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Gate to grid, a responsible model for integrated energy production.

Written by:

Thomas Clark NSch

November 2024

A NUFFIELD FARMING SCHOLARSHIPS REPORT

KINDLY SPONSORED BY:

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A NUFFIELD FARMING SCHOLARSHIPS REPORT (UK)

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

Date of report: November 2024

Title	Gate to grid, a responsible model for integrated energy production.
Scholar	Thomas Robert Clark
Sponsor	Elizabeth Creak Charitable Trust (a Clyde Higgs scholarship)
Objectives of Study Tour	To explore global changes in weather patterns and consider ways to succeed with climate mitigation measures. To consider the potential role of renewables and review the alternatives. To try and determine what are the responsible methods of integrating technologies into mixed farming. To review the potential benefits of implementing responsible strategies.
Countries Visited	Australia, New Zealand, Canada, Italy, France, Norway, Netherlands, United Kingdom
Messages	Farmers as custodians of the land hold great potential to mitigate climate change through our practices. Specifically, the implementation of rotational renewables is highly beneficial. Integrating production systems can bring financial diversification to business, additional area for biodiversity and more opportunities with future technologies. A balance of land uses in a solid rotation to maintain soil heath and fertility is essential for long term success.

EXECUTIVE SUMMARY

With the race on for net zero by 2050, agriculture must realise the potential of implementing renewable technologies if it is to stay relevant and operational. Modern society now relies heavily on readily available energy to eat, heat and power our day-to-day life. As a result, securing new green generation to feed this cycle is key to reaching future sustainability goals. We as farmers, mangers, and landowners are already in the business of energy production. We convert the elements of wind, sunlight and moisture into a calorie harvest such as grains, fruit, pulses, roots, and animal protein.

Historically, horses were the solar powered engines. The oats and hay we grew using the sun's energy was converted by Shire and Clydesdale horses to power machinery and work the lands. With increasing reliance on outsourced inputs, we have lost touch with this circular economy of farming and we need to re-envision this cycle for a sustainable farming future.

The production of a KW is similarly a conversion of the elements into a unit of energy.

The calorie output on farm is no different to the potential KW output on farm. Farmers are therefore ideally placed to lead innovation in this field; to not only feed the world but meet its power demands as well. I believe with the right industry leaders and governmental support; agriculture has huge potential to capitalise on the route to net zero. We need not just a five-to-ten-year plan but a one-hundred-to-two-hundred-year plan, with achievable and ambitious solutions to drive the industry forward to the 2050 targets set in the Paris Climate Agreement (UNCCC 2015).

It is the objective of this report to investigate solutions that will bring benefit to the agricultural industry, highlighting benefits to farming systems across biodiversity, technology and profitability. For instance, looking into business risk mitigation linked to environmental changes will hopefully highlight sustainable solutions to help address climate goals. Countries such as Australia balance on the edge of changing weather patterns. Extreme weather has become more frequent with high temperatures causing bushfires, increasing flood events and crop failures. It has therefore become essential for farmers to de risk their business against changing climates. The review of emerging technologies across Europe has proved valuable in highlighting opportunities to mitigate climate risk in business.

In particular, on farm electricity production can stabilise the price and supply of energy. Where looking at Agrivoltaics (AV), shading and subsequent moisture retention can be utilised in farming systems to safeguard from future changes in climate. The upgrade of the countryside's connectivity and electrification will allow monitoring technologies and robotics to develop and become more common place. Farmers must therefore integrate energy assets on a per hectare basis allowing these new technologies to flourish. In the future, finding the correct balance of food, power and biodiversity will create the right environment for technologies to be embraced, enabling a leap forward in farming production and opening the gates for the next agricultural revolution.

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DISCLAIMER

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

Please note that the content of this report is up to date and believed to be correct as at the date shown on the front cover.

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Nuffield Farming Scholars are available to speak to NFU Branches, agricultural discussion groups and similar organisations.

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CHAPTER 1: INTRODUCTION

Figure 1: Author; Elizabeth Clark

I am Thomas Robert Clark, I farm in Perth, Scotland in partnership with my father at T.W.Clark & sons. We are the seventh and eighth respective generations of our farming family. The family began farming at Netherlee farm, Cathcart in what is now Glasgow's south side. We have a strong link with our heritage and origins, still possessing old family trees with well recorded history. The farm moved as the family grew and split, with the move to Perthshire in 1910 to Pitlandie farm, Luncarty and shortly after Muirton farm, Perth. With the latter now having been built on becoming part of Perth city, I am lucky enough, along with my wife Siobhan and daughter Fiadh to call Pitlandie farm my home. We farm 4 sites across Perthshire amounting to 450 hectares, through a mix of soils from loam clays to sandy loams. There is a diverse mix of agricultural enterprises on farm. We run a traditional crop rotation compromising of spring malting barley, winter wheat, winter barley, winter oil seed rape, seed potatoes, grass silage and grazing pasture. Across the pastures we run a herd of one hundred head of Simmental cross suckler cows, keeping replacement heifers and finishing progeny from Aberdeen Angus and Simmental bulls. Store lambs are routinely purchased and fattened on farm, overwintering on winter forage. There are several let properties on farm that are split between staff accommodation and commercial lets.

We run a Clydesdale stud under the Muirton prefix with two stallions Muirton Saber and Muirton Spirit. The stallions are currently working between Scotland and Northern Ireland along with breeding mares and young stock on farm. These are shown in hand and ridden. The Clydesdales have been a long-lasting part of the family business and go as far back as the farming itself; our horses were the engine of yesteryear. As my focus is on energy production, I must highlight we currently have on farm small-scale wind and small-scale solar technologies which contribute towards powering our farming units with surpluses sold back to the grid. The systems are now over ten years old and are still working well.

I was brought up on the home farm and since I was knee high, I knew a career in the farming world was waiting for me. As a modern farmer I knew I would need to have some underpinning theory to my agricultural practical knowledge. When I left school at 17, I gained a place at Edinburgh's Scottish Agricultural collage (SAC) or Scotland's Rural Collage (SRUC) as it is better known today. I graduated in 2009 with a BSc in agriculture. I then returned home on a full-time basis and have gained experience and expertise in most of the roles on the farm to date. In 2018, I was selected as part of the Tesco future farmer foundation, which saw me tour the UK looking at supply chains across the agricultural sector. This was an invaluable opportunity and gave me a new perspective on the business, having observed supply chains in detail. It was at this time my interest in business risk and mitigation techniques was sparked. I became particularly interested in the changing climates we work in, and with weather patterns in Scotland starting to become exaggerated. I wanted to learn more.

CHAPTER 2: WHERE IT ALL BEGAN

I have for many years now always had an interest in gaining deeper learning and understanding of what farming is to me. A hunger I believe I very much inherited from my grandfather Thomas William Clark. He was always questioning why and challenging the status quo. He travelled many times in his older age exclusively through farming tours where he would bring back many insightful ideas regarding technology and the direction of agriculture to the farming business. I have always valued travel for the ability to learn and broaden horizons. I therefore felt aligned with the Nuffield principles of travelling for a better tomorrow, where meeting forward thinking minds are facilitated. When looking to the future I often question, what will be the pressures on land usage if the UK is to meet the growing call for clean, green electricity? Daly et al (2022) have interestingly stated that UK energy consumption is set to decrease but electricity demand will almost double, see figure 1. However, in - The Sixth Carbon Budget Agriculture and land use, land use change and forestry (Government Climate Change Committee, 2020) there is no mention of renewable technology and its relationship with agriculture. I knew this was something I wanted to find out more about.

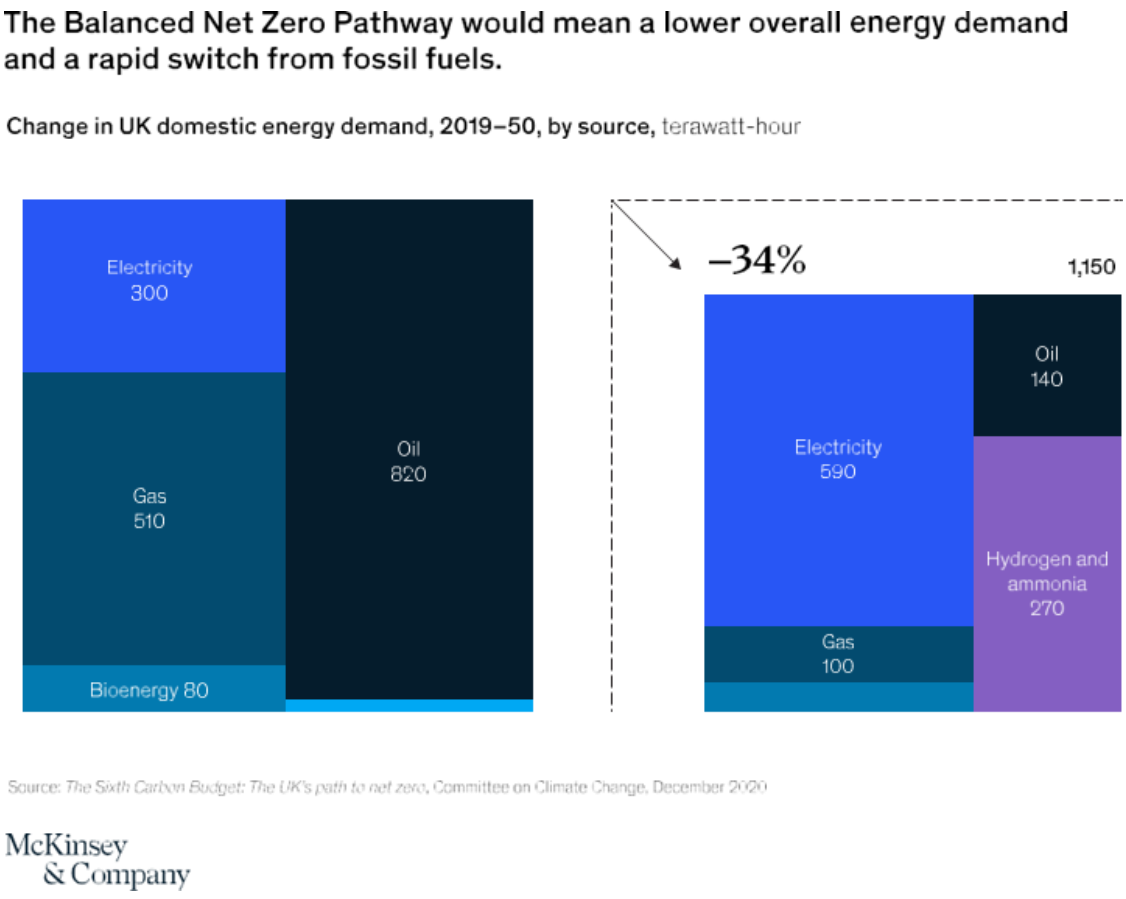

Figure 2: Facing the future: Net zero and the UK electricity sector

This is where I believe it is our responsibility as farmers, managers and custodians of the land to stand up and take responsibility for the hectares under our protection. My three key pillars are:

- Food security
- Energy security
- Biodiversity

Implemented in harmony with a mindful integrated approach there is a future for sustainable agriculture. Furthermore, this will provide a truly sustainable life support system for the wider public if a good balance can be established. I believe that we must act now to implement the correct solutions on a best fit for practice within our farming systems, sooner than later. The need for a climate and business solution needs to be discussed before inappropriate policies and strategies are put in place to achieve the climate goal of net zero by 2050 (UK Government 2023a). I intend to offer you a vision and proposals within my topic: 'Gate to Grid: a responsible model for integrated energy production'.

Figure 3: Thomas William Clark, Muirton stud; Authors own

We as farmers, mangers, and landowners are already in the business of energy production. We convert the elements of wind, sunlight and moisture into a calorie harvest such as grains, fruit, pulses, roots, and animal protein. Historically, as farmers we had control of our inputs, with farm yard manure and actual horse power. The oats and hay we grew using the suns energy were converted by Shire and Clydesdale horses to power machinery and work the lands. I would argue that we have lost touch with this circular economy of farming, and we need to re-envision this for a sustainable farming future. Farmers are ideally placed to lead innovation in this field of integrated renewable energies; to not only feed the world but meet the power demands as well. I believe with the right industry leaders and governmental support; agriculture has huge potential to capitalise on the route to net zero. We need not just a five-to-ten-year plan but a one-hundred-to-two-hundred- year plan, with achievable and ambitious solutions to drive the industry forward to the 2050 targets set in the Paris Climate Agreement (UNCCC 2015). The extension to deadlines within the Government's policies for achieving net zero, highlights the challenges arising from a lack of infrastructure and the changes needed in wider industry. These large changes need to offer the opportunity for farming to be central in future green energy developments. We must integrate our energy assets on a per hectare basis allowing the next agricultural revolution to flourish. By finding the correct balance of food, power and biodiversity, I strongly believe we will create the right environment for technologies to be embraced, enabling a leap forward in farming production.

CHAPTER 3: MY STUDY TOUR

Throughout 2023 and 2024 I embarked on a study tour which enabled me to explore different approaches to climate issues, across a broad range of farming environments. Table 1 indicates the countries that I investigated.

Table 1: Travel Log

Country	Date of Travel	Type of travel
Canada	March 2023	CSC
New Zealand	March/April 2023	Triennial conference
Italy	June/October 2023	World Food forum/ Individual travel
Australia	November 2023	Individual travel
France	May 2024	Individual travel
Norway	July 2024	Family/Individual travel
Netherlands	July 2024	Individual travel
Scotland, Wales, England	2023/2024	Individual travel

It is the variety in different climate stresses that interests me greatly across the countries I have travelled through, each bringing new and different solutions to the table, which in some cases have great synergies with agriculture. A crucial aspect of these solutions included risk appetite and the influence on risk through any climate mitigation factors. From a business perspective these approaches can support smarter decision making and greater resilience against changing trends within consumerism, climate and business.

From a farming perspective we are all aware of how weather patterns impact agriculture, but I made some pertinent observations during my travels. Having farmed and run a business through changing climate patterns over the past ten years I am very aware of climate pressure. I also had the chance to observe this firsthand in the many countries I travelled to as part of my scholarship. I found that the frequency of erratic weather patterns, with more violent and frequent peaks and troughs, seemed to be a common concern and challenge amongst farmers across the world.

Figure 4: The long road ahead, Australia; Authors own

CHAPTER 4: THE CURRENT CLIMATE

Figure 5: October flooding, Scotland; Authors own

In the UK, climatic conditions dominate the agricultural sector, with some of the most buoyant patterns of weather in recent history. With 2023 being close to the wettest year on record for many areas of the UK, it is important to consider human influence and risk mitigation factors that may be implemented. There are potentially two ways to do this: by influencing weather patterns or by employing more practical ways to work with the different weather extremes. Only when both are considered, will a long-term solution be possible. With the drive to influence weather patterns through decarbonisation, solar power is viewed as a source of clean electricity and there has been a growth in installations of large solar fields. In the UK many landowners are turning to larger energy providers and subsidiary companies to effectively let out land for solar and wind energy production. From visiting various wind farms in Australia to various proposed solar sites in Scotland this trend can be observed in many countries around the globe, with more extreme cases in some than others depending on government policy.

Figure 6: Waradarge Wind farm, Australia; Authors own

While this may be a fast and efficient way of scaling such projects to fast track a renewable source to market, there are concerns that mono blocking and long contract terms will see land taken out of agricultural production for a generation. This may also lead to sites being re-contracted for future generation due to the high cost of infrastructure upgrades required for connecting sites, thus locking land away from production for much longer. The potential problem of this method is that it channels upgrades away from more remote locations and concentrates the density of grades in a local area. Generally, this leaves only one or two beneficiaries of these projects, whilst many in the local community are unable to gain benefits from these projects.

Taking a counter perspective, the oil industry's transition in Norway has had clear positive impacts across many sectors. Specifically in Haugesund, the fitting and commissioning of an off shore electrical converter, for transmitting wind power from 3 wind parks, has retained jobs in the engineering Industry, helping to benefit the wider community and industrial areas.

Figure 7: 900MW transmission platform Haugesund, Norway; Authors own

As stated in the UK government report "Strengthening Britain's energy security means moving from fossil fuels to home-grown, clean energy to eliminate emissions and tackle climate change." (UK Government 2023b:27). I would suggest there are none better suited to growing than farmers. However, this paper sets out the potential for electricity demand to increase by 60% by 2035. Nuclear power is projected to take the lion's share of demand by 2050 to supply approximately 25% of British electric energy requirements, while ground and roof top solar power is projected to grow fivefold by 2035.

"Solar and farming can be complementary, supporting each other financially, environmentally and through shared use of land. We consider that meeting energy security and climate change goals is urgent and of critical importance to the country, and that these goals can be achieved together with maintaining food security for the UK." (UK Government 2023b:38).

There is massive opportunity within solar energy growth for farming to be central in ensuring that the industry develops for the enrichment of agriculture. From a consumer's perspective, farm generated solar power is more palatable than nuclear power with a better environmental footprint and sustainable credentials with regard to waste disposal. A pertinent point when discussing with individuals at all levels throughout my travels. Particularly, when it is considered that 3% of radioactive waste material is long lived and requires isolation from the environment for thousands of years.

The UK national grid infrastructure is arguably outdated, with real limitations on renewables which is reflected in the long-term waiting list for connection. It is believed some 250GW is waiting for connection compared with current connection of 80GW (UK Government 2023b:50). With the widespread need for electrical connection to supply remote projects, coupled with the intermittent fluctuations in the supply of energy from renewables, there are real challenges to invest in the correct infrastructure for maximum public gain. This is where government needs to be building the right infrastructure to include and support the delivery of projects within communities. In the next chapter I will review some examples of renewables in action and consider the benefits they bring.

CHAPTER 5: IN THE FIELD

5.1 Le Greenhouse, Italy: Benefits to cropping systems

The organisation at La Greenhouse is an impressive example of Agrivoltaics (AV) at work. AV is the process of running both agricultural practices and solar energy production in tandem on the land. The company farm approximately 100 acres of citrus fruit across southern Italy, some of which are covered greenhouse sites and others open fields. The integration of AV's is primarily on greenhouse roofs where 50% of the area is covered with a cost- effective solid solar PV panels and the other half carries clear glass, to allow a good level of sunlight ingress. The successes achieved by Le Greenhouse are a more uniform crop with larger fruits and more uniform colouring from the shade produced.. However, an increase in pruning has been noted as plants bolt for the light, though with a better quality and more marketable crop the cost implications are minimal. This is highlighted more so in the premium and traditional Cedro (citrus medica) citrus fruit used in perfumeries and religious crops, and green ceremonies which commands a premium. The water usage has been reduced in the greenhouses by sixfold, as less evaporation occurs in the shade, a real step forward in the move towards a sustainable system. Having this secondary income from the land has allowed Le Greenhouse to have more confidence in selling produce for profit and therefore not just being held as price takers in the marketplace. In 2017 the area was hit by cold frosts in the winter damaging many citrus trees. The trees under solar were mostly unaffected and survived the frost allowing new plants to be grafted and tree numbers recovered quickly. They have also started trials into integrating field AV to the business by growing citrus trees under gantries approximately 3 meters tall which provide shelter for the crops and protect moisture levels in the soils from the intense sunlight. They are mounted on electric pivots to follow the sun's path through the daylight hours, increasing production, and are set horizontal during the night to protect the crops from the cold in winter months. La Greenhouse continues to develop innovative ways of integrating renewable energy and agricultural production and have engaged in the development of 430MW of AV projects in Sardinia and Calabria.

Figure 10: Cedro (citrus medica); Authors own

Figure 8: Solar greenhouse; Authors own

Figure 9: Agvoltaics over lemon trees; Authors own

5.2 Strike energy: Land use

In the Perth basin of Western Australia (W.A) lies great potential in oil fields and natural gas reserves. Strike energy is an on-shore energy producer which seeks to supply sustainable gas to W.A. They are focused on Australia's energy transition and what potential lies within the move away from coal powered industry. The drive for sustainability is highlighted in the recent development of the Precinct, a land holding of some 3500 hectares. This site is currently farmland, let on a contract basis but will be transitioned to provide a diverse mix of renewable energy in wind and solar, along with the potential for carbon storage and hydrogen production. The farmland is an attractive opportunity as this is productive land and has different constraints to land with native vegetation or uncleared bush. Australia has strict rules and protocols for any application to expand into the bush and clear native vegetation, while agricultural land is at a premium in this area as it is considered the wheat belt of W.A. The land assets therefore must be sweated, and by taking an integrated approach to energy production, the Precinct area is well on the way to doing just that, making the most of land available. To run existing plant and machinery there is a research and development strategy for renewables aimed at finding the best integrated methods. With potential of up to 100MW in wind power, coupled with 70MW in solar power, and a location near the main transmission lines for Geraldton and Three Springs with connections to the large city of Perth in the south; the site has great potential in supplying sustainable energy far and wide, with surplus renewable energy being sold offsite or utilised in green hydrogen production on site. On top of clean energy generation there is also potential for carbon storage in a non-hydrocarbon sandstone layer identified in the depths of the soil structure. Giving the site a circular sustainability, where inputs and outputs can be utilised onsite through the production process. This is an excellent example of the scale of opportunity there is within integrated systems, when implemented by the energy industry itself.

Figure 11: Author and Sean Daniels South Erregulla gas rig; Authors own

5.3 Waverleigh Farm, Karin Stark and Jon Elder: Cost to farmers

Waverleigh farm is situated outside Narromine, New South Wales (NSW) and is a 2500 hectare cropping farm consisting mainly of irrigated cotton and dry land wheat. The pressures of the changing weather patterns have been felt by the family with floods, droughts and hotter summers. With cropping becoming more diffcult and not having a viable wheat crop for a couple of years, an increased production pressure was put onto the irrigated land. It was across the irrigated cotton area of approximately 550 hectares where rising diesel costs, over $300,000, were being noticed in running the bore and pump infrastructure. Opportunity was highlighted in new technologies and in 2018 the decision was taken to install 500KW of solar panels on 1HA of land, seizing the potential to produce their own green electricity on farm. The power generated is used to power the country's largest solar-diesel hybrid pump, Figure 12. In doing this, fuel costs were reduced by 40% and carbon dioxide emissions reduced by 500 tonnes per annum.

Figure 12: Solar-diesel hybrid pump; Authors own

However, this large-scale hybrid system does have its challenges, as there can be an inconsistency in generation on a cloudy day, or in mornings and evenings. This results in fluctuations in supply where the diesel generator can fail to match power demand smoothly, with drops causing shutdown of the bore pumps. The current solution to this is battery storage. However, this is another costly investment that is not currently justified in their opinion. Despite these challenges, the system is still on track for a five-year payback. Importantly this highlights some of the challenges faced for a cleaner future; as well as many benefits that can be drawn from an integrated system. Until the high costs in technology are reduced or grants are made available to fund such projects, they will be slow to gather pace throughout the industry.

Karin Stark is also the founder of the 'National Renewables in Agriculture Conference and Expo' and director of her own business 'Farm Renewables Consulting'. Karen is a firm advocate for the integration of renewables with agriculture, in particular, she has a passion for Agrivoltaics (AV). The limitations with grid connectivity in rural areas, ultimately limit businesses to cost effective self-sustaining, micro grid systems. This limits the ability to unlock the lands true potential for AV and its role in supply to the bigger populations.

Figure 13: Karin Stark and Author with Agrivoltaics; Authors own

5.4 Pecora Dairy: Changing climate patterns

In a small parcel of land, in the tropical south highlands of Robertson, New South Wales (NSW, lies Pecora Dairy run by Michael and Cressida Cains. They are both incredibly knowledgeable individuals and together are a driving force in the agricultural industry. They run a flock of East Friesian sheep on a modest 75 hectares, of which two thirds is cleared, in grass with a light touch, low input approach. There is a clear respect for the biodiversity on farm and they strive to have minimal impact when carrying out operations in the day to day running of the farm.

Figure 14: Michael Cains and Author in sheep milking parlour; Authors own

They also process their milk into a range of cheeses, one of which is a raw cheese product requiring strict quality and safety protocols. Executing this on-site alongside the dairy gives them a reliance on stable power inputs. This is challenging when living near to the coast in such a unique climatic zone. A change in climate patterns has been noted with rain fall in 2022 more than doubling to over 4000mm from a previous average of 2000mm. The frequency of storms in the area had started to pose a problem with several power outages. The repair to grid infrastructure took a number of days in some of the most severe storms experienced and older infrastructure was damaged in lighter storms. A solution had to be found to maintain a smooth operation in milking and processing. A decision was made to install 28KW of solar Photo Voltaic (PV) on to the dairy roof and a 40KW flow battery. On average the combined system saves them approximately 80% on energy costs. This puts control of generation back into the hands of the farm and de risks it form storm damage or inconsistent supply, providing them with energy security on stormy nights. This system is also grid connected and using a smaller scale distributer, energy can be traded between sites. This is something that the Cains family do well: by selling excess energy to neighbouring farms and running their cheese and wine shop in the local village. This ultimately makes investment into electrically demanding systems more viable and becomes a profitable, as well being the preferred, low impact choice. Notably the most recent investment into an electric crate and handling system, allows for more effcient use of labour and less stress on the sheep, enabling greater frequency in use, feeding into better management.

Figure 16: Pecora dairy flow battery; Authors own

Figure 15: Pecora dairy rooftop solar; Authors own

CHAPTER 6: INDUSTRY POTENTIAL

6.1 Opportunity on farm: UK

I have found many compelling examples from around the globe and the UK of integrated systems to bring benefit to businesses and communities. The biggest success stories from the UK are where renewable systems are owner operated with the majority of generation consumed on site, either for existing usage or utilised in new enterprises. Wind and solar technology has been well embraced in the UK. Where affordable, there are many advantages of bringing in battery storage to stabilise supply caused by low periods of generation due to variable wind and light patterns. The use of energy crops in Anaerobic Digestion (AD) is also commonplace, however, with lower energy yields per hectare they must be used in a fit for purpose rotational cropping system. When relied on too heavily in one area, cropping systems become unbalanced and food security is put under pressure, though AD can work exceptionally well where waste materials are in abundance.

6.2 Global potential: Food and Agriculture Organisation of the United Nations (FAO), World Food Forum (WFF)

The opportunity to attend the World Food Forum came to me via some of the Australian and Dutch scholars I had met during the Contemporary Scholar Conference (CSC). At this event I had the opportunity to talk with representatives of some of the world's largest banks. This provided insight into the structures and risk appetite for putting into place loans to better the global development of agriculture and food systems. The forum was an incredible opportunity to discuss agriculture and the wider industry on a global scale, at the Food and Agricultural Organisation for the United Nations (FAO). As a global network of scholars from Japan, Netherlands, Canada, Scotland, Australia and Tasmania, we engaged in a rich dialogue touching on wide reaching topics across the globe. Life support systems in food, energy and biodiversity were discussed. The consensus was, there is real development potential in bringing responsible high-level individuals together to navigate the global need for responsible sustainability to be implemented in developing countries. If this is done correctly utilising local intellect, skill and provenance, then real society leading change can be made.

Figure 17: International delegates, FAO Rome; Joanna Mendes

One such opportunity became apparent. From speaking with Rob Fisher, from Zimbabwe, over dinner at the triennial conference in New Zealand I gained insight into large scale operations in small farming communities. Within this there were many parallels in establishing energy resources. This link became apparent when speaking with various delegates from Africa at the WFF. For example, in communities in Africa, where solar technology is already being used in the cold chain to refrigerate milk haulage, there are opportunities to bring renewable power into the homes of rural communities, enabling them to store food or boil water. The health benefits alone merits finding a system that works. Agrivoltaics (AV) could be the best fit for this situation and therefore play a vital role in these communities. There is also the

potential to provide shaded areas for moisture retention in cropping and shaded areas to reduce heat stress in livestock. Farmland could be worked as it is now, with smaller farms and basic technologies, paired with integrated energy production. In this way communities would be able to lead the way in sustainable production.

6.3 Community: Supporting the city

While travelling I had the chance to stay with energy consultant Nathan Tineline and his family in Perth W.A. He is the Discipline lead in Energy Innovation for BG&E Resourses. We had the chance to talk in-depth about the opportunities and challenges within the wider renewable industry. Perth as a city is similar in structure to UK cities. However, with a growing population of 2.6million (Government WA, (a)2024) one key concern is fresh drinking water. Due to declining rainfall, the WA government has backed desalination since 2006, by processing salt out of sea water. The city has an integrated water supply and uses approximately 45-50% desalinated water depending on rainfall and river flow. Desalination plants use a vast amount of energy and in collaboration with energy companies, there has been the construction of large-scale wind and solar energy production sites.

This is backed by the WA government and a new Alkimos desalination plant is planned for 2028 (Government WA, (b)2023) with a $2.8 billion investment. The power requirements to run such a plant will mean sourcing 400MW in renewable energy generation (800ha in solar area). I took the chance to talk with W.A government green energy project manager Guy Chandler on implementing strategies in W.A. To achieve the population's power demands creates a reliance on new projects being set up throughout the distribution network area and puts pressure on these areas to produce a KW harvest alongside farmed land within the wheat belt and native bush lands.

Another demand on the land in WA comes from the mining companies in the north, where the drive for sustainability and green credentials have seen a push for land acquisitions to execute renewable electricity sites. This electricity will be used in 'Green' mineral production, replacing existing oil-based fuels with hydrogen produced on site. In a discussion with a cattle station owner, Will Baston in north WA, I saw another aspect of renewable energy use. He was in the midst of conflicting land usage with larger mining companies purchasing farmed land for green energy production and out competing farmers. The concern here is that farmed land and farmers are being left behind and farming production is diminishing, while the mining companies install renewable technologies. Much of this renewable energy will go into hydrogen production and eventually feed into WAs new hydrogen export industry. WA hopes to have a 12% global market share by 2030 (Government WA (c) 2023:13). This new demand on the land, puts further pressure on the balance of energy production on a per hectare basis, pressing farmers to adopt integrated systems to remain competitive.

Figure 18: W.A Government; Guy Chandller, Project Manager

CHAPTER 7: FUTURE STRATEGIES

7.1 Utilising energy asset's

It is critical to the modernisation of agriculture that renewables play a part in achieving sustainable practices. These are no longer new technologies passing through, but are here to stay. With significant government backing to big scale projects from large companies, we as farmers must implement renewables on farm simply to remain competitive. All areas of the farm must be looked at and assessed by competent individuals to find the best system fit for practice, as all farming systems vary. The low hanging fruit will generally be the installation of roof top solar PV panels on existing buildings, where cabling routes are minimal and the solar PV is close to the connection points and uses on-site. Where crop rotations that lack diversity are highlighted, consideration must be given to energy crops to improve rotational cropping, benefiting soil structures.

Figure 19: Keithick Biogas, Scotland; Authors own

Figure 20: Solar roof, Australia; Authors Own

7.2 Solar fences

Witnessing the Agvoltaics system at La Greenhouse in Italy there were clear opportunities for UK applications. Solar can be run on gantry systems along fence lines allowing energy to be generated from marginal land already marked out with fences. In doing so these structures would pull cabling infrastructure to field boundaries facilitating access to power.

Figure 19: Solar gantry, Italy; Authors Own

This may carry a higher cost as the panels are not so densely grouped and additional cable would be required. However, with increased infrastructure and connectivity, the ability to bring sensors and robotics into the field becomes more attractive, allowing key production decisions to be supported and profitability increased. As service tracks will be required, this additional lane would be incorporated into additional biodiversity belts with establishing wild grasses or native flora to increase the credentials and integrated pest management (IPM) benefits of these areas. Solar fencing is a low disturbance method of securing electrical generation from productive landscapes with added positive benefits to the biodiversity. As seen in Neice, France figure 24, the addition of green tramways has created additional areas for biodiversity bringing positive impacts to the area highlighting successful integration of biodiversity and infrastructure projects.

Figure 20: Crop boundary margin, Italy; Authors own

Figure 21: Biodiversity in margins, Scotland; Authors own

Figure 22: Biodiversity positive city tram ways, authors own

7.3 Rotational wind and solar power

Where good productive arable ground is required for electricity generation then modular wind and solar could be used in rotation. Modular systems already exist in the construction industries with remote sites and equipment being powered by solar technologies. In figure 25 a modular system can be seen providing power to construction works in metropolitan Perth, W.A. Farms should be looked at in a similar way, with many areas of potential from set aside areas, land with marginal productivity and biodiversity sites that can all be integrated with renewables.

Figure 23: Modular solar PV; Authors own

The energy production from 1 hectare of cropped land can produce an approximate 32MWh of energy based on 8 tonnes per hectare of wheat, compared with 480MWh from solar generated from a 500KW array (Goodall 2022). Equating this to approximate revenues; for solar power, electricity at 5p/KWh would be £22,500/ha and wheat at £195/tonne would be £1560/ha. This high profit generation reflects the current industry where mono-bloc solar farms are constructed in the most cost eff ective densely packed sites. Sites which often take land out of production for a contract period in the region of 30-40years. To run a fixed site for this long will inevitably see compaction issues along service routes, a need for chemical weed control as burdens build on the longer-term lays and reinstatement works to revive dormant soils. A much more ethical method of production would be to rotate such infrastructure on a modular basis and create a rotation. Such rotation could be carried out alongside or on top of fallow lands, or incorporated within Economical Focus Area EFA or Sustainable Farming Incentive SFI areas, 'Target management for pollinators on solar parks located in homogenous and intensive agricultural-dominated landscapes'(Blaydes et al. 2021:10) this will maximise the output of farmed assets. Speaking with Marcel Vroom, industrial designer from the Netherlands, there are good solutions in modular and robotic solar that can be used on productive agricultural ground. Interestingly the Netherlands cap the solar canopy of agricultural land at 10% and Germany caps at 15%, closely aligned with areas SFI or EFA in the UK.

'solar parks offer areas of land for enhancement with different geometries (i.e. squarer compared to conservation strips around arable fields), provide opportunities for the creation of different habitats and minimise the impacts of agricultural edge effects (e.g. spraying).' (Blaydes et al. 2021:11)

Furthermore, as stated by Blaydes et al. in research for Reading University, breaking up the landscape with renewable projects bring beneficial biodiversity in an area and can help mitigate any negative impact from agricultural operations.

7.4 Utilisation of renewables: HydroGlen, Glensaugh, North east Scotland

Having the chance to talk with senior scientist at The James Hutton institute, Professor Alison Hester explained the HydroGlen, a green (renewable) hydrogen farming community project. The project will study the feasibility of modular green hydrogen production on farm and how this can work for farming communities as part of the energy transition. Glensaugh currently has a 50KW wind turbine and 70KW of solar that will be used in the production of hydrogen, that will be stored on site. The hydrogen will go on to fuel vehicles and power machinery or be further processed by a fuel cell producing electricity on demand. Stored hydrogen is another form of battery power that has multiple uses, making it a flexible alternative to standard battery storage. Enabling farms to create their own fuel would build resilience to fluctuating market prices and help make farms more economically viable and sustainable. In finding a solution that works for rural communities farmers can once again move towards becoming energy self suffcient.

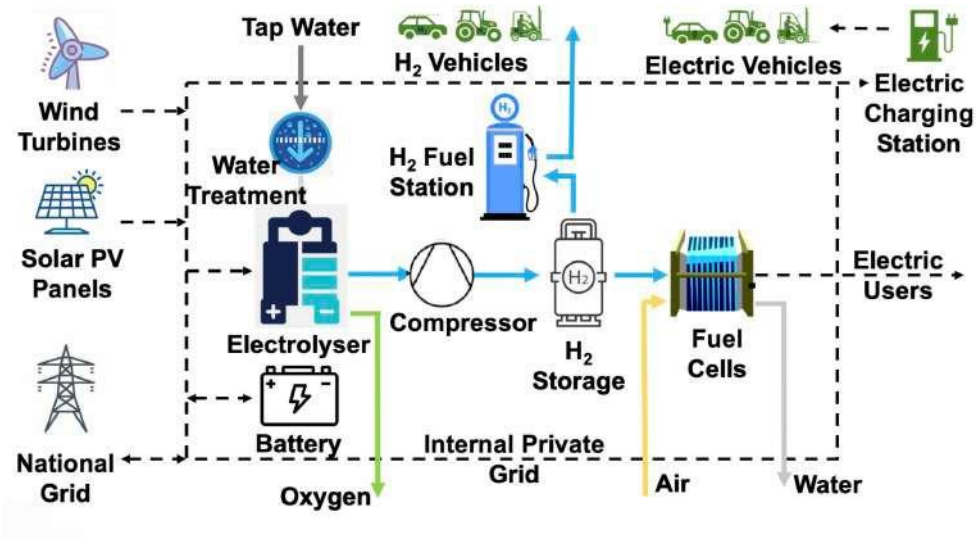

Figure 24: A Non-Technical Summary of the HydroGlen Project Feasibility Study, March 2021

CHAPTER 8: CONCLUSION

Currently with low KW prices being paid for electricity generated, renewable technology may only be justifiable on smaller projects where electricity is used onsite. For full utilisation of renewables, battery storage is necessary to cope with the ebbs and flows of power generation coupled with erratic usage from the end user, and this has cost implications. Technology is consistently advancing, resulting in lower cost solar and wind technology and the introduction of lower battery storage costs. This improved cost effectiveness will allow for the adoption of full systems for circular energy generation on farms, where inputs for production come from within the business. As a result, farms will once again become the self-sustaining engines of the countryside, powering themselves. We as farmers, will only be able to provide for the wider public when we can provide for our own energy needs. This vision of the future requires collaboration with energy distributers and the Government to unlock the full potential of the countryside as an electricity generator. This in turn will allow technology to become common place throughout agriculture, with low running costs enabling a leap forward in operations and the execution of productive agriculture in a sustainable manner, from "Gate to Grid".

Figure 25: Author, Scotland; Authors own

CHAPTER 9: RECOMMENDATIONS

1. Sweat your energy assets with:
    - Productive agriculture
    - Roof top solar PV
    - Fence-lines incorporating solar and wind renewable technologies
    - Fixed renewables on marginal ground and modular rotational systems on productive ground.
    - Rotational energy crops
2. Do not be negligent of the future; capitalise on government funding when available.
3. Government must enable farming to be part of the strategic energy solution for sustainable net zero.

CHAPTER 10: AFTER MY STUDY TOUR

It has been a real honour to have spent the last 18 months travelling and producing this report for the agricultural industry. I will continue to develop energy generation strategies for farmers and landowners alike. Upgrading infrastructure will be made a priority within the farming practices at home, working towards a self-suffcient business model. I will continue to pursue strategies that will safe guard the productive hectare, enabling future generations to live off the land.

Figure 26: For the next generation, Pecora Dairy; Authors own

It is our responsibility to become the life support for this living world.

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"He aha te mea nui? Māku e kii atu, he tāngata, he tāngata, he tāngata."

"What is the most important thing in the world? Well, let me tell you, it is people, it is people, it is people"

whakataukī (Māori proverb)

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GLOSSARY

W - Watt = a measure of the rate of energy transfer over a unit of time.

KW - Kilowatt = 1000 watts

MW - Megawatt = 1000 kilowatts

GW - Gigawatt = 1000 megawatts

TW - Terawatt = 1000 Gigawatts

1 k calorie per hour = 4.1868 k joules or 1.163 watts

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