A Nuffield Farming Scholarships Trust Report

Award sponsored by

The Royal Highland and Agricultural Society of Scotland

Opportunities for farmers in the "New Energy" sector

Alex Fowlie

September 2015

NUFFIELD UK

NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

TRAVEL AWARDS

"Nuffield" travel awards give a unique opportunity to stand back from your day to day occupation and to study a subject of interest to you. Academic qualifications are not essential but you will need to persuade the Selection Committee that you have the qualities to make the best use of an opportunity that is given to only a few – approximately 20 each year.

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A Nuffield (UK) Farming Scholarships Trust Report

Date of report: September 2015

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	Opportunities for farmers in the "New Energy" sector
Scholar	Alex Fowlie
Sponsor	Royal Highland and Agricultural Society of Scotland
Objectives of Study Tour	To put the renewable energy industry in the UK into context and understand how farmers can best maximise opportunities the sector offers going forward.
Countries Visited	Netherlands Germany Singapore China USA UK
Messages	• The Renewable Energy Industry is a massive global industry and it plays a vital role in powering the world. • There are fantastic opportunities to contribute and benefit from this sector; be it through developing a project, hosting a development, installing infrastructure or producing the fuel source. • New technologies and businesses are going to increase the opportunity to farmers – we are just at the start of something big but there are challenges to overcome.

DISCLAIMER

CONTACT DETAILS

Alex Fowlie
Inverquhomery Farm
Longside
Peterhead
AB42 4TU
07786068701

Alex.fowlie@duncanfarms.co.uk

Nuffield Farming Scholars are available to speak to NFU Branches, Agricultural Discussion Groups and similar organisations

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Southill Farmhouse, Staple Fitzpaine, Taunton TA3 5SH
Tel : 01460 234012
email : director@nuffieldscholar.org
www.nuffieldscholar.org

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1. Introduction

I am a 27 year old farmer's son from Aberdeenshire and have always been interested in agriculture and business, with an involvement on the family farm from a young age. I studied Business Management at Edinburgh University and thoroughly enjoyed all aspects of student life!

After graduating university I couldn't see an opening in agriculture and opted to apply for jobs in the energy sector. Coming from Aberdeenshire the majority of these were oil related and to be honest I hadn't thought about the renewable energy sector until I heard a local farming enterprise was looking for someone to work on their new business – Muirden Energy, developing wind turbine sites.

Figure 1: The author, Alex Fowlie

Five years after saying I would only work there for two I am now managing the business with a small equity share and enjoying it more than ever. The business has grown from one employee to eleven with in-house planning, construction and finance expertise and sites under development ranging in size from £500,000 to £35m.

Along with this I have, with the support of my family, been able to develop a couple of energy projects in my own right on the family farm.

I love the challenges growing a business throws at you and feel very fortunate to have had the opportunities I have. I applied for a Nuffield Farming Scholarship to give me a new perspective and enthusiasm for what I was doing, which it certainly has done.

2. Background to my study subject

When I applied for my Nuffield Farming Scholarship just over two years ago the renewable energy sector in UK agriculture was booming. The government had introduced attractive incentives through the Feed In Tariff (FIT) and Renewable Heat Incentive (RHI) scheme and new businesses were developing across the country. However it felt as if this had created a bubble which was bound to burst. I questioned how sustainable the industry in its current form was and how best we as farmers could position ourselves to maximise our opportunities going forward.

This gave me a desire to explore other countries which were ahead of us in terms of renewable energy generation and see what they were doing now. I also wanted to visit developing countries further afield to see if this new sector was purely a luxury or whether it could compete on an open market and provide cheaper power than more conventional sources.

The UK renewable energy sector is facing its most challenging outlook to date

I wanted to explore new technology and get an understanding of where the energy storage sector was, as I feel this is going to be the most important key to unlocking our full renewable energy potential.

Two years on as I write this report the UK renewable energy sector is facing its most challenging outlook to date. The UK government has slashed the Feed in Tariff by up to 85% and raised doubts about the support for any onshore wind and solar projects larger than 1.5MW beyond next year, so my Nuffield Farming study couldn't have come at a better time for me.

3. Where I travelled and why?

I therefore set out to travel to Germany and Holland where the renewable energy industry, particularly onshore wind, has been developing for over 20 years. This visit encompassed visiting farmers who had diversified into renewable projects 15 years ago and a large business that, from a standing start, had grown into a multi billion pound organisation. I wanted to see how the industry had worked out for those who had taken the step from a traditional agricultural background and to get an idea of where these businesses see the future going.

I then travelled to China with the aim of exploring a country which I understood to be ruthlessly efficient and with little regard for its social responsibility, and see what their views on the industry were, and the reasons they were pursuing it.

Finally I travelled to the US, specifically California, which I view as being at the forefront of Green Energy advances. Renewable energy across the globe has always come up against the same issue: Energy Storage. Until this is cracked can a technology dependent on variable forces such as the weather be considered a genuine contender for powering the planet? California is leading the way with storage due to legislation that requires all utility providers to have storage for 20% of the power they sell. I wanted to explore the technology they were using and see how this part of the industry was developing.

This was all intermixed with various trips and visits throughout the UK, and I am proud to say some of the most impressive farm scale projects I have seen are being developed on our doorstep.

Date (month/year)	Country	Reason for Choice
Various	Holland and Germany	15 years + ahead of the UK in terms of renewable energy deployment.
March 2015	China	I felt China was a country which was not concerned about its social responsibility or its environmental reputation yet it has been the number 1 installer of renewable energy for the last 3 years running.
September 2015	USA	California is at the forefront of renewable energy with considerable investment and development in energy storage solutions
Throughout study	UK	To learn from others

Figure 2: Countries visited

4. The renewable energy industry

4a. Size of the opportunity

In 2013 renewable energy produced 5070 TWh globally which accounted for almost 22% of total global power generation and was worth over $600 Billion. These figures are hugely important when considering the opportunity of the sector: firstly 22% is a significant share of the energy mix and highlights the importance of the industry globally in supplying the world's energy needs. Secondly at a value of $600bn it also represents a sector that should not be ignored. Predictions are that this is only going to increase further with 45% growth (to 7310 TWh annually) expected by 2020[1]

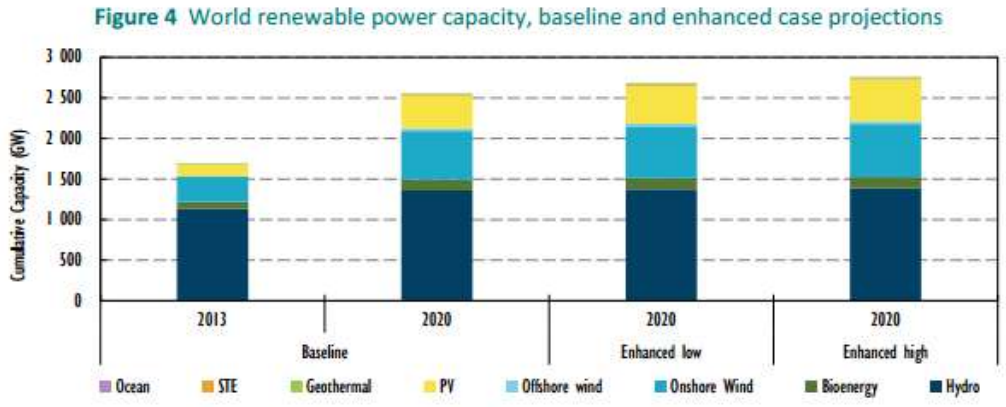


Figure 3: Global renewable capacity and predictions

4b. Global investment

China is the largest investor in renewable energy worldwide, investing $83.3 billion in renewables in 2014 alone. This is 39% up from 2013. The US came second with $38.3billion in 2014 - 10% up on the previous year. Interestingly Japan came third with $35.7 billion – this is following the Fukushima disaster which saw Japan stop all nuclear power generation and set a target of 20% renewable energy production by 2030[2]. The UK came 4th with $13.9bn and Germany 5th with 11.4Bn.

This however doesn't tell the whole story as the UK is now lagging behind its previous year's achievement and at the end of 2014 the top 5 countries for cumulative capacity installed looked like this: *(see chart on next page)*

[1] https://www.iea.org/Textbase/npsum/MTrenew2014sum.pdf
[2] http://www.cbsnews.com/news/after-fukushima-a-glut-of-green-energy-in-japan/

TOTAL CAPACITY OR GENERATION AS OF END-2014

	1	2	3	4	5
POWER					
Renewable power (incl. hydro)	**China**	United States	Brazil	Germany	Canada
Renewable power (not incl. hydro)	**China**	United States	Germany	Spain / Italy	Japan / India
Renewable power capacity *per capita* (among top 20, not including hydro[3])	**Denmark**	Germany	Sweden	Spain	Portugal
Biopower generation	**United States**	Germany	China	Brazil	Japan
Geothermal power capacity	**United States**	Philippines	Indonesia	Mexico	New Zealand
Hydropower capacity[4]	**China**	Brazil	United States	Canada	Russia
Hydropower generation[4]	**China**	Brazil	Canada	United States	Russia
Concentrating solar thermal power (CSP)	**Spain**	United States	India	United Arab Emirates	Algeria
Solar PV capacity	**Germany**	China	Japan	Italy	United States
Solar PV capacity *per capita*	**Germany**	Italy	Belgium	Greece	Czech Republic
Wind power capacity	**China**	United States	Germany	Spain	India
Wind power capacity *per capita*	**Denmark**	Sweden	Germany	Spain	Ireland
HEAT					
Solar water collector capacity[2]	**China**	United States	Germany	Turkey	Brazil
Solar water heating collector capacity *per capita*[2]	**Cyprus**	Austria	Israel	Barbados	Greece
Geothermal heat capacity[5]	**China**	Turkey	Japan	Iceland	India
Geothermal heat capacity *per capita*[5]	**Iceland**	New Zealand	Hungary	Turkey	Japan

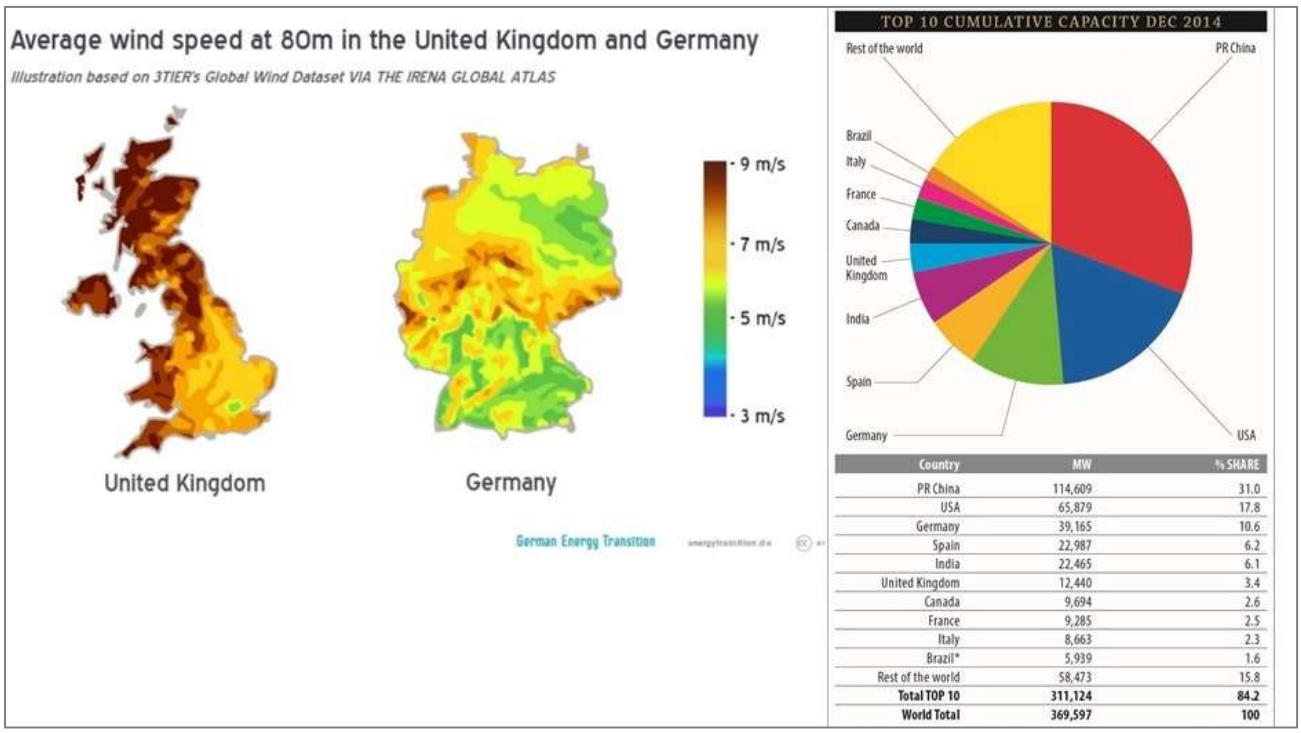
Figure 4: Top 5 countries for total Capacity at end of 2014

Taking wind power as an example, technology in the UK lags well behind its EU rivals despite having a far superior wind resource. We have twice the wind resource of Germany yet less than a third of the installed wind power capacity and are clearly not making the most of our competitive advantage as the table on the next page shows.

4c. Demand for the product

There is significant demand for renewable energy throughout the world. In the UK we have committed to the Kyoto Agreement which means we must be generating 20% of our energy needs from renewable energy by 2020. There is significant world pressure to set more ambitious global targets beyond this with announcements expected at the United Nations Climate Change Conference in Paris (December 2015). This pressure comes on the back of global scientific evidence that we need to tackle climate change and reduce our carbon footprint.

In the UK however there is another pressure often not talked about and that is simply to keep the lights on. A recent National Grid report showed that the "safety buffer" between total electricity generation capacity and peak demand is likely to fall to just 1.2% this winter forcing them to pay energy suppliers to reopen closed power stations in a cold snap. This "buffer" was 4.1% last year which demonstrates the severity of the problem.



Country	MW	% SHARE
PR China	114,609	31.0
USA	65,879	17.8
Germany	39,165	10.6
Spain	22,987	6.2
India	22,465	6.1
United Kingdom	12,440	3.4
Canada	9,694	2.6
France	9,285	2.5
Italy	8,663	2.3
Brazil*	5,939	1.6
Rest of the world	58,473	15.8
Total TOP 10	**311,124**	**84.2**
World Total	**369,597**	**100**

Figure 5: UK wind resource and capacity vs Germany

4d. Cost competitiveness

Despite renewable energy getting a reputation for being an expensive energy source, the cost has reduced drastically over the last few years, making it competitive with fossil fuel energy generation yet receiving no support. The table *on the next page,* taken from a Bloomberg report, shows the costs per MWH generated by various technologies.

As this shows, onshore wind has the cheapest levelised (discounted lifetime cost of ownership) cost per MWh, and hydroelectric power is not far behind. This is the most up to date table I can get my hands on and is from December 2013. However the cost of solar has reduced significantly since then, and today large scale solar is on a par with onshore wind.

Historically, of course, the picture was very different. Tony Seba in his "Clean Distribution Book" stated: "*Solar PV is 150 times cheaper today than it was in 1970. Oil is over 16 times more expensive*."

Required Cost per MWh for New Power Installations	$		
Plant type	**Minimum**	**Average**	**Maximum**
Dispatchable Technologies			
Coal without CCS	65.9	70.9	80.8
IGCC with CCS[2]	65.9	71.0	80.8
Natural Gas-fired Combined Cycle	65.8	71.4	80.7
Advanced Nuclear	68.4	72.1	82.0
Geothermal	70.7	70.9	71.0
Biomass	66.0	71.7	80.9
Non-Dispatchable Technologies			
Wind	60.6	64.6	69.0
Wind – Offshore	64.6	71.5	78.1
Solar PV	61.6	80.4	92.3
Solar Thermal	59.4	83.0	89.4
Hydroelectric	64.8	69.5	80.0

Figure 6: Cost of Energy by source, taken from Bloomberg Report

Statistics can often hide what is important and I recognise the limitations of renewable energy generation: being mainly the unpredictability of output due to its reliance on the weather. But if a cost effective storage solution can be found there is no reason why renewable energy can't compete on a level playing field with fossil fuel generation. In 2013 developing countries invested $131.3 billion in renewable energy generation and this was done to save cost, demonstrating that the industry is already competing without support.

5. Germany study

5a. Enercon

The focus of my first trip to Germany was to visit the Enercon Factory and interview the management team behind the company. Enercon is a family-owned business and was founded by Alloys Wobben in 1984. It is now the third largest wind turbine manufacturer in the world with Aloys Wobben himself amassing an estimated personal wealth of $3.5bn. This success is on the back of their direct drive wind turbine which started out as a 55KW project and now spans over 10 models ranging in size from 500KW to a 7.5MW machine which is 200m to tip.

On arriving at the factory the first thing that hit me was the sheer scale of the business. The headquarters are based in Aurich where there is an assembly line, blade production, innovation centre, foundry and state-of-the-art testing facilities. A dedicated rail system has been built from the factory by Enercon to improve logistics. The business also has production facilities throughout the rest of Germany and in Brazil, Sweden, Turkey, France and Portugal, giving Enercon a global production area of over 400,000m^2, and it employs over 13,000 people worldwide.

... it felt like we are only playing at turbines in the UK and to get the most out of our resource we need to embrace and encourage larger wind turbines

A short distance from the factory is Aloys Wobbens's house where he first developed the 50KW prototype turbine in his garden – and it's still working today.

The rationale at Enercon is that onshore wind power is only going to increase. Having considered looking at offshore wind turbines the decision was taken that developing in this industry could detract from their focus onshore and therefore they do not offer an offshore turbine. There is a strong focus on further improving efficiencies and reducing costs. With a global market, the business has seen many different subsidy support mechanisms in their time but has elected to not let this affect their direction. A good example of this was when they discontinued the E33 (300KW) turbine in 2012 just when the UK was heavily supporting this size of machine. They could have sold hundreds of these into the UK but at an installed cost of approximately £3m per MW it was not cost competitive per MW. Instead they are focusing on selling larger machines which can be built for less than £1m per MW installed.

In some ways it was disappointing to see that the E48 model, which in the UK is considered to be a large machine, is one of their smallest. Coming away it felt like we are only playing at turbines in the UK and to get the most out of our resource we need to embrace and encourage larger wind turbines. I understand that there are people who don't like wind turbines but I don't think there is a big visual difference between an 80m and 100m-to-tip

turbine, yet the 100m-to-tip will give three times the output; so by encouraging larger machines you are actually reducing the number of wind turbines required.

Figure 7: Enercon factory generator production line

Figure 8: Enercon factory foundry

Figure 9: Enercon Factory generator assembly

5b. WTN

From Enercon I then went to visit a manufacturer of smaller turbines – WTN – which specialises in 225KW and 250KW wind turbines. Again it is a family business which has only

recently re-opened their production facilities due to the demand from the UK for smaller turbines. Until the FIT was introduced there was no significant demand for this machine and the business had been focusing on re-powering their own wind turbine sites, which involved taking down the 225KW turbines (which had been operating successfully for over 20 years) and replacing them with larger turbines.

The WTN production facility was much smaller but they have placed solid emphasis on getting up to date certification and procedures in place, resulting in them being the one of the market leaders in the UK for this size of turbine. Given the recent FIT cuts the business will need to evolve again but it is a process they have been through already and, with over 75 turbines already supplied to the UK, I'm sure it has been a worthwhile exercise.

Figure 10: AD plant in Germany

5c. Farms visited

I visited some farms in Germany that had diversified into Anaerobic Digestion (AD) Plants over 10 years ago. The message from these farmers was positive – the majority had expanded their AD output since their first installation. They were extremely knowledgeable and focused with the majority having a hands-on approach. This is something which has so far put me off developing my own AD plant at home as it appears very time consuming for the lifetime of the project (20 years) so would not work well alongside having a full time job, although I do find the process an exciting one.

5d. Conclusions from Germany

Wind turbines are increasing in size and, to be cost competitive, this is something the UK industry needs to embrace.

There are many different renewable technologies on farms which work well – Solar, Wind, AD – and each one has different requirements.

The production side of the industry is huge and Enercon has built a massive business in a relatively short time. It would be great if the UK was able to be a part of this, either through encouraging existing foreign business to have production facilities here or, even better, a UK business innovating and developing a superior product!

Figure 11: WTN factory in Germany. See page 10

6. China study

6a. Nuffield Farming tour

My visit to China started off with a two week Agri-business tour organised by Nuffield Australia. I can't speak highly enough of this. It involved 14 days of intense travel and meetings with 20 Nuffield Farming Scholars, going from Hong Kong in the south up to Harbin in the north. This part of my China travels was somewhat off topic with the focus being on agricultural businesses rather than renewable energy. We visited ANZ Bank, Syngenta, vegetable marketing cooperatives, government officials, hydroponic growing facilities, vineyards, sheep farms, dairy farms, a cherry farm, wholesalers, port authorities, fish markets, Nestle, a plastic and resin factory, commodity exchanges, import & exporters, drinks factories, an arable farm, meat processors, East Rock and the Australian Embassy: all while managing to make great friends with the other Scholars and a couple of nights out.

The above could fill its own report and therefore I am not going to get into the specifics of each visit here but the main things I took away from this part of my trip were:

> *Firstly* the sheer scale of China and the consumer potential were astonishing. You hear the figures on growth and population but until you see it you can't comprehend it. There were major building and infrastructure projects going on in every town. In Scotland we have the new Forth Crossing being built just now, which is an impressive piece of engineering, but something on this scale was being built in every city we visited. I have also never seen so many new high rise flats being built and, speaking to the locals, there is concern that a property bubble is being created.
>
> *Secondly* China is not the communist country I was expecting. I saw more Ferraris and Lamborghinis on our tour than you do in London. On meeting various business people it is clear that business is encouraged to thrive and the government appear committed to growing a successful economy.

The success of each business appeared to be down to the individual and the trait which came over time and time again was enthusiasm and energy for what they were doing.

Finally from the businesses we visited there appeared to be far greater equality between men and women in managerial positions than I have experienced anywhere else I have visited.

6b. Renewable study

Once I completed the above Nuffield Farming tour I embarked on my own to study the renewable energy industry in China. This involved visiting a government official to gain an understanding of their views of the sector, some recent projects, wind turbine and solar panel manufacturers, and a battery storage manufacturer.

The Chinese government is hugely supportive of renewable energy. The two main reasons I was given for this were:

> *Firstly* the government view the smog and pollution in the cities as their biggest concern and threat to their rule. This is something they want to fix in the short term and recognise that moving to clean energy generation is key to this. Currently renewable energy accounts for approximately 10% of the country's energy needs and they have committed to doubling this to 20% by 2030[3]. To achieve this, government has introduced support mechanisms for renewables which can vary in each area but translates to approximately a total income (including the electricity sales) of 12p per KWh for solar and 10p for wind. This is slightly above what the ROC regime was worth in the UK (which the UK government has recently scrapped) and, given the lower cost of developing projects in China, represents a good return for developers.
>
> *Secondly* the importance of the sector to the economy is also recognised and mainland China's richest person, Li Hejum, has built his wealth ($26bn) through his solar panel manufacturing business Hanergy. The vast majority of technology utilised was made in China and the government placed particular emphasis on exporting their products - having recently installed Chinese solar panels on our farm in Aberdeenshire it is obvious they are having some success with this!

6c. Yingli Solar

My first visit was to the Yingli Solar manufacturing plant in Baoding. Yingli was the largest module manufacturer in the world in 2012 and 2013, and second largest behind Trina in 2014, and has over 16,000 employees. They manufacture both monocrystalline and multicrystalline PV panels. The monocrysltalline offers a maximum efficiency of 17% compared to the multicrystalline at 19%. However, due to the cheaper manufacturing costs, the multicrystalline is their number one seller.

Unfortunately photos of the production line were not allowed. However it was an impressive set up with automation installed throughout the plant and a strict quality control procedure which randomly checked panels both visual and operationally under test conditions.

See photo of Yingli Solar HQ on next page.

[3] http://thinkprogress.org/climate/2014/11/12/3591433/china-renewable-energy-commitment/

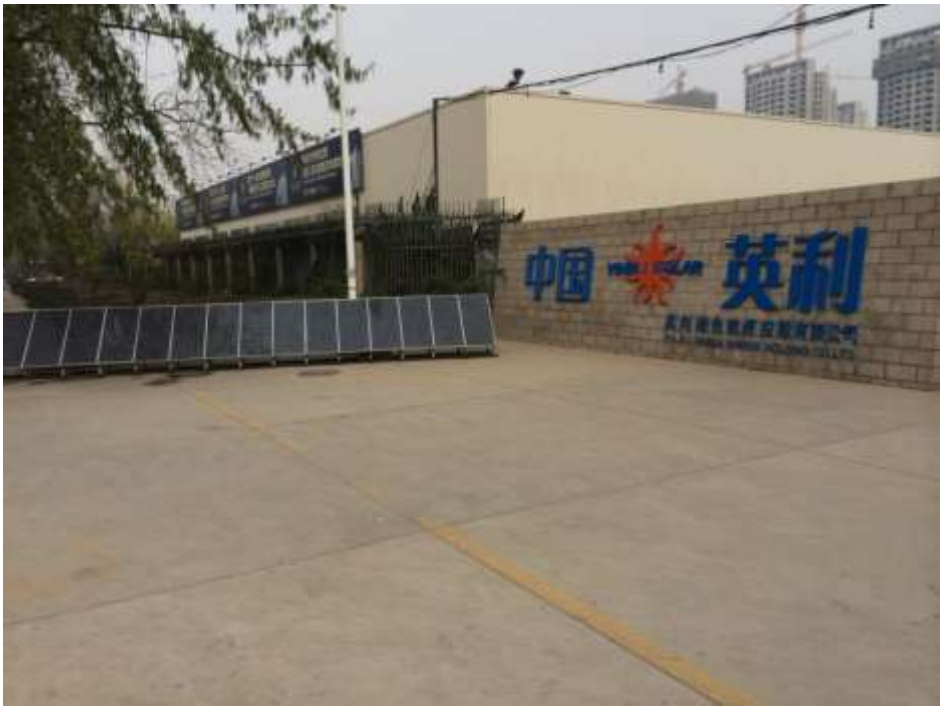


Figure 12: Yingli Solar HQ

One of the main things to strike me from this visit was the lack of new product development and innovation. The business was clearly committed to throughput and driving the cost per panel down but, when asked on what future products they were working, they didn't give much away but this could have just been tactical!

Financial accounts of Yingli recently published show they are struggling financially – described as the curse of the largest panel manufacturer due to the fact several of the other historically largest manufacturers are in a similar position. It shows just how competitive the industry is. More on this can be read here:

http://www.forbes.com/sites/michaelkanellos/2015/05/18/yingli-in-trouble-the-number-one-curse-in-solar-strikes-again/

6d. Prostar Electric

My next visit took me to Prostar Electric in Beijing. They were a smaller family-owned business that specialised in research and development. The products they offered were mainly transformer and battery chargers; however they did manufacture their own solar panels and historically had made small scale wind turbines.

Rifle Shao, their marketing director, showed me round for the day and his enthusiasm and understanding of the sector were very impressive. I couldn't believe that it made financial sense for them to be manufacturing their own panels on such a small scale but he assured

me they were able to do it for 75% of the cost of buying in the panels, and to a higher standard.

On their battery storage they were very excited about a new lead carbon battery they had developed. This was on a small scale for domestic use but they offered four times the warranty for this battery than their traditional gel battery (8 years vs 2) and it could charge three times as fast as their traditional battery at a similar cost (approx. $120 per KW). They were predominantly selling this to businesses with solar panels installed to extend energy saving. Energy storage is the area where I think we will see the biggest advances in the next 5 years. Improvements in storage are also required to improve electric vehicle ranges although the lead battery is extremely heavy so may not be so suited to this use.

Energy storage is the area where I think we will see the biggest advances in the next 5 years.

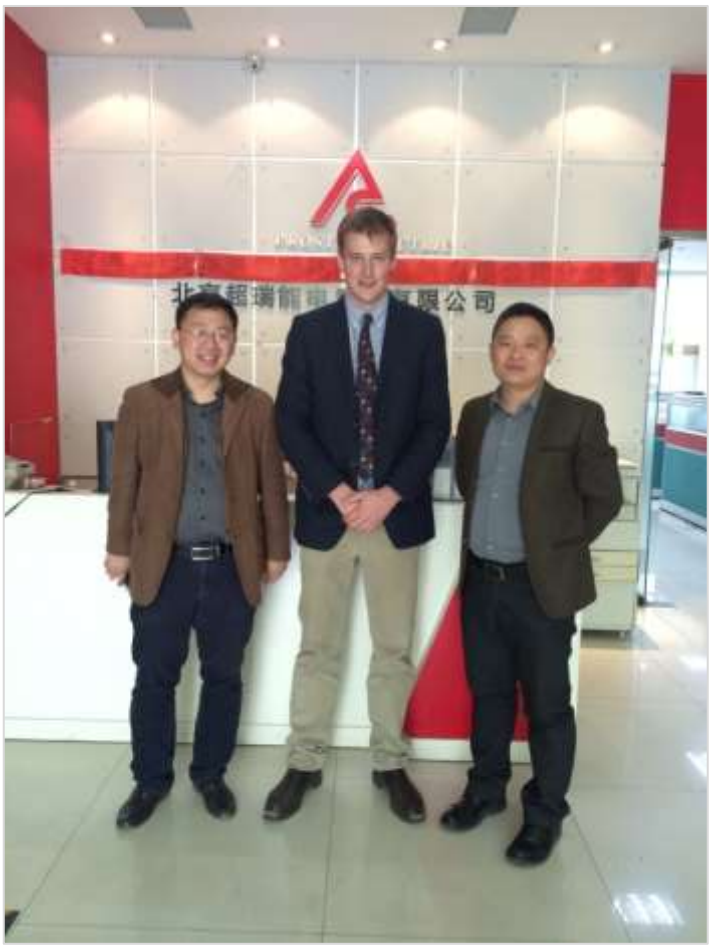


Figure 13: At Prostar Electric with Rifle Shao and Renjing Zhu

6e. Goldwind

I then visited Goldwind who are a Chinese wind turbine manufacturer. The company was set up in 1998 and to date has installed over 15,000 wind turbines globally. They manufacture a direct drive machine with similarities to the Enercon design. However the Goldwind design uses permanent magnets to create their elector magnetic field where Enercon use an annular generator with separate excitation to avoid using permanent magnets. There have been recent articles on the use of permanent magnets with Neodymium, a rare earth material, being used. When I questioned Goldwind on the use of these magnets they did not share the same concerns some environmentalists have with their uses – pointing to the amount of carbon they save over their lifetime.

Goldwind's largest market is the home one, China, where they have a 25% share of new wind turbines being installed. Given China is installing wind turbines at a rate of 1 per hour, every hour, this is a significant market although they see the largest growth potential in the international market. They already have sales to the US but are very keen to get into the European market and in 2008 bought a German turbine design business. They are committed to driving down the cost of installations and, if this can have an effect anything like the solar industry experienced form the European/Chinese price war, it can only be good for the sector as a whole and ultimately the consumer.

China is installing wind turbines at a rate of 1 per hour, every hour.

6f. Conclusions from China trip

For me the most important thing I learnt from my trip to China was the massive scale and commitment they had to renewable energy. I was pleased to see that this was not caused by global pressure or a desire to save the world. It was purely driven by a need for the power, and the opportunity to improve the quality of life of their citizens.

To be honest I was less impressed with the technology being developed within China than I had expected to be, especially within the solar industry. Perhaps this was just down to the visits I made, but I did not see huge advances in technology. However within the wind sector I think the presence of a Chinese turbine on the global market will reduce the costs of energy production and, looking at the speed with which other Chinese manufacturers have overtaken traditional sector leaders, it will accelerate advances as well.

On battery storage I could see that Prostar think this is an area which offers huge growth potential and I totally agree with that assessment. Coming back from China I wanted to understand battery storage in more detail and this decision helped plan my next trip – to the US.

7. US Study

The main driver behind my trip to California was to gain a better understanding of battery storage. As mentioned in the last chapter, I believe energy storage is going to be the "game changer" for renewable energy and California is one of the only places which has significant storage capacity built into its legislation. I therefore organised a trip to visit policy makers, the energy storage association, a university, a windfarm developer, a utility company, an advanced technology lab, a large scale wind farm, traditional solar developments, a large scale solar thermal development and Tesla.

I started my tour with meetings in San Francisco where I met Bruce Tang from LIghtbeam Electric, Alex Moris from the California Energy Storage Alliance and Nancy Radar from the California Wind Energy association. The opinion of all three was that the renewable energy industry in California is exciting and growing.

California has always been ahead of the curve when encouraging renewable energy. In 2002 they introduced legislation stating that 20% of their energy mix had to come from renewable power by 2017. That target was increased in 2006 to 33% by 2020. They are already exceeding the original 20% target. Onshore wind is the largest contributor with 30% of total output, with geothermal having 27% and solar 23.5%.

The renewable energy industry in California is exciting and growing.

This has been achieved through various tax credit systems, with grants and penalties for utilities that fail to source enough of their energy from renewables. However, in discussion with various sources, it appeared that the value of these credits, grants and penalties has only been the equivalent of 2 cents per KWH. That is approximately half what the ROC (Renewables Obligation Certificates) system was worth for onshore wind in the UK.

It was also interesting to hear that the initial tax credit system was based on MWs installed rather than produced, which did not work well, and saw cheaper-to-build systems being used rather than those which would produce the most power. So the calculation was quickly changed from "installed" to "production" based.

7a. Tehachapi Pass Wind Farm

I made a point of visiting the Tehachapi Pass Wind Farm which is the 2nd largest wind farm in California with 5,000 wind turbines. Driving to it from the south the first wind turbines you come across are the original 20-year-old machines which varied in size from 25 to 50KWs. Many of these were on lattice towers which in my opinion are unsightly compared to tubular towers. These are being replaced by new machines as shown on next page.

Figure 14: Wind turbines at Tehachapi Pass

In the above picture the large wind turbine in the centre will produce more power than every other wind turbine in the photo combined.

Due to new transmission lines and storage solutions the Tehachapi wind farm is expected to grow to cover 50 square miles with an installed capacity of up to 4,500MW which would represent an investment of approximately $4.5bn.

The other thing which I happened to come across when driving through the Windfarm was this:

Figure 15: New Development at Tehachapi Pass

I could not work out what it was and presumed it must be something to do with radar or similar; but it actually turns out that it is up for a 4-month trial and improves output by 3% by pushing the wind which would normally go through the centre of the turbine (which is at the blade's narrowest point) over the wider parts of the blades showing that the technology is constantly developing and being worked on.

7b. Ivanpah solar thermal

The Ivanpah solar development is the world's largest concentrating solar thermal power plant and consists of a 392MW solar thermal project built approximately 50 miles south of Las Vegas, just on the Californian side of the California/Nevada border. Construction commenced in 2010 and was completed in 2013 with 2,600 construction workers employed at its peak and costing approximately $650m in employee wages along the way. (*See photo on next page).*

It consists of three 1,000-acre "fields" of mirrors which reflect the light onto a centre tower which has a water boiler at the top. The water is heated by the mirrors to create high temperature steam which is piped to turn a conventional turbine with the electricity generated going into the grid system. The system is totally automated with all 300,000 mirrors being software controlled to track the sun and optimise output. This system generates enough power for 140,000 homes and involves significantly less land use than traditional photovoltaic panels, and 95% less water than wet cooled panels.

The Ivanpah project cost $2.2 billion with the main investors being Google NRG, Bechtel Corporation and the Department of Energy. It has had its controversies with a reported 150 bird mortalities in its first month due to birds flying through the concentrated rays and catching fire or flying into the mirrors. Details of how much the scheme is receiving per KWh are strictly confidential but one internet source[4] put the figure at 12 cents per KWh which was significantly less than standard PV could create electricity for when the contract was signed in 2008.

However the system would now be approximately double the cost to install due to the vast reduction in PV panel costs against only a small reduction in the solar mirror system cost: so today a new PV system could produce power at approximately half the price (6 cents per KWh). Without knowing the full details of costs and pros and cons I am unable to evaluate its effectiveness vs. standard systems but it was an extremely impressive piece of engineering to see first-hand.

See photo on next page.

[4] http://www.greenbiz.com/blog/2014/02/19/largest-solar-thermal-plant-completed-ivanpah

Figure 16: Ivanpah solar plant

7c. Tesla

My main aim with the US trip was to get a better understanding of energy storage and what advances were likely within the industry. The first company I visited was Tesla.

Tesla is the leading all-electric vehicle car manufacturer and has Elon Musk as its CEO who has invested more the $70m into the business personally. Followings its public offering in 2012 the business now has a market capitalisation of $25 billion, of which Musk owns 23% and sold 55,000 electric cars last year. The development of electric vehicles is likely to play a significant role in the growth of renewable energy not only through increasing demand but these vehicles also have the potential to act as an energy store when not in use. The battery is the most important part of the electric car and its range is limited (approx. 200 miles). It is often touted as the biggest limitation of all-electric vehicles. The battery is therefore something that Tesla are spending huge sums on developing and the range of their vehicles is constantly increasing. The charging speed is also going up with the Model S able to recharge 80% of the battery in 40 minutes.

The development of electric vehicles is likely to play a significant role in the growth of renewable energy, not only through increasing demand, but these vehicles also have the potential to act as an energy store when not in use.

The battery is such a crucial part of the vehicle development that Tesla are building their own "Gigafactory" to build these themselves and, with an expected cost of $5 billion, it

shows just how much potential they see in the battery industry. All their batteries are Lithium-ion as found in a mobile phone or laptop and they plan on developing "powerwall"[5] which will be available to homes and businesses to provide independent energy storage. Tesla has said that with their Gigafactory they will be able to halve the cost of these batteries. Today they would cost approx. $8,000 for a 10KWh capacity battery. Tesla are offering delivery in 2016 with work well under way on the Gigafactory which will produce 50GWh in annual storage by 2020 – enough for 500,000 Tesla cars. Currently Tesla are getting their batteries from Japan.

7d. Southern California Edison Company and storage

Southern California Edison Company (SCE) provided me with a space on the internal company tour of one of their advanced technology labs which is at the forefront of their future technology and operational offerings. Here I saw everything from the above mentioned "powerwall" system being used on a pilot scheme where a group of houses was being run totally from renewable energy, to smart grids which could isolate and repair circuit problems without human intervention. What they were doing was fascinating and again energy storage was one area where they were expecting the biggest advance in the coming years.

They have already built a 32MW battery storage warehouse next to the Tehachapi Windfarm. This is simply banks of Lithium-ion batteries. When I requested a tour of the plant I was told that no one worked there and it was very boring with nothing to see other than banks of batteries, and they sent me this picture in lieu of a visit:

Figure 17: Tehachapi Storage

[5] Powerwall is a home battery that charges using electricity generated from solar panels, or when utility rates are low, and powers your home in the evening.

Within the advanced technology lab I saw powerwall storage first hand (but on a smaller scale) and this is the reason I am most excited about this form of energy storage. I have been to a hydrogen storage centre in the UK and seen pumped hydro storage solutions but, being a simpleton, these have always been too technical and required too much operational input for me to be excited about the opportunity of owning such storage; whereas a simple bank of batteries within a shed and requiring zero input is something I feel I could just about manage. The cost per KWh used over the lifetime of the residential powerwall is predicated to be between $0.10 to $0.25. So, at $0.10, if you are only getting $0.05 for the power you are selling to the grid (from your residential solar installation) and are paying $0.20 for the power you are buying in, you can see that the "powerwall" stacks up. However at $0.25 per KWh used it does not.

The reason for such a big variance is that if you can install the system yourself the cost of it would be half the cost of paying for an installed system. However the latter comes with warranty issues etc. so it is fair to assume that the viability of the system is marginal on current electricity price differentials[6]. For utility scale storage the cost is predicted to be $0.05 per KWh so becoming much more competitive.

Looking at the UK energy sector the difference we are being paid between peak and off-peak production is only 1.5p per KWh so, at this level, it does not stack up. However, if you compare it to a monthly-system selling price the values do fluctuate by more than 5p per half hour period, so such a monthly system could be viable if usage was high enough.

This issue of half-hourly metering and electric sales values leads on to the next major development SCE were predicting: and that was a huge role for smart metering. They plan on installing a smart meter on all their transformers throughout their network in California. This equates to over 5m smart meters and there was talk of whether this would eventually evolve to every existing meter which would be an additional 20m + systems for SCE alone.

This … leads on to the next major development SCE were predicting: and that was a huge role for smart metering.

For SCE it offers huge advantages in that currently they do not have much idea on data for transformer loading, energy theft and grid optimisation. If they could get real time data from their transformers it would allow them to manage this so much better. If they could get it from every point of connection it should stop energy theft overnight. They admitted that they did not know the size of this problem but suspected it to be $millions for their organisation alone.

[6] http://cleantechnica.com/2015/05/09/tesla-powerwall-powerblocks-per-kwh-lifetime-prices-vs-aquion-energy-eos-energy-imergy/

7e. US conclusions

One of the key messages from my US trip was that some of the most successful businessmen in the world were betting big on renewable energy. Microsoft has pledged to invest $2bn in solar developments, Apple is investing over $3bn in wind and solar developments, and Google has already committed over $1.8bn on renewable energy projects[7]. Elon Musk (Entrepreneur of the year in 2007) has put huge sums of his personal money on the line[8] with his renewable energy, electric vehicle and storage investments - and continues to do so. This gives me far more confidence and hope for the sector than the negativity of any government uncertainty.

One of the key messages from my US trip was that some of the most successful businessmen in the world were betting big on renewable energy.

It has also reinforced my belief that, to be efficient, larger more advanced technology is needed, especially when it comes to wind power. To see another country replacing smaller turbines with larger more efficient ones reinforces my belief that the UK government got it wrong with the Feed in Tariff which supported smaller wind turbines.

Finally energy storage and smart metering has a vital part to play in the development of the industry and significant investment in these sectors is already underway in the US and I fully expect this to follow on in the UK.

Figure 18: Tesla HQ. See page 21

[7] http://www.bloomberg.com/news/articles/2015-02-26/google-makes-biggest-bet-on-renewables-to-fund-solarcity

[8] http://www.entrepreneur.com/article/245713

8. UK Meetings

As I am in the renewable energy industry it is my job to try to keep up to date with what is going on within the UK industry. During my Nuffield Farming study tour I have visited Anaerobic Digestion Plants, Combined Heat and Power Plants (CHP), Biomass Plants, Hydro and Hydrogen storage solutions within the UK. I have run countless feasibility budgets on all these systems and, along with increasing our wind turbine portfolio, my company Muirden Energy has also installed biomass systems and various roof-mounted 50KW solar systems. I am not going to go into the detail of the various technologies but have provided my rough budgets for some of the technologies in Chapter 10. As support levels reduce, the key is very much picking your technology to optimise on-site conditions and demands; and what is right for one site is not necessarily right for another.

Through using the Nuffield Farming banner I managed to secure two interviews I would not otherwise have pulled off. The first of these was with Dale Vince OBE, often described as Britain's wealthiest "hippy", with an estimated personal wealth of £100m made through his renewable-energy-developing and energy-trading business Ecotricity. From being a penniless traveller in his 20s he built his first wind turbine in 1996 and now has over 60 in operation in the UK plus numerous solar farms and an energy trading business with over 70,000 customers. He agreed that farmers were in a position to benefit from the renewable energy sector and is convinced that electric vehicles have major advantages over hydrogen. He is investing in an electric network at fuel stations. An important part of his success has been his management of risk and ensuring that risk is minimised where possible, and that each project can stand up on its own. He stated that it was relatively easy to become an energy company when he did in 1995, but says it has now become far more difficult to operate as such and would not encourage entrepreneurs to do it now.

The second was with Sir Ian Wood, one of Scotland's most successful businessmen with an estimated personal wealth of £1.32bn. I wanted to speak to him because, when he became involved in the family business it was a fishing business, and he took it from there to becoming one of the largest oil service businesses in the world. He told me that there was some hostility to his change of direction from the management within his own company, and others in the wider fishing industry accused him of abandoning their traditional interests, but he was convinced the oil industry offered huge potential and with support from his family successfully made the transition. His biggest challenge was getting the correct expertise and he spent a lot of time at the start getting the right people with industry experience involved in his company. He told me his biggest critic was himself and he constantly questioned the major changes he was making and, along with key colleagues, examined the risks and mitigated these as much as they could.

9. Discussions

This report has highlighted the size of the renewable energy sector and the fact it is a global industry which the UK is currently not at the forefront of. With a competitive advantage in terms of resources, whether that be high wind, or the fact that we are an Island with opportunities from the ocean on every side, I feel we need to make more of our potential.

In the UK the government uncertainty and changes of direction have not helped the industry but, in our favour, I feel there is a fundamental need for the product. We need the government to decide what is important to them and stick to it. The IMF recently reported that Britain spends £30bn a year subsidising the fossil fuel industry: that's over £1,000 per household per year. Onshore wind by contrast currently costs £10 per household in subsidy. As someone involved in the renewable energy industry I do not want to rely on subsidies but at least let us be given a level playing field for all energy sources. Climate change is real and the best scientific minds are saying we need to do something about our carbon footprint. What better way to encourage a transition than introduce a carbon tax – this of course was in place with the Climate Change Levy but was scrapped by the government in the recent budget. It was not a big levy – less than half a pence per KWh – but consistency is needed.

Britain spends £30bn a year subsidising the fossil fuel industry: that's over £1,000 per household per year. Onshore wind by contrast currently costs £10 per household in subsidy.

As an industry I think we need to look beyond the mess the government is currently making. Our product is needed and we are competitive on price with any new energy source - but we still have a lot to do. We need to drive down the cost per KWh of all renewable technologies. Planning policy has an important role to play in this and we need to be fighting to get policy to encourage the most efficient technologies and use of sites by allowing higher tip heights which will result in far more energy being produced per turbine.

Another vital part of the industry which needs to be improved is smart grids and the better use of grid capacity. Currently I do not believe that the grid is being used anywhere near its capacity yet grid connections are becoming the 2nd largest cost to projects, with many projects being unnecessarily delayed waiting for grid upgrades. The technology is there to better manage networks through smart metering and real time controls, and the network operators need to start using these or face being held responsible for the cost of these delays.

I also believe an overhaul of the charging structure for power is needed. When I sell power at my wind turbine to the grid I get under 5p per unit for it, yet when I am buying power

500m away at the farm buildings I am paying 12p. The system needs to be more transparent to ensure the network operators are not unfairly profiteering and allow better systems so power can be bought and sold locally, reducing the hefty transmission charges.

New technology has a part to play and it is great to see big businesses are spending huge sums of money on new product development to drive down the cost and increase efficiencies. I am sure this will continue and we need to make sure we are utilising these improvements as soon as possible.

The battery storage Tesla is developing is extremely impressive, and the fact they are investing so heavily in it gives me confidence that this sector is going to be massive.

The battery storage Tesla is developing is extremely impressive, and the fact they are investing so heavily in it gives me confidence that this sector is going to be massive. There are other storage technologies out there and I do not know which one is best but I liked Tesla's batteries for the simplicity of them.

If energy storage can be operated in parallel with a smart grid optimising local usage we can create an energy network far more efficient than the one we currently have.

Figure 19: The foundation steel rebar of the next turbine at Inverquhomery, my family farm.

10. Specific opportunities for UK farmers

I hope this report has demonstrated that the renewable energy sector is viable and here for the long term. As discussed already, with reducing returns any development needs to be carefully considered and advantages sought.

One major advantage I can see going forward is for farms which are situated near sites with high energy use. Whether this is factories using a lot of electric, or even housing schemes with a high heat demand, this drastically improves the economics of a project and can make a technology viable where it would not be without it.

For example with electricity generation the most you can get for power being sold back to the grid today is 5p, whereas any business buying-in power will be paying in excess of 10p. If you can split this difference with the end user it represents an increase in your power-sold figure of 50%. Suddenly totally unsubsidised solar and wind power can stack up. It is also likely to make grid connections easier and cheaper.

10a. Biomass

For heating, a 999KW Biomass boiler will cost approximately £200k installed for the boiler alone with tie-ins and district heating pipe above that. The current RHI (Renewable Heat Incentive) for this size of boiler is 5.18p.

999KW Biomass boiler			
Boiler			£225,000
Civil work			£5,000
Construction work			£30,000
Connection work			£20,000
contingency			£10,000
Total			**£290,000**
Income	KWh		
tier 1	1312686	0.0518	£67,997
tier 2	0	0.0224	£0
fuel saving - gas@ 3.7p/KWh			£48,569
Total			**£116,567**
Running costs	tonnes		
Wood chip @ £80t	437.562		£35,005
Insurance			£250
Electric			£1,500
Man hours			£10,000
Interest at 6% (half capital)			£8,700
Total			**£55,455**
Payback (years)	4.74542		

Figure 20: 999KW Biomass Budget

The above budget shows a payback of under 5 years for the system. However if you remove the fuel saving it would take longer than 20 years to pay the system back, so it is vital to the scheme that the heat generated is replacing an existing cost.

10b. 500KW Anaerobic Digester

The following is a budget I have used when considering Anaerobic Digestion based on current tariff levels. The first budget (below) assumes a 95% capacity factor and using all the heat generated, which not only qualifies for the RHI but also makes a fuel saving against gas on the full amount.

500KW Anaerobic Digester: Original Budget			
Groundworks - site preparation			£50,000
Construction Works			£625,560
Mechanical Equipment			£950,500
Electrical and Control equipment			£143,000
Engineering Services			£112,500
Digestate Storage			£100,000
Grid Connection			£150,000
Heating Solution			£100,000
Contingency			£50,000
total			**£2,281,560**
Income			
Generation @90% cf	3942000		
Electricity Export Tariff	£0.05		£197,100
FIT Revenue	£0.087		£342,166
Heat RHI (100% use)	£0.055	3,800,000	£209,000
Heat Savings - gas@3.7p			£140,000
total			**£888,266**
Running costs			
Feedstock -silage	9,500t	£28	£266,000
Servicing			£70,000
Insurance			£15,000
Operational Costs			£40,000
Interest at 6% (half capital)			£68,447
total			**£459,447**
Payback period (years)	5.32057		

Figure 21: 500KW AD: standard budget

As you can see, the payback period for the above is 5.32 years but I think there are some assumptions which need to be added into this budget. Firstly, at a cost of £2.2m it is likely that project financing would be required, which will add over £50,000 due diligence costs plus an arrangement fee of approximately 3%.

Having spoken to others in the industry I think the 95% capacity factor being quoted is high. The plants in Germany I saw were operating at around 85 to 90% so I have changed this to 85% in the budget. I also think the amount of heat being generated is very large and, given the fact most AD plants will need to be a significant distance from houses, replacing an existing heat usage is unlikely. I have still assumed that 100% of the heat generated will be eligible for RHI but that there are no fuel savings. Finally I have added in £25k per year of repairs as all the systems I have seen have components which need replacing during the project, from pumps to the engine - which is unlikely to last for the full 20 years. Depending on the service package you get from the manufacturer it may include certain parts so £25,000 is a fair figure in my opinion. That makes the new budget look like this:

500KW Anaerobic Digester: Revised Budget			
Groundwork's - site preparation			£50,000
Construction Works			£625,560
Mechanical Equipment			£950,500
Electrical and Control equipment			£143,000
Engineering Services			£112,500
Digestate Storage			£100,000
Grid Connection			£150,000
Heating Solution			£100,000
contingency			£50,000
Banking DD fees			£50,000
Arrangement fee			£69,947
total			**£2,401,507**
Income			
Generation @85% cf	3723000		
Electricity Export Tariff	£0.05		£186,150
FIT Revenue	£0.087		£323,156
Heat RHI (100% use)	£0.055	3,800,000	£209,000
Heat Savings - gas@3.7p			£0
total			**£718,306**
Running costs			
Feedstock -silage	9,500t	£28	£266,000
Servicing			£70,000
Insurance			£15,000
Operational Costs			£40,000
Repairs			£25,000
Interest at 6% (half capital)			£72,045
total			**£488,045**
Payback period (years)	10.4295		

Figure 22: 500KW AD: revised budget

This changes the payback to 10.43 years which is not as attractive. It also highlights how important it is to maximise the efficiencies of a project and ensure that the supplier of the system is giving adequate warranty packages so there are no surprises down the line.

The above budgets are a very rough look at the viability of some of the technologies on offer and should not be relied upon but they do demonstrate the variables which can have big impacts on project viability, and give ballpark figures for the technology.

10c. Political risk

As the above demonstrates, the support each technology receives still has a big impact on the project's viability and this is obviously subject to political changes. I think fundamentally the industry is getting closer or has even arrived at a place where it could compete on a level playing field; however the playing field is not level today.

At the same time as announcing massive cuts to the renewable energy sector the government has agreed that EDF Energy should receive a guaranteed minimum price of 9.25p per unit produced for 35 years (the above FIT terms are 20 years) and a £2bn loan guarantee for their nuclear project at Hinckley Point. Costs and support for this project are expected to only increase. The recent budget also announced tax breaks for North Sea oil and with the IMF report mentioned earlier showing that Britain spends £30bn a year subsidising the fossil fuel industry, which is £1,000 per household vs. onshore wind which receives £10 per household support. It is easy to question the government's commitment.

There is massive global pressure to create a cleaner environment

However I think it is important to look beyond the current government and at the wider picture. There is massive global pressure to create a cleaner environment and the most intelligent scientists in the world are saying it is critical we reduce our carbon footprint. With each 100m turbine saving over 2,700t of carbon per year this almost-forgotten benefit will become extremely important again. Renewable energy devices are already producing power more cheaply than consumers can buy it for, so by creating a better link to the end user and using smart grids to reduce transmission charges, projects will be viable without any political input.

11. Conclusions

1. The most important thing my Nuffield Farming study has given me is confirmation that the renewable energy industry is a massive global opportunity and some of the most successful businesses in the world are making big bets on the success of it.

2. Farmers have a critical part to play in the industry with all technologies requiring land in some way; whether it's simply a site for wind turbines, or growing energy crops for AD, the sector is directly linked to the land – even offshore renewable developments require right of way over land to connect up to the national grid.

3. Although government changes and uncertainty can have big impacts on the short term viability of projects, the long term future of the industry is positive and it can compete in a free market.

4. Technology is improving and advancing at a fast rate and we should look at global trends when maximising our opportunities.

5. Energy storage and smart grids are going to play a vital role going forward, and battery storage and smart metering are the two game changers I have come across during my study tour.

12. Recommendations

1. I think all farmers should consider renewable energy developments as an income stream and look to see what technology is suitable for their situation. Not all farms will have a viable project and the risks need to be considered and minimised but this can be done through robust maintenance contracts, joint ventures with developers or renting out the site so that someone else is taking the risk but the farm is still getting a benefit.

2. I understand it can be a contentious subject but, given the potential and size of the industry, I think farming bodies such as the NFU should embrace the sector more and help farmers benefit from it.

3. Agricultural lenders also need to be forward thinking in their approach and use their experience from previous developments to highlight successes and dangers with developments, and offer cost effective funding for robust projects.

4. I think renewable developers should be more long term in their thinking, both in terms of the technology they are installing and project viability, to ensure that the sector continues to thrive.

5. Importantly I think the government needs to come up with a robust strategy and stick to it in order to improve investor confidence. I don't want the sector to be subsidised and think it can prosper without subsidies, but the government strategy and targets need to remain consistent and policy needs to ensure that the most efficient projects are encouraged.

13. After my study tour

My optimism for the future of the renewable energy industry is stronger now than it has ever been, despite all the recent uncertainty with government cuts and change of policy. A recent Ernst and Young report stated "*The Government has sentenced the UK renewables sector to death by a thousand cuts*": but I don't believe this to be the case.

At Muirden Energy the next 18 months are going to be our busiest to date with over twenty wind turbines to build. Looking beyond that, we are actively taking on new projects on the basis that we believe fundamentally that wind power can offer one of the most cost effective sources of power going forward. We are having to work harder and be smarter with our projects and are only taking on sites which will be in the top 10% of production per £ installed, but perhaps this should have always been the case.

Since the government announcements we have opened our first satellite office and taken on three new full time employees, underlying our continued belief in the industry.

In terms of my own projects on the family farm, through the period of my Nuffield Farming study tour I have installed a 50KW solar system, two 100KW biomass boilers and a second 500KW wind turbine and, by December this year, there should be another 500KW turbine up, plus two 980KW boilers installed to dry our grain and provide district heating for the farm cottages.

We will continue to look at new technologies and opportunities as they arise and are actively looking at opportunities for using energy storage alongside our existing and future developments.

My biggest ambition is to start farming in my own right alongside my current work with Muirden, and this is something I hope to achieve in the next 5 years.

Alex Fowlie

14. Executive Summary

The renewable energy industry has developed significantly in the UK over the last 5 years with many farms now having some form of renewable energy generation on their land. With $13.9bn invested in renewable energy in the UK in 2013 alone, and all renewable energy devices requiring land in some way, this sector represents a massive opportunity for farmers.

With the recent UK government changes cutting subsidies for new projects in the short term and creating uncertainty over any support for new projects in the long term, the sector is at a cross roads on where it goes next but this report demonstrates the potential of the sector and that the future is very positive.

The industry has had a bad reputation for not being cost effective in the past but this is something which has already changed. Over the last few years the cost of wind and solar power has reduced drastically to a level which can compete directly with new fossil fuel generation and costs are predicted to reduce even further. With new generation required to keep the lights on and predictions of blackouts if we have an extremely cold winter this year, the importance of new renewable energy generation is only going to increase.

My travels have shown that the renewable sector is a massive global industry. Worldwide investment in renewable energy is already exceeding investment in non-renewable energy generation year on year and the predictions are that this will only continue. Some of the most successful global businesses are investing heavily in the sector and some of the brightest minds are involved in its future development which gives me real optimism and excitement for the future.

The game changer for the sector is energy storage which would allow intermittent renewable energy to be produced when available and stored to be used when in demand. With Tesla investing $5bn in a new battery manufacturing plant it is fair to say this revolution is already underway and this is only going to increase the viability of renewable energy generation further. Combining this with smart metering and improved grid utilisation would allow the UK network to be managed far more efficiently which would not only lower energy costs but also allow cheaper and faster grid connections for projects.

Although the UK is nowhere near the top of the industry in terms of the amount of renewable energy generated or the on-going development, we have a huge competitive advantage in terms of our natural resources with three times the wind resource of mainland Europe and oceans on every side so we could not be better placed to benefit from this growing industry.

There are various technologies available all of which offer different solutions and careful consideration of each site's requirements and natural resources is required to determine what will offer the best return for a given farm.

15. Acknowledgements and Thanks

A huge list of people deserves my thanks and appreciation for the support they have given me during my Nuffield Farming Scholarship.

Firstly to my sponsor – The Royal Highland and Agricultural Society of Scotland. I am hugely grateful for the opportunity they have given me I hope I have done them justice.

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My colleagues at Muirden Energy deserve special thanks as without their support I would not have been able to complete this scholarship. They have risen to any challenge thrown at them and more than covered for my absence during extremely busy periods.

A huge thank you to the all the people who have helped me out along the way, be it introducing contacts, hosting visits or pointing me in the right direction. There have been too many to mention individually but I have been amazed and humbled at the help and hospitality I have received during this scholarship.

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