Even the 500m3 of concrete at the bottom of a large wind turbine will have a carbon footprint that can be repaid in 3-4 months of the turbine running.
- Security. Wind, water and sun are all sources we have in the UK so we need not depend on other nations to guarantee supply.
- Sustainability. The resources we harness are free and will be around for millions of years to come.

- Localised production. Not only will this cut down on losses but the benefits to the local communities and local economies should be significant.

- Jobs. Germany, with 18% of electricity produced at present from renewable sources, has over 400,000 people employed in the sector. By 2020 Germany aims to produce 47% of its electricity from renewable sources.

- Flexibility and sustainability of supply. Wind and solar cannot meet the demands due to their erratic peaks and troughs however when you take renewables as a package, the likes of biomass and biogas production along with pumped hydro storage provide an elite supply profile capable of level supply and also has the flexibility to deal with peak wintertime demand.

- It is estimated by the German Biogas association that should each household in Germany pay 56 euros/year more on their energy bills, that would cover the cost of 100% renewable energy generation.

Cons

- High cost of capital outlay.

- To deliver a truly renewable economy, attitudes must change and preconceptions must be binned.

5. Motives and Driving Factors

Understanding not only the pros and cons of renewable energy supply but also the motives driving the people I met proved vital in understanding their systems and adopted methods. From governments through to individual entrepreneurs, the same goal was quite often driven by two contrasting motives.

One of the clearest contrasts involved Denmark and America. Along with ourselves in the UK, these two countries were hardest hit by the OPEC oil embargo in the 1970s. The Danish government recognised the need for change and increased its efforts to secure greater supplies of natural gas and renewable energy at home. The USA on the other hand, after a brief flirtation with home produced energy under the Carter administration, followed the free market strategy in pursuing the cheapest form of energy at the time which was Middle Eastern oil. Many of those I spoke to in America's mid west now appreciate that Jimmy Carter may have been a man ahead of his time.

The issues driving those I met on my travels ranged from

- **Reducing greenhouse gas emission.** Surprisingly I can remember very few people who were out to save the planet. However this cannot be overlooked as this factor is one of the key issues determining FIT rates set by governments across the Western world.

- **Energy independence** from external influences. Even though the US government decided to pursue foreign oil in the 80s and 90s many of the individuals I met were influenced in such a way by OPEC's oil embargo, they felt the need as individuals to bring about change.

- **Intolerance of grid operators**. Those such as Dennis Haubenschild believed that for farm generated energy to become viable, it must be converted to a form where it can be stored. Having no choice but to sell straight to the grid makes the seller vulnerable.

- **In Bavaria,** Robert Bugar of AgriKomp spoke with passion about the need for energy to be in the hands of the people and not the government or large companies. He claimed that only 4 of the 5 most dominant politicians over the last 15 years have vested interest in large scale energy (Putin - Russian Gas, Schroeder - Russian Gas, Chirac - Nuclear, Bush - oil with Tony Blair the only exception, preferring to entangle himself in the more civilised world of J P Morgan)

- The motives of changing the energy supply from the failed status quo festers inside even the most unlikely of people. Ted Hollinger, whose father was pivotal to the success of Henry Ford, earned substantial wealth through the petroleum industry. He has since turned his back on fossil fuels and advocated investment in the hydrogen/ammonia economy as the only way America can drag itself out of the quagmire of Middle Eastern oil. Ted has since founded the “Hydrogen Engine Center”.

6. The countries I visited: a snapshot of their historical and political background

6.1 Sweden

In October 2009, the first country I visited outwith the UK was Sweden. Here are a few points documenting the energy scenario in Sweden.

- Electricity is provided by two sources: nuclear power in the south and hydro dams in the north. Although Sweden has recently closed down 1 of its 5 nuclear plant, this was absorbed by the upgrading of the other 4.
- Electricity price is cheap (6-7 euro cents equivalent)
- Green certificates have a value of between 2-3 euro cents/kw. Grants are available for green energy production at a level of 33%
- Electrical grid is publicly owned
- Sweden has no supply of natural gas, all of which is imported from Denmark and is due to run out in 2016. So the options are either to find an alternative home grown supply or buy from Russia.
- At present, private and public enterprise are looking to advance the production of upgraded Biogas to the level of natural gas and fuel grade Biogas (compressed natural gas equivalent)
- At present half of the cars run on gas in Sweden are run on Biogas.
- Gas grid is limited and is privately owned

6.2 Denmark

After forking out the £37 toll to cross the bridge from Malmo to Copenhagen, Denmark was second on my list. Again here are a few of the important points that governs energy sourcing and production in Denmark.

- Denmark has the greatest level of experience of Biogas in the whole world.
- Denmark has more wind energy per capita than any other industrialised country in the world. Also, 80% of Denmark's wind turbines are owned by the landowner.
- The Danish government has since restricted the development on wind turbines. Developers are required to take one existing turbine down in order for one new turbine to be erected.

- During the late 70s Centralised Biogas plants were used as a method to sustain the intensive pig and dairy sectors on the East coast by redistributing nutrients to less intensive areas. After this had been achieved, the plants became a tool for reducing greenhouse gasses in the 1990s and now the aim is to utilise as much of the biogas as a fuel by upgrading to substitute the natural gas that will run out in 2016.

- During the Kyoto target year of 1990, rainfall levels in Scandinavia were much higher than normal. This led to Denmark purchasing a lot of cheap Hydro electrical generation from Sweden. As a result, Denmark's carbon footprint in the base year of 1990 was very low which makes the targets imposed by the Kyoto agreement, all the more difficult to achieve.

- When the centralised plants were introduced large grants were given by the government with the rest of the money being guaranteed by local farmers. In return for the grants the Danish Government demanded the acquisition of the resulting gas at the cost of production. In my opinion, this has created a barrier to technology and efficiency as the resulting plant operators had no incentive to drive the cost of production down.

- Measures are afoot to relinquish the Danish Biogas sector from the chains of government and allow the experience gained over the last 30 years to be unleashed on the free market.

6.3 Germany

Possibly the country at the forefront of renewable technology and engineering, Germany, is proving itself to be the engine room of renewable technology advancements in the world. The background of Germany's focus on renewable consists of:-

- In 1990, the German government saw biogas production as a way of reducing the overproduction of food from conventional agriculture as well as a way of supplementing farm incomes in return for green electricity production.

- A new pipeline is being built by Germany through the Baltic to increase the security of supply of gas from Russia. At present the pipeline runs through the old Eastern European bloc. This contrasts against Germany's Scandinavian neighbours by having a subsidy structure in place that encourages the utilisation of biogas through CHP units and not upgrading stations.

- In 2009, Germany has 400,000 people employed within the renewable sector

- In 2020, Germany projects to have 47% of it's electrical production coming from renewable energy. At present the figure stands at 18%. The increased number of Biogas plants as well as the spread of photovoltaic panels in the South will see Germany easily reach it's 47% target.

- Public opinion sees renewable generation as essential to reduce reliance on Nuclear power stations and Russian gas.

6.4 USA

America's unswerving desire to embrace the free market was obvious throughout my travel in March/April 2010. While any government desire to interfere with energy markets was low, the craving by individuals to "find another way" and make renewable devices work, made my trip one of the most inspiring and eye opening times of my Scholarship. The factors governing clean energy generation in the States included.

- Tax breaks. At present, much of the wind energy in the states comes from the utilisation of tax breaks on large profits made in the City.
- The free market. While America tried to create an environment of energy independence in the late 70s, the Reagan policy of pursuing cheap oil in the 80s was seen as the key behind one of the most successful periods in American history.
- Like the UK, America's electrical generation comes from coal and Nuclear. The oil peak of $147/barrel in 2008 has jolted many individuals and businesses to think of how the addiction of oil can be broken.
- Due to the moderate stocks of natural gas, it is believed coal will play a major role in the ability to end the reliance on foreign sources.
- There is no huge public opinion to implement a green energy subsidy. Local "cap and trade" schemes are being implemented but only at voluntary levels. Any government interference in the free market is perceived as being "un American" and against the constitution. Change towards a green economy will be pursued through economic drivers alone.

7. Biogas and Anaerobic Digestion - a snapshot of the process

Throughout my Scholarship, I was able to expand my knowledge on the different systems of AD from business set up through to utilisation. In this section, I would like to outline a few of the facts and standard figures associated with the industry.

The process involves the digestion of organic material under anaerobic conditions to produce typically a mix of methane and carbon dioxide. The carbon dioxide is then removed and the methane is then inside a gas engine. The engine produces heat which is captured to heat the fermenter but there is also extra saleable heat produced. The gas engine is connected to a generator which produces the electricity.

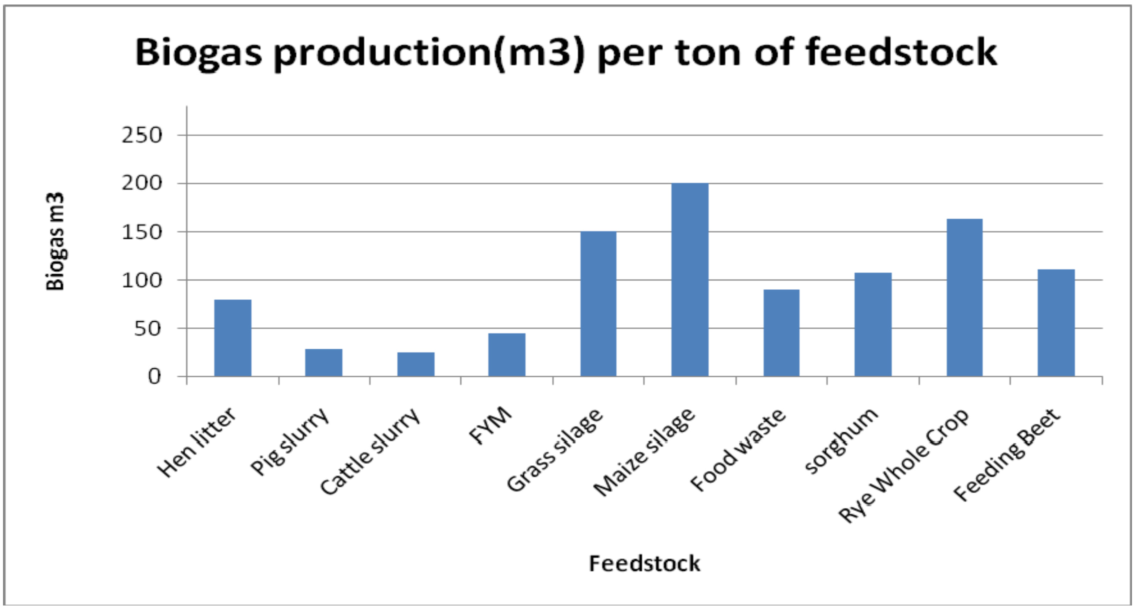
7.1 History

Biogas was first pioneered by a Cornishman by the name of Donald Cameron who constructed a septic tank and collected the gas to power street lights. Denmark used the process for sewage sludge treatment in the 1920s but one of the most famous examples of biogas utilisation came through the 2nd world war where German power stations were hit by the Allies. However the street lights remained on as they were powered by biogas.

7.2 Feedstock

The basic term for the organic raw materials is feedstock. Feedstocks vary not only in their biogas yield but also on the proportion of Methane to CO2 produced. Figure **7.2(i)** (below) shows the potential biogas yield from different feedstocks.

7.2(i)



7.2(ii)

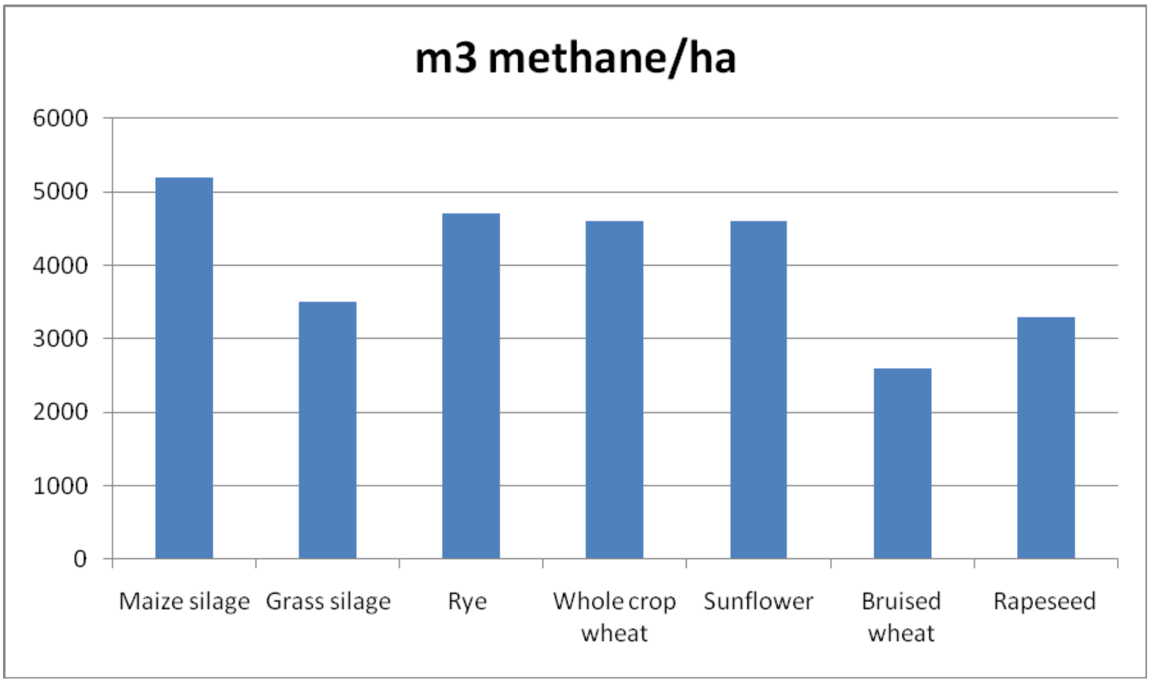
Feedstock	% methane
Pig slurry	65
Hen litter	60
Cattle slurry	60
FYM	60
Grass silage	54
Maize silage	52

Table 7.2(ii) (above) shows the potential methane content from gas derived from the feedstocks

Crops grown purely for energy production are known as virgin crops.

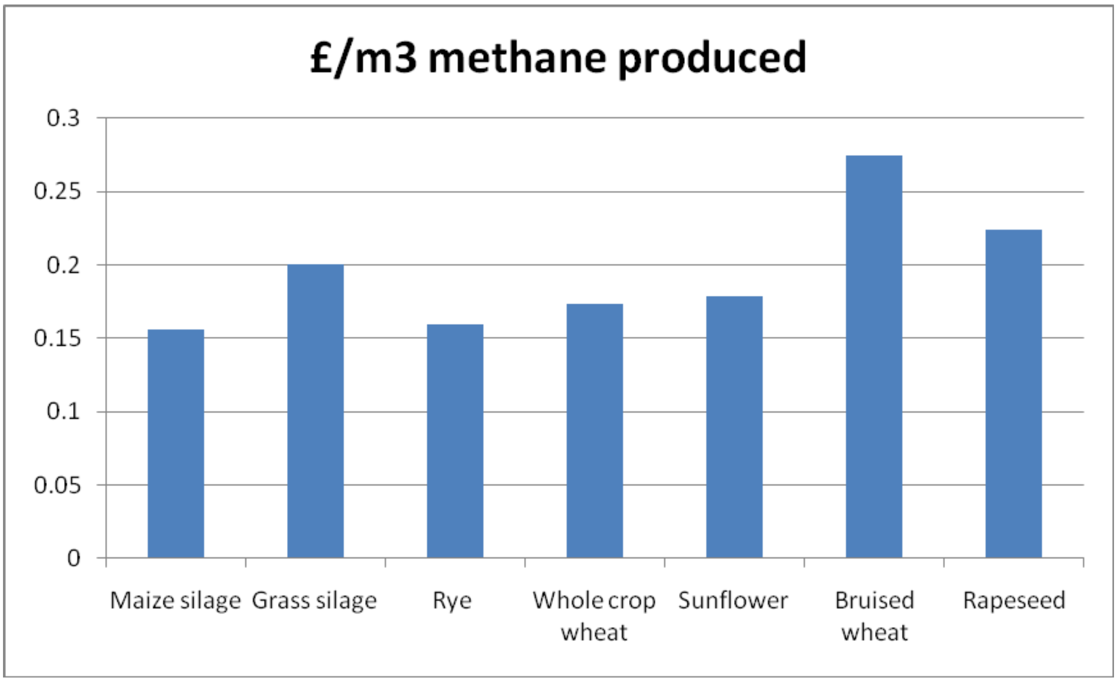
7.2(iii)

Figure **7.2(iii)** (below) shows the potential per hectare of different crops for producing methane.



7.2(iv)

Figure **7.2(iv) - below -** shows the cost of growing virgin crops for methane production.



7.3 Biochemical Process

There are 3 stages to the breakdown of the organic matter. Firstly the Proteins, Carbohydrates and Fats are broken down to Amino acids, sugars and long chain fatty acids through the process of *Hydrolysis*. Secondly, through *Acidogenesis (fermentation)*, the aforementioned products are converted to acetic acid, hydrogen and CO2 before *Methanogenesis* produces the Methane.

Bacteria

The bacteria that carry out the process come in 3 different forms that have their optimum temperature range. As a general rule, the rate of the biochemical process will double every 10 degrees. Listed below are the 3 bacterial/temperature ranges

1. Psycrophiles. A Psycrophilic would take place between the temperatures of 0-20 degrees. Very uncommon due to the low productivity of the process

2. Mesophiles. A Mesophilic process would range in temperature between 15-45 degrees. Most Mesophilic AD plants will run at around37-44 degrees. This process is very popular on farm AD plants due to the high level of productivity and the resilience of the bacteria to moderate temperature fluctuations (+/- 2 degrees). As an AD plant is unlikely to change more than half a degree a day, this provides a system where medium levels of supervision can be acceptable.

3. Thermophiles. The Thermophilic process will normally operate at 52 degrees. Because of the high level of supervision needed as a result of the low tolerance of the bacteria, Thermophilic AD plants are usually large, centralised operations with specialised plant managers.

4. All bacteria have optimum working conditions. As well as temperature, other factors influencing the performance of bacteria include:

   - Ph. In most cases, the optimum would be ph7.2

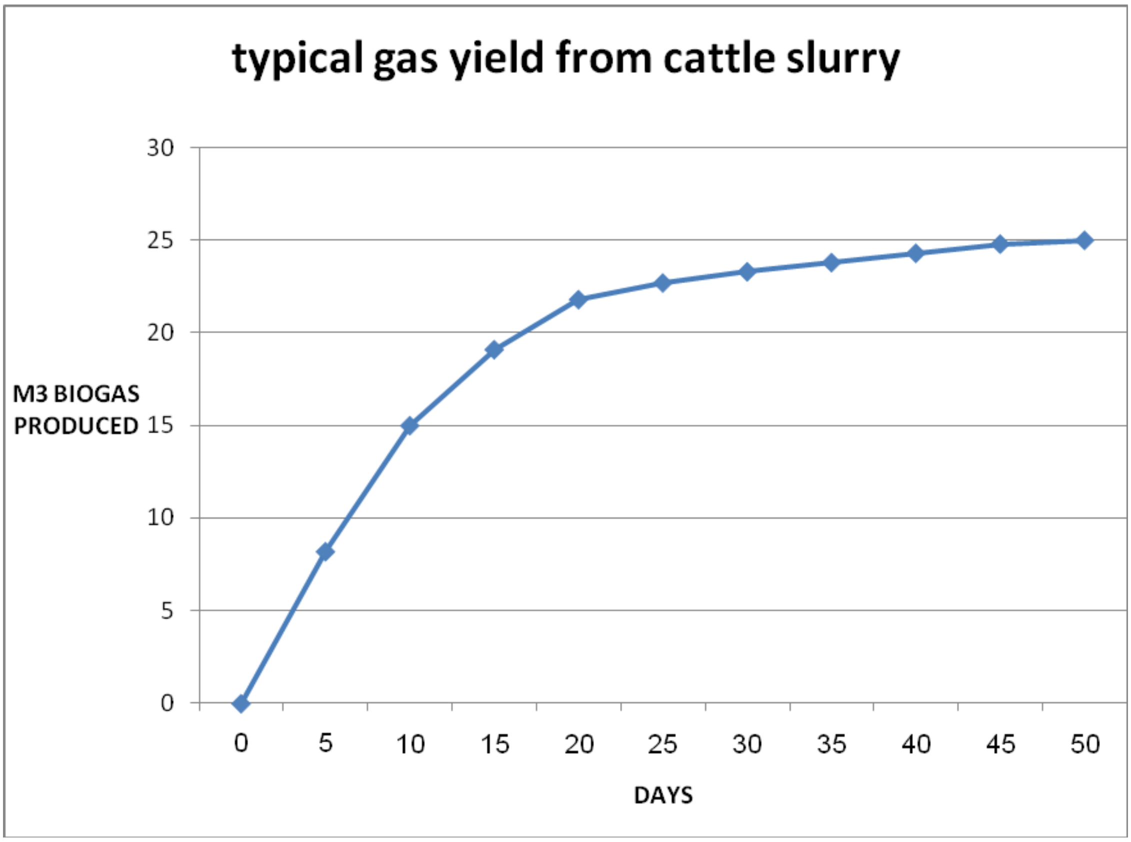
   - Nitrogen content. Slurries such as hen litter and pig slurry contain high levels of Nitrogen and can be dangerous unless mixed with another feedstock

   - Trace elements/micro nutrients. Many people in Germany predict that up to half of Germany's 4000 biogas plants are not functioning at their full potential due to incorrect levels of trace elements.

Process timescale

Most digesters will retain the digestate for around 50 days. Lower retention times will result in a lower percentage of the gas collected from the feedstock however the process becomes more productive over time. See chart **7.3(i)** (below) for the typical gas yield from cattle slurry.

7.3(i)



7.4 Standard Utilisation

By far and away the most common way of exploiting the energy value of gas is through a Combined Heat and Power unit (CHP). The expected yield output would be as follows

- Electrical output between 35-42%(around 2.5kwh/m3 biogas)
- Heat output would be expected to be between 45-50%(around 10kwh/m3 biogas). Half of the heat would be needed to maintain digester temperature.
- Around a 15% loss can be expected.

7.5 Digestate

AD is best known as a clean form of energy production but there are other commercial benefits to be had by converting feedstock to digestate. The main change comes when organic Nitrogen is converted into mineral Nitrogen in the form of Ammonium (NH4). This allows greater Nitrogen uptake by the plant.

7.6 Greenhouse Gas Emissions.

While everyone has differing views on Global warming and the cause, the reduction of greenhouse gasses is possibly the most powerful argument for the advancement of AD.

Agriculture produces 7% of the world's greenhouse gasses. Much of the total figure is made up from the emissions of methane (21 times more harmful than CO2) and Nitrous Oxide (310 times more harmful than CO2). The CO2 produced by burning biogas is said to equate to the level of CO2 that has been absorbed by the crops that were grown to produce the feedstock. This, like the burning of wood, is said to make the process CO2 neutral. However, this does not tell the full story of Biogas. When the Methane and N2O is converted into CO2,H20 and atmospheric Nitrogen, the benefits become all the more apparent. Table **7.6(i)** (below) shows the environmental benefit from digesting slurry in CO2 equivalent.

7.6(i)

Source	kg CO2 saved/kwh (electrical)produced
Using CO2 neutral fuel over coal fired power station	0.64
Conversion of methane and N2O into CO2, H20 and atmospheric Nitrogen	10.4
Total CO2 equivalent saving/kwh	11.04

This table proves Biogas production through slurry utilisation to be the greenest fuel on the marketplace. During a visit in Denmark, the concept of Biogas as a fuel was put into context for me.

> *"When you want to reduce your car's emissions by 100%, you would turn off the engine. If you want to reduce your car's emissions by 167%, you'd run it on Biogas".*
> *Bruno Sander Neilson, Biogas Association of Denmark*

7.7 Quick and Easy rough rules of thumb for Anearobic Digestion

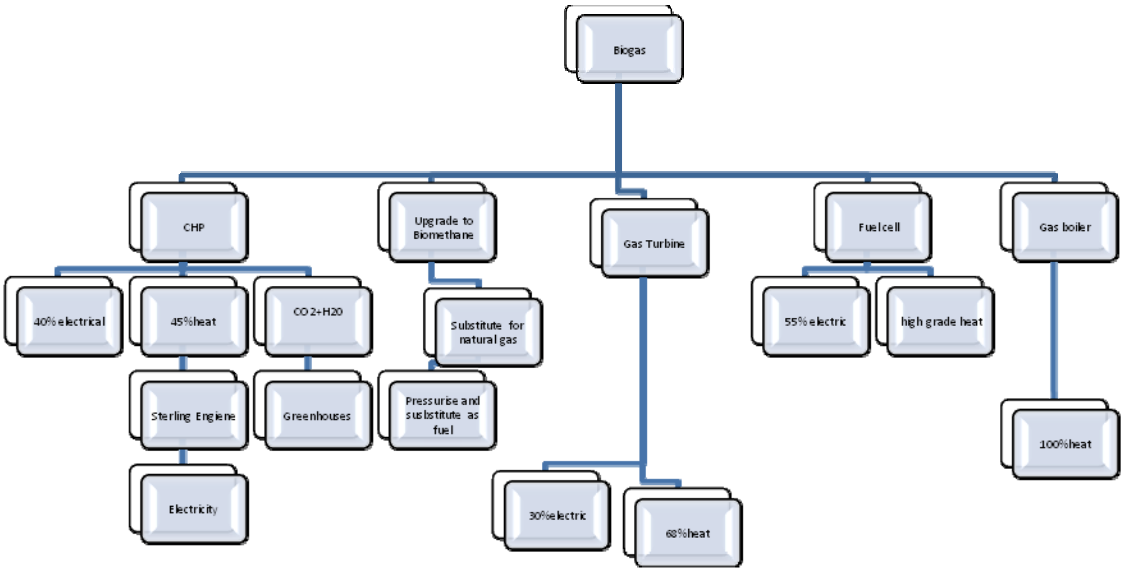
- One hectare will produce 2.5 kwh electrical for 1 year. e.g. 100 ha will produce enough feedstock to feed a 250kwh AD plant.
- One M3 Biogas produced will yield 2.5 kwh electrical so the production of say, 250m3 biogas would expect to convert into 625kwh electrical through a CHP unit.
- Capital investment costs range between £3500/kw installed to £6000/kw installed. Take a small installation of 250kw at £5000/kw would lead to an approximate capex of £1,250,000

8. Biogas Utilisation

Raw Biogas is only the start of the utilisation process. In effect, biogas is like crude oil and can be refined in different ways to suit different end uses. The utilisation of biogas was, for me, the most fascinating and interesting part of the process. Flowchart **8(i)** (below(shows the different possibilities and uses from raw biogas.

In this section I have highlighted the basic steps of each process as well as comment on where you'd find each method, why it's suited to that business/location and the pros and cons.

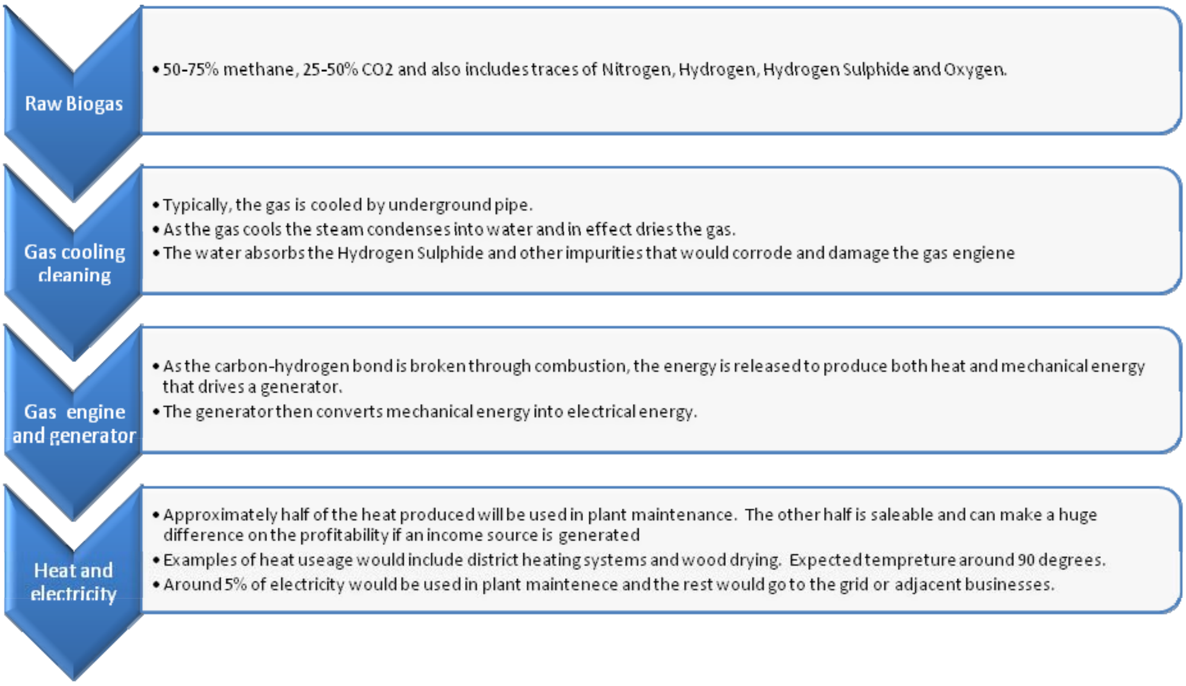
Fig. 8(i)



8.1 Combined Heat and Power Unit (CHP)

Char t **8.1(i)** illustrates the steps involved with utilising Biogas through CHP.

Fig. 8.1(i)



Where?

CHP (also known as co-generation) is regarded as the standard and most common way of utilising Biogas. The normal location would be on farm as the capital cost is low enough to justify relatively small levels of generation (190kwe was the lowest I saw). I visited numerous CHP units in Germany from Sleishvig Holstein to the Rhine valley to Bavaria. Also in America, CHP was the preferred method of utilisation. Larger scale CHP utilisation would often take the form of satellite digesters on farm with the gas being piped to a CHP unit near a built up area

Why?

- Small scale nature of on farm AD suits the lower cost of a CHP unit.
- Electrical generation can easily be transferred to the grid or utilised on farm
- Because of the small scale of CHP, the volume of heat produced has far greater chance of being utilised locally.
- Much of the maintenance can be done by farmer.

Pros

- Financially viable down to 190kw/hour production
- Engine relatively cheap to maintain and will last 40,000-50,000 hours before major overhaul.
- Simple and reliable

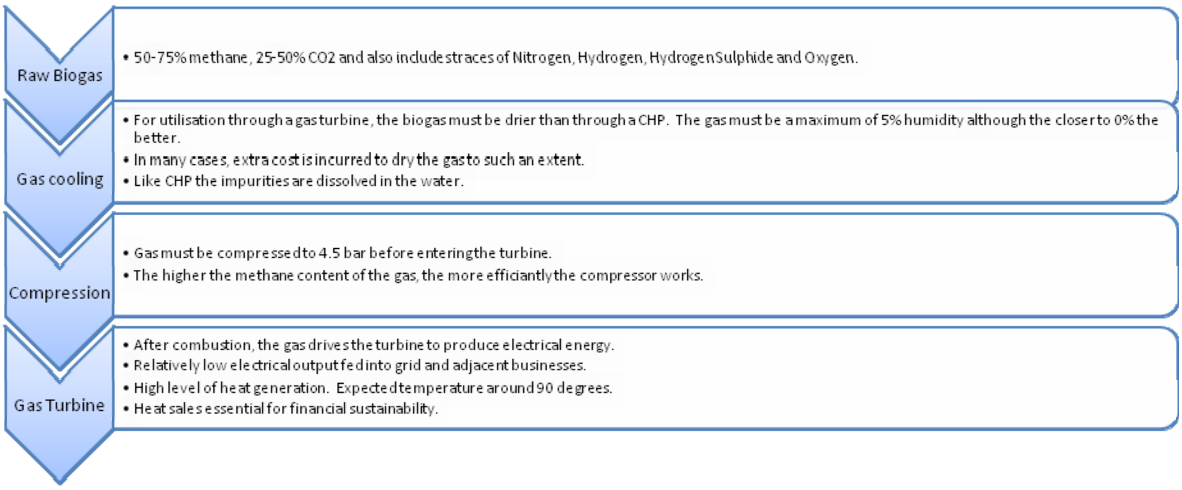
Cons

- Relies on viable electrical grid connection
- Depending on the feed in tariff, heat utilization may be needed to increase viability.

8.2 Gas Turbine

Chart **8.2(i)** illustrates the steps involved with utilising Biogas through a gas turbine.

Fig. 8.2(i)



Where?

At present, gas turbines are found mostly in subsidised research stations. The on-farm viability is a long way off, especially with the advancements of CHP. The turbine I visited was within an agricultural college called Schloss Einhoff near Kassell in central Germany. They were still experimenting with gas pressure and humidity on the appliance.

Why?

Research stations and colleges can apply for capital grants on such appliances. Also, with the high level of heat production, college halls of residence provide an excellent way of consuming the heat.

Pros

- Very high overall efficiency at 97%.
- Quiet running
- Low maintenance cost
- Turbine can run at 35% methane content. This is considerable lower than any other method of utilisation.

Cons

Capital cost

- Even with the high overall efficiency, the low electrical output means that 100% heat utilisation is a must for it to stand any chance of being viable.

Table **8.2(ii) (below)** is a rough cost comparison between a 200kw gas engine and a 200kw CHP unit under a German feed in tariff structure.

Fig. 8.2(ii)

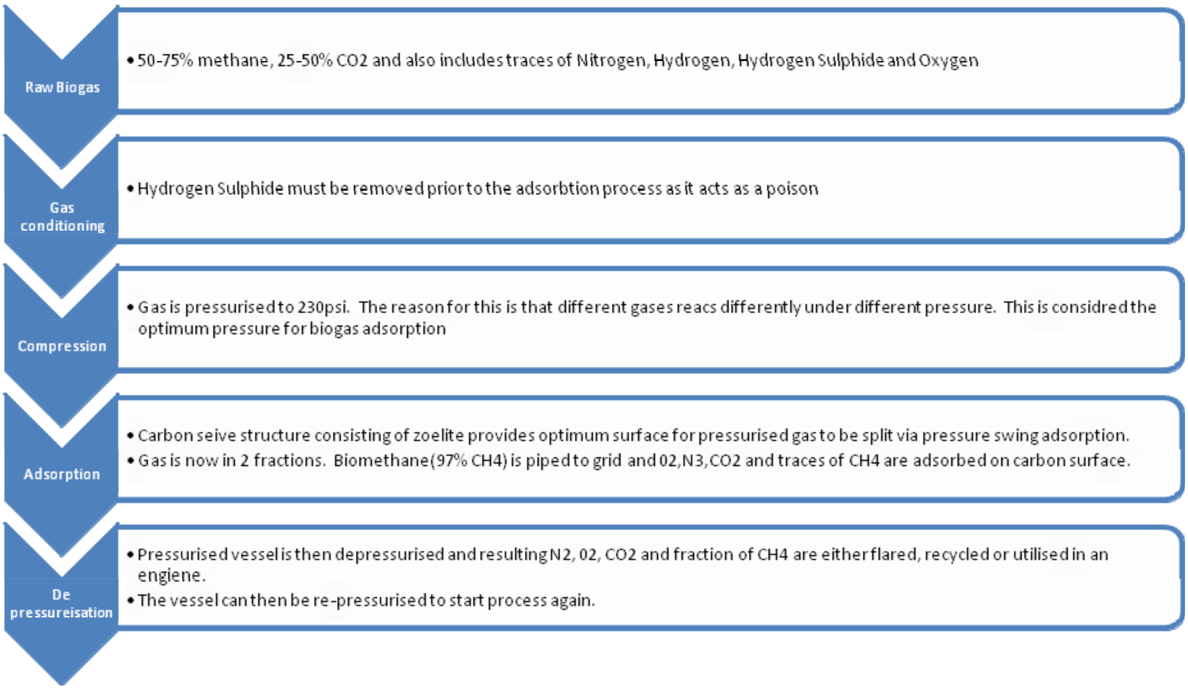
	Financial Benefit of CHP over Turbine
Electrical Sales/year	+35,000 euros
Heat sales/year	-13,500 euros
Mantenance cost/year	-20,000 euros
Total benefit of CHP over Turbine	**+1500**

The capital expenditure is almost double for a gas turbine over CHP coming in at 1500 euros/kw installed compared to 750 euros for a CHP. These figures only include the utilisation parts of the AD system.

8.3 Upgrading

Chart **8.3(i)** (next page) show the steps involved in upgrading Biogas to natural gas level via pressure swing adsorption.

Fig. 8.3(i)



Where?

Upgrading stations are most commonly found in countries where a greater value is placed on natural gas and fuel reserves than electricity. A typical example is Sweden where the largest upgrading station in the world can be found at Jonkoping. Upgrading stations do not need to be on farm or close to a centre of population due to the ease of which the gas can be transported through existing natural gas pipelines. They suit the larger Biogas operations.

Why?

Biogas upgrading stations are found on larger operations for 2 reasons.

1. The cost of the equipment means that only plants with a high output of gas can justify the high spend. It is thought that an excess of 200m3 biogas per hour is needed to make upgrading worthwhile.

2. Large plants will often if not always struggle to find a heat consumer on site. By upgrading the gas, it can be transported by the existing natural gas pipeline to the point of utilisation.

Pros

- Allows larger plants to remain efficient.

- No need for electrical grid connection or localised heat consumer.

- Replaces natural gas and fuel- 2 forms of energy that are finite and have dubious/volatile sources.

Cons

- Cost of upgrading equipment mean it's only viable on a large scale.
- Highly specialised maintenance.
- Energy intensive. Up to the equivalent of 25% of gas energy value consumed in the process.
- 2-5% of the methane content is lost.

8.4 Fuel cells and Hydrogen

Throughout my Scholarship, nothing has quite bitten me like the fuel cell bug! I would never try to depict biogas as being sexy. However, if there is a sexy wing to biogas then this is it! This is a line of technology where farming will be a vital partner to in the future even though the level of technology is at the very forefront of human capabilities. When I visited MTU fuel cell manufacturers in Ottobrun, Munich, I was soon to realise that the reason my sat nav couldn't find the street was because the building was enclosed inside an American military base.

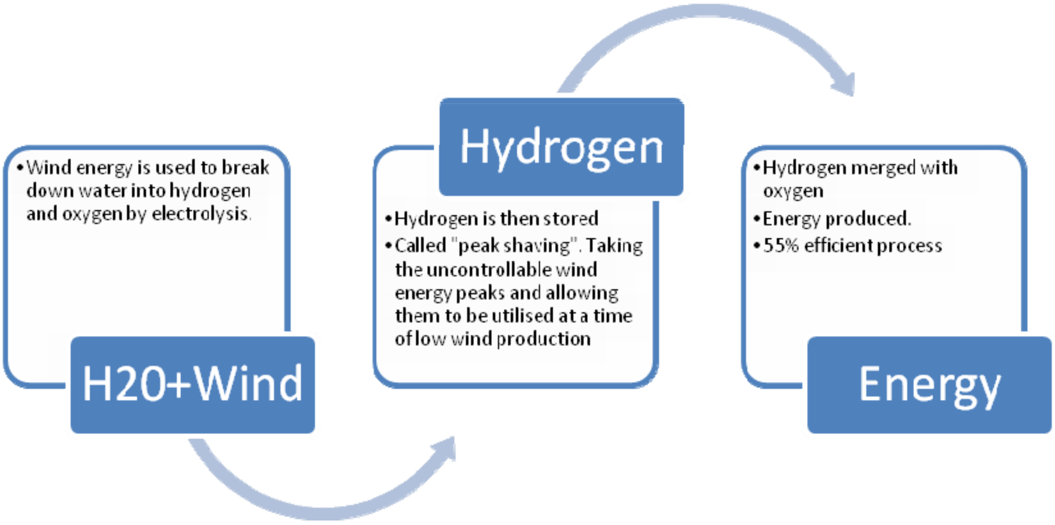
Fundamentals

Fuel cells are similar to a battery. They both convert chemical energy into electrical energy. However fuel cells require refuelling unlike batteries that require recharging.

A battery is an energy storage device. The maximum energy supplied by a battery is dependent on the chemical reactant contained within the battery. Once the chemical reactants are consumed/discharged, the battery will cease to produce electrical energy. In a rechargeable battery, the chemicals/reactants are regenerated by energy from an external source.

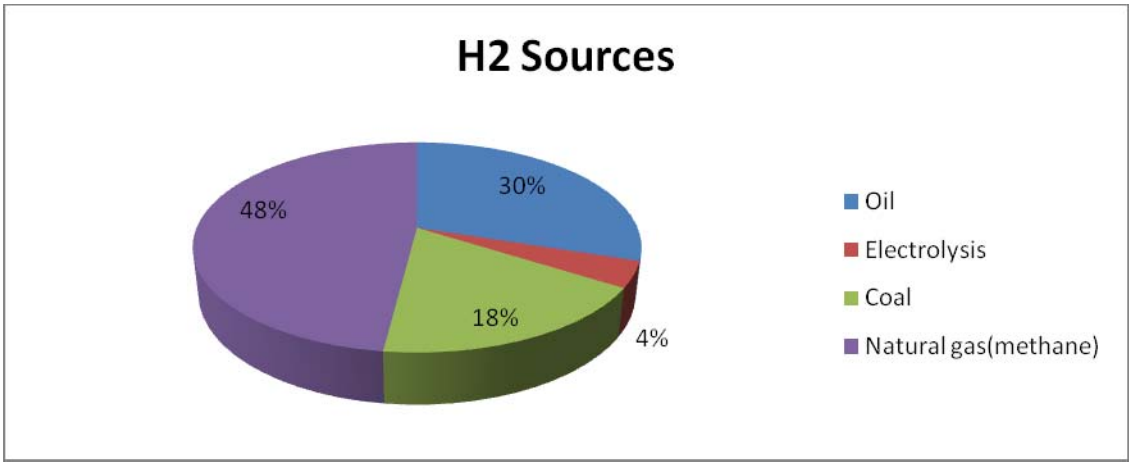
A fuel cell will generate a high level of electrical efficiency and heat by converting hydrogen into water via the presence of oxygen. If pure hydrogen is used then water is the sole emission. The fuel cell will cease electrical production when the fuel supply is cut or the electrolyte (catalyst between the negative anode and the positive cathode) is poisoned.

Fuel cells run on hydrogen. Hydrogen is not actually a fuel in itself but more a carrier of fuel i.e. energy is taken in to produce hydrogen from it's original source but when the hydrogen is then merged with oxygen through a fuel cell, energy is released. This means that hydrogen can only be considered a green form of energy if renewable energy was used to reform the source. An example of a green source would be the production of hydrogen by wind energy.



It is thought that hydrocarbon reforming to produce hydrogen is 3 times more efficient than electrolysis even though some hydrocarbons at present are obtained from finite resources. Chart **8.4(i)** (below) shows the sources of hydrogen at present.

Fig. 8.4(i)

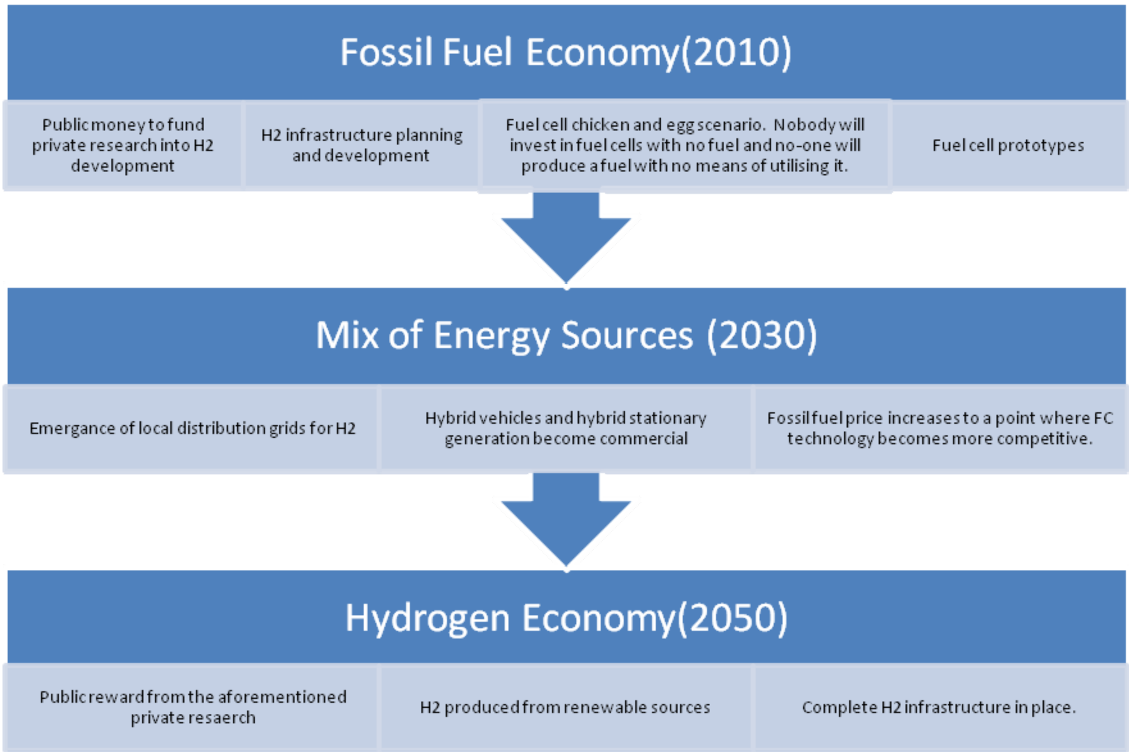


At present two things must happen.

1. The components of fuel cells must become more affordable.
2. The price of fossil fuels must rise

These 2 things will happen. Chart **8.4(ii)** (next page) shows the predicted timescale and developments in the move to an h2 economy.

Fig. 8.4(ii)



Present day fuel cell applications.

- **Military**. The need for silent and efficient energy generation has seen fuel cells utilised in several military operations.
- **Rocket science**. Rocket fuel is so expensive that the higher the level of efficiency of utilisation the better. Effectively, Rocket science is not about cost it's just about getting the shuttle into space.
- **Companies that place a large value on green marketing**. Deutsche Telecom have their fuel cell on display to boost their green image as well as propelling the image of a company at the forefront of technology.

Types of fuel cell

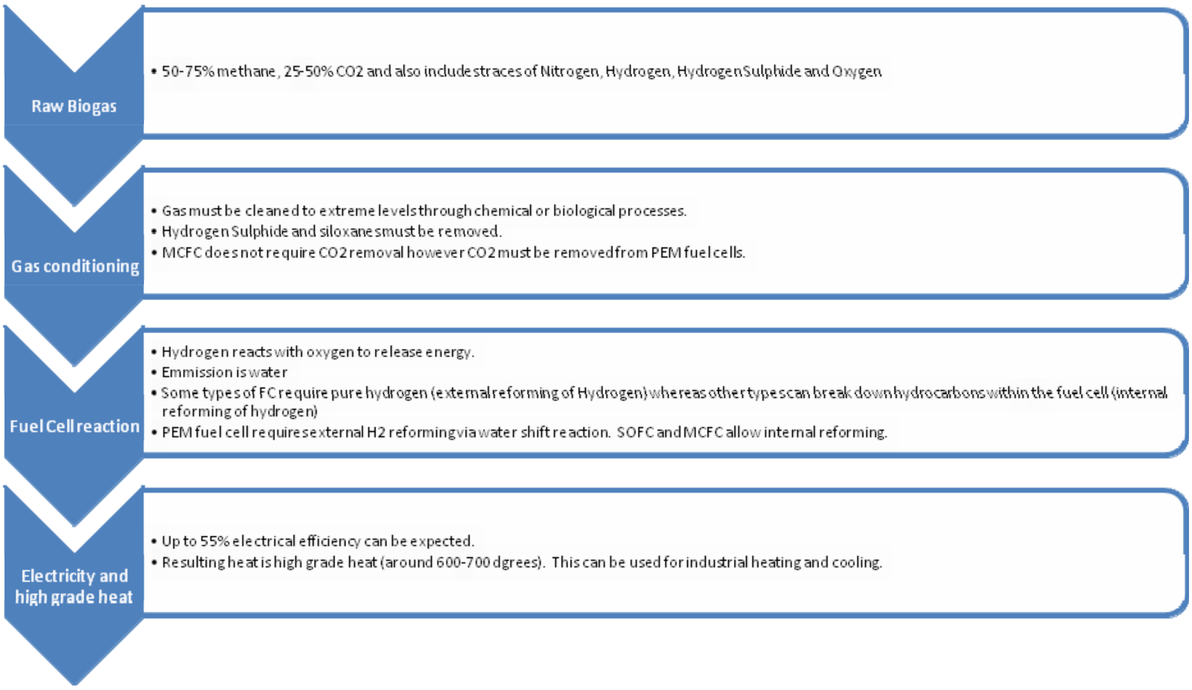
- Internal reforming. This is where the hydrogen would enter the fuel cell in another form for example a hydrocarbon such as methane.
- External reforming. This requires hydrogen to enter as the h2 molecule only. External reforming fuel cells could not utilise anything other than pure hydrogen.
- Table 8.4(iii) (below) lists the properties of different fuel cells

Fig. 8.4(iii)

	Solid Oxide Fuel Cell	Alkaline Fuel Cell	Molton Carbonate Fuel Cell	Proton Exchange Membrane Fuel Cell
Fuel	Hydrogen, natural gas, diesel, syngas and biogas	Hydrogen	Hydrogen, carbon monoxide, carbon dioxide and natural gas	Hydrogen
Internal or external reforming	Both	External	Both	External
Variable load generation or base load generation	Base	Variable	Base	Variable
Operating temperature(degrees)	600-1000	65-250	600-700	60-90
Poison	Sulphur greater than 0.1ppm. HCL and siloxanes	CO2, CO ,HCL, NH3 and Sulphur	Hydrogen sulphide greater than 10ppm. Siloxanes and HCL	CO2,CO,NH3,HCL and sulphur
Electrical Production(%)	45-50	60-70	48	30-40

Chart **8.4(iv)** (below) shows the basic process involved in hydrogen utilisation from Biogas

Fig. 8.4(iv)



Alkaline fuel cell (AFC)

While the Alkaline fuel cell is suited more to portable vehicle applications, it's low tolerance to contaminants limits it's use to very expensive, pure fuel.

Proton Exchange Membrane (PEM)

The proton exchange membrane fuel cell is possibly the highest profile fuel cell in agriculture. New Holland have developed the NH2 prototype tractor that runs on hydrogen. After meeting with New Holland in Germany the concept was explained. New Holland is owned by Fiat. Fiat has lots of money. Fiat recognise that fossil fuels are finite and there is a responsibility as well as a huge commercial benefit if they can find an alternative way of fuelling propulsion. Their partners, New Holland have the contacts and experience in agriculture to generate clean, renewable fuel so the NH2 project came to fruition.

The reason the proton exchange membrane fuel cell was chosen was because it could vary it's output making it suitable for propulsion. It also operated at low temperature which makes start up much easier and safer. The problem exists that it's very expensive to externally reform the hydrogen. Pure hydrogen is also difficult to store at atmospheric temperature and pure hydrogen itself is not the densest of fuel.

In my opinion, the PEM fuel cell is not the most ideally suited to agriculture and the NH2 project will remain a prototype long after other fuel cells become established. The PEMFC will realise it's full potential only when a true hydrogen economy is realised.

Solid Oxide Fuel Cell

SOFC shows reasonable potential for future agricultural application for the utilisation of biogas but will be more suited to industrial situations involved with the gasification of coal.

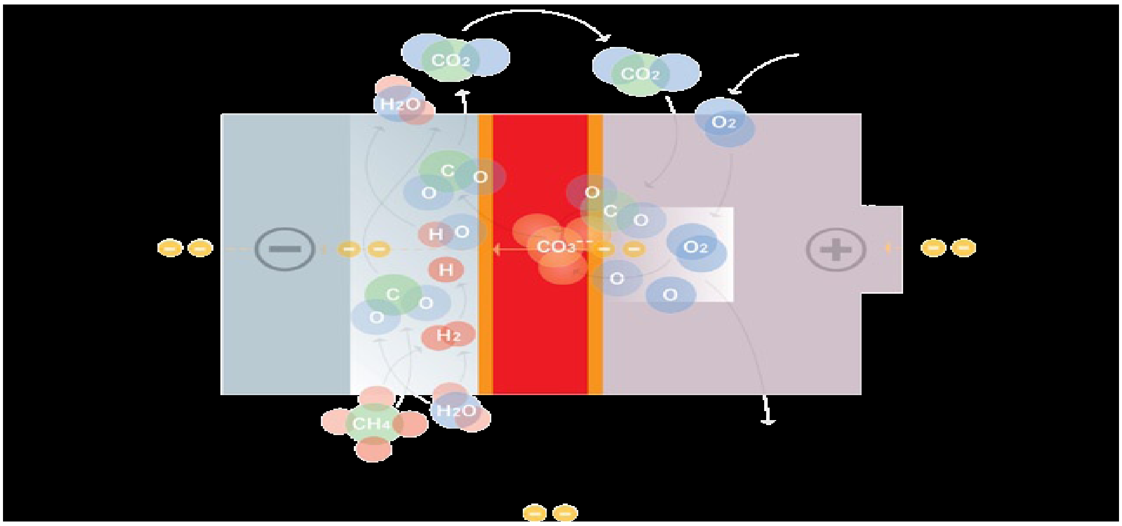
Molton Carbonate Fuel Cell

The MCFC will be the fuel cell most closely associated with agriculture for the following reasons.

- The MCFC can utilise the CO2 produced in biogas and use it to increase the electrical efficiency. In effect, the CO2 is converted into carbonate molecules and so aids the efficiency of the carbonate fuel cell.
- Well suited to the internal reforming of methane.
- 100 times more tolerant to Hydrogen Sulphide than the SOFC
- Produces a high grade heat. This is very important as it is needed for the next stage in the fuel reforming process- hydrogen to ammonia (see section 8. Ammonia Production)

Illustration **8.4(v)** (below) shows the internal workings of a MCFC.

Fig. 8.4(v)



Fuel Cells- the benefits.

- High electrochemical efficiency
- MCFC ideally suited to Biogas.

- Miniscule emissions (zero if pure hydrogen used).
- Allow the storing of energy through electrolysis and hydrogen production - ”peak shaving”.
- Quiet

Fuel Cells -the disadvantages

- Cost of components. At present they are difficult to make any economical case for them. In my pursuit of and economical solution, I was labelled a “British bean counter!”
- Lifetime of stack. It is predicted that the fuel cell at present has a lifetime of 30,000 hours.
- Gas cleaning. Biogas must be cleaned to extreme proportions to remove hydrogen sulphide and siloxanes. This adds cost and if not done properly will kill the stack.
- Chicken and egg/Catch 22 scenario. No established fuel structure in place. This will only come about when there are fuel cells to utilise the fuel.

9. Centralised Biogas plants

During my Scholarship, I visited 3 large centralised plants. Centralised plants can take many forms, both in terms of financial structure and practical gas production methods. The main benefits of centralised Biogas plants over individual plants are

1. Economies of scale. Upgrading equipment is often utilised on operations over 500kw. This allows more of the potential of the gas to be utilised as it would be transported through the mains network to a site where it can be utilised for heat production alone.

2. Specialised managers. Having the scale to employ someone on site will result in a more productive, efficient operation.

3. Redistribution of nutrients. Centralised plants are more likely to cope with the logistics of transporting slurry from one part of the region to another.

4. Reduced distribution cost to the Farmer. With centralised plants, farmers need 2 storage tanks, one for untreated slurry and another for returned digestate. This allows the farmer to have his digestate/returns tank placed strategically away from the farm and close to the point of application.

5. Easier access to funding. Multiple investors will always secure funds more easily than a single entrepreneur.

9.1 Falkenburg

The first of the centralised plants I visited was Falkenburg in the South West of Sweden where site manager Andreas Petterson described the operation.

Ownership

Falkenburg is owned by 3 different parties:

- EON. Eon’s involvement in the plant is purely financial. EON requires a return of greater than 10% on it’s investments.

- The local Council. Unlike the UK, government in Sweden plays a much more prominent role in society and the council’s investment in Falkenburg is both for financial and environmental reasons.

- A large local retailer owns a third. Their return is in the form of cheap upgraded transport grade biogas to run a fleet of vehicles on.

Plant manager Andreas Pettersson introduces me to the reception pit at Falkenburg Biogas.

Farmer involvement

- 14 farmers supply the plant with 10,000t of crops (various mix) and 100,000t of slurry.
- All the slurry is transported via tanker with the furthest away farm being 15km away. Tankers carry 37.5t (5362kw). If the tanker was to do 5 miles per gallon on average, that would make the total fuel energy spent on a 15km(30km round trip) to be the equivalent of 207.5kw with the sum of 5154.5kw surplus.
- Farmers are obliged to receive the same volume of digestate back as the volume of slurry they submitted. It is estimated that the nutrient value of the digestate increases to the tune of 75p/t.
- No organic farmers can partake as the AD process cannot segregate organic digestate from conventional.
- The main benefits of this centralised plant to farmers are increased fertiliser value and the redistribution of nutrients.

Plant statistics

- Intake capacity of 350m3/hour. Intake shed has the air filtered and scrubbed to reduce odour to local communities.
- 12000m3 biogas/day produced.
- Coaab chemical mixed to the biogas to absorb the CO_2 and take the gas to 99.5%methane. 2% propane is then added to comply with grid regulations. The gas has now been "upgraded" from biogas to biomethane
- Digestate is pasteurised post digestion to ensure a more consistent supply to the pasteuriser.
- Pasteuriser capacity is 25m3 and digestate must reach 72 degrees for 1 hour. Heating is provided from 3 sources. Heat exchange from the upgrader takes the temperature from 23-40 degrees. Heat exchange from the previous batch of pasteurisation takes the temperature from 40-60 degrees with the final 12 degrees receiving the heat through a gas boiler.

Swedish Plans- The EON Challenge

During my time in South-west Sweden I met with the equivalent of the Swedish NFU and I also visited the "Bioenergy Centrum Halland". At the centre, this government funded body was issued with a challenge to bring together research, business and politics in a bid to create a sustainable future with the production of Biofuel, marketable digestate and green energy obligations with the end goal of bolstering the Swedish economy. A major part of this is the future development of more centralised Biogas plants and a new gas grid.

At present EON has laid down the challenge to the NFU to find areas in Halland county where there are more than 3000 cows within a 15km radius to justify the expenditure involved with laying a pipeline from Gothenburg to Halland county.

The NFU are in the process of getting farmers to sign letters of intent. However the project depends upon the government subsidising gas priced to allow the production of Biomethane to be comparable to that of Natural Gas.

9.2 Linkogas, Denmark

Denmark is unique in its experience with centralised Biogas plants. As biogas production was primarily driven by Government, farmers had little choice but to co-operate with one another. Memberships range between 15 and 80 farmers. At present, Denmark has 20 large centralised Biogas plants but the government has plans to increase this number to 70 to combat the ever decreasing supplies of natural gas. As all centralised plants in Denmark were set up by government, they all have similar structures to them. One of the plants I visited was the Linkogas operation in Knorborg, central Denmark.

Ownership

Like all other centralised plants, Linkogas, Knorborg was set up by a 40% government loan with the other 60% of finance coming from bank guarantees from local farmers. Farmers were all but obliged to invest in the plant should they want to maintain their level of intensive farming. Should the Danish government relax its laws on the purchase of Biogas then private investment would flood in. The government stake is a tool to protect Danish heat and electrical consumers. The farmer stake is a way of maintaining an intensive, environmentally friendly, livestock economy

Farmer involvement

Every ton of slurry submitted to the plant costs the farmer 15 euro cents (12p). However that is conditional on the return of the digestate to a separate store. Should the farmer submit the slurry without accepting the return volume, a charge of 2 euros/t is made. 25 farmers supply the plant. The average distance is 7km away with the farthest 25km away.

Plant Statistics

- 160,000t cattle slurry and 40,000t abattoir waste per year.
- Average gas yield 45m3/t
- 9 people employed - 5 of them are tanker drivers.
- In 1999, the plant changed from Mesophilic production to Thermophillic. This allowed the plant to increase in throughput without major capital expenditure.

9.3 Pleining, Germany

One of the largest centralised plants I visited was in Pleining, Bavaria. As Biogas plants in Germany tend to be smaller and located on farm, Pleining was a unique operation in many ways.

Ownership

The project was initiated by Aufwind Shcmack, a large biogas equipment manufacturer in Germany. From the outset a share issue was implemented to generate capital. 6 million euros were raised which allowed a further 14m to be levered from the bank to achieve the 20m euros needed. The cost of the share option was considerable and amounted to 1m euros (5% total spend) and was to cover the fees of brokers and lawyers. 33% of the total project cost was crop storage.

Farmer involvement

- 80 farmers supply the plant.
- These 80 farmers were offered discounted shares but turned them down. It was perceived that the share ownership would compromise their ability to receive the best price possible for the feedstock they supply.

- Farmers will supply maize, grass and sorghum to the plant; however the majority is maize.

- The price paid for feedstock varies depending on several factors such as DM, distance from Pleining and the length of contract. Longer contracts will result in higher prices; however no farmer has taken out a contract longer than 10 years. The majority shareholders, Aufwind Schmack see the power that the supplying farmers hold as the greatest weakness in the long term effectiveness of the operation.

- Maize is bought between 16-25 euros a ton depending on the aforementioned factors.

- All the logistical operations of harvesting and ensiling the crops are sub contracted to the local machinery ring.

Plant Statistics

- 3 dry fermenters of 3000m3 capacity each and a post digester of 7200m3 capacity work to produce a gas output of 900m3 biogas /hour.

- Biogas is upgraded to produce biomethane. 5 % of the energy is lost in the upgrading/pressurisation process.

- 2.2m euros needed for upgrader, access pipeline and computer monitoring equipment.

- Heat for the fermentation process is provided by a 300kw gas boiler. All the heating for digesters must come from renewable sources.

- Biomethane piped to companies with large heat consumption and sold at a price of 6-9.5c/m3 CH4 depending on market conditions and quantity of purchase.

- Some of the gas is sold to Deutsche Telecom where it is used to produce heat and electricity through a MTU hotmodule fuel cell. The fuel cell is displayed in a glass cage outside their offices in Munich for the general public to see.

"I can't believe Aufwind left all the negotiating power in the hands of the farmers."
Thomas Wagner, Aufwind Schmack

9.4 Bavarian Dairy Biogas Collaboration

Unlike the majority of Germany, Bavaria was populated by small, family owned dairies. Many of these businesses were struggling to sustain profitable milk production with the low milk price. This was resulting in deals between farmers that would see quota (still a valuable commodity in Germany) being transferred from one business to another for the return of cattle slurry.

The result was a larger dairy with the ability to capitalise on greater economies of scale, free quota and no slurry restrictions while the other farmer could specialise into Biogas with plentiful feedstock.

Many would comment that the expanding dairy farmer would increase his turnover however the biogas producer was more profit orientated.

10. Organic Biogas

During a visit organised by KWS to look at sugar beet as a feedstock on a large centralised biogas plant in Reimlegen, Bavaria, I had one of the most enlightening and interesting tours of my Scholarship.

The biogas plant was similar to many I had seen before. The main points of interest included

- 2 MW plant operating on dry fermentation.
- 5 partners/owners supply 450ha of feedstock with the remaining 350ha of feedstock bought in.
- At present the feedstock includes 60% maize, 20% clover silage and 20% whole crop triticale
- All gas is utilised trough CHP with spare heat being sold to a local hospital however plans are in place to upgrade ¾ of the gas and leave ¼ to remain in CHP.
- Cost of production at present is 14c/kw. Price received is 16c/kw.

When I arrived, the trials of sugar beet were causing concern. The plant manager, Karl-Heinz Guiss had agreed to a trial of sugar beet on his plant. However the "hassle factor" was starting to bite. It normally takes 2 days to harvest 200ha of maize. It had just taken 4 days to harvest 10ha of sugar beet. Also, the extra cost of processing the sugar beet had not been accounted for and the associated bills were starting to mount. It would be fair to say I didn't learn a lot about sugar beet biogas production that day but what I did learn was to be somewhat eye opening.

As a part time lecturer at the local college/university, Karl-Heinz would also oversee his own organic farm and the management of the Reimlegen Biogas plant. His plan was to convince the farmers supplying the feedstock to go organic. Until this moment, I could not see the concept of organic farming working with biogas production. This was my Eureka moment.

Organic Biogas.

There are 2 motives behind the concept.

1. Financial
2. Soil sustainability

Organic farming in Bavaria would consist of the following 3 crop rotation.

1. Red clover. This would have the dual purpose of fixing nitrogen and killing weeds. The crop would be topped up to 4 or 5 times a year and would return no direct financial benefit

2. Maize. The resulting crop of maize would be competitive with standard maize due to the lack of weeds and the available nitrogen in the soil. Cobs would be sold as organic produce to Switzerland.

3. Any conventional crop e.g. onions or wheat. After the maize has taken the Nitrogen out of the soil, little is left resulting in a standard organic crop that cannot compete with the yield or quality of non organic produce.

Once this system is coupled with Biogas production, the financial benefits start to stack up. This is the system Karl-Heinz advocates and is hoping to convince the local Reimlegen farmers to adopt.

Here is the 3-crop organic rotation but integrated into and AD operation.

1. Red clover. 4 cuts/year are taken producing 60t/ha dm and a net price of 900euros/ha from the gas plant. Like before, the clover has fixed 200kg/N/ha but 100kg has left as part of the clover and gone into gas/digestate production.

2. Maize. Instead of selling the cobs, the whole maize plant is harvested and utilised in the AD plant. The maize would utilise the 100kgN/ha fixed by the clover. This results in a net fee of 1500 euros/ha to the farmer.

3. Unlike the previous organic system, the incorporation of AD means that the digestate can then be used to fertilise the onions/wheat. 50kgN/ha is spread on the land with the remaining 50kg from the clover left for pelleting and used as a heat source or sold to a local apple orchard. The substantial organic onion/wheat crop would have a yield almost comparable to conventional production but would still command the organic premium.

Karl-Heinz Guiss (right) discusses matters with his organic crops inspector. When I commented on the excellent relationship he had with his organic scheme inspector Karl Heinz replied, "if you shout in the woods, the woods will shout back!"

Should Karl-Heinz Guiss be successful in converting the Reimlegen suppliers to organic farming, his plan would be to build an onion drying store next to the remaining CHP unit (pictured below is the conventional drying shed, fuelled by natural gas off site).

"If I can change the mindset of farmers, everything else will take care of itself"
Karl-Heinz Guiss, Managing Director, Reimlegen Biogas Plant

11. Community Biogas. Introducing the "Bioenergy Town"

Across Europe "Bioenergy towns" are cropping up. These are settlements that are sourcing the vast majority of their electricity and heating fuel from renewable sources. The largest of these towns is Lunen near Dortmund in Germany. The population there is 91,000 people. However it was on Denmark's North West Coast at a town called Lemvig where local councillor, Steffen Damsgard and Biogas Plant manager, Lars Kristiansson introduced me to the concept of the Bioenergy town.

"The Centralised Biogas plant has been a source of pride for our town for nearly 2 decades. It makes sense- the neighbouring councils are planning to replicate what we've got"
Steffen Damsgaard, local councillor, Lemvig

The principle was set up in 1992 by the mayor of Lemvig. A pioneer in that time, he believed it was possible to harness the growing Biogas and Biomass sectors to benefit his town. A total of 34 farmers along 45 other local people guaranteed 3.16Danish Kroner (40,000 each). Added to the 37.84DK that the council guaranteed, national and EU government delivered a grant of 14m DK. this allowed the development of a centralised biogas plant as well as wood chip boiler to commence. The loans were to be repaid at 5% over 20 years. These 2 installations were to provide a town of 3000 people with cheap electricity and heating for the next few decades.

Lemvig Biogas

- The feedstock is primarily cattle and pig slurry (182,000t/year) with treated sewage(45,000t/year) and dairy waste/whey(10,000t year) also contributing.
- 80% of biogas (1600m3/hour) is pumped to a CHP unit at Lemvig. 20% (400m3/hour) is utilised by a CHP unit on site however there are no heat sales from this 20%. The CHP unit at Lemvig is owned 100% by the council.
- As chart 11(i) illustrates overleaf, the woodchip boiler is used to back up the biogas plant in wintertime when heat demand peaks.

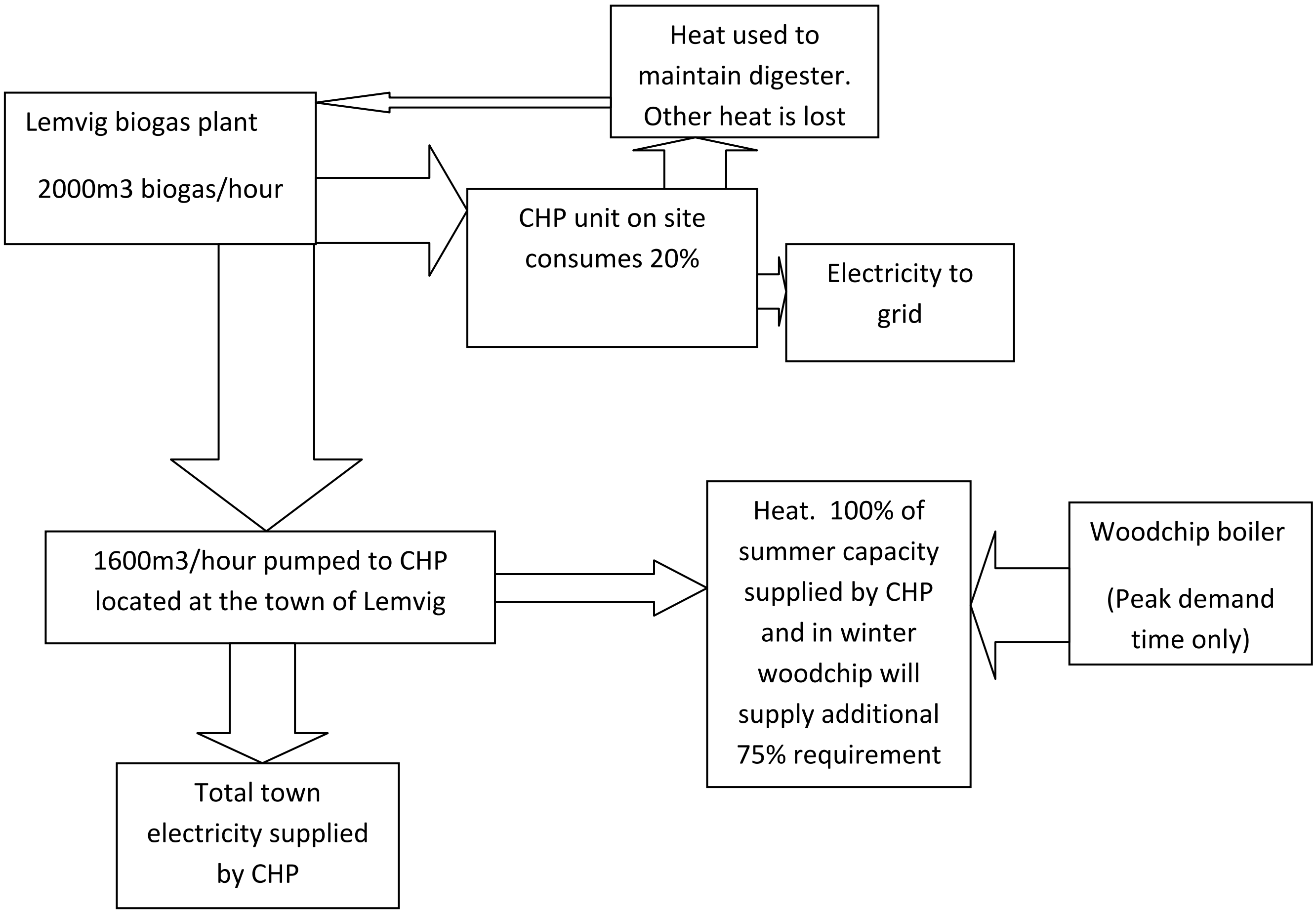
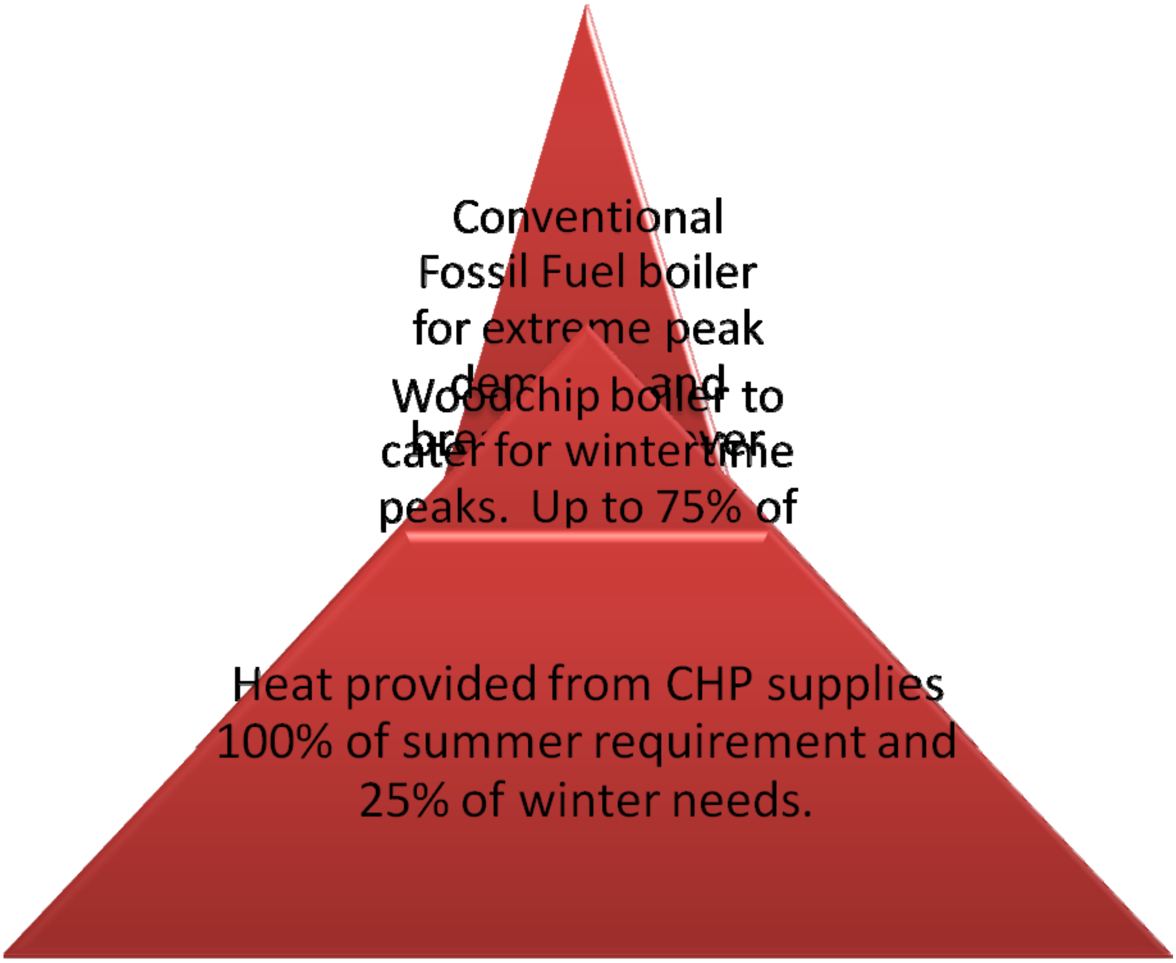

Heat used to maintain digester. Other heat is lost
Lemvig biogas plant
2000m3 biogas/hour
CHP unit on site consumes 20%
Electricity to grid
1600m3/hour pumped to CHP located at the town of Lemvig
Heat. 100% of summer capacity supplied by CHP and in winter woodchip will supply additional 75% requirement
Woodchip boiler
(Peak demand time only)
Total town electricity supplied by CHP

Fig. 11(i)



17 years on - a success?

Unlike many of my visits, I was given the luxury of judging the project after many years in operation. These are the judgements I came to after my visit.

Positives

- At present, natural gas in Denmark is 5 DK/m3. The residents of Lemvig are making considerable savings as the equivalent price of biogas is 3.26DK/m3.
- Local pride in having an independent clean source of electricity that is insulated from worldwide price hikes.
- 2 neighbouring councils have looked on in envy and have now put plans into place to replicate the project.
- Brings the local community and farming closer and allows greater appreciation of agricultural practices.
- Local employment in both renewable energy and maintaining the intensive livestock economy.

Negatives

- Local residents have often expressed their disgruntlement at having to pay more for the heat from biogas. They argue that a complete woodchip heating system would provide cheaper heating. The contract that was written up in the early 90s, however, states that it's all part of the one package, or back to coal natural gas for electricity and heating. Otherwise, the discounted electricity would need to increase in price. Effectively the project has become a victim of its own success.

12. Digestate Management

One of my main reasons for visiting the States was to see how Anaerobic Digestion can be financially viable without feed in tariffs for green electricity.

On many large dairy farms in the mid west, AD is all about local community acceptability. People see the 1000+ cow herd as having environmental issues because of the large volumes of slurry produced. While AD is by no means compulsory for new units, it's seen as good PR to alleviate concerns over odour.

With the low electricity price received from biogas production, some farmers found it more economical to flare the gas and concentrate on the utilisation of the digestate to provide income and offset current costs. Flaring the gas still allowed the farmer to claim the carbon credit (available in some States) without the large capital expenditure of buying a CHP unit. Whatever the practice deployed over gas utilisation, making the most of the digestate was an economical necessity on US farms. The benefits of digestate slurry over conventional slurry are as follows.

12.1 Nutrient improvement

In organic matter, NH4 (ammonium) is in equilibrium with NH3(ammonia). In raw slurry the balance is about 50% NH4 to 50% NH3. During digestion the ph changes from ph7 to ph8 and the temperature rises to above 40 degrees. These 2 factors affect the balance of equilibrium. Post digestion the equilibrium stands at 80% NH4 and 20% NH3. This means that the mineral fraction (the NH4) has now an uptake potential of 80% compared to 50%. Quick incorporation is essential as the equilibrium will change back to 50:50 should the digestate be allowed to sit on the soil surface for any length of time.

Table **12.1(i)** (below) shows the benefits to plants by contrasting the potential between raw slurry and digestate.

Fig. 12.1(i)

Input	Amount kg/n	Loss kg/n after spreading	N available to plants	Efficiency of uptake
1 t raw slurry	5	2.5	2.5	50
1 t digestate	5	1	4	80

Effective Separation

Separation post AD can also act as a tool to pinpoint nutrients and can allow a better application of organic materials with the result being a reduction in bought-in inorganic fertiliser. Due to the consistent nature of digestate, separation is much more efficient than in conventional slurry. Up to 35-40% of solids can be extracted from digestate compared to between 20-25% from conventional slurry.

Table **12.1(ii)** (below)shows a typical analysis of the fibrous and liquid **fraction.**
Fig. 12.1(ii)

	1 t liquid fraction	1 t fibrous fraction
DM	300	4.3
Water	700	995
Total N	15.6	4.1
Total NH4	3.8	4
Total P	8.8	0.2
Total k	2.5	2.8

As the table highlights, the available Nitrogen will tend to travel with the liquid fraction and the phosphorous will travel with the fibrous faction. This allows the redistribution of nutrients and stops the build up of phosphorous in dense cattle regions and the build up of Nitrogen in areas not suitable for large levels of N application.

In Denmark, intensive livestock regions in the west coast were maintained by exporting the phosphorus to the arable orientated east coast.

Crave Cheese

At Crave's Dairy in Wisconsin, I was shown how the separation of nutrients made a significant impact on the farm,s fertiliser bill. At present the large dairy business is complemented by a cheese production business. The dairy incorporates an AD plant; however it is owned by Clear Horizons, a separate biogas equipment and installation business run by family member Mark Crave.

The benefits to the dairy business from the AD plant were odour reduction, the ability to purchase the digestate for bedding ($7/cow/month), cheese marketing and nutrient management.

Before the installation of the AD plant, phosphorous levels in the slurry were above stated regulation level. Effectively, this meant that even though the crop required a high level of Nitrogen that *could* be supplied by slurry, inorganic Nitrogen was needed as the land had reached its upper phosphorous limit from slurry application. A ceiling of 12,000gallons/acre was imposed with large quantities of straight Nitrogen bought in.

After effective separation, the solid fraction (40% of total and phosphorous rich) is used as bedding for cows and also sold off farm in a value added gro-bag which allows 20,000 gallons per acre of liquid digestate to be applied. This results in a very close matching between crop requirements and digestate content. At present only $5000 worth of inorganic fertiliser is bought for application over 1800 acres.

12.2 Odour Reduction

The reduction of odour from processing raw slurry to digestate has become a powerful tool in the planning application for large herds. During the process, many odorous compounds are converted into compounds that are either undetectable or less detectable to human senses. Also, during spreading, compounds are more readily taken up by plants from digestate which makes the spreading of nutrients on the fields more acceptable to local communities.

12.3 Sterilisation of Slurry

As the digestate has been heated for a number of weeks, the potential for bacteria, most notably streptococcus, to survive, is very limited. Also, the potential for weed seeds to survive the process is low, thus allowing easier weed control in crops over raw slurry. Many countries will advocate a Thermophillic process for complete bug and seed kill however in practice, a Mesophillic process is more than adequate.

12.4 Belt Drying

Drying digestate is not common due to the fledgling technology, economics and loss of Nitrogen in the evaporation process; however there were some places in Germany implementing the technology. The heat incentive payment overcame the high capital cost of a belt dryer that ran off the heat from the CHP. The intention of the German government was to reduce the consumption of fossil fuel in transport by cutting out the large volumes of water.

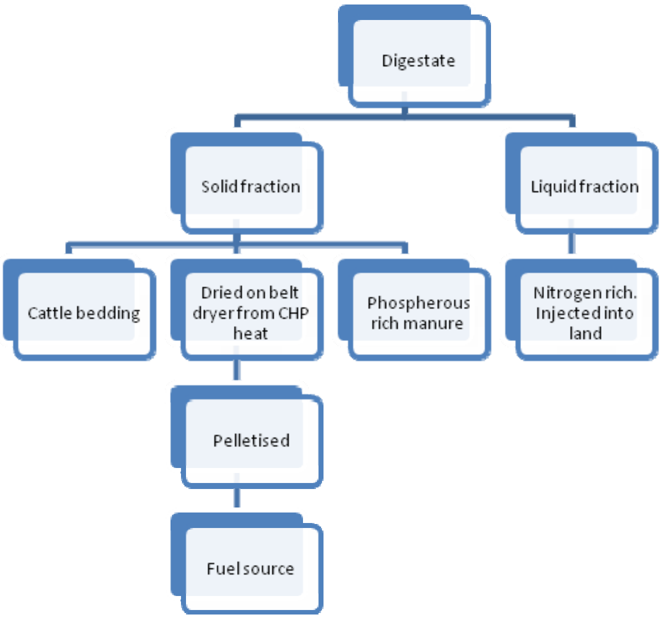
Rough rules of thumb

- After separation, it is predicted that the solid fraction can be dried from 25%DM to 100% from the total available heat.
- Non separated digestate is only likely to have 40% of the water removed from the total heat available from the CHP.

13. Markets and uses

Chart **13(i)** (below) shows how digestate, like the biogas, can be refined and find different uses.

Fig. 13(i)



13.1 Bedding

Many large herds in the States were using the digestate as bedding for dairy cattle. The dry climate meant that, after separation, the digestate didn't require any drying and could be used straight away. Lee Jenson at 5 Star Dairies in Wisconsin was a fan of the material. After digesting cattle slurry and glycerine (a by product from a nearby biodiesel plant), the digestate is separated and blown through a cyclone. The solid fraction is then emptied into a cattle court and topped up with sawdust and tilled once a week to let any heat out and maintain a dry bed. Over time the digestate will shrink so the extra sawdust will not contribute too much to the overall bulk.

At 5 Star dairies Lee Jenson estimated that the cell count of the cows dropped by 100 when he switched from straw to digestate bedding. Charlie Crave also saw a drop in cell count when Crave Dairies switched from bedding on oat hulls to digestate although they did report a rise in e-coli mastitis.

"If it smells like shit, it is shit. If it don't then it aint!"
Lee Jansen when questioned on the viability of bedding cows on their own waste
"I swear you could see those cows smile that day"
Phil Goodrich couldn't help but be impressed the day that Dennis Haubenschild switched onto digestate bedding.

A typical cow bedded on digestate at 5 Star Dairies.

13.2 Plant Bedding

At Crave Dairies, Clear Horizons were marketing the separated digestate as unique, environmentally friendly, bedding for *plants* called Energro. The main selling point was it contained 100% material with no artificial inputs. Although carbon footprint is not as big an issue in the States as it is in Europe, I felt that a huge marketing opportunity was being passed up as the product had a negative carbon footprint. In effect, each 10kg bag had a negative carbon footprint of 6.9kg carbon before transport.

At present only 10% of the digestate was being bagged and sold however it was seen as an expanding market that carried great potential for rolling out on a bigger scale.

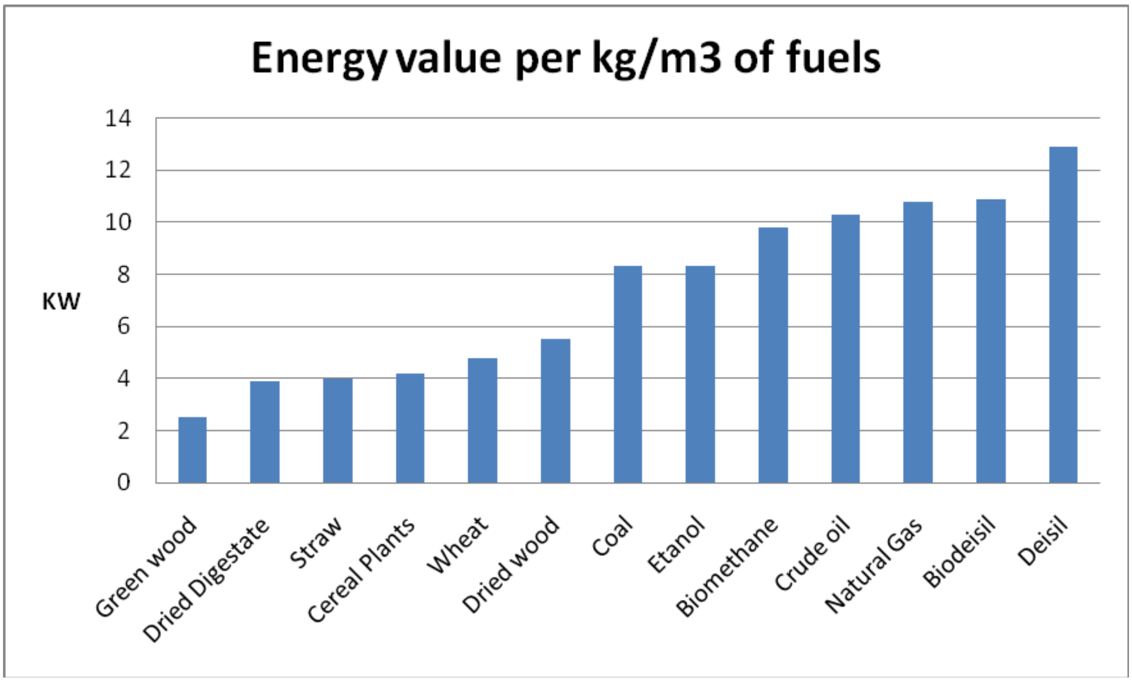
The digestate store at Crave's Daries

The profit from the digester at Crave Daries was 50% from electrical sales and 50% from digestate sales.

13.3 Digestate as a Fuel

Although I never encountered a digestate pelleting operation, there was considerable potential to dry the digestate after separation then run it through a pelletiser. Table **13.3(i)** shows the comparative energy value of digestate compared to other fuels.

Fig. 13.3(i)



14. Plant Breeding

In a world where there will be increased competition for land between energy and food production, plant breeding will play a major part in our ability to satisfy our needs. At present, only 2% of the world's land is used for energy production. However in Germany the story is somewhat different. The potential for plants to be fed into AD is huge. Normally when a cow consumes a plant the D value would be around 70%. AD has the ability to reach up to 89% D value of the plant.

In Germany I was fortunate enough to meet with Ernst Bommer of KWS. Ernst is a terrifically colourful and charismatic Bavarian whose passion was very much involved with energy plants.

"The way forward is Biogas production. It is our future"
Ernst Bommer, KWS, Germany

As Germany has the most experience in Biogas production, it was very clear to me that they also had the most experience in plant breeding for biogas. At present, over 1.7m ha of German land is utilised to produce energy and that figure is growing year on year. Chart **14(i)** and **14(ii)** shows the difference in Maize production in the UK compared to Germany.

Fig. 14(i)

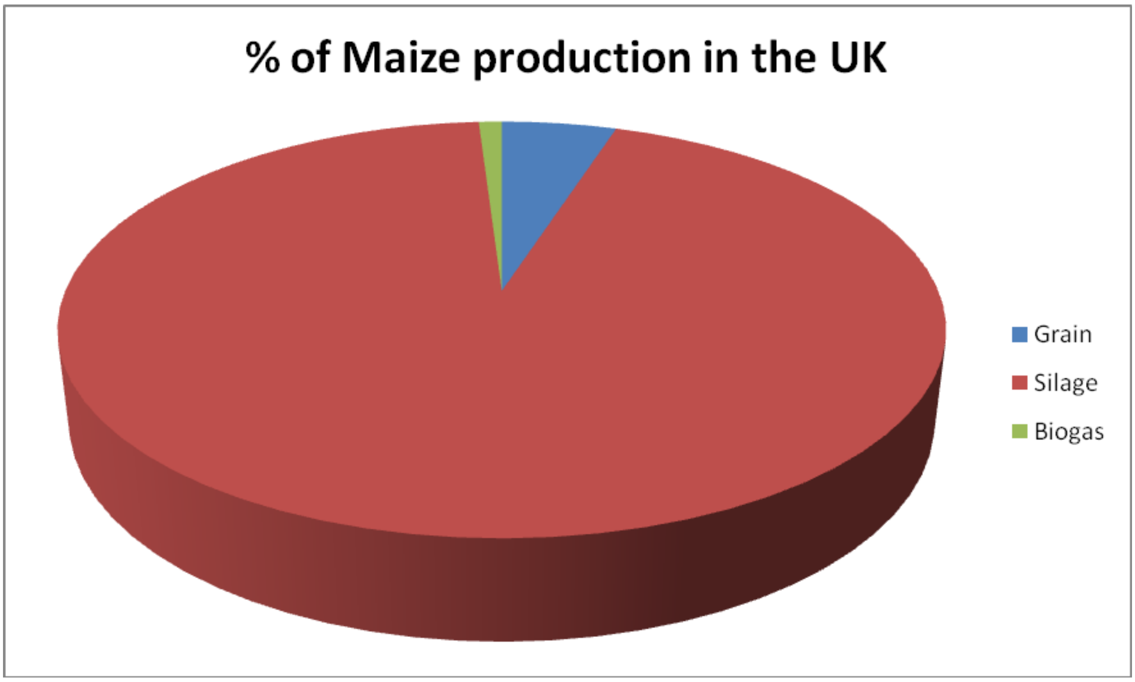
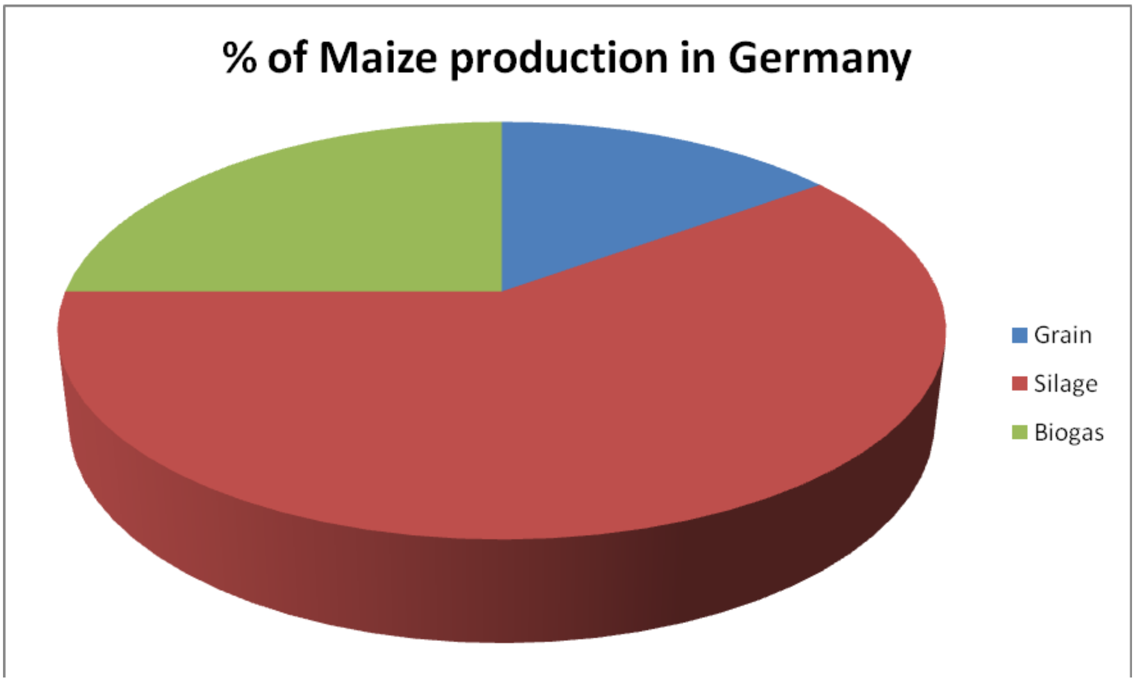


Fig. 14(ii)



What affects Gas Yield?

The 3 parts that consist of total yield in plants are lignin, cellulose and Starch. As it is fungi and not bacteria that break down lignin, the lignin parts of the plant are not suited to gas production. This means that steamy and woody plants will not perform in the AD process and are better suited to gasification.

As cellulose and starch are both fermentable, the overall DM of the plant is what's important and not the size of the cob. Photosynthesis happens on the leaf so the overall potential of the plant depends as much on leaf content as the cob mass. It is interesting to note that there is no difference in biogas yield between varieties on a per kg basis. The difference in varieties comes in DM per plant.

KWS see the advancement of plant breeding for biogas as vitally important for the following reasons.

- Greater energy efficiency as the whole plant is used for energy production through biogas
- No expensive and inefficient drying processes needed.
- Maximum potential per hectare realised
- Boosting the rural economy
- By advancing the potential of plants into AD, the greater the potential to include slurry to compliment the process.

At present KWS predict that their top maize plant can yield 61MW per hectare through biogas production. The goal they are aiming for is a 30t/ha DM yield and a 105MW/ha plant potential through biogas. The two pictures below show John Burgess of KWS UK highlighting the difference between energy maize and conventional silage maize.

The plant on the right hand side of the left photo and the plant John is holding are the energy maize varieties. The difference in gas yield is likely to be between 10-15% when compared to conventional varieties

Harvesting

Harvesting of Energy Maize requires slightly different timing to conventional Maize. Energy Maize would have an optimum DM of between 27-31% whereas silage maize would be between 32-36%. Below 27% and there is a risk the crop may become too acidic for fermentation and above 31% the bacteria have difficulty extracting the gas from the material. While the cob size is not relevant to gas yield, it is still used as the indicator with regards harvest timing.

GM Potential in Energy Crops.

At the start of my study I was very excited to learn how GM could influence the production of energy. Unfortunately the GM benefits towards energy production will be limited due to the following reasons

- The low financial value of energy maize means that it is not the most economical market for plant breeders. At present GM technology is more focussed on larger more lucrative markets.
- GM is seen to have greater potential to alleviate pest and disease problems rather than boost yield. Yield is controlled by many hundred genes within the plant whereas disease and pest resistance is controlled by only a few genes making it easier to target.
- Many of the organisations involved in green energy production were against GM advancement. They see problems with creating a plant monoculture and effectively giving Monsanto ownership of nature.

German OSR Trials.

In a quest to maximise gas production per hectare, KWS are experimenting with the planting of 2 crops in a year.

The concept being examined would include a C3 plant being planted in September/October and harvested in May as a silage. C3 plants such as rape or ryegrass would be ideally suited due to their ability to cope with frost.

As a C4 plant, maize would be planted in May and harvested in September/October. This would allow the C4 plant to capitalise on the intense sunlight and not be hindered by frost.

The advantages of this system would be an energy yield of nearly 100MW/ha. However doubts remain about the high sulphur content of the rape and the affect it will have on the gas.

15. Wind Energy Generation

"You have the feed in tariffs and the resources- what are you waiting for?"
Ivo Rathmann, Enercon

In truth, this phrase was repeated to me time and time again on the continent. Many of the German, Swedish and Danish entrepreneurs I met were deeply jealous of the climatic and market conditions we have here in the UK. Put simply, we as farmers in the UK have the potential to own a significant proportion of the energy generation through wind generation. Should we continue to sell ourselves down the river and give away our most valuable resource to Square Mile companies and foreign developers, our children and grandchildren will never forgive us. This is a unique point in history. The fossil fuel era is at the beginning of the end and the technology to harness wave and tidal is not here yet. On shore wind energy generation will be the most economical and beneficial form of energy in our country for the next 20-30 years and those that own the land, own the vistas and ultimately hold the keys to the UK energy market.

My studies into wind production took me all the way to the brink of the Arctic circle in Sweden through Denmark and Germany before heading to the States. I met many farmers who have installed turbines; however I also got the chance to meet large scale developers (for on shore and off shore) as well as those spearheading community led initiatives. Before I comment on my experiences abroad I feel it is only right to highlight some of the problems and opportunities in the UK.

Where have we gone wrong?

Quite simply we have underestimated the value of our wind resources and we have fallen for the myth that large conglomerates are the only ones capable of developing wind farms. We have sold our most valuable resource to someone else because we were unaware of the revenues it could generate and were happy with the land rental on offer. In short, we lacked ambition and knowledge. This part of my report will hopefully go some way to addressing these problems.

Where are we going wrong?

The introduction of the Feed-in Tariff in April 2010 proved to be the point where the UK caught up with its European neighbours in promoting small scale renewable energy. In fact, in many cases we have passed many countries in our funding for small scale renewables. It has opened our eyes to the potential of owning our energy resources; however it has some significant negative implications as well such as:

1. It suppresses ambition. The FIT scheme is geared to small scale thinking. The smaller the generation the more you get paid per kw.
2. It promotes subsidy milking and not energy production.

3. It is a tax on the electricity bill payer. Unlike the vast majority of our taxes, the FIT is similar to VAT in that all of society bears the brunt. Once the bottom 10% of earners learn that their green levy on their electric bill is used to subsidise six figure incomes, the long term security may alter, especially when energy prices rise.

4. It promotes the use of second class sites for wind production. Like all subsidies it allows inefficient production to flourish.

It is my opinion that a collaborative large scale venture between farmers can yield far more both in terms of energy production and financial returns than many small scale individual FIT driven projects.

Many of the small scale turbines do not come with maintenance contracts. This poses serious questions over their reliability - and don't expect banks to lend without maintenance contracts.

The best way forward?

The FIT is there to be capitalised on. If external factors are limiting the turbine size and capacity then the FIT provides a good way of harnessing an income from natural resources on a small scale. It must not be used as an excuse for small scale thinking. Many of the best wind projects I saw in Europe had a similar theme.

1. Local ownership. Wind turbines are an emotive issue for many, especially when those taking the returns do not have to live close to them for 25 years.

2. Collaboration. Even more important than in conventional agriculture. Collaboration between farmers can secure the best sites, allow easier access to finance and also allow them to capitalise on economies of scale. Collaboration with the community is also important as it allows the true returns to be distributed and more importantly, increases acceptance of the development within the area.

3. Ambition. The bigger the better. Any wind development should be tailored towards maximum capable energy generation and never should ambition be the limiting factor.

15.1 Understanding the payments

The FIT is relatively self explanatory. Take a 100kw turbine for example operating at an average windspeed of 5.5 metres per second.

100(maximum output of turbine)

*8760(hours in the year)

*0.23(at 5.5m/s average windspeed this would equate to around a 23% efficiency factor)
*£0.295(this is the price of the fed in tariff at 24.5 pence added to a standard electric price received from a green energy broker of around 5 pence)

=£59,437(gross income)

The Renewable Obligation Certificate (ROC) is less well understood. As the feed in tariff covers production up to 5 MW, the ROC is only applicable over and above this threshold.

Many people see the ROC as having a value of 4.5 pence per kw. This is not strictly true. The ROC has a value of 3.6 pence per kw and the rest is made up of recycled ROCs. Recycled ROCs are effectively the fines from large electrical companies not hitting their renewable obligation levels and so the money is redistributed into the ROC price. At present levels the ROC stands at 45.45 pence per kw. However it is expected that with the increase in renewables over the coming years, the total ROC value will level out at around 4 pence per kw.

Take an example of a 10MW (4*2.5 MW turbines) project under the ROC umbrella.

10(total output in MW)

*8760(hours in year)

*0.27(at a similar site to the 100kw turbine, a larger turbine will be more efficient as it can harness the higher wind speeds from the higher mast.)

*£95(price per MW when you take the ROC at £45 and a standard electricity price at £50/MW– remember a MW is 1000 kw)

=£2,246,940(gross income)

Taking the 100kw project to 10 MW gives an interesting comparison on the level of subsidy.

100kw*100=10MW

100kw subsidy =24.5 pence per kw or £245 per mw so for 10MW annual production the level of subsidy would be £4.9 million compared to £725,000 for the 4*2.5MW project. Same level of production but over 4 million worth of difference in subsidy.

In Sweden I visited Morgan Johnsson who lived between Ostersund and the Arctic Circle in the Northern part of the country. This was where I started to become aware of the possibilities facing landowners who were willing to embrace wind energy generation.

Morgan Johnsson had implemented numerous measures on his farm and had turned it into a renewable energy wonderland. The measures include:

- A Ram pump that pumps 1000 litres of water up 75m daily to the farm house with zero energy input.
- A woodchip boiler to heat the water.
- A 22kw hydro turbine generating 100,000kw/year.

- After inheriting 400 acres of woodland from his sister, he cleared the woodland and used the money to invest in a 900kw turbine.
- Also on the same patch of land, he developed the land for 11*2MW turbines. He then sold off the leases to local buyers.

Table **15.1(i)** shows the income that would be possible under UK conditions.

Fig. 15.1(i)

Device	Annual income	Value
Hydro turbine	£23,000	n/a
900kw wind turbine	£350,000	n/a
Leases for 11*2MW turbines	n/a	£10-11 million

15.2 Wind Turbines- The Myths

- They're inefficient- they only work 30% of the time.

  Wind turbines are frighteningly efficient- it's the wind that isn't! I learned in Germany that the maximum theoretical energy capture is 59% should the wind be allowed to pass through the other side of the turbine. To achieve 100% then there would need to be a complete blocking of the wind put in place so effectively there would be no wind on the other side. At present, wind turbines are harnessing up to 90% of the total theoretical potential. Be aware also that a diesel internal combustion engine will only work at 40% efficiency.

- We can't base our electrical generation on an intermittent source.

  There are 3 flaws to this argument.

  1. The wind will blow in different places at different times. Admittedly, this is not the most robust of arguments for wind power.
  2. As part of a larger renewables package, level and flexible supply can be achieved. Large scale trials in Germany set the level of electrical generation above what could be supplied from the solar and wind troughs and backed it up with biomass, biogas and pumped hydro storage. The result was production could be set at a required level or increased and decreased when demand dictated. It is my belief that in the future, pumped hydro storage will act as an accumulator tank for wind energy. During surplus/peak production the energy will be used to pump water up a hill and during deficit/trough production, the energy will be reclaimed from the water on high by running it through a hydro turbine and generator. Pictured overleaf is a pumped hydro storage project in central Germany.

Pumped hydro storage project in central Germany

3. We are at present, in the transition between the fossil fuel economy and the hydrogen economy. Right now, there is no need for wind generation to stand alone as we have the other fuels to back it up. In the future, as we come to rely more on wind energy, peaks will be stored as hydrogen and utilised in the troughs.

- They kill Birds.

  Some of the earlier, smaller turbines killed the odd sparrow. Dogs, cats and cars kill birds, rarely turbines.

- Noise.

  Noise is an overplayed argument by the opponents of wind energy as anyone will know if they have been to a large wind project. While it cannot be denied that during certain windflows, noise is emitted, it is dwarfed by existing noise in the area for example traffic and wind and rain.

15.3 Second Hand Turbines

In Denmark an interesting situation has arisen. The government has capped the number of wind turbines that can be erected and that level has now been reached. This does not mean an end to wind farm development in Denmark though. I travelled with wind farm developer Morgan Skovgard for a day and he explained some of the challenges facing the Danish wind sector.

Because of the limit put on turbine numbers, should a developer want to erect a wind turbine then they must take one down. This is leading to developers erecting 3MW turbines and taking down 10-15 year old 250kw turbines. This has became a major cost to the developer however it has resulted in what is effectively a scrapage scheme for turbines paid for by the private sector.

The offset of this is there are now shedloads of good quality 2nd hand turbines in Denmark. While we cannot capitalise on this in the UK as the FIT scheme demands new installations, a massive opportunity is there for the Northern Ireland market where the ROC based system does not require new installations. While many saw the turbine regulations as a millstone around the neck of development, Dan Kyellgren had turned it into an opportunity. He owned the company DanRunWind where he would recondition 2nd hand turbines by replacing the bearings. Dan would typically sell the turbine for 70% of new price and attached a 2 year warranty with it. At present most of his turbines are going to Poland to help them reach their green targets. Picture **15.3(i)** shows me in one of Dan's 2nd hand turbine warehouses.

15.3(i)

Morgan Skovgard was also keen to show me the experiment he was carrying out for Siemens involving concrete towers. It is expected that concrete will become cheaper than steel in a decade's time. With the size of turbines increasing all the time, Siemens feel it is important to start experimenting now to capitalise in the future. Also, concrete, unlike steel, absorbs noise so it would put to bed the argument over noise. Picture **15.3(ii)** shows the construction of the concrete tower.

15.3(ii)

15.4 Enercon, Germany

During my time in North Germany, I was fortunate enough to be shown round the Enercon factory and some of the nearby turbine installations. Enercon are one of the largest turbine manufacturers in the world with 10% of the world market and 60% of the German market.

Enercon turbines differ when compared to the more conventional turbine due to the absence of a gearbox. The current is converted from AC to DC, regulated, then converted back to DC. The theory is that it makes the turbine more reliable due to the removal of the gearbox. This is backed up by the endorsement of the main money lenders in the UK. The elimination of a gearbox also gives the Enercon turbine its unique appearance, having the hub resemble an egg instead of a long rectangular box.

Other features unique to the Enercon turbine include

- Short blade length. The longer the blade length the higher the wear. This is because the windspeed is different from the top tip of the blade circumference to the bottom tip of the blade circumference. Enercon's philosophy is to compensate for the lower productivity of a shorter blade length, they have a taller mast.

- The wing at the root of the blade. In order to increase conversions of up to 20%, a flange/wing is inserted at the root near the hub.

- Aluminium hub instead of fibreglass. Aluminium copes with heat stress better and increases the recycling value of the turbine at the end of it's life.

15.5 Community Wind

One of the most important aspects of wind farm development is involving the local community to increase acceptance at local level. While many parts of Europe were implementing community schemes to a far higher level than we have in the UK, the furthest forward in this field was the USA, in particular Minnesota.

Minnesota has became a leader in community wind where in the early 1990s a band of early adopters paved the way for what was to become a commonly used template.

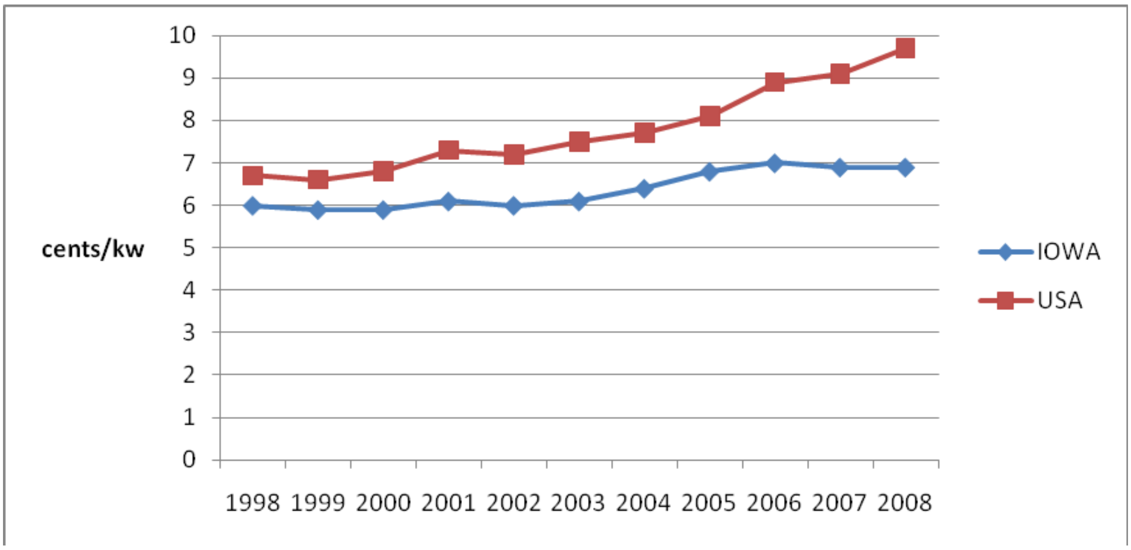
These early pioneers developed a structure for community ownership in wind turbines commonly known as, and referred to as, ”the Minnesota Flip”. This is a concept where local communities come together with large companies in a win-win situation. The large companies will invest their profits into a wind farm and take 90% of the returns from the first 10 years. More importantly, they get a 1.5c/kw tax credit so effectively, they make more from the tax credit than they do from the net returns from the electricity sales. Once they reach their allocated tax credit limit, the ownership of the project “flips” and the community will then own 90% with the large company owning 10%.

While every project structure is different, the flip point will usually take place 10 years into the project allowing the majority of the profits to come back into community hands over the 2^{nd} half of the project’s lifespan. The flip point is ultimately decided upon when the tax credit limit is reached.

Due to this structure, Minnesota has the largest amount of community owned wind farms anywhere in the world. A total of 180MW (more than 15%) is in community hands and growing.

To give an idea on the impact local ownership can have on local communities graph **15.5(i)** shows the relationship between the average electricity price in Iowa compared to the rest of the United States. These results highlight the difference between Iowa, with large number of wind farms operating in the State (20% of all Iowa’s electricity generation is from wind) and a large number of community owned “flip” schemes compared to the rest of the USA.

15.5(i)



This shows the benefits to Iowans for having invested in wind generation to a higher extent than any other State.

16. Hydro Generation

Like my attitude towards nuclear generation, my perception of hydro generation changed throughout my Scholarship. My original thoughts and experiences with Hydro were all very positive for the following reasons:

1. Consistency of generation. Although generation levels will vary, hydro delivers a far greater consistency than wind and PV

2. Lifespan. Hydro, above all other forms of renewable or conventional generation, will command the longest lifespan. Hydro turbines can expect to last over and above 70 years with many predictions of 100 years.

3. Zero input and low maintenance once running.

4. Low construction cost. While economies of scale naturally come into play, hydro will generally come with a lower capital expenditure than wind at under £1000 per kw installed

Throughout my Scholarship it became apparent that the benefits of Hydro generation were not as apparent as I first thought for the following reasons:

1. Lack of viable sites. The need for a water source, high flow and a large drop(head) makes hydro generation the most poorly distributed renewable generation source.

2. Environmental impacts. Many of the larger turbines were built in an era when electricity generation took precedence over the environment. At present, the disturbance of river flow is a major concern to environmental agencies and further limits the viable sites available.

Terms of scale

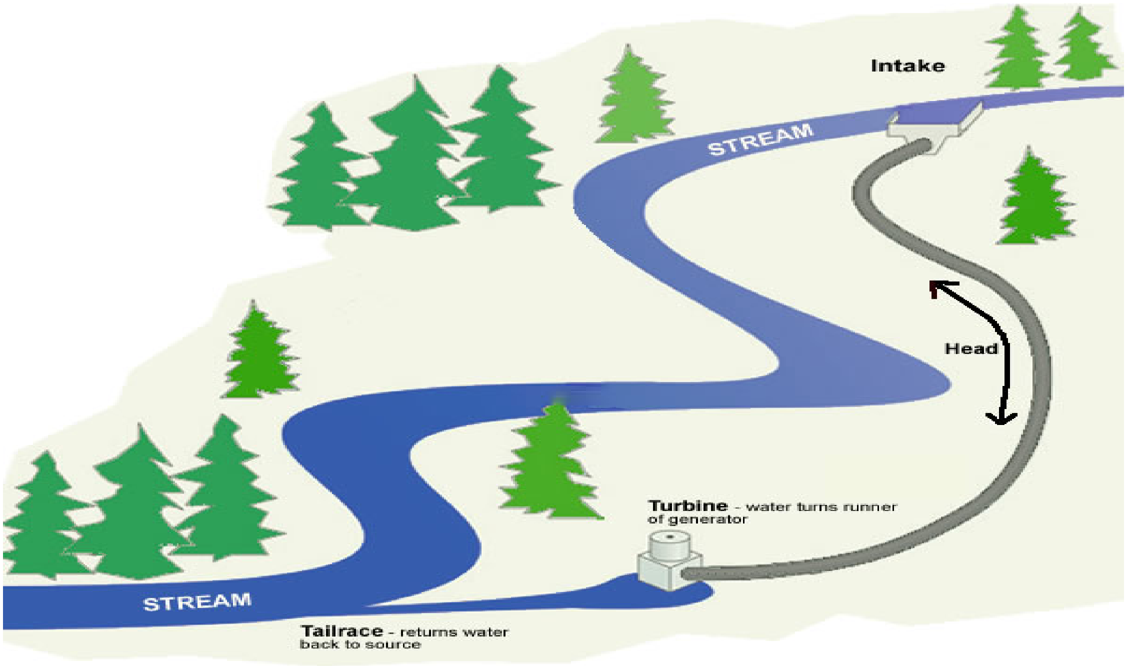
Term	**Level of generation**
Pico Hydro	0-5kw
Micro Hydro	5-100kw
Mini Hydro	100-1000kw
Small Scale Hydro	1-10MW
Large scale Hydro	10MW+

The scale of Hydro generation depends on 2 factors:

- the flow of water
- and the head.

The "head" is the term used to refer to the drop in water. Figure **16(i)** shows a typical layout for a run-of-the-river micro hydro generation plant.

16(i)



The standard calculation for power output would be:

WATTS = FLOW(l/s) x HEAD(metres) x 9.81(weight of water) x TURBINE EFFICIENCY

The other more simple way of calculating the output that was often used when I was in Sweden would be:

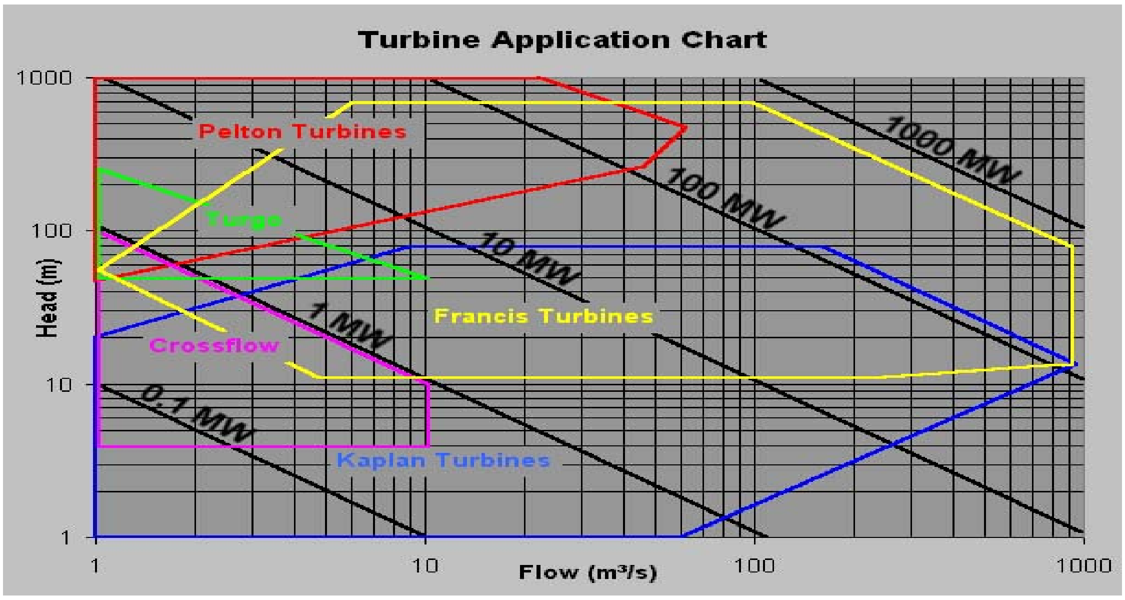
1 l/s over 75 metres drop results in 1 horse power (735 watts) *

**but this does not take into account turbine efficiency.*

Turbine efficiency will normally range from between 45-70% and depends on several factors

- Scale
- Consistency of flow
- Head
- Flow
- Type of turbine. Different turbines are developed to work at optimum conditions. Figure 16(ii) shows the different makes of turbines and their suitability for different heads and flow rates.

16(ii)



Pictured below is an example of a Pelton turbine I saw in Northern Sweden. The Pelton takes advantage of the high head and uses a jet of water to drive a bucket clad wheel inside the casing which in turn drives the generator. As the dam created a reservoir, this would be an example of a conventional hydro electric plant and not a "run-of-the-river" plant. As you can tell by the casing, this particular turbine qualifies under grandfather rights for environmental regulations!

Picture **16(iii)** shows a large conventional hydro plant in Northern Sweden. Many of the large plants in Sweden act as a bridge for public access as well as a point of generation. This particular plant generates 36MW/hour.

16(iii)

Possibly the most famous hydro electric plants I visited was near Kassell in Central Germany. The Edersee dam (pictured below) is Europe's largest hydro electric generator. Again, an example of a conventional large scale hydro electric plant. Although it has been in operation since 1911, it doesn't like bouncing bombs!

17. Photovoltaics (PV)

Photovoltaic panels allow us to turn daylight into electricity. Unlike other forms of renewable energy sources, PV can be utilised in rural as well as urban settings making it one of the most popular forms of generation in Germany, especially in the south. However drawbacks include:

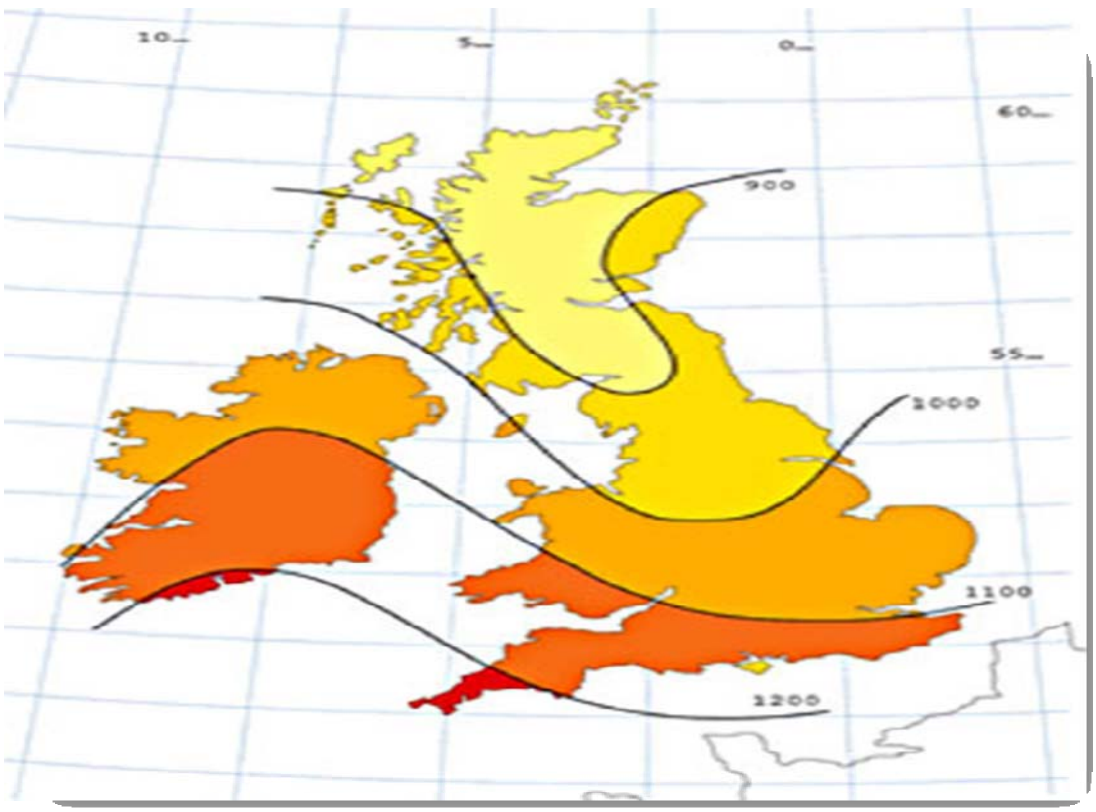
- a low level of electrical generation
- high carbon footprint in their manufacture
- and high capital expenditure making them highly dependent on inflated feed in tariffs.

It is worth noting that feed in tariffs for PV in Germany are decreasing every year as the price of new PV cells are decreasing year on year.

Potential

Map **17(i)** shows the potential kwh/m2/year from a PV panel in the British Isles before deductions for tilt, orientation, panel type and grid connection.

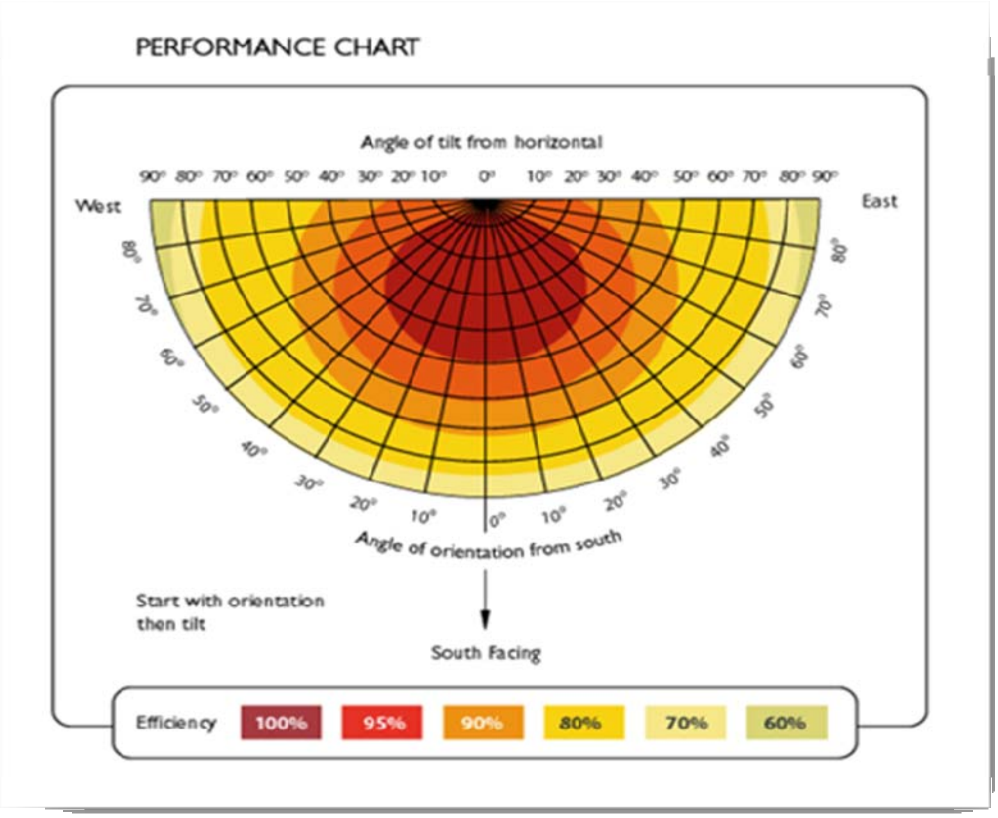
Fig 17(i)



Tilt and Orientation

Figure **17(ii)** shows the deduction needed for tilt and orientation. It is recommended that the best position for panel performance is at 25-30 degrees and south/south west facing. Although many farm buildings were not built with PV panels in mind, struts can be inserted to increase tilt level although obviously, no action can be taken to decrease tilt.

17(ii)



Quality of Panel

After taking into account reductions in tilt and orientation, consideration must be given towards the quality of the panel.

Type of panel	Efficiency(%)	Cost per kw installed	Output (kwh/m2/year)
Mono-crystalline	15-19	£8000	Up to 200
Poly-crystalline	12-15	£6000	Up to 150
Thin Film	6-8	£4500	Up to 90

Grid or Battery?

Most PV panels would be hooked into the national grid. This would result in an 80% efficient connection although some PV panels are used to recharge batteries making the connection efficiency 70%. The benefit of a battery is it discounts the need for an expensive grid connection and also allows greater use of electricity generated on farm.

Taking into account the factors mentioned above I shall do the output calculation for a 1m2 mono-crystalline panel situated in Cornwall at a tilt of 25% and facing south west connected to the grid:

> 1200(potential)*1.0(no tilt and orientation deduction)*0.19(mono-crystalline efficiency)*0.8(grid connection)=182kwh/m2/year.

Siting

Many farmers in Germany were taking advantage of the high feed in tariff (48 cents/kwh) by siting their sheds in a south westerly position like at Seivers Dairy, pictured below.

Shed pitch and positioning has become one of the most important considerations in Germany when planning a new shed. Many farmers see the roof as a greater source of income than the cattle inside the shed. Even for those who won't make the investment in owning the panels, companies will pay 1 euro/m2/year to farmers for access to a well sited building.

Picture **17(iii)** - next page - shows how industrial units are capitalising on PV panels with this unit in Merkendorf, Bavaria strategically built to harness a mixture of Mono-crystalline(upper) and polycrystalline(lower) panels.

17(iii)

Taking the concept to the extreme, farmers in Bavaria have installed a whole field of PV panels as illustrated in picture **17(iv).** Should the EU ever allow permanent set-aside again, this would be a formidable use of land!

17(iv)

18. The Innovators

One of the highlights of my travels was getting the opportunity to quiz some of agriculture's finest innovators. Many of those whom I met had ventured out from conventional agriculture and found their feet in a new, energy producing world. There were 2 people however, that really pushed the boundaries further than most and they were John Vrieze of Baldwin Dairies, Wisconsin, and Dennis Haubenchild of Princeton, Minnesota. Both men were awarded the USA innovation in Agriculture award (John in 2000 and Dennis in 2009) and their passion is energy from agriculture.

Before I describe their systems, it is only right however, to highlight the work done by certain government/privately funded bodies to allow a platform for great people to go on and achieve great things.

In America, I met up with Ryan Stockwell of the Minnesota Project. The MP is funded by tax breaks for large companies. Effectively, a company with a large profit can invest that money with the proceeds going to non profit organisations like the MP. The large profit making company can withdraw its money at any time; however it must then pay tax on its profits.

The MP has 2 objectives.

1. To allow demonstration projects to be set up in order to cultivate the confidence of others to follow suit. Initial projects can be funded up to 60%. "*It's all about the person. If we have the right person with the passion and drive to make things happen it gives us the confidence to fund the project*", said Ryan

2. Education. Like many countries in the world, America's youth is growing ever more unaware of where their food comes from. The MP role is to reach out to schools and city communities to help educate.

Both Dennis Haubenchild and John Vrieze talk highly of the work done by the Minnesota Project.

18.1 John Vreize, Baldwin Dairies

John admits, "*being the innovator isn't easy - my bank manager keeps telling me to give it up and concentrate on milking cows!"*

John operates what he calls a closed loop system which allows energy to be generated from waste then utilised on other enterprises on farm. At present the enterprises at Baldwin Dairies include:

The Dairy Herd

- Produces milk and slurry
- The slurry is the put through an AD plant to produce heat and power

Fish production

- The power from the AD unit is used to heat and areate the fish tanks.
- The resulting effulent has no e-coli.
- Fish are sold between 6-8 moths at 1.5lbs and command a 30% "green" premium

Hydroponic Lettuce production

- The electricticity produced from AD is used to light, heat and power the pumps within the greenhouse
- 500,000 plants per year produced
- The effulant from the fish is used to fertilise the lettuce production

Future considerations include

Processing dead calves	• Protien used for fish food
Algae Production	• Once the technology is there to extract oil from algae John would grow algae in his green house • Algae is very responsive to CO2 so the CO2 would be piped in from the biogas to stimulate rapid growth
Fat Boiler	• At the time of my visit, John was in the process of installing a fat boiler to utilise waste fat to increase greenhouse capacity

18.2 Dennis Haubenchild

Dennis Haubenchild is a man at the very forefront of what can be achieved with agriculture, energy and hydrogen. Simply typing his name into Google results in 40,000 hits. Previous to my visit Dennis had just received the Innovator in Agriculture award. He was the first person to refine hydrogen from biogas and store it and utilise it on farm.

It must be said that the help Dennis got from Phil Goodrich and the University of Minnesota was considerable. Phil was my tour guide for a couple of days and the conversations I had with Phil were tremendously enlightening to say the least.

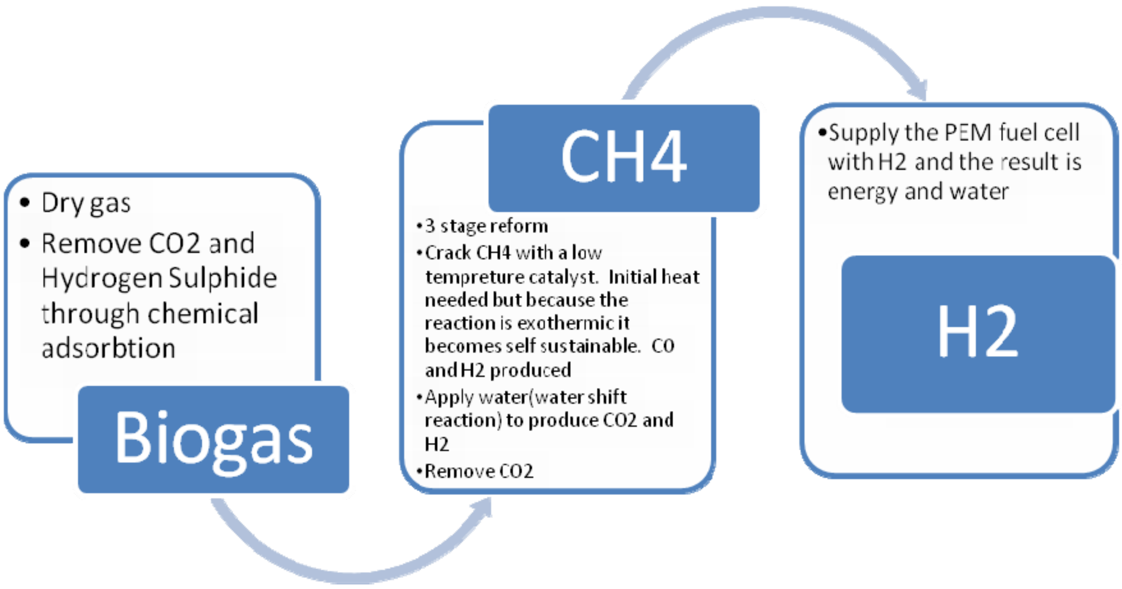
Dennis' name first came to me when I met with Christophe Le Maitre from New Holland in Germany. I was interested in the concept NH were developing with fuel cells to create energy independent farms. Christophe was very honest when he said that they learned a great deal from Dennis' project. I knew at once that my Scholarship would not be complete without a trip to Haubenschild's dairy in Princeton, Minnesota.

Dennis was primarily driven by securing energy independence, both for the United States and on farm. *"All the easy energy is gone and we need to start generating energy we can use in 21 days, not 21 million years. Agriculture can produce 60% of the world's food and 100% of the world's energy"*. Like in many countries, the main stumbling block to a prosperous renewable economy is the national grid. Dennis was not sympathetic to the grid operators and part of his drive to produce hydrogen was to be able to store energy and bypass the national grid.

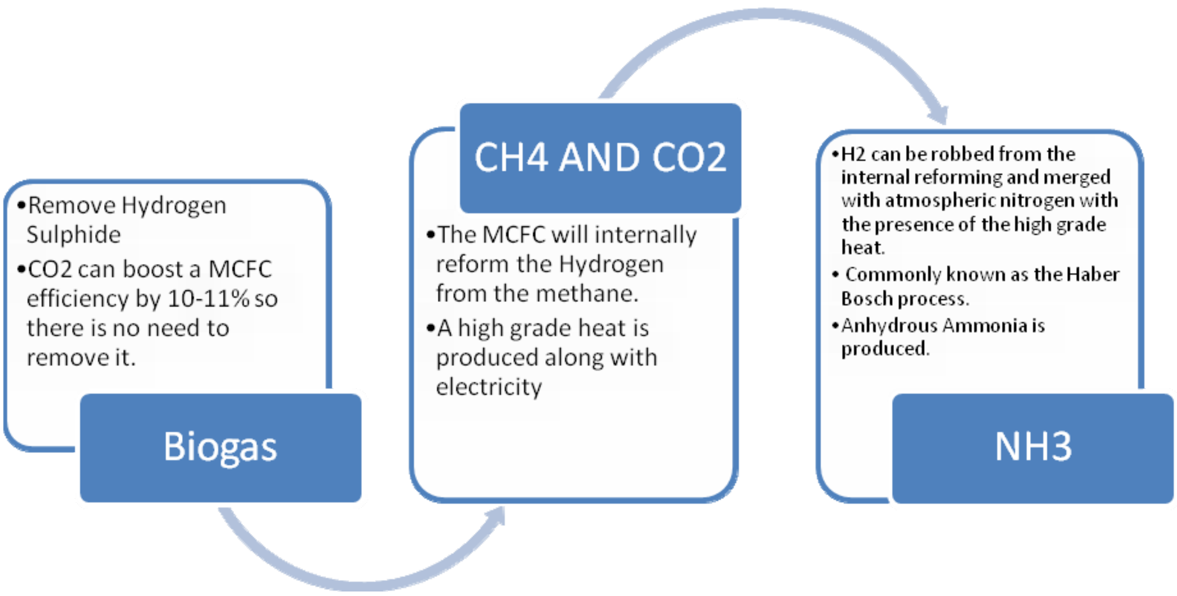
Pictures **18.2(i)** shows Dennis Haubenschild and myself next to the Fuel Cell in question

18.2(i)

Dennis' desire was to implement a high temperature fuel cell. However the funding available limited him to a Proton Exchange Membrane Fuel Cell that worked at low temperature and on externally reformed pure hydrogen. Here are the steps of the process:



Dennis had greater dreams than simply the production of hydrogen. He wanted to take hydrogen to the next level which is ammonia through a high temperature fuel cell (Solid Oxide or Molten Carbonate). This would be the process he would have chosen had the funds been available.



In my opinion, the Molten Carbonate fuel cell is far more suited to agricultural practices than the PEM fuel cell. Due to the ability of the MCFC to utilise biogas in a highly effective manner and the advancement of hydrogen to ammonia by harnessing the high grade heat produced, the PEM fuel cell remains destined for vehicular prototypes for now.

19. Renewable Ammonia Production

Without inorganic fertiliser, we wouldn't be able to feed the world. It is thought that inorganic fertiliser provides the world with half of its food. It was not until I embarked on my travels to the States that I realised what an important part ammonia has to play in the world's fuel production.

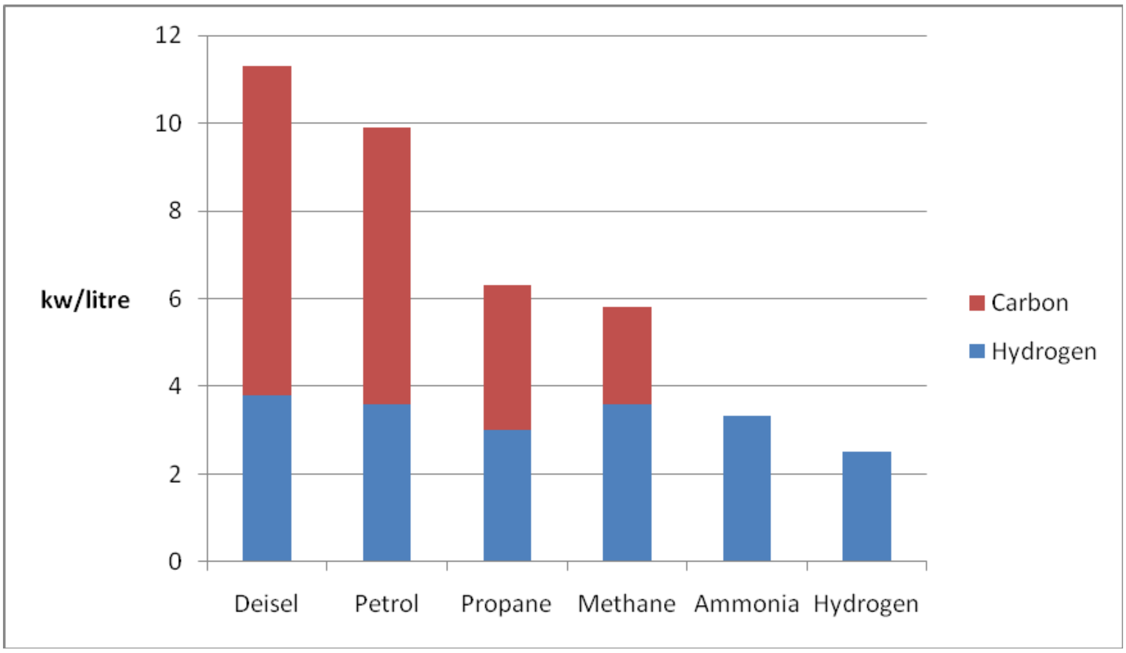
19.1 Ammonia as a fuel

Ammonia can be produced from any fuel (nuclear, fossil or renewable) and can be utilised in any engine with minimal adaption.

Energy Values

Graph **19.1(i)** shows the energy values of hydrocarbons, pure hydrogen and ammonia.

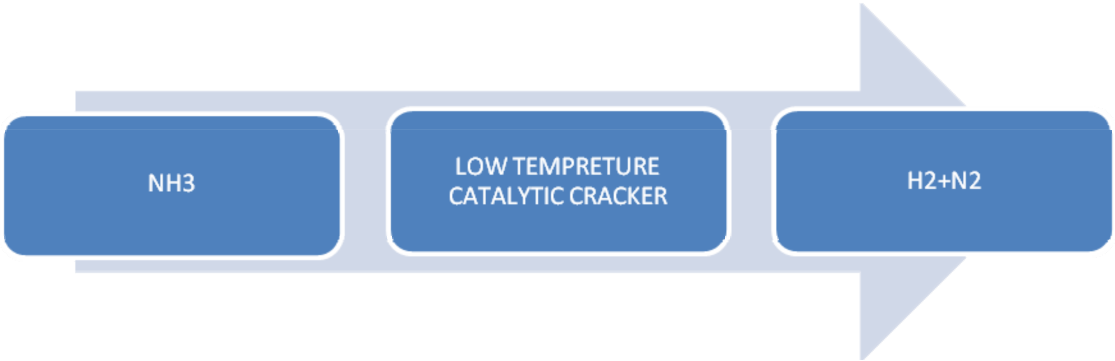
19.1(i)



As NH3 is a denser form of hydrogen than straight hydrogen itself, it would be considered the superior fuel.

Emissions

When a hydrocarbon is oxidised (burned) it will produce CO2 and H2O. When a source of fuel that contains no carbon is oxidised it will not produce any CO2, just H2O. This is what makes NH3 and H2 so attractive as a fuel. A problem will arise when oxides of Nitrogen are produced from the burning of ammonia. This can be countered by simply adding more NH3 to produce N2 and H20 or by breaking the molecule down via a low temperature catalyst to release the nitrogen into the atmosphere before the hydrogen can be oxidised to produce water.



Safety

Ammonia has a greater potential to cause low level injury than hydrocarbons. This would be through burns when refuelling or inhalation of gaseous ammonia. Hydrocarbons however have a greater potential to cause serious injury through combustion.

As Norm Olsen from Iowa's biomass conversion centre explained:

> *"gasoline will kill you close up, ammonia won't, but you are likely to suffer inhalation problems further away from the source".*

Ammonia has a very high flash point which means that, unlike petrol, it will not readily ignite under a naked flame. In short ammonia is a far safer fuel than hydrocarbons. However, it still carries the potential to do harm.

Storage and Transportation.

This is where ammonia really scores over hydrogen. The boiling point of hydrogen is -253 degrees compared to -28 with ammonia. This means that the possibilities for ammonia to be utilised as a liquid fuel are far higher than for hydrogen. Not only are there temperature benefits but the pressure at which hydrogen needs to be stored and transported is incredibly high in comparison to ammonia which can be stored and transported in liquid form at atmospheric pressures.

At present there are natural gas pipelines stretching from the gulf of Mexico (source) to the major cities. Should an ammonia economy develop, these same pipelines are suitable for ammonia transportation. This would mean that natural gas could be converted into ammonia at the source and other sources could then "feed in" to the ammonia grid.

Cost competitiveness.

Almost always the downfall of clean fuels is the cost. However in some cases, ammonia disproves that.

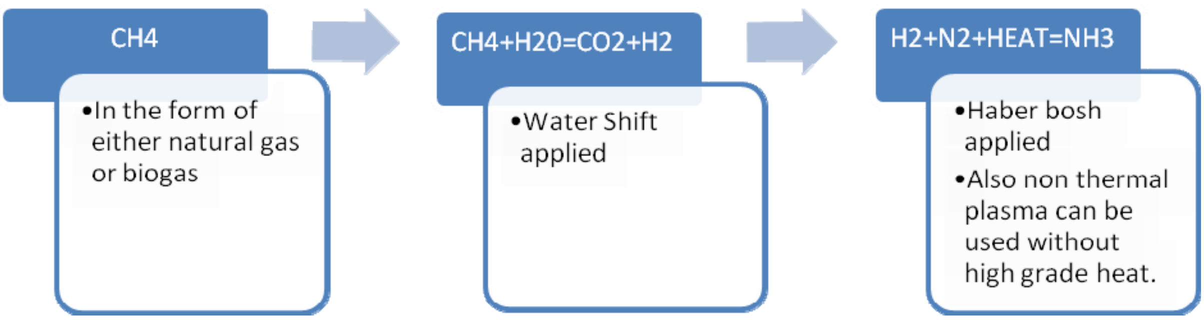
Renewable ammonia is the dearest form of ammonia and cannot be considered cost competitive in today's free market - however the possibilities in the short term involving other sources look promising.

The fuel source America has in abundance is coal and, to a lesser extent, natural gas. At present, coal and natural gas represent a cheaper form of fuel than petrol. The exciting prospect is that, should coal and natural gas be converted into ammonia via clean coal and water shift technologies, the ammonia produced is a greenhouse gas-free fuel on a cost equivalent to petrol.

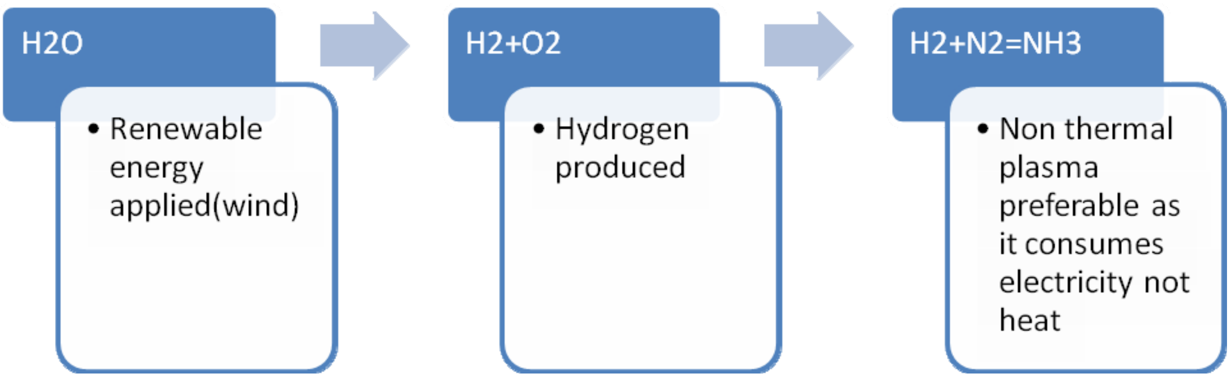
Ammonia Synthesis.

Reforming hydrocarbons is seen as the most cost efficient as well as the most energy efficient way of generating ammonia. As a rough rule of thumb, hydrocarbon reforming is seen as being 3 times more efficient than producing ammonia from wind/electrolysis.

Hydrocarbon reforming:



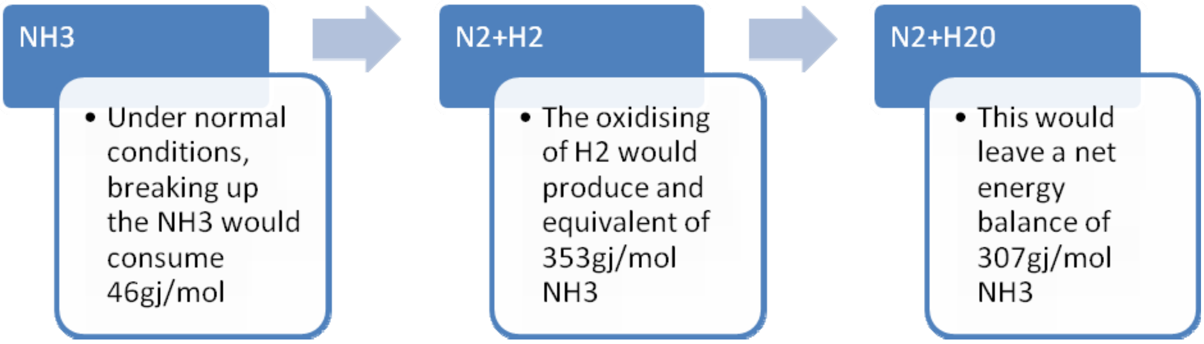
Wind synthesis



Realising the Fuel

One of the most beneficial aspects of ammonia over hydrogen or any other alternative clean fuel is its ability to be utilised in conventional internal combustion engines with minimal adaption. These adoptions would include:

- All plastic copper and brass parts must be converted to stainless steel to overcome corrosion problems.
- A catalytic cracker would be installed to break down the ammonia into atmospheric nitrogen which would be released and hydrogen can then be oxidised.
- Due to the high flash point of ammonia, a fuel with a lower flash point would be needed to start the cracking. After the initial ammonia is broken up, the energy released from the hydrogen oxidation would supply the cracker.



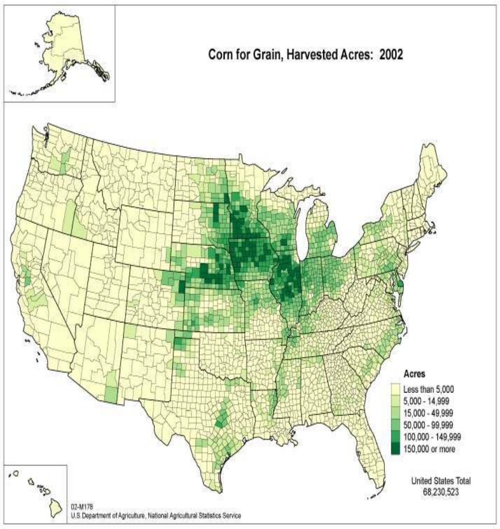
19.2 Ammonia as a fertiliser

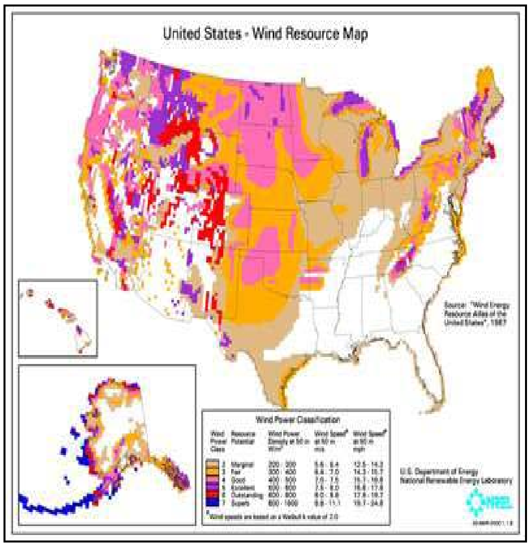
Over 80% of America's inorganic fertiliser application comes by way of anhydrous ammonia application. Since 2001, the amount of fertiliser that is home produced has declined from over 70% to under 50%. Many are concerned that the ever increasing pressure on natural gas reserves will drive up the cost of fertiliser to levels which are at best unaffordable and at worst unavailable.

At present, there are prototypes demonstrating the synthesis of ammonia production through wind. I visited the project at the University of Minnesota Morris to meet Mike Reese where he showed me the theory and concept.

Geographical convenience.

See map on next page





The map on the left shows where the majority of America's corn is grown and hence the greatest use of inorganic fertilisers.

The map on the right highlights America's wind resources. The purple and orange show where the strongest and most consistent windspeeds occur.

In effect, the corn grows where the wind blows which makes America's Mid West the ideal area for ammonia synthesis and utilisation.

Cost of production

At present ammonia produced through wind is estimated to be around double the cost of conventional ammonia at $1000/t compared to $500/t.

The fertiliser needs of Minnesota are said to be around 600,000t of ammonia. This would need 2000MW of installed wind capacity at a cost of $3.5b.

However, what Mike Reese is proposing would be a 10% mandate for renewably produced fertiliser.

The cost implication of a 10% mandate for Minnesota would be as follows:

> 60,000t needed
>
> 200MW wind needed at a cost of 350m which equates to $1000/t to produce
>
> =$60m for 10% of fertiliser requirement
>
> The conventional 90% of fertiliser would have a retail value of $260m.
>
> Add the cost of the renewable ammonia and the total is $330m compared to $300m conventional.

This works out at a per acre rate of $45.83 instead of $41.67

Other mechanisms for bringing about renewable ammonia would include :

- production subsidy
- tax credits
- equipment grants

The benefits of investing in the ammonia economy this way would include

- Utilisation of peak wind production
- Reduced greenhouse gas emissions from NH3 production
- Increased utilisation of wind
- No grid needed
- Secures domestic fertiliser market
- Bolsters rural economy
- Stabilises future fertiliser prices in the future


The photo on the left shows Mike Reese escorting a tour party onto the 1.65MW turbine at Morris that is designed solely for the electrolysis of water.

The photo on the right shows Iowa Farmers Co-operative members and the vessels used to store NH3(g).

Table **19.2(i)** below, shows the comparisons between gas, liquid and solid NH3 application.

	NH3(s)	NH3(l)	NH3 (g)
%N	46	32	82
Cost per lb(cents)	22	14	26
Application cost/acre	4.5	4.5	6.7
Total cost/acre ($)*	76.20	70.12	54.02

*standard application rate of 150lbsN/acre for maize

20. Dairy Energy Efficiency

For me, this was where my study had begun. I realised that I was spending a disproportionate amount of time focussing on vet bills whereas my energy bills were roughly of a similar amount and commanded a lot less of my time and efforts. Added to this, the impact I could have on my energy bills were far greater than what could be achieved by spending all my time trying to source cheap drugs. While my study expanded from simply looking at energy reduction and generation to offset consumption, I nonetheless gained a great deal from my time looking into the possibilities of energy reduction in the dairy business.

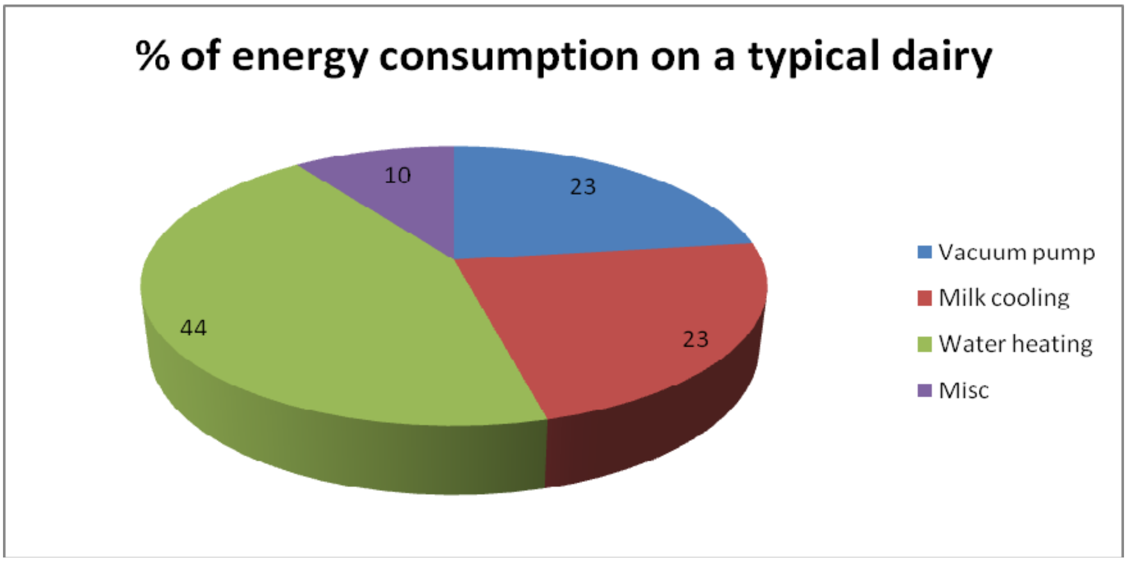
Average Dairy Energy Consumption

The average consumption per cow in the UK is 296kw/cow/year; however the range is from 100-550kw/cow/year. Economies of scale are not always relevant in energy consumption. Larger herds tend to be more automated which reflects on the electrical consumption.

On dairy farms there are 4 major parts to energy consumption

1. Vacuum pump and milking equipment
2. Milk cooling
3. Water heating
4. Miscellaneous such as lighting , feeding, manure handling and ventilation(ventilation in US herds accounts for much more than in Europe due to the nature of management and climate)

Chart **20(i)** shows typical dairy energy consumption (with a plate cooler).



Throughout this section I will concentrate on the 3 main aspects of energy consumption on dairy farms and highlight where I think the greatest improvements can be made.

If it can be measured it can be managed.

Having toured many of the most energy efficient dairies in Europe and America, there were many different theories to energy efficiency. However there was one thing all energy efficient farms had in common- an energy consumption monitor. Devices like the "current cost" energy tracker allow you to know exactly what device consumes how much energy and hence allows for improvements to be made. Never has the term, "*if it can be measured it can be managed"* been more appropriate**.**

Knowing your electrical consumption will motivate you to drill into electrical bills like never before and will be far more beneficial and cheaper than an energy audit done by a consultant.

20.1 Milk Cooling

Milk cooling savings are very much dependent on the efficiency of the plate cooler. The efficiency will be determined by

- The size of the plate cooler. Is it big enough to handle peak milk flow?
- The water: milk ratio. A minimum ratio should be 1:1 Many are running at 0.5:1. Ideally 3:1 should be achieved.
- Water from the coldest possible source should be used, usually bore hole.

20.2 Vacuum pump/milking equipment.

One of the easiest decisions I made after returning from my European travels was to dispose of my aquasilent vacuum pump and replace it with a variable speed drive pump.

The capacity of non variable vacuum pumps is set to manage peak load. Peak load occurs during the washing out phase as the process of delivering a "slug" of water is vacuum hungry. This means that because the vacuum rate is constant, the vacuum levels throughout the milking period are overcompensated, even when all the clusters are attached.

Savings

Depending on the capacity of the previous vacuum pump, energy savings are usually around 60% although they would range from 30-80%.

Table **20.2(i)** (on next page) shows the operational time needed for a 5 year payback on different sizes of variable speed pumps based on an average electricity price of 7 pence/kw

20.2(i)

Pump size (kw)	Operational hours per day required for a 5 year payback
5	12
7.5	8
10	6
15	5
20	4

Other less obvious ways to save on energy consumption in the parlour include:

- Should the operator reduce the loss of vacuum when attaching the unit, a 10% saving in energy can be expected.
- Cluster design. At GEA, Heinz Joseph Beiwinkel showed me the technology being implemented to reduce vacuum loss via the IQ system. Effectively a ball will shut off vacuum when the cluster is not in the milking position. When a conventional cluster is kicked off, vacuum losses of around 1200 litres can be expected whereas, under the IQ equipment, losses are kept to 25 litres.

20.3 Water heating

There are many options open to farmers who want to reduce energy bills by reducing their energy consumption for water heating. Although water heating will usually equate to around 40% of total energy consumption, the total percentage of cost is always considerably less as normally all water heating is done off peak.

Heat Recovery Units

Heat recovery units are almost always economical when using electricity to heat water. Typically a good rule of thumb to use is that a HRU will reduce the water heating bill by 50%.

- To heat water by electrical means, for every kwh of electricity you use, this would result in 0.4kwh heat into the water.
- For every kwh electricity you use cooling milk, a HRU will convert that into 2-2.5kwh heat. This makes the process around 225% more efficient than heating water by conventional means.

A conflict occurs between an efficient milk cooling process and heat recovery. The more efficient the plate cooler, the less potential there is for an efficient heat recovery from the compressors that cool the milk. In dairies less than 100 cows, there would only be enough potential for *either* a plate cooler *or* a heat recovery unit. However in dairies over 150 it becomes economic to implement both devices. My visit to GEA in Dortmund allowed me to see that, on dairies with a heat recovery unit installed, the cooling compressors ran at 5-20% over and above their normal level to capitalise on the efficiencies of the HRU.

1 litre of milk cooled from 37-4 degrees through refrigeration will heat 0.3 litres of water to 45 degrees. After plate cooling, 0.15 litres would be the volume of water that could be heated to a similar heat.

Instantaneous water heaters

Many farms in the States were installing instantaneous LPG water heaters. This allows the water to be heated at the time of use. The benefits include:

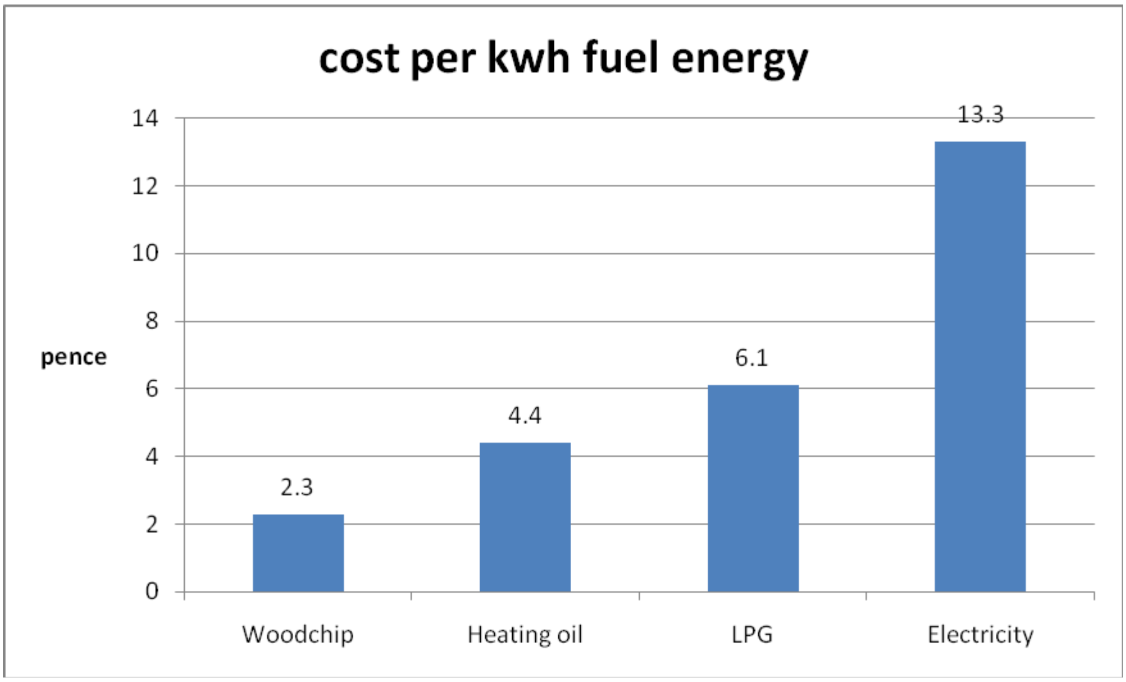
- No need for water storage tanks
- Eliminates heat loss in storage
- Allows a more precise control of water temperature.
- 83% less greenhouse gasses emitted than from electric heating

The downside is the installation cost and maintaining the correct flow rate and, hence, the correct temperature. Reliability is also an issue.

Woodchip boilers

There is no cheaper form of heat than wood fuel. Graph **20.3(i)** shows the cost comparison between fuels for heat production.

20.3(i)

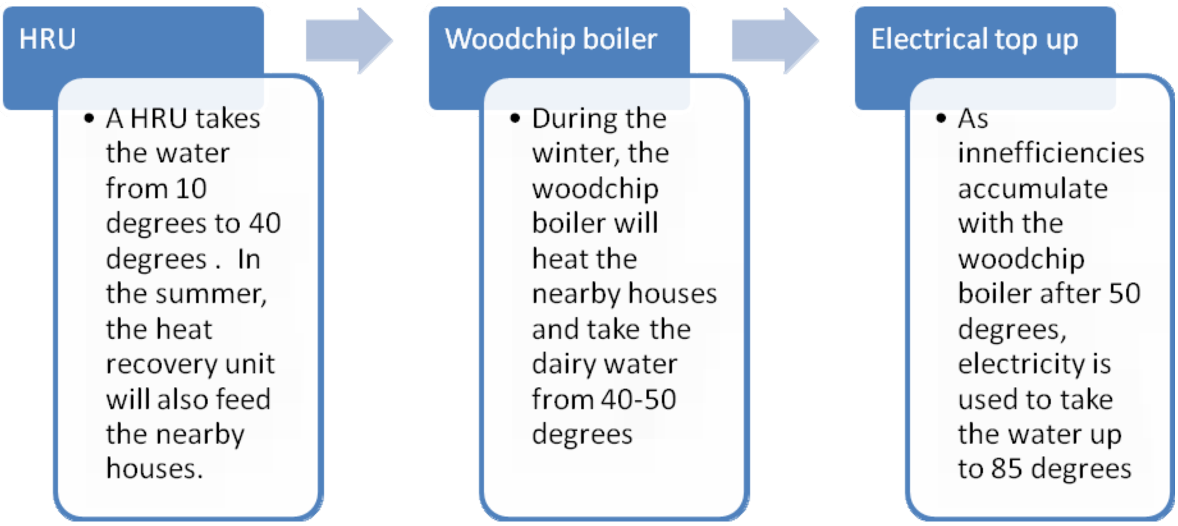


In Sweden the use of woodchip is widespread. It was rare for farmhouses to be heated by anything other than woodchip. On the dairies I visited, the woodchip concept was continued with positive results. The woodchip system would encompass the farmhouse, farm cottages and the dairy as well as allowing any surplus heat from a HRU to be utilised.

The downside to woodchip is the extra manual handling of the fuel and the increased labour costs this incurs. However, when integrated with local housing, woodchip can be looked upon as an extremely cheap and effective fuel for dairies.

Figure **20.3(ii)** shows how water was heated at Sven-Erik Eriksons dairy in Ostersund, Sweden. Shortly after my visit the farm was awarded the title of Europe's most energy efficient farm.

20.3(ii)



Solar heating

At present the capital expenditure cannot be justified when heating water for the dairy. However, should the Renewable Heat Incentive become applicable in 2011, the financial situation may change. At present, solar remains further down the list of options than either a HRU or woodchip for heating water in dairies.

21. Back where the home fires burn

Since returning home from my travels I have started work on 3 renewable projects:

1. A 330 kw turbine on farm. Due to the highly attractive feed in tariff rate of 18.4 pence/kw under 500kw, this level of project in my opinion represents the best return on investment.

2. A 250 kw biogas plant. Having learned from my experience in Europe about collaboration and the utilisation of break crops I have started work on this small scale biogas project. The structure involves me inputting slurry into the plant. Also I have convinced my 2 arable neighbours to grow red clover as a break crop instead of OSR which I will use as a feedstock. The benefits to my neighbours include:

   - Growing a low input crop for a fixed price.
   - Increasing the soil structure through the clover's advanced root system
   - Capitalising on the "free" nitrogen the clover will fix
   - Greater utilisation of existing silage equipment

   The benefits to myself include:

   - Receiving a feedstock locally that will secure the gas output I need for a viable project.
   - Minimal adaption to existing silage pits will allow for the greater volume of silage.

3. Securing the rights to develop 20.7MW of wind production on a farm ideally suited for wind energy generation within the Borders. After having my ambitions for a larger development at home crushed by grid, radar and transport problems, I decided that the best route forward was to secure the legal rights to a farm that didn't have such issues and had a much higher wind speed to boot. At present, I'm negotiating with local communities about the best way forward with the hope they will realise the potential and secure part of the project for community investment and take ownership of a stake.

Over the next 12-18 months my fate will be in the hands of planning officers and local councillors. However, should I succeed, then hopefully it will allow others to realise for themselves the potential in renewable energy. Time will tell.

22. Recommendations

To Farmers

1. **Own it.** Whatever renewable path you choose to go down, make sure you realise the true returns. For the last 10-15 years, we as farmers have a shocking record of selling off our most valuable resources to the Square Mile and beyond for a tiny proportion of the income. The risk you will take in planning is real. However, should you be successful, the reward is huge.

2. **Collaborate.** Collaboration is even more important when implementing a renewable device than it is in conventional agriculture. In all the countries I visited, collaboration was evident not just between farmers but between local businesses, local communities, local councils and large investors. The benefits include:

    - Access to the best sites for development
    - Easier access to finance
    - Greater acceptance at local level
    - Capitalisation on economies of scale

3. **Be Ambitious.** If you have the resources then harness them. You wouldn't graze Highland cattle on prime arable land so don't underutilise your natural resources either. Putting a 15kw turbine on a site that could accommodate 10MW helps no-one other than ill-informed NIMBYs. Should you have a site capable of producing 10MW of production and, for whatever reason, don't want to develop it yourself, my number is at the end of this report!

4. **Don't feel morally obliged to utilise your land for food production**. The increase in prices paid for energy production will inevitably see a reduction in food production. Let the market decide your route. If food processors and retailers want food, then they must be prepared to pay over and above what can be achieved through energy.

5. **Whatever your opinion on global warming**, we in agriculture have the opportunity to use the concept to our advantage when selling ourselves. When it comes to saving the planet, we are the solution. We must use this argument to our advantage.

"You have the resources and the Feed in Tariffs- what are you waiting for?"

See next page for Recommendations to Government

To Government

1. **Sort out the grid.** The installation of the FIT is being undermined by some grid operators. In my opinion, the grid is the only thing that isn't nationalised that should be. At present, local energy generators are at the hands of the dictatorship presided over by the operators. A non-monopolised, fair, transparent and smart grid would set the rural economy free.

2. **Simplify planning applications**. Planning for wind turbines is at present governed by job creation and not necessity. Dogs, cats and cars kill birds, not wind turbines. Most ecology studies will add considerable cost to a planning application.

3. **On farm energy saving devices** will account for considerable use of Pillar 2 moneys. However, the most **effective** use of Pillar 2 money would be for **energy monitoring devices**. These would allow farmers to identify for themselves how energy can be saved and justify any subsequent spend on energy saving devices.

4. **A renewable fertiliser incentive**. The fertiliser market in the UK is attracting political attention due to the monopolies involved. A scheme that promoted renewable generated fertiliser would help break monopolies, secure supply and reduce greenhouse gas emissions as well as bolster local economies.

5. **There is no perfect energy source** but do not be frightened to pursue the renewable route. Shortly, fossil fuels will pose a heavy weight on the UK economy. Investment in renewable energy will secure supplies, reduce greenhouse gas emissions, bolster local economies and, in time, prove to be an incredibly reliable and cost efficient energy source. Investment in renewable will also help bridge the gap from the fossil fuel economy to the hydrogen/ammonia economy.

23. Conclusions

1. We are at the beginning of the end of the fossil fuel era and our dependence on renewable energy is going to increase dramatically.

2. The potential we have as farmers to embrace the forthcoming era of clean energy is massive. Many of those whom I met within my travels indicated their belief that farming will be asked to produce 100% of the world's food and 60% of the world's energy. This may seem ambitious; however projections (not predictions) indicate that Germany will produce 47% of its electricity through renewable sources by 2020. This shows us that we need not be daunted. All renewable markets are at present being driven forward by the politicians' willingness to "do good" on climate change. We have reached peak oil and will soon be very close to reaching peak gas and coal. In the near future renewable markets will be driven by necessity. **Necessity will drive us to produce 100% of food and 60% of energy from agriculture.**

3. It is my belief that the greatest potential to produce energy from agriculture will come in the form of **Biogas and Wind** for 3 reasons:

    - Firstly, throughout my studies and travels I have been shown how flexible these energy sources are and how great is their ability to contribute to stationary generation and propulsion through different utilisation processes.

    - Secondly, the ability of biogas and wind to deliver maximum levels of energy from the available land

    - Thirdly, they offer the most cost competitive and widely accessible routes to energy generation within rural locations.

4. The rural economy holds the keys to a sustainable and vibrant Hydrogen economy in the UK. At present the Hydrogen economy is in deadlock. The lack of fuel hinders the production of consumption devices and the lack of consumption devices hinders the production of fuel. The generation of ammonia for fertiliser will help stabilise inorganic fertiliser prices and allow the Hydrogen economy to develop.

5. Sometimes when you see two concepts like biogas and organic farming thrown together you realise that the unexpected can yield fantastic results. The potential to produce organic energy is a marketing opportunity from heaven.

6. My Nuffield Scholarship has certainly grown and developed from my initial aim of realising the energy saving potential from dairy farming. My experiences allowed me to appreciate the potential we have as farmers to make significant impacts not only on the finances of our existing businesses, but to play the role of energy producer as well as food producer. I've seen how the unconventional can work and where the future might lie. I've seen the great things that can be achieved with the foresight of

an individual and I've seen the mountains that can be moved when individuals work as a team.

7. The impact my Scholarship has had on me has been significant. It's not all been plain sailing but I've emerged stronger and more ambitious from the experience.

8. Once again, my thanks go to my family, my staff, Nuffield and the Trehane Trust for the support they have all given me over the past 18 months.

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