The Industrial Biotechnology Innovation Centre



SUGAR BEET: A Just Transition for the Chemicals Sector and a Net Zero Solution for Manufacturing

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SUGAR BEET: A Just Transition

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CONTENTS

EXECUTIVE SUMMARY

Rationale

The need for a scalable, sustainable bio-based feedstock for the chemicals and industrial biotechnology industry has become more critical recently as the Scottish Government and UK Government have set a net zero mandate for 2045 and 2050 respectively. Sugar can be converted, through fermentation, into a wide range of bio-based chemical products including biochemicals, bioplastics and biofuels (including bioethanol) previously derived from petrochemicals. In turn, bioethanol can be used as a building block for a range of chemicals and products or used for fuel blending.

Currently Scotland imports bioethanol from outside the UK for fuel blending to meet the new E10 mandate requirement (September 2021). The increase to 10% bioethanol effectively doubled Scotland's demand overnight. Growing sugar beet in Scotland could create a local supply chain for this feedstock, and not only safeguard the Scottish chemicals sector of the future but provide substantial carbon savings.

Sugar also provides the essential source of carbon for a wide range of industrial biotechnology products – from food and feed ingredients, speciality chemicals and even medicines. The UK has an ambition to build a £440bn economy by 2030[1] , biotechnology and a secure supply of sugar will be vital to achieve this. By growing sugar beet as a sustainable source of carbon, the areas of chemical and industrial biotechnology in Scotland will have access to an alternative, net zero feedstock. This will ensure their sectors are future-proofed, enabling them to grow, create jobs and generate more sustainable supply chains.

This study explores the techno-economic analysis of the re-introduction of sugar beet as a rotational crop in Scotland for use as an industrial feedstock. It builds on evidence gathered through a feasibility study commissioned by Scottish Enterprise in 2019.

Key Findings

Crop trials in 2020, provided evidence that Scotland can grow sugar beet varieties at competitive yields. Many Scottish farmers already grow sugar beet for feed and biogas production. Sugar beet is grown as a break crop in the rotation, and this means it provides a break or a rest from the more intensively farmed cereal crops that dominate most arable rotations.

A break crop is sown to provide diversity to help reduce disease, pest and weed levels and improve soil health. As a break crop, sugar beet 'breaks' the cycle of many pests, weeds and diseases, and without this, these threats could increase and ultimately could mean the land is unsuitable for growing some crops. Sugar beet as break crop also reduces the need for pesticides.

Scotland can grow sugar beet on a strip of land that roughly parallels the east coast of Scotland from Angus down to the Borders. While sugar beet can be grown across a wide area, bioethanol production from the refined sugar is most cost-effective if done at a single large site at scale. A centralised model has very little risk attached and, indeed, such centralised bioethanol plants already exist globally. Creating smaller, regional processing units may be possible in the future, but the technology is still at an early stage of development and no commercial units are currently available.

1 https://www.gov.uk/government/publications/bioeconomy-strategy-2018-to-2030

EXECUTIVE SUMMARY

The optimal location for a centralised bioethanol plant is either in Grangemouth or Dundee. Dundee is the best location based on proximity to suitable agricultural land (most lying within 50 miles of the city). Grangemouth is the best location based on logistics and access to utilities as it has access to power generation, water treatment, an existing chemical cluster and a major port.

A realistic target would be to grow up to 1M tonnes of sugar beet within a 50-mile radius of a bioethanol processing plant, with a land requirement of between 10,000 and 15,000 Hectares (Ha). Assuming a relatively conservative yield of 60 tonnes per hectare, this area of land could grow sufficient sugar beet to produce 110 million litres of bioethanol; this is around 75% of Scotland's current bioethanol needs for transport. To meet 100% of Scotland's demand (145M litres), transport of sugar beet further than 50 miles of the plant could be considered. Despite increased transportation costs, financial modelling shows that this option is still viable.

This study developed its own financial modelling to understand the production cost of bioethanol. The model takes into consideration the full value chain, from farm to the bioethanol plant. The report's financial modelling suggests that it would be profitable for Scotland to grow its own sugar beet to manufacture bioethanol, as an initial target product. Three different scales were modelled (100M, 200M 400M litres, all operating at maximum 85% capacity) and the conclusions are that all of these options should be profitable. Larger plants are more efficient due to economies of scale but this is balanced against land availability to supply feedstock. The main drivers for financial viability of the plant are input costs of the raw materials (almost entirely beet price paid to farmers) and the output price for ethanol and related by-products (mainly feed and biogas). These variables were tested and provide confidence that all scales in the study can remain profitable within a wide range of cost/revenue values if production can remain near capacity (maximum 85%).

It will be challenging for Scotland to grow sufficient beet to supply a larger (300-400 litre) plant which are more typical globally. Imported sugar was considered to make up the shortfall were considered, though modelling shows importing sugar is not a viable option as the additional revenue streams from beet by-products are not available (biogas and animal feed). A further option identified as part of this study which could be considered is an ethanol plant utilising beet mixed with an alternative existing feedstock. This could de-risk the introduction of a new crop (beet) and make up any potential shortfalls but beet would be the preferred option. Another study on alternative crops would need to be undertaken as it was out with the scope of this report.

Though there is widespread support for innovation and transitioning industries to low carbon manufacturing, there is a clear gap in terms of support from governments at all levels sufficient to support a development of a new bio-based feedstock supply chain such as sugar beet (Scottish, UK & EU).

This report projects at least 815 additional jobs would be created directly through this project and as well as indirect jobs that will be created through the supply chain and logistics. Additionally, the development of a new sustainable feedstock would help safeguard some of the 11,000 existing jobs in the chemical industry and create new jobs in Scotland's ever growing biotechnology sector. Many of these jobs will be created in rural areas, and in some of the most deprived areas in Scotland.

Formation of a growers' co-operative will be essential to satisfy the needs on both supply and demand sides. Many Scottish farmers are already part of co-ops as they help reduce the risk of growing new crops, improve efficiency, and increase profit margins. An experienced professional team can manage

EXECUTIVE SUMMARY

all aspects of the process - crop establishment, agronomy, harvesting, to haulage, processing, and marketing -on behalf of co-op members without the need for additional overheads or equipment. Farmers will need clarity on the benefits and advantages of growing sugar beet, and the confidence of long-term (5-10 year) supply contracts at attractive pricing. A price point of £35 per tonne provides a very good return for farmers and is around the current price paid for beet grown on Scottish farms for biogas which benefits from renewable energy incentives. From the demand side, the ethanol producer only needs to work with a single supplier (rather than potentially hundreds of individual farmers). Contracts for pricing and delivery can be negotiated between plant operator and coop while the coop manages the farmers to ensure delivery schedules are met year on year.

Conclusion

Scotland could grow sufficient sugar beet as a rotation crop to feed a profitable 100 to 200-litre bioethanol plant, based at either Dundee or Grangemouth. A Scottish bioethanol plant could produce 170M litres of bioethanol per annum, meeting the needs of 100% of Scotland's bioethanol demand for E10 fuels, with a surplus for smaller chemicals and/or industrial biotechnology manufacturing. A larger plant may be viable by drawing an alternative feedstock such as wheat and could become a critical part of the total UK demand for almost 1.7Bn litres bioethanol.

Sugar beet offers an attractive new crop for Scotland's farmers, providing revenue and benefits to the soil and local biodiversity. In particular, sugar beet has a carbon footprint significantly lower than common crops including cereals, oilseed rape and pulses.

A domestic supply would capture the supply chain emissions associated with bioethanol production, capturing over 280,000 tonnes of CO_2 equivalent from the atmosphere, which is the same as removing almost 61,000 cars off the road per year. At present bioethanol is imported from Europe which incurs a substantial carbon footprint for Scotland currently.

Supporting sugar beet production would further the ambitions of the current administration in terms of securing economic prosperity and a sustainable environmental future, whilst positioning Scotland as a leading example within the UK domestic market. Policy incentives and levers to consider include financial measures that encourage domestic production or encourage re-location to Scotland for production purposes (grants, loan guarantees etc), and creating sustainability accreditation that goes beyond current carbon credits to include wider efforts in the supply chain to support the drive to net-zero. This study details successful policy mechanisms in the USA that should be considered in this space.

The growth of Scottish of sugar beet will create jobs, drive new opportunities for agriculture, and provide the essential bio-based sugar feedstock for accelerating growth of Scotland's industrial biotechnology sector and most importantly, secure a biobased alternative to fossil carbon for Scotland's manufacturing sector.

**If you have an enquiry relating to this report, please contact:
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1. Introduction

1.1. Purpose of the Study

This study was funded by Scottish Enterprise to gain insight into the techno-economics of re-establishing a sugar beet supply chain in Scotland as a feedstock for industrial chemical / fuel manufacturing. The rationale for the study was three-fold; to locally manufacture bioethanol instead of relying on imports, to safe-guard the future of the Scottish chemical manufacturing industry by enabling biobased production of in-demand chemicals, and to develop a sustainable Scottish bioeconomy by introducing a feedstock which can be used in a wide range of biobased processes to make green products.

Grangemouth is home to Scotland's sole refinery and a high proportion of the nation's chemicals manufacturing. *The Future Grangemouth Vision 2025*[2] set out a vision for Grangemouth to be globally recognised as a main location for biorefining using industrial biotechnologies as part of the chemical manufacturing process, with pilot and demonstration facilities alongside full-scale manufacturing facilities. It also sets out a goal for Grangemouth to accommodate a globally competitive refinery with reduced support costs and improved supply chain management capabilities, focusing not just on traditional refining but also on biofuels.

Grangemouth is a major source of emissions, given the energy intensive industries based at this site, it produces over 4M tonnes of CO2 per annum. The Scottish Government has legislated for Scotland to have net-zero carbon emissions by 2045 and at the UK level HM Government's net zero target is by 2050. This means that many industries must change the way they currently operate.

Following on from the net-zero targets announced by both governments, many large multinationals have since announced that they will be changing the way they manufacture and purchase in the future which will impact on their current supply chain.

Several major chemicals companies have made pledges to use eliminate fossil-derived carbon from their supply chains[3,4,5]. Currently Scottish chemical manufacturing is heavily reliant of fossil-derived carbon. However, change will be needed to continue to sell into these large multinationals and ensure Scotland's chemical industry remains competitive internationally.

As of 1st September 2021, the UK has mandated that all petroleum will be E10 increasing the Ethanol (E) content from the current E5. Scotland currently imports all of its bioethanol from Europe as it has no means to manufacture its own at scale. Following the move to E10, we expect imports of bioethanol to double. Pre-COVID the UK demand for petrol was almost 17Bn litres of petrol demonstrating a demand for around 1.7Bn litres of ethanol in total now E10 has been introduced. Reintroducing sugar beet growth means Scotland would have the ability to re-shore its bioethanol supply chain and reduce its carbon footprint by manufacturing locally. Current UK capacity is less than 1Bn litres and supplied mainly by to plants operating on Teesside (Crop Energies AG, formally Ensus) and Humberside (Vivergo) each of which has a maximum capacity of around 400M litres. A 170M litre biorefinery in Scotland could meet the country's total demand with some additional ethanol for chemical and industrial biotechnology processes.

This study follows on from a feasibility study ("An Assessment of the Opportunities for Re-establishing Sugar Beet Production and Processing in Scotland") undertaken by the National Non-Food Crops Centre

2 https://www.evaluationsonline.org.uk/evaluations/Browse.do?ui=browse&action=show&id=636&taxonomy=CHE
3 https://www.croda.com/en-gb/sustainability
4 https://www.unilever.com/planet-and-society/
5 https://www.loreal.com/en/commitments-and-responsibilities/for-the-planet/

1. Introduction

(NNFCC) – The Bioeconomy Consultants in 2019[6].

The feasibility study yielded positive outcomes and suggested some recommendations for follow on work, which included:

- Work with SRUC, SSCR at The James Hutton Institute or Scottish Agronomy, to establish variety trials in Scotland, to identify the best suited modern variety and to verify yield potential.
- Liaise with the National Farmers Union Scotland, to engage with farmers in the early stages, to allow any concerns to be addressed from the outset.
- Identify any pre-existing grower groups or collectives who may have a particular interest in the sugar beet industry or be looking for solutions to address production challenges currently faced.
- Undertake further work on markets for co-product streams from bioethanol production, to ensure processing efforts are demand-driven; this will enable plant configuration and the range of outputs to be optimised from the outset, to deliver the most economically robust and stable development. A number of potential partners have been identified in this work, but others undertaking research or early- stage development work may exist and should be engaged, should the project be pursued.
- Undertake further analysis on technical and commercial opportunities for importing molasses as a feedstock for the processing facility, to make use of the redundant capacity when sugar beet is no longer available, prior to the following years harvest; knowledge gaps remain on the technical requirements, specifically the compatibility and ability to switch between feedstocks, the environmental impact and lifecycle GHG emissions, and the economics of importing molasses to produce ethanol for local supply.
- Engage with operators at Grangemouth refinery, to explore options for supply of bioethanol, for local blending into the Scottish transport fleet.
- Engage with Scottish Government to communicate the contribution a local processing facility would make to decarbonisation targets, energy and food security objectives, and the wider Scottish economy.
- Seek public-sector support, in the form of supply chain facilitation, direct investment or specific legislative mandates for producing or using the biobased fuel, chemical and energy outputs from such a facility domestically.

Since the conclusion of the feasibility study, Scottish Enterprise and partners have been working to address these recommendations, many of which are covered in this techno-economic study.

1.2. Progress to Date

1.2.1. Sugar Beet Crop Trials

Following on from the recommendations set out in the feasibility study, crop trials were undertaken by the James Hutton Institute (JHI) and four grower sites s across the east coast of Scotland. These sites included the JHI based in Invergowrie, Stracathro Estates based in Angus, Peacehill, Wormit in Fife, Charlesfield, St Boswells in the Borders, and Savock, Ellon in Aberdeenshire.

Trials were organised in the spring of 2020 shortly after the establishment of the Sugar Beet Working Group (SBWG). The SBWG is discussed in more depth in the next section. A randomised trial was also established at JHI. Small scale demo crops were established on the four farms, which were already growing beet as a feedstock for their AD plants. 0.2 Hectare bags of seed were obtained for five sugar beet varieties for each demo farm. The results can be found in chapter 4.

6 https://www.nnfcc.co.uk/publications/report-sugar-beet-scotland

1. Introduction

Figure 1: Aerial view of growth site

Each site grew five different beet varieties (Degas, Eldorana and Hadyn from Xbeet, Flixter from Maribo and BTS 1140) (see Figure 2 below).

Figure 2: The five varieties of sugar beet trialled across Scottish sites

1. Introduction

1.2.2.RISS Group Work

Following on from the feasibility report publication, Scottish Enterprise (SE) applied for support from the Rural Innovation Support Service (RISS). RISS is a jointly funded initiative through the European Commission and the Scottish Government which provides professional consultancy support for novel agricultural projects. Through the initiative, SE received support from Scottish Agricultural College Consultancy (SACC). SACC developed the Sugar Beet Working Group to take the project forward.

The Sugar Beet Working Group (SBWG) is a collection of organisations, farmers and agricultural supply chain groups who are keen to re-establish the sugar beet crop on farms in eastern Scotland with a view to supplying the raw material for fuel additive and bioplastic manufacturing.

Members of the group include farmers, IBioIC, SAC Consulting, JHI, the Scottish Agricultural Organisation Society Ltd (SAOS), National Farmers Union of Scotland (NFUS), Agricultural Co-ops, Agricultural supply trade and Machinery Rings.

The group was formed in February 2020, assisted by £9k of Scottish Government RISS funding for facilitator support delivered by SAC Consulting, part of SRUC. RISS funding was targeted at farmer groups to provide facilitation and access to industry expertise to take an idea, scope it, refine it and turn it into a project plan. Focusing primarily on agricultural production to initial refining stage (farm to refinery), the group built on the findings of the NNFCC Feasibility study through regular meetings from March to August 2020, and a core group has continued to meet monthly thereafter. An Open Meeting was held in February 2020 in Dundee, with 46 attending, mainly farmers, agricultural Co-ops, agricultural contractors, and industry organisations, who were generally positive about the re-introduction of sugar beet, with many volunteering to join the RISS group. The Sugar Beet Working Group (SBWG) took a number of actions around the issues outlined below.

- **Aligning farmers and chemical industry objectives** Bringing together the farmers who would grow the crop with those in IBioIC with chemical industry knowledge, to ensure that the group worked cohesively toward a unified objective.
- **Growing and harvesting** Several farmers grow energy beet and sugar beet as a feedstock for Anaerobic Digestion plants. The group drew on their experience and organised some field demonstrations of sugar beet varieties in 2020. JHI organised some small-scale trials near Dundee. Agronomy and machinery requirements were also discussed.
- **Governance and structure** The group identified a clear need for production and sales to be overseen by a Co-op or Producer Group, and to provide professional organisation and collective bargaining power. SAOS provided guidance in this area.
- **Processing** The group discussed two models: a central refinery for all production; smaller local processing hubs that produce a concentrated sugar syrup that is less bulky than sugar beet and can then be transported to a chemical plant for further processing.
- **Publicity and Influencing** The group identified the four key groups that needed to be influenced if the initiative was to prove successful – farmers, government ministers, investors, and industrial chemical companies. A press campaign was initiated to publicise the groups objectives.
- **Carbon accounting** Making the case for use of plant-derived feedstock to replace fossil fuels in ethanol and bioplastic manufacturing, and how farmers might be credited financially for their contribution to Scottish industrial decarbonisation.

1. Introduction

1.2.2.1.Next steps

The key next step identified from RISS was to obtain funding to undertake a detailed viability study, building on the NNFCC report but specific to local conditions and current markets. The main issues that were identified and needed to be addressed in the study were:

- Fully understanding the opportunities for the Scottish chemical sector and bioeconomy.
- Understand the political implications.
- Explore the land availability and production processes required.
- Explore models for production including cooperatives.
- Develop a financial model to understand the costs associated with the full value chain.
- Explore potential options for financing the project.

Following on from the recommendations outlined in the NNFCC feasibility study, and the recommendations from the RISS group, this Technoeconomic Analysis and report aims to address many of these. The chapters covered in this report include economics (both agricultural and chemical), carbon accounting and societal benefits, cooperative structure, and investment. A model to understand the economics and investment has been developed to compliment the work in this report.

2. Economics

2.1. Market Analysis

2.1.1. UK Bioethanol Overview

As of the 1 September 2021 the standard (E5) petrol grade in the UK (excluding N.I.) became E10. E10 petrol contains up to 10% renewable ethanol, which will help reduce carbon dioxide (CO_2) emissions associated with petrol vehicles, currently only up to a 5% blend of bioethanol (E5) is used. E10 petrol is already widely used around the world including Europe, the US and Australia[7].

CO_2 is one of the greenhouse gases that contribute to climate change and the main benefit of E10 is it reduces the overall levels of CO_2-based vehicle emissions. By blending petrol with up to 10% renewable ethanol, less fossil fuel is needed, helping to reduce carbon emissions and meet climate change targets.

This change in legislation means that the volume of bioethanol required for blending in the UK will double to satisfy demand. The UK has the capacity to produce 1.5B litres of biofuels, and 890M litres of bioethanol. Pre-COVID the UK used 16.9Bn litres of petrol [8]. Now that E10 has been mandated, it is estimated the UK will require approximately 1.7Bn litres of ethanol for blending. Based on the NNFCC report, Scotland requires 145M litres to meet the Scottish demand for E10, which is approximately 9% of the UK's requirement.

The UK currently has three plants – Vivergo, Crop Energies and British Sugar - which together have a capacity to produce 890 million Litres of bioethanol per annum. These plants are all based in England, see Figure 3 below.

Figure 3: UK Biofuels production sites[9]

7 https://www.gov.uk/guidance/e10-petrol-explained
8 https://www.racfoundation.org/data/volume-petrol-diesel-consumed-uk-over-time-by-year – accessed 12-10-21
9 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/308142/uk-biofuel-producer.pdf

2. Economics

Company	Location	Year of Operation	Investment (£ millions)	Owners	Jobs	Capacity (M litres)	Feedstock
British Sugar	Wissington, Norfolk	2007	-	British Sugar	30	70	Sugar Beet
Crop Energies AG (formerly Ensus)	Wilton, Teesside	2010	£310	Crop Energies AG	100	400	Wheat
Vivergo	Immingham, Hull	2013	£350	AB Sugar, BP, DuPont	80	420	Wheat

Table 1: Overview of UK Bioethanol Plants

British Sugar

British Sugar opened the UK's first bioethanol plant in 2007 at Wissington, Norfolk. The plant produces up to 55 kTonnes (70 million litres) of bioethanol per year and uses around 650 kT of sugar beet (equivalent to around 110 kTonnes of sugar) as the feedstock.

The Wissington biofuel plant is co-located next to an existing sugar plant which supplies 400 kT of sugar and 100 kTonnes of dry animal feed per year, as well as a variety of other products (including topsoil and lime). The plant also captures the carbon dioxide from the sugar fermentation which is sold to the food and drink sector. The site employs 240 people in total, of which around 30 are directly involved in the biofuel plant[10].

Vivergo

Vivergo officially opened the UK's largest biofuel plant in July 2013, at a cost of £350 million (initial production started in Q4 2012). At full capacity the plant can produce up to 420 million litres of bioethanol per year and 500 ktonne of animal feed as a co-product, utilising 1,100 ktonne of (locally grown) feed grade wheat per year[11].
Vivergo is a joint-venture between AB Sugar, BP and DuPont, set up in 2007. The company employs 80 people directly. In addition, Vivergo estimates that over 1,000 additional jobs are supported through the supply chain (including agriculture, logistics, professional services, engineering support and other fields)[12].

In September 2019, Vivergo also ceased operations due to the ethanol price, input (wheat) price and the uncertainty around E10 in the UK. Now the UK government has mandated E10 the Vivergo plant will

10 https://www.britishsugar.co.uk/Bioethanol.aspx
11 Wheat yields are typically 7te / ha in the UK. 1,100 kTe requires 157,000ha land
12 https://vivergofuels.com

2. Economics

resume operations in early 2022[13].

Crop Energies AG (formerly Ensus)

Ensus, now Crop Energies AG, started up its bioethanol plant at the Wilton International site on Teesside early in 2010. The plant refines around a million tonnes of UK grown feed grade wheat to produce over 400 million litres of bioethanol and 350 kTonne of high protein animal feed per year[14].

The plant also captures 300 kTonne of pure carbon dioxide each year, which is liquefied on site and sold to Yara for distribution to food, drinks and industrial customers in the UK and Europe[15].

In July 2013 the plant was purchased by German company, CropEnergies AG, who also operate bioethanol plants in Germany, Belgium, and France with a total production capacity of around 1.2 billion litres of bioethanol per year.

The biorefinery initially cost around £250 million to build and a further £60 million investment has subsequently been made. Crop Energies AG also intend to invest an additional £50 million in improving the competitiveness of the site. The plant directly employs around 100 people, and according to Crop Energies also supports 2,000 jobs in the wider supply chain, including farmers, hauliers, engineering support and storage firms.

The plant halted production in November 2018 due to high wheat prices affecting the security of its feedstock but is due to restart production to support the UK's move to E10.

Conclusion

To satisfy the bioethanol demand required to meet blending obligations for E10, the UK will require nearly 1.7 billion litres. Current capacity is less than 900M litres demonstrating a clear gap which could be partially filled with new Scottish capacity.

There is currently no bioethanol production in Scotland[16], meaning Scotland's sole refinery Petroineos must import all bioethanol to Scotland for fuel blending.

2.1.2.Products Derived from Bioethanol and Sugar

The chemicals industry in Scotland is estimated to be worth £4.4 billion per annum in exports[17]. There are at least 250 companies operating in the chemicals industry in Scotland including multinationals such as INEOS, Fujifilm, and GlaxoSmithKline.

The petrochemical industry manufactures many of the key raw materials for the wider chemicals industry.

13 https://vivergofuels.com/news/vivergo-fuels-site-in-hull-set-to-re-open-as-department-for-transport-mandate-e10-fuel-from-september/
14 https://www.ensus.co.uk/Home/
15 https://www.yara.co.uk
16 Scotland obviously has a long and distinguished history in "bioethanol" manufacturing, namely its whisky industry. It is informative to note that the Cameron Bridge Distillery operated by Diageo makes around §30M litres of distilled spirt annually. The scale of the Cameron Bridge distillery is of a similar magnitude to the proposed biorefinery. William Grant's Girvan distillery makes a similar quantity of spirit each year (115M litres)
17 https://www.sdi.co.uk/key-sectors/chemical-sciences

2. Economics

These raw materials are primarily derived from oil and gas.
One key raw material produced by the petrochemicals industry is ethylene. Ethylene can be produced a number of ways, but the main method currently employed is steam cracking of hydrocarbons. Global production of ethylene exceeds any other chemical. Over 150 million MT of ethylene was manufactured globally in 2016 and it is a key starting block for a number of other critically important chemical products which include:

- Polyethylene (over 100MT of polyethylene resins were produced in 2017 which accounts for 34% of the plastics industry).
- Ethylene oxide which is a key raw material in the production of surfactants and detergents. It is also used to manufacture ethylene glycol which is a raw material in the manufacture of polyester fibres and in antifreeze formulations.
- Ethyl benzene that can be converted to styrene, which is the basis of polystyrene and in styrene-butadiene rubber for tyres and footwear.

However, ethylene can also be produced by dehydration of ethanol that can be produced biosynthetically by fermentation of the sugar contained in a range of different crops including sugar beet. Bio-based ethanol can also be used as a biofuel and in sanitiser formulations. Therefore, there is an opportunity to build a bio-based chemical industry in Scotland that is derived from sugar beet (see figure 4). In addition, sugar derived from sugar beet can also be converted to a range of other bio-based chemicals used in a diverse range of market sectors including pharmaceuticals, surfactants, solvents and food additives.

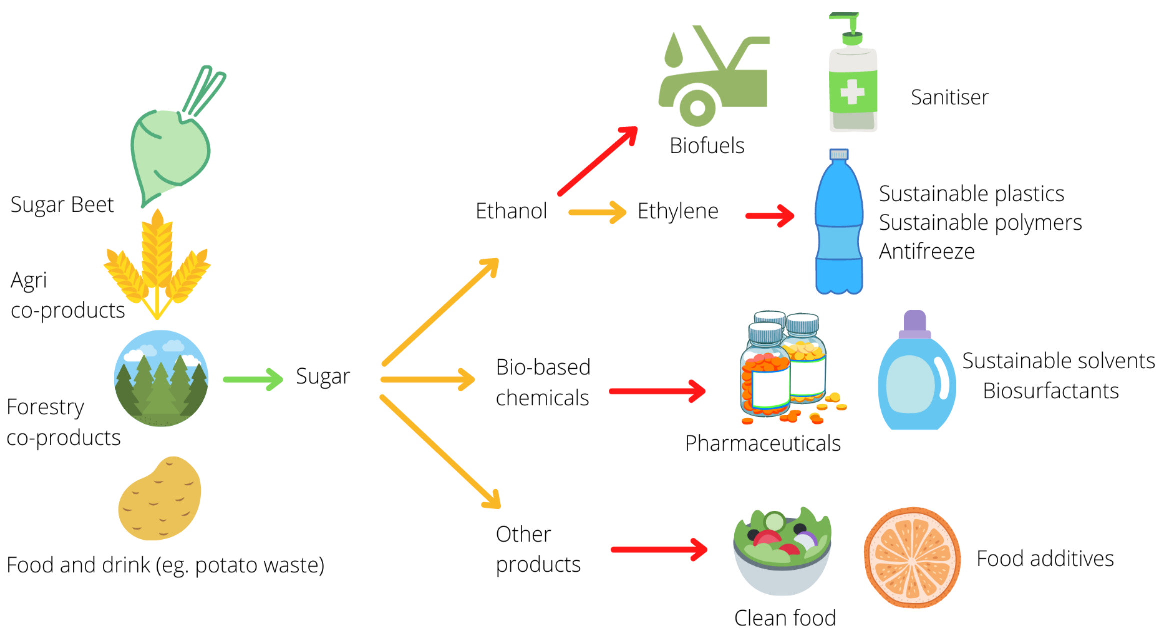

Figure 4: Schematic of products derived from sugar beet

2. Economics

2.1.3. Scottish Companies Benefiting from Sugar Supply Chain

The Scottish Industrial Biotechnology Sector

The National Plan for Industrial Biotechnology set out goals to have a £900m turnover and 200 companies active in industrial biotechnology (IB) by 2025[18]. Many of the IB companies in Scotland have developed microbial fermentation processes. Local sugar could provide a feedstock for fermentation. The introduction of a Scottish sugar supply chain would help to anchor companies in Scotland as well as attract inward investment into the country.

Glaxo Smith Kline

Glaxo Smith Kline (GSK) have a footprint in Scotland and have two facilities based in Irvine and Montrose[19]. GSK's site in Irvine accommodates a major proportion of its secondary global production operations. It produces. Wide range of chemicals and antibiotics, including Penicillin G, which is used to treat many different types of severe infections. To manufacture Penicillin a glucose feedstock is required and currently GSK relies on imported glucose so a local sugar source would be highly beneficial for their production process.

As well as deriving value from the sugar extracted from sugar beet, the by-products can also be valuable. The NNFCC Feasibility study outlined the potential opportunities for by-products and side streams. Not all of these opportunities will be realised in Scotland but there are existing Scottish companies that have capabilities and an interest in utilising sugar beet by-products and side streams as sustainable feedstocks.

Cellucomp

Cellucomp is a Scottish-based company located in Fife. They have developed a process for producing materials from micro fibrillated cellulose from root vegetables, including sugar beet. Cellucomp extract cellulose nanofibers to produce their proprietary product Curran® which allows for the production of composites with performance characteristics comparable to those based on conventional carbon fibre technology. Biocomposites based on Curran® can be based on a variety of conventional resins such as epoxy, polyurethane, and polyester. The platelet structure of Curran® fibres makes them effective rheology modifiers in end uses such as paints and coatings, concrete, drilling fluids, cosmetics, personal care, and home care products. The same platelet structure provides impressive reinforcing effects in paints and coatings, concrete and some personal care products with 'anti-cracking' properties[20].

Enough

Enough have developed a sustainable protein source, Abunda, which is produced by fermenting fungi with sugar. Enough's process to produce Abunda through a zero-waste fermentation process which recycles water. Enough co-locates with bioethanol facilities to utilise their wastewater and if a facility was in Scotland, it would offer them a plant to co-locate their production with. As the world's population grows, so does the demand for food, the development of sustainable food sources will become increasingly important as well as playing a key role in reducing carbon emissions.[21]

18 https://www.sdi.co.uk/media/1673/national-plan-for-ib-2019-pdf.pdf
19 https://www.gsk.com/en-gb/contact-us/worldwide/united-kingdom/
20 https://www.cellucomp.com
21 https://www.enough-food.com

2. Economics

2.1.4 Inward Investment

The introduction of sugar beet is an attractive offering for Scotland as it may attract companies who are looking to utilise a biobased, sustainable feedstock for manufacturing to the region. A major plastic manufacturer has already expressed an interest in Grangemouth as a suitable location for a new biobased plastics plant if a suitable sugar beet supply chain was in place.

2.1.5. Use of Alternative Feedstocks

Ethanol can also be produced using alternative feedstocks other than sugar beet, which are described in this section.

Corn and Sugar Cane

In North America, corn is the most widely used feedstock for bioethanol production, primarily in the Midwest. Nearly 90% of ethanol plants are dry mill due to lower capital costs. Dry milling is a process that grinds corn into flour and ferments it into ethanol and co-products of distillers' grains and carbon dioxide[22].

In South America, sugar cane is the most widely used as it readily grows in this region. Brazil is the world's largest sugarcane ethanol producer, in 2019-20 is produced nearly 32.5 billion litres. Biofuels now play a central role in Brazil's low carbon emissions strategy where most of their ethanol is absorbed by the domestic market as either pure ethanol (E100) or blended with petroleum (E27)[23]. American bioethanol plants are discussed in more detail in chapter 6 when exploring different cooperative models.

Scotland doesn't have the correct climate to grow either corn or sugar cane, but is ideally suited to grow sugar beet to produce bioethanol.

Starch Feedstocks – potatoes

The main starch-based feedstock currently grown in Scotland and could be used to produce ethanol are potatoes. In 2019 28,500 Ha of Scottish arable land was used to grow potatoes[24].

Scotland has a reputation for growing high quality potatoes, particularly seed potatoes. This is reflected in the price that can be achieved by farmers, currently the highest priced potatoes, Agria potatoes, can achieve a price as high as £400/t and even the lower priced potatoes, such as Maris Piper, can achieve £200/t. When compared with the price per ton of sugar beet, it would make no economic sense for farmers to grow potatoes as a sugar source for ethanol[25].

Until recently there was significant quantities of brock (waste) potatoes from packing units within Scotland, made up of damaged, diseased, and out-of-specification potatoes that did not meet the retailers' requirements. However, in the last few years the retailers have been looking to reduce waste as a part of their sustainability strategies and have instructed the processors to pass the rejected potatoes over the graders a number of times to create new potato Stock Keeping Units (SKUs) (such as Baking Potatoes, small potatoes, misshapen potatoes etc.) on their shelves. This has reduced the volume of

22 https://afdc.energy.gov/fuels/ethanol_production.html
23 https://www.sugarcane.org/sugarcane-products/ethanol/
24 https://www.gov.scot/publications/final-results-june-2019-agricultural-census/pages/5/
25 https://www.fwi.co.uk/prices-trends/arable-prices/potato-prices

2. Economics

brock potatoes considerably in Scotland meaning that a high-volume potential feedstock is now almost insignificant.

Cellulosic Feedstocks

Cellulosic feedstocks are non-food based and include crop residues, wood residues and dedicated energy crops. These feedstocks are composed of cellulose, hemicellulose, and lignin. In Scotland the most abundant is woody lignocellulosic biomass. However, it's more challenging to release the sugars in these feedstocks for conversion to ethanol. The process is 2-step:

First, lignocellulose must be pre-treated in order to separate lignin from cellulose and enhance the penetration of hydrolysis agents without the chemical destruction of cellulose and hemicellulose. Second, the pre-treated cellulose is converted to ethanol by hydrolysis and fermentation. The pre-treatment stage is very energy intensive compared with sugar beet and the upstreaming processing is much more costly.

There are some innovative pre-treatment technologies currently in development which are much less energy intensive, however these are still at pre-commercial stages.

In summary, given range of crops that can be grown in the Scottish climate, and ease of sugar extraction, sugar beet is the only viable source of biomass for producing bioethanol in Scotland.

2. Economics

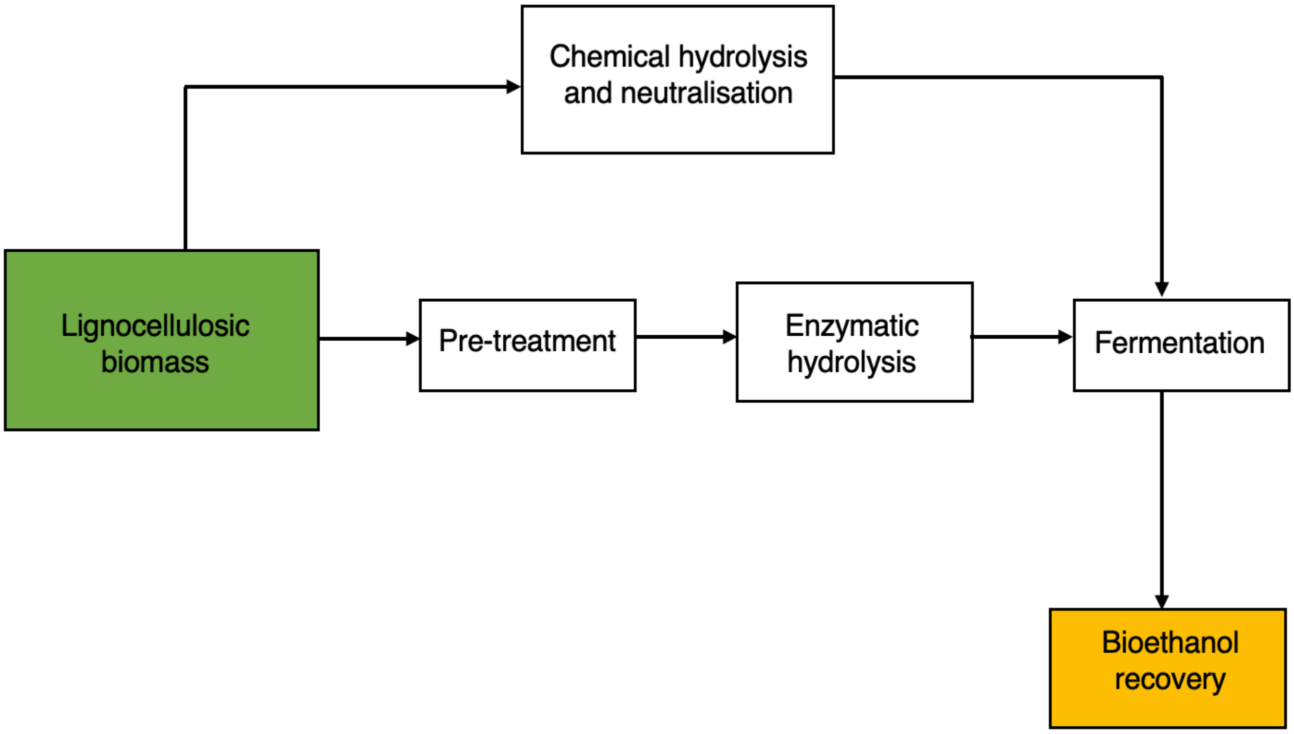

Figure 5: Schematic process of lignocellulose to ethanol[26]

Wheat

Wheat is used to produce bioethanol, as discussed above, at both Crop Energies AG and Vivergo in the UK. We understand that wheat-derived ethanol is cost effective at a wheat price of less than £135 per tonne (te)[27] . UK wheat prices are currently over £206/te[28] and have only been less than £135 for a short period between mid 2014-mid 2017.

A mixed beet-wheat ethanol plant could be viable with beet as the preferred feedstock and wheat making up any shortfall, subject to the economics being viable. Another study on alternative crops would need to be undertaken as it was out with the scope of this report.

26 https://www.intechopen.com/chapters/67553
27 Personal communication, Ian Archer, IBioIC.
28 https://ahdb.org.uk/cereals-oilseeds-markets

3. Policy Landscape

Introduction: political context

The Scottish Government's Programme for Government is published every year at the beginning of September and provides information on action the Scottish Government intends to take, including the legislative programme for the next parliamentary year. The latest 2021-22 Programme for Government was published on Tuesday 7 September and was the first jointly negotiated between the SNP and the Scottish Green Party. Plans for a Circular Economy Bill had been included in the 2019-20 Programme for Government, but work was paused due to the pandemic. The government has said this will now be introduced "later in the parliamentary session".

Following this year's election, Michael Matheson was appointed Cabinet Secretary for Net Zero, Energy & Transport. He has responsibilities for areas including cross-government co-ordination of Net Zero policy; circular economy; renewable energy industries; National Public Energy Agency; and Zero Waste Scotland. Mairi Gougeon is Cabinet Secretary for Rural Affairs & Islands, with her responsibilities including agriculture.

The 2021 SNP manifesto included a commitment to hold an independence referendum once the immediate COVID-19 crisis had passed. This is expected to take place by the end of 2023. A draft Independence Referendum Bill was introduced in March 2021. Currently the UK Government has said it would not consent to a new referendum and the Conservative, Labour and Liberal Democrats in Scotland have also rejected plans for a vote to take place in the immediacy. The SNP intends to take legal action if it is blocked from holding a referendum in the event MSPs vote in favour of the Referendum Bill.

The Scottish Government and Scottish Green Party published details of a co-operation agreement and shared policy programme on Friday 20 August. The programme is expected to develop during the parliamentary session and proposals for amendments can be made by either the government or the Green Group (GG). The government will consult the GG on its Programme for Government, legislative programme, and non-legislative strategies.
The agreement included commitments on holding an independence referendum; Sectoral Just Transition Plans across chemicals, nuclear and other industries; support for continued/accelerated deployment of renewable energy, including growth of the supply chain and infrastructure; set out the process to deliver a draft of the next Climate Change Plan for consideration in the first half of this parliamentary session; and the introduction of a Bill to replace the current Common Agricultural Policy framework in 2023.

Patrick Harvie is now Minister for Zero Carbon Buildings, Active Travel & Tenants' Rights, with responsibility for areas including energy efficiency, heat networks, heating, and domestic energy transformation, and serving as a member of the Cabinet Sub-Committee on Legislation. Lorna Slater is now Minister for Green Skills, Circular Economy & Biodiversity and her responsibilities include Green Industrial Strategy, Zero Waste Scotland, plant health, nature recovery targets, biodiversity, and serving as a member of the Cabinet Sub-Committee on Climate Emergency.

The Queen's Speech (11 May 2021) made a number of references to innovation and related funding, including the £400m "Strength In Places" Fund[29], which has made investments in Glasgow, Edinburgh, Belfast, Cardiff, Bristol, Liverpool, and Kent. BEIS published an Innovation Strategy[30] this summer and will invest £14.9bn in R&D in 21-22 and includes funding for association to Horizon Europe, investing at least £490 million in Innovate UK in 2021-22 and providing £800 million by 2024-25 for a new Advanced Research and Invention Agency (ARIA). Life sciences and R&D are key commitments in the Queen's

29 https://www.ukri.org/our-work/our-main-funds/strength-in-places-fund/
30 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf

3. Policy Landscape

Speech and a new Life Sciences strategy[31] was published in July 2021.

The Net Zero Innovation Portfolio is a £1 billion fund, announced in the Prime Minister's ten-point plan for a green industrial revolution[32], to accelerate the commercialisation of low-carbon technologies, systems and business models in power, buildings, and industry. This replaces the BEIS Energy Innovation Programme (EIP) which ran from 2015-2021.

The UK Government will publish[33] a Levelling Up White Paper later this year, which will focus on policy interventions to improve livelihoods across the UK during the pandemic recovery. It will also focus on improving living standards, growing the private sector, and increasing and spreading opportunity. Potential areas of constitutional friction could come from the Internal Market Act 2020, which legislates for the replacement of EU Structural Funds. Prior to the Act, the Scottish Government had control over the spending it received from the EU, to invest in sectors to produce smart, sustainable, and inclusive growth. From 2014-20, £780m of investment was delivered through this funding, including the £30.7m Resource Efficient Circular Economy programme administered by Zero Wate Scotland.

31 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf
32 https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution
33 https://www.gov.uk/government/news/government-to-publish-levelling-up-white-paper

3. Policy Landscape

3.1.1. UK and Scottish Government Policy

KEY	Policy at UK level inc HM Government
	Policy at Scotland level inc Scottish Government
Policy Area	Name of policy document
Bioeconomy	Growing the Bioeconomy: A National Bioeconomy Strategy to 2030 (2018)
Bioenergy	Clean Growth Strategy (2017)
	Bioenergy Action Plan (expected 2023)
Biomass	Biomass strategy (expected 2022)
	Net Zero Innovation Portfolio Biomass Feedstocks Innovation Programme (2021)
Chemicals	Chemical Science Scotland Eight-year strategic plan (2018) *backed by the Scottish Government
	Shaping Scotland's Economy: Scotland's Inward Investment Plan (2020)
Circular economy	Making Things Last (2016)
	Circular Economy Bill expected (2021/22)
Energy	Energy White Paper (2020)
	Scottish Energy Strategy (2017)
Industrial Biotechnology	Scottish Industrial Biotechnology Development Group (SIBDG) National Plan for Industrial Biotechnology (2019) *backed by Scottish Government (update expected 2022)
	The Biorefinery roadmap for Scotland (2019)
Land use, agriculture, & rural innovation	Agri-renewables strategy for Scotland (2014)
	Scotland's Third Land Use Strategy 2021-26 (2021)
	Scottish Rural Development Programme (2021)
	Stability and Simplicity (2018)
	A Future Strategy for Scottish Agriculture: Final Report by the Scottish Government's Agriculture Champions (2018)
Net zero & climate change	Ten Point Plan for a Green Industrial Revolution (2020)
	Climate Change Plan (2020 last update)
	Just Transition Commission
Soil & crops	Plant biosecurity strategy for Great Britain (2014)
	Scottish Plant Health Strategy (2016)
CLIMATE CROPS	*No relevant strategies or publications that support energy crops for carbon sequestration or bio-based manufacturing*

Table 2: Relevant policy for the sugar beet project

3. Policy Landscape

Please note that given the reserved and devolved nature of policy areas, there will be gaps in the table above.

Bioeconomy

A refreshed National Plan for Industrial Biotechnology[34] was launched in 2019, with the aim of boosting industry growth and innovation while also raising public awareness. Key themes include skills, innovation, biorefining and industry engagement. The plan will next be refreshed in 2022. The UK Government published Growing the Bioeconomy: A National Bioeconomy Strategy to 2030[35] in 2018. Its four main goals were to maximise productivity and potential from existing UK bioeconomy assets; create the right societal and market conditions to allow novel bio-based products and services to thrive; capitalise on research, development, and innovation to grow the bioeconomy; and deliver real, measurable benefits for the UK economy.

Chemicals

Chemical policy is a mixture of reserved and devolved competence. Environmental protection, waste management and public health are devolved while product safety, animal testing and health and safety at work are reserved. The EU REACH[36] Regulation was brought into UK law on 1 January 2021 and is known as UK REACH[37].

In 2018 Chemical Science Scotland published its eight-year strategic plan[38], which was backed by the Scottish Government. Priorities included creating a key European hub in Grangemouth for the chemical sciences cluster, growing industrial biotechnology-related turnover in Scotland to £900m and establishing biorefinery and biochemical operations in Scotland. Shaping Scotland's Economy: Scotland's Inward Investment Plan[39], published in October 2020, includes the transformation of chemical industries as one on the nine identified priority areas for Scotland's inward investment activities.

Biomass

The UK Government has also committed to publishing a new Biomass Strategy in 2022, which will set out the amount of sustainable biomass available to the UK and how this can be best utilised. A consultation on the strategy[40] was launched on 20 April 2021 and closed on 15 June 2021. Views are sought on areas including availability of sustainable biomass from domestic and international sources, the sustainability of the supply chain, accounting of greenhouse gas emissions from biomass use, and opportunities for innovation to support wider deployment of technologies with potential to support net zero.

As part of the Net Zero Innovation Portfolio, a Biomass Feedstocks Innovation Programme[41] has been

34 https://www.sdi.co.uk/media/1673/national-plan-for-ib-2019-pdf.pdf
35 https://www.gov.uk/government/publications/bioeconomy-strategy-2018-to-2030/growing-the-bioeconomy-a-national-bioeconomy-strategy-to-2030
36 https://echa.europa.eu/regulations/reach/understanding-reach
37 https://www.hse.gov.uk/reach/about.htm
38 https://www.lifesciencesscotland.com/news/new-strategy-scotlands-chemical-sciences-sector-chemical-sciences-scotland-unveils-new-strategic-plan
39 https://www.gov.scot/publications/shaping-scotlands-economy-scotlands-inward-investment-plan/pages/6/
40 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/978812/role-of-biomass-achieving-net-zero-call-for-evidence.pdf
41 https://www.gov.uk/government/publications/apply-for-the-biomass-feedstocks-innovation-programme

3. Policy Landscape

launched with £4m of funding. The objectives are to bring down costs and reduce barriers within the full biomass to energy value chain. This includes improving the productivity of the UK's biomass supply, the availability of conversion technologies, and the generation processes for energy vectors such as biomethane, green hydrogen, biofuels, and electricity.

Energy: Fuels & Biofuels

The Scottish Energy Strategy[42] was published in 2017 and includes an ambition of 50% of all energy consumed in Scotland coming from renewable energy sources by 2030. One of the actions to achieve this was a commitment to develop a Bioenergy Action Plan. In preparation for this, the Scottish Government commissioned research, published by ClimateXChange[43]. The findings of the study included:

- Bioresources equivalent to 6.7 TWh per year (in primary energy terms) are currently used for bioenergy purposes. Just over three-quarters of this is wood.
- Increasing the contribution that bioenergy makes by 2030 would require additional bioenergy plant to be built and deployed within the next decade.
- Based on typical capital, operating and feedstock costs, all of the bioenergy conversion technologies considered produce energy or fuel at a price that is higher than that produced by conventional technologies, based on current fossil fuel prices.
- Estimates of domestic bioresources suggest that several additional anaerobic digestion plants are technically feasible, but utilising the resource fully is likely to require the use of a mixture of feedstocks in some plant.
- Advanced conversion technologies such as gasification for power or to produce synthetic natural gas and advanced biofuels production could be commercially proven by 2030.
- Allowing for competing uses of some bioresources in other sectors of the economy, there is another 5.3 TWh per year (of primary energy), that is currently not collected or is disposed of as waste, that could potentially be utilised for bioenergy.
- By 2030, further bioresources equivalent to 2 TWh per year (of primary energy) could be available.

The Scottish Government stated it would work closely with stakeholders in preparation for a bioenergy action plan, including the UK Government as it develops its bio-economy strategy as detailed in its Clean Growth Strategy [44] A bioenergy update[45] was published in March 2021 which noted a number of key developments that had to be considered further before a bioenergy action plan could be agreed. This set out plans to engage with a wide range of sectors including agriculture, forestry, energy, waste, planning, transport, and environment, guided by an Expert Panel which was to be established over summer 2021. The update notes the intention to develop a strategic framework or set of guiding principles that complement the government's waste hierarchy and wider circular economy drivers and commitments. A Scottish Government working group comprised of staff from across all relevant policy areas will be assembled. Issues to be considered will include existing domestic biomass supply chains, the potential to increase the market for biomethane production, the need to ensure the policy is compatible with wider sustainable land use policy and what new support schemes at both a UK and Scottish level may be required. The Bioenergy Action Plan is expected by 2023, in time to inform the next Climate Change Plan update and take account of decisions that are reserved to the UK Government. In 2015 Scottish Enterprise published The Biorefinery Roadmap for Scotland[46] to support the ambition of increasing industrial biotechnology turnover from £189m to £900m by 2025. A further industry-led document,

42 https://www.gov.scot/publications/scottish-energy-strategy-future-energy-scotland-9781788515276/
43 https://www.climatexchange.org.uk/research/projects/the-potential-contribution-of-bioenergy-to-scotland-s-energy-system/
44 https://www.gov.uk/government/publications/clean-growth-strategy
45 https://www.gov.scot/publications/bioenergy-update-march-2021/pages/5/
46 https://www.lifesciencesscotland.com/wp-content/uploads/2017/08/BiorefineryRoadmapforScotland.pdf

3. Policy Landscape

Biorefinery Roadmap for Scotland – Building a Sustainable Future[47], was published in July 2019 and identified opportunities in whisky co-products, municipal solid wastes and food processing by-products, agricultural biomass, forestry biomass and marine biomass.

The Programme for Government[48] includes a commitment to begin scoping out the use of hybrid and low carbon energy sources in the public sector marine fleet and to phase out the sale of new petrol and diesel cars by 2030. It also committed to investing £180m in an Emerging Energy Technologies Fund.

The UK Government Energy White Paper[49] was published in December 2020 and proposes commitments on bioenergy. These include, by 2022 establishing the role bioenergy with carbon capture and storage (BECCS) could play in reducing carbon emissions across the economy, and as part of a wider biomass strategy, setting out how technology could be developed. The paper also states the government will increase the proportion of biomethane in the gas grid, with the Green Gas Support Scheme (GGSS) to launch in 2021 and run for four years. This scheme will support the continued deployment of anaerobic digestion biomethane plants in order to increase the proportion oof green gas in the grid, with the aim of trebling this between 2018 and 2030.

Biomass

The UK Government has also committed to publishing a new Biomass Strategy in 2022, which will set out the amount of sustainable biomass available to the UK and how this can be best utilised. A consultation[50] on the strategy was launched on 20 April 2021 and closed on 15 June 2021. Views are sought on areas including availability of sustainable biomass from domestic and international sources, the sustainability of the supply chain, accounting of greenhouse gas emissions from biomass use and opportunities for innovation to support wider deployment of technologies with potential to support net zero.

As part of the Net Zero Innovation Portfolio, a Biomass Feedstocks Innovation Programme[51] has been launched with £4m of funding. The objectives are to bring down costs and reduce barriers within the full biomass to energy value chain. This includes improving the productivity of the UK's biomass supply, the availability of conversion technologies, and the generation processes for energy vectors such as biomethane, green hydrogen, biofuels, and electricity. The projects receiving funding[52] were announced in August.

Renewable Energy

Scotland's energy strategy was published in December 2017[53] and sets a target for the equivalent of 50% of the energy of Scotland's heat, transport, and electricity consumption to be supplied by renewable sources by 2030. The Climate Change (Scotland) Act requires Scottish Ministers to report annually on progress towards meeting the target of useful renewable heat generated in Scotland. The most recent

47 https://www.sdi.co.uk/media/2092/biorefinery-roadmap-for-scotland-building-a-sustainable-future.pdf
48 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/09/fairer-greener-scotland-programme-government-2021-22/documents/fairer-greener-scotland-programme-government-2021-22/fairer-greener-scotland-programme-government-2021-22/govscot%3Adocument/fairer-greener-scotland-programme-government-2021-22.pdf
49 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf
50 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/978812/role-of-biomass-achieving-net-zero-call-for-evidence.pdf
51 https://www.gov.uk/government/publications/apply-for-the-biomass-feedstocks-innovation-programme
52 https://www.gov.uk/government/news/4-million-funding-to-boost-uk-biomass-production
53 https://www.gov.scot/publications/scottish-energy-strategy-future-energy-scotland-9781788515276/

3. Policy Landscape

update was October 2020[54]. The Programme for Government[55] indicates a refreshed energy strategy will be published in the next 12 months. It also states it will ensure National Planning Framework 4 (NPF4) actively enables renewable energy by supporting the repowering of existing wind farms and expansion of the grid.
The UK Government published The Ten Point Plan for a Green Industrial Revolution in November 2020[56]. The Energy White Paper was published in December 2020, described as a "decisive and permanent shift away from our dependence on fossil duels, towards cleaner energy sources". Commitments on renewables include targeting 40GW of offshore wind by 2030, alongside the expansion of other low-cost renewables technologies. The paper also set out plans to establish a Ministerial Delivery Group, bringing together relevant departments to oversee the expansion of renewable power. A consultation[57] on how industry is approaching the financing and deployment of renewable technologies, and how this may change in the future, closed on 8 March. Responses will be used to explore how the Contracts for Difference could evolve beyond 2021.

Agriculture

A number of plans for agriculture were set out in this year's Programme for Government[58]. These included ensuring future policy was broadly in line with the objectives of the Common Agricultural Policy (CAP) in order for Scotland to re-join the EU when independent; develop a preliminary package of measures to reduce greenhouse gas emissions from agriculture by COP26; shifting half of all funding for farming and crofting from unconditional to conditional support, with targeted outcomes for biodiversity and low carbon approaches, by 2025; appoint a new Chief Scientific Advisor on Environment, Natural Resources and Agriculture; support the development of vertical farming technologies; commitments to ensure tenant farmers and smallholders have access to climate change and mitigation measures; and put in place measures to seek to double the amount of land used for organic farming by 2026.
Applications[59] for the continuing Basic Payment Scheme opened on 15 March, with rules remaining largely unchanged, with the exception of some greening amendments. A Farming and Food Production Future Policy Group[60] was established in January 2019 with a remit to make recommendations on future policy. Its report has been delayed, with a government spokesperson suggesting[61] this is due to COVID-19 and Brexit.

Scotland's Third Land Use Strategy[62] covering the period from 2021-26 was published in March 2021 and takes an overarching holistic picture of what sustainable land use in Scotland could look like. It is

54 https://www.gov.scot/publications/update-renewable-heat-target-action-2020/
55 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/09/fairer-greener-scotland-programme-government-2021-22/documents/fairer-greener-scotland-programme-government-2021-22/fairer-greener-scotland-programme-government-2021-22/govscot%3Adocument/fairer-greener-scotland-programme-government-2021-22.pdf
56 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf
57 https://www.gov.uk/government/consultations/enabling-a-high-renewable-net-zero-electricity-system-call-for-evidence#history
58 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/09/fairer-greener-scotland-programme-government-2021-22/documents/fairer-greener-scotland-programme-government-2021-22/fairer-greener-scotland-programme-government-2021-22/govscot%3Adocument/fairer-greener-scotland-programme-government-2021-22.pdf
59 https://www.ruralpayments.org/topics/all-schemes/basic-payment-scheme/basic-payment-scheme-full-guidance/greening-guidance-2021/greening---introduction-and-updates-for-2021/
60 https://www.gov.scot/groups/farming-and-food-production-group/
61 https://www.pressandjournal.co.uk/fp/news/politics/scottish-politics/2833531/farmers-report/
62 https://www.gov.scot/publications/scotlands-third-land-use-strategy-2021-2026-getting-best-land/

3. Policy Landscape

anticipated that the strategy will be followed by a delivery plan that will include details on policies and actions.

The SNP manifesto included pledges on encouraging the adoption of technology and innovation in agriculture; creating a single implementation board with representation from all farming sectors; and applying an enabling approach to planning to help farm diversification.

Soil & Crops

Although there is no one-size-fits-all soil protection policy for Scotland[63], there is a range of policies and legislation that protects some aspects of soil and influences how our soils are managed.

Greening guidance from 2021[64] dropped requirements for two/three crop rules. Requirements to protect permanent grassland and farming 5% of arable area in a manner that promotes biodiversity is to continue.

The Scottish Plant Health Strategy[65] was published in March 2016, setting out the Scottish Government's approach to the protection of the health of plants, including agricultural and horticultural crops.

The SNP manifesto includes commitments to maintain GM free cultivation status; review and reform urea fertiliser usage; invest in and promote the use of suitable methane inhibitors.

3.1.2. EU Policy

EU's Recovery and Resilience Facility

The EU's Recovery and Resilience Facility[66] will make €672.5bn in loans and grants available to support reforms and investments undertaken by member states. It aims to mitigate the impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient, and better prepared for challenges and opportunities of green and digital transitions. A minimum of 37% of expenditure on investments and reforms contained in each national recovery and resilience plan should support climate change objectives.

EU Circular Economy Action Plan

The EU Circular Economy Action Plan[67] was adopted in March 2020 and is described as one of the main building blocks of the European Green Deal. Its objectives include making sustainable products the norm in the EU, focusing on sectors that use the most resources and where the potential for circularity is high (such as plastics) and ensuring less waste. In response to the plan, MEPs backed a report in February 2021 calling on the Commission to set binding 2030 targets for materials use and consumption footprints[68]. Although binding targets would no longer apply in Scotland, the Scottish Parliament backed legislation that included provisions to ensure continuation of guiding principles on the environment in

63 https://soils.environment.gov.scot/soils-in-scotland/soil-protection/
64 https://www.ruralpayments.org/topics/all-schemes/basic-payment-scheme/basic-payment-scheme-full-guidance/greening-guidance-2021/greening---introduction-and-updates-for-2021/
65 https://www.gov.scot/publications/scottish-plant-health-strategy/
66 https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en
67 https://ec.europa.eu/environment/pdf/circular-economy/new_circular_economy_action_plan.pdf
68 https://www.europarl.europa.eu/news/en/press-room/20210204IPR97114/circular-economy-meps-call-for-tighter-eu-consumption-and-recycling-rules

3. Policy Landscape

Scotland post Brexit. A Circular Economy Package policy statement[69] was issued jointly by Defra, DAERA, the Welsh Government and the Scottish Government in July 2020, setting out is approach of transposing the EU plan into domestic law.

3.1.3. Brexit Implications

Post Brexit EU Structural Funds replacement

The 2017 Conservative manifesto[70] included plans for a Shared Prosperity Fund to replace EU Structural Funds. Further details were set out in the 2020 Spending Review[71]. The new fund will be launched in 2022 and will operate throughout the UK. It is described as being the Government's flagship policy in its "commitment to level up the country" and is expected to at least match EU funding. A long-term vision for the fund will be set out in a UK Shared Prosperity Fund Investment Framework expected to be published later this year. Devolved administrations will have a role within the governance structures of the fund, but concerns have been raised that the fund will be used in areas of devolved competence. To help prepare for the introduction of the new fund, the UK Community Renewal Fund is being provided[72] for 2021-22. It aims to support communities to pilot programmes and new approaches, aligning national and local provision. 100 priority places have been identified based on an index of economic resilience, with projects targeting investment in these communities prioritised for funding. In Scotland bids for this will be managed by local authorities. Final decisions on bids will be made by the Ministry of Housing, Communities & Local Government, with the UK Government stating it will seek advice from devolved administrations at the shortlisting stage on projects that will be delivered in their geographical areas. Local areas will continue to spend investment from EU structural funds until the end of 2023. Other investment programmes announced by the UK Government include the £4.8bn Levelling Up Fund[73] and the £150m Community Ownership Fund[74].

The future UK Shared Prosperity Fund (UKSPF) will be administered by Westminster, which would provide an opportunity for the UK Government to directly invest in Scottish sectors and projects which it sees as politically valuable. The Scottish Government has claimed this form of investment amounts to an erosion of devolution in bypassing devolved administrations for investment decisions. The UK Government has said it expects to leverage £1.5bn per year across the UK for the UKSPF, with distribution to be made clear at the next Spending Review, while the Scottish Government has argued Scotland must receive at least £1.283bn for a replacement seven-year programme for 2021-27. City Region Deals and the Levelling Up Fund also provide opportunities for the UK Government to invest directly in capital projects, with particular focus on improving and regenerating communities.

Potential areas of constitutional friction could come from the Internal Market Act 2020, which legislates for the replacement of EU Structural Funds. Prior to the Act, the Scottish Government had control over the spending it received from the EU, to invest in sectors to produce smart, sustainable, and inclusive growth. From 2014-20, £780m of investment was delivered through this funding, including the £30.7m Resource Efficient Circular Economy programme administered by Zero Wate Scotland.

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69 https://www.gov.uk/government/publications/circular-economy-package-policy-statement/circular-economy-package-policy-statement
70 http://ucrel.lancs.ac.uk/wmatrix/ukmanifestos2017/localpdf/Conservatives.pdf
71 https://www.gov.uk/government/publications/spending-review-2020-documents/spending-review-2020
72 https://www.gov.uk/government/publications/uk-community-renewal-fund-prospectus/uk-community-renewal-fund-prospectus-2021-22
73 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/966138/Levelling_Up_prospectus.pdf
74 https://www.gov.uk/government/publications/community-ownership-fund/community-ownership-fund

3. Policy Landscape

Agricultural policy post Brexit

The Scottish Government published Stability and Simplicity[75], its consultation proposals for the Brexit transition period in the agricultural sector in June 2018. This followed a report published by the Scottish Government Agriculture Champions, which included recommendations for a five-year transition period[76]. A Simplification Taskforce was set up to consider some of the responses to the consultation and published its report in January 2020[77]. The Scottish Government adhered to the Common Agricultural Policy whilst in the EU transition period. The Agriculture (Retained EU Law and Data) (Scotland) Act received Royal Assent on 1 October 2020[78], creating powers to ensure CAP payments could continue beyond 2020, as well as retaining the ability to make improvements to the scheme following Brexit. The Act also improves the legal basis for collecting information about the agri-food supply chain and activities relating to agriculture.

The allocation of agricultural subsidies in Scotland will continue to follow the same rules as CAP until 2024. The Government has stated it will replace this with a scheme that rewards good environmental practice and land use, with greening criteria a precondition of obtaining support. This is expected to require farmers to change their practices over a transition period. Farmer-led groups were established for each part of the sector to set out the practical steps of reducing climate impact. A consultation[79] on the key themes and recommendations from these groups was launched in August 2021, with it stated this will help inform wider work on the development of agricultural policy and the replacement of CAP. An Agriculture Reform Implementation Oversight Board has also been established[80], with this helping to develop new proposals for sustainable farming. A new agriculture bill is expected in 2023.

The SNP manifesto included commitments to re-join the EU and returning to CAP when independent; staying broadly aligned with EU measures; encouraging the adoption of technology and innovation in agriculture; creating a single implementation board with representation from all farming sectors; applying an enabling approach to planning to help farm diversification. On soils, the SNP manifesto commits to continuing to adhere to EU standards for plant health.

3.1.4. Climate Change Policy

Green Recovery

The Advisory Group on Economic Recovery was set up in April 2020 and asked to focus on Scotland's economic recovery, with emphasis on the period after the immediate emergency created by COVID-19 had been addressed. The remit of the work included how Government policy could help the transition towards a "greener, net-zero and wellbeing economy". A number of recommendations are made in the June 2020 report[81], including prioritisation and delivery of green investment, with the group endorsing the six principles for a resilient recovery set out by the Committee on Climate Change. The group also

75 https://www.gov.scot/publications/stability-simplicity-proposals-rural-funding-transition-period/
76 https://www.gov.scot/publications/future-strategy-scottish-agriculture-final-report-scottish-governments-agriculture-champions/
77 https://www.gov.scot/publications/report-simplification-taskforce/
78 https://www.legislation.gov.uk/asp/2020/17/enacted#:~:text=An%20Act%20of%20the%20Scottish,collection%20and%20processing%20of%20information
79 https://www.gov.scot/publications/agricultural-transition-scotland-first-steps-towards-national-policy-consultation-paper/pages/3/
80 https://www.gov.scot/news/delivering-a-new-future-for-rural-scotland/
81 https://webarchive.nrscotland.gov.uk/20210821081540/www.gov.scot/publications/towards-robust-resilient-wellbeing-economy-scotland-report-advisory-group-economic-recovery

3. Policy Landscape

calls for the financial services sector and the Scottish Government to develop and promote nature-based investments to protect and enhance natural capital. Other recommendations include greater use of conditionality in business support, with it suggested this could include applying green conditions and the Scottish Government, regulatory bodies and local authorities reviewing their key policy, planning and consent frameworks to accelerate projects and meet low carbon generating targets. The Scottish Government responded to the report in August 2020 and set out how the recommendations would be taken forward[82].

It committed to developing new partnerships and taking forward existing ones and said it would go further than the report's recommendations. Plans included continuing to explore the role for bespoke approaches that linked business support with climate change objectives, the launch of the Green Investment Portfolio, work with local authorities on the Green Growth Accelerator, continue to develop work on measurement of Scotland's Natural Capital and introducing Regional Land Use Partnerships. The Government publications also commits to regular updates to ensure the recovery plan is progressing.

The Programme for Government 2021-22[83] committed to ensuring a recovery which is green and fair. Commitments included the investment of £500m across the parliament to support new, good, and green jobs, including upskilling and reskilling people to access these. An update[84] was provided to the 2018-2032 Climate Change Plan in December 2020, setting out the approach to a green recovery and the pathway to deliver climate change targets.
The UK Government Energy White Paper includes commitments to support a green recovery through measures including increasing the ambition in the Industrial Clusters Mission four-fold and investing £1bn up to 2025 to facilitate the deployment of CCUS[85].

Just Transition for Scotland

The Just Transition Commission: A national mission for a fairer, greener Scotland report was published in March 2021[86]. The Commission held a series of meetings and engagement events with stakeholders during its work. It calls for the delivery of just transition to be a 'national mission' and be implemented fairly. The report makes 24 recommendations, including ensuring sufficiently develop roadmaps exist for net-zero transition and the establishment of a Just Transition Plan for Scotland's land and agriculture. Recommendations are also made on funding, including aligning broader support for innovation with other funding streams from the Scottish Government and enterprise agencies to develop expertise in the whole-life cycle of projects. The Scottish Government's initial response[87] to the report was published in September 2021, accepting all of the Commission's recommendations. A commitment was made to the first Just Transition Plan being the forthcoming Scottish Energy Strategy and a Just Transition Planning

82 https://webarchive.nrscotland.gov.uk/20210822212901/www.gov.scot/publications/economic-recovery-implementation-plan-scottish-government-response-to-the-advisory-group-on-economic-recovery
83 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/09/fairer-greener-scotland-programme-government-2021-22/documents/fairer-greener-scotland-programme-government-2021-22/fairer-greener-scotland-programme-government-2021-22/govscot%3Adocument/fairer-greener-scotland-programme-government-2021-22.pdf
84 https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/
85 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf
86 https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2021/03/transition-commission-national-mission-fairer-greener-scotland/documents/transition-commission-national-mission-fairer-greener-scotland/transition-commission-national-mission-fairer-greener-scotland/govscot%3Adocument/transition-commission-national-mission-fairer-greener-scotland.pdf
87 https://www.gov.scot/publications/transition-fairer-greener-scotland/

3. Policy Landscape

Framework. A new Just Transition Commission will also be established. The Programme for Government mentioned work with stakeholders to set out a Just Transition Plan for land and agriculture in time for the post-CAP subsidy regime. The SNP manifesto included a appoint a Minister of Just Transition, with Richard Lochhead taking up this role. The party also pledged to work with trade unions to bring forward sectoral just transition plans and develop a robust monitoring framework to measure progress. Friends of the Earth Scotland, Scottish Trade Union Congress, Communication Workers Unions Scotland, Public and Commercial Services Union Scotland, Unite Scotland, Unison Scotland, University and College Union Scotland and WWF Scotland issued a joint statement[88] calling for a Just Transition in 2017.
The UK Government published its Green Financing Framework[89] in June 2021. It set out six types of green expenditures that will be financed across the UK by the Green Gilt and retail Green Savings Bonds: Clean Transportation; Renewable Energy; Energy Efficiency; Pollution Prevention and Control; Living and Natural Resources; and Climate Change Adaption.

Plans for a Circular Economy

The Scottish Government published its circular economy strategy Making Things Last in 2016[90] and includes an ambition for an increasing proportion of biological wastes to be used for the production of high value materials and chemicals. The 2019-20 Programme for Government included plans to introduce a Circular Economy Bill, the objectives of which was to reduce waste, litter and carbon and resource footprint, as well as increasing recycling rates and maximising economic opportunities.

A consultation on the bill[91] on the bill took place at the end of 2019 and included a proposal on the mandatory reporting of waste and unwanted surplus, with reference made of the potential for food waste to be used as a resource with value that could have other uses. It was announced on 1 April 2020 that, as a result of the COVID-19 pandemic, the bill would not be introduced in that parliamentary session. Roseanna Cunningham told the Environment, Climate Change & Land Reform Committee it would be up to a new administration to take forward work on the circular economy. The 2021-22 Programme for Government included a commitment to bring forward a bill later in this parliamentary session. Lorna Slater has responsibility for the circular economy in her ministerial role.

3.2. Policy recommendations and conclusions

Given the support for innovation and transitioning industries for the future that spans the wide range of departmental policies outlined in this chapter, there is a clear gap in terms of support from governments at all levels (Scottish, UK & EU) for bio-based alternatives in the policy areas of climate change, energy, chemicals, agriculture, and soils.

There needs to be a policy scheme that directly encourages domestic production with a view to securing local supply chains. When considering supportive policy, measures should take the form of a financial subsidy to encourage domestic production or a financial incentive to set up a production facility in within Scotland. An additional measure should be to create a sustainability accreditation that goes beyond current carbon credits to include wider efforts in the supply chain to support the drive to net-zero.

In order for the transition to a sustainable future to take place, namely for the chemicals and agricultural industries, there needs to be policy support from respective levels of governments. Should the Scottish

88 https://foe.scot/resource/joint-statement-just-transition/
89 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1002578/20210630_UK_Government_Green_Financing_Framework.pdf
90 https://www.gov.scot/publications/making-things-last-circular-economy-strategy-scotland/
91 https://consult.gov.scot/environment-forestry/circular-economy-proposals-for-legislation/

3. Policy Landscape

Government seek to support these proposals it would further the ambitions of the current administration in terms of securing economic prosperity and a sustainable environmental future, whilst positioning Scotland as a leading example within the UK domestic market.

Chapter 6 Stimulus for growth in the USA of this report details successful policy mechanisms in the USA that should be considered in this space.

4. Sugar Beet Overview

4.1. Scottish Sugar Beet History

Sugar beet was grown in Scotland from 1926 to 1972 as part of the British Sugar Corporation. Beet was processed into sugar at a processing site in Cupar, Fife, that benefitted from a ready supply of water from the nearby river Eden and rail links to a wide area of the east coast from Easter Ross down to Northumberland. The plant was designed to process beet from 15,000 to 16,000 acres, or approximately 6,000 hectares. Scottish yields at that time were at best 15 tons per acre (37 tonnes per hectare) by the mid 1960's, averaging around 11 tons per acre (27 tonnes per hectare). Full capacity must have been around 165,000 tonnes. By 1967, the operation was in decline with the beet acreage having reduced to 7,000 acres. Various reasons are given for its demise, primarily the exceptionally cold winter of 1963 and poor crops in subsequent years, the removal of transport subsidies and less attractive prices[92][93].

However, since sugar beet was last grown in Scotland, the strains of beet have developed, and yields are considerably higher. Scottish yields are discussed in more detail in section 3.2.3.

4.2. Rotational Considerations

This section investigates arable cropping in Scotland and how sugar beet could fit in to the cropping mix. The following tables identify which crops are grown and trends in hectarage.

Most Scottish arable farms grow different crops in sequence, or rotation, as this can help reduce weed or pest competition and build and utilise soil fertility to maximise crop profitability. Sugar beet, along with oilseed rape, potatoes and vegetables are described as 'break crops' as they provide a break from continuous cereal growing, which enhances the following cereal crop yields as well as being important crops in their own right. Financial margins can be compared for each individual crop, but it is the overall margin of all of the crops in the rotational mix that provides a better guide to arable crop profitability.

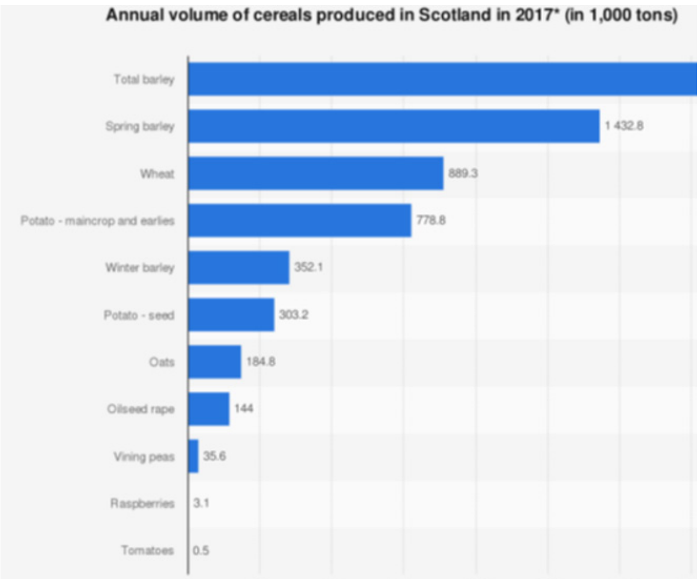

Figure 6: Scotland's output by volume (in 1,000 tons) by crop type 2017

In 2019, the combined output of arable produce (cereals, other crops, horticulture, and vegetables) in Scotland accounted for a third of agricultural output with a value of £1.1 billion: around 580,000 hectares were used to grow cereals, crops, fruit and vegetables, accounting for around 10% of Scotland's total agricultural area. This is equivalent to 12% of the total arable land in the UK: Barley and wheat are the main cereal crops grown in Scotland, (Figure 6) accounting for around 75% of the area of crop-land and much of it goes into whisky production. Looking to the requirements of Scotland's whisky production, 87% of barley and 50% of wheat requirements are sourced in Scotland.

92 https://www.pressandjournal.co.uk/fp/business/farming/1768545/days-when-sugar-beet-played-important-role-in-food-chain/
93 https://api.parliament.uk/historic-hansard/commons/1967/apr/19/sugar-beet-industry-scotland

4. Sugar Beet Overview

Over the last decade there has been a progressive decline in the area of land classified as temporary grassland (grassland <5yrs) within Scotland's arable cropping rotation (Figure 7 & 8). The area has more than halved from 411,179ha to 185,685ha with 80% of that area transferring into permanent pasture increasing it by 19% compared to the area recorded in 2011.

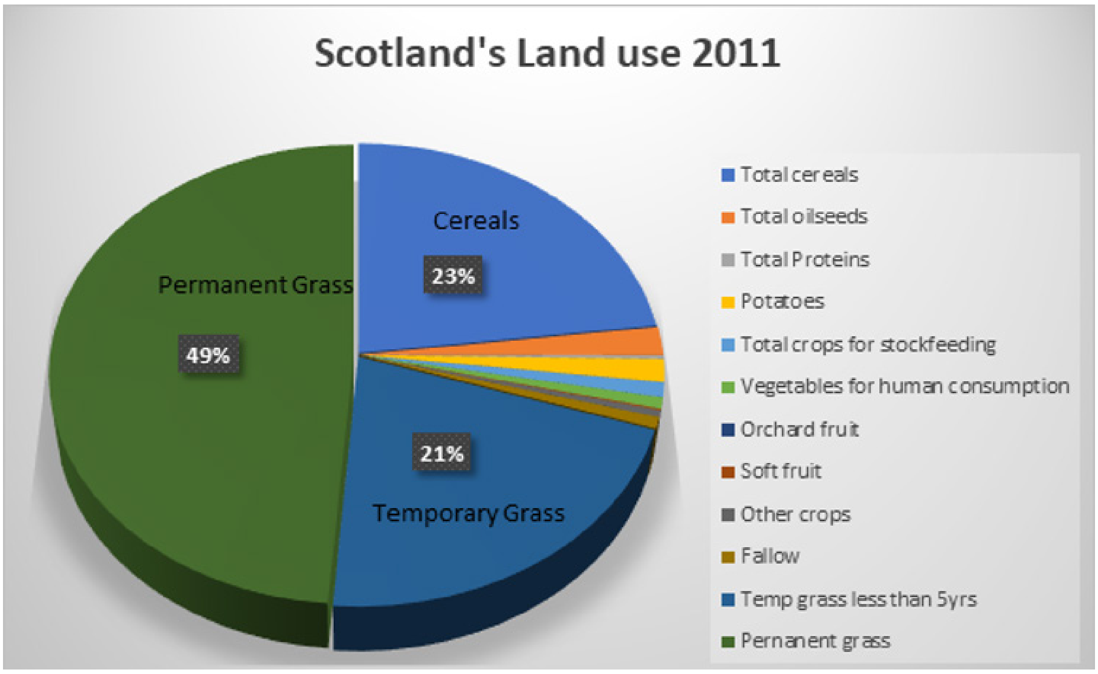

Figure 7: Scotland's land use 2011

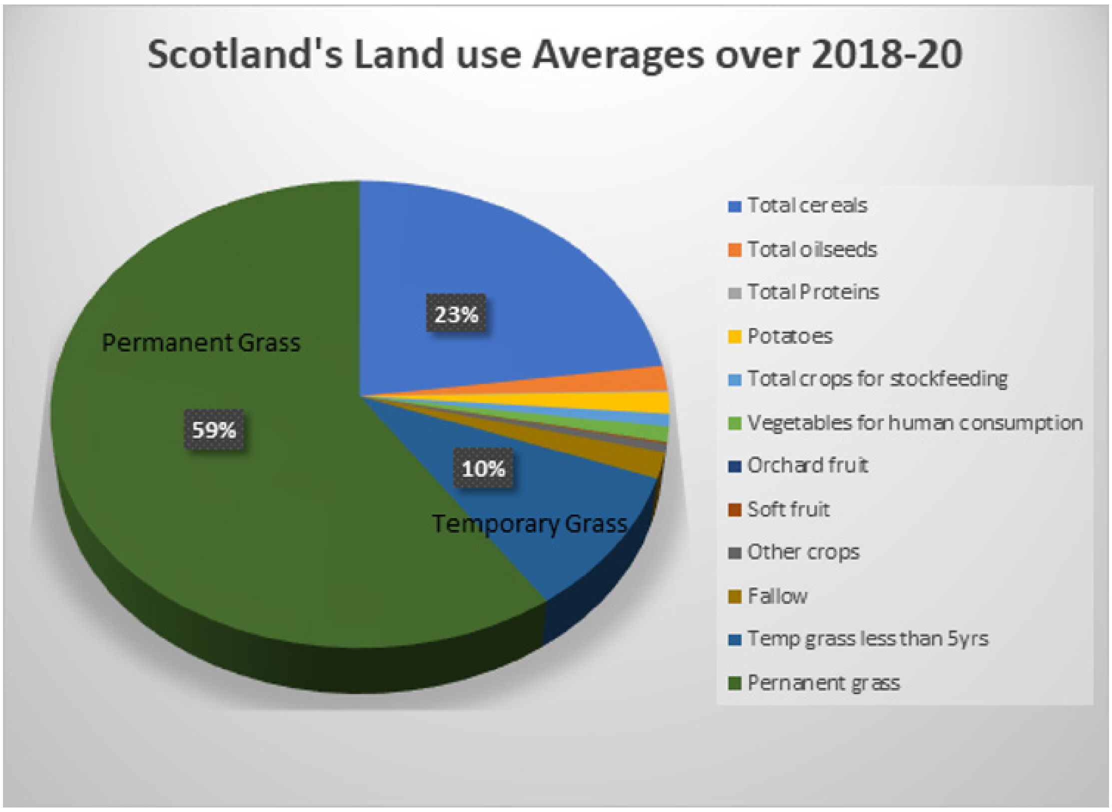

Figure 8: Scotland's Land Use Averages 2018-2020

4. Sugar Beet Overview

The reduction of temporary grass within Scotland's arable rotation is one of a number of shifts in land use over this 10-year period. There have been marked falls in cropped areas to peas and beans (proteins), oilseed rape and to a lesser extent, potatoes. In contrast the areas growing vegetables and fallowed land has increased (Table 3 & Figure 9).

Crop Type	**2011 ha**	**Average 2018-2020 ha**	**Rise or Fall ha**	**%**
Total cereals	447,104	432,952	-14,152	-3
Total oilseeds	38,526	31,834	-6,692	-17
Total Proteins	4,936	2,445	-2,491	-50
Potatoes	31,073	28,049	-3,024	-10
Total crops for stock-feeding	19,989	16870	-3,119	-16
Vegetables for human consump-tion	15,246	19,503	4,257	28
Orchard fruit	67	128	61	91
Soft fruit	1,981	2,089	108	5
Other crops	8,990	11,208	2,218	25
Fallow	15,055	33,592	18,537	123
Temp grass less than 5yrs	411,179	185,685	-225,494	-55
Permanent grass	946,372	1,126,649	180,227	19
	1,940,518	**1,891,004**	**-49,564**	

Table 3: Change in land use 2011 to 2018/20

4. Sugar Beet Overview

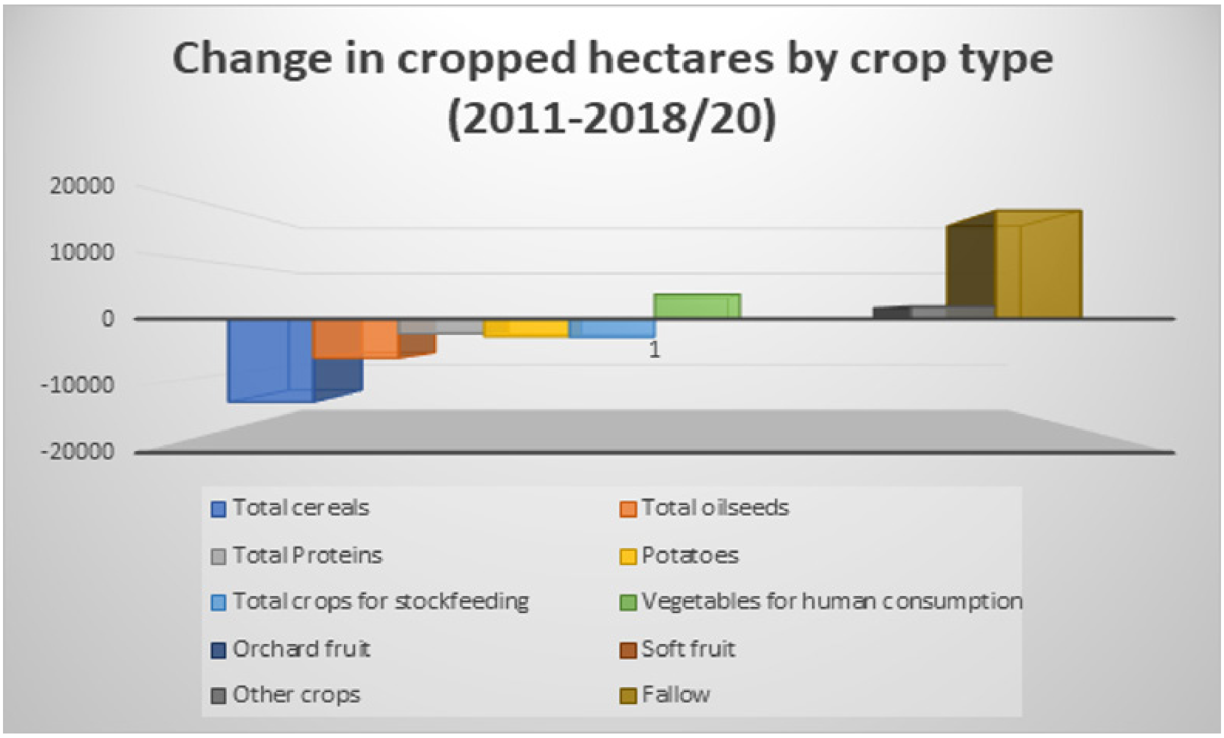

Figure 9: Change in cropped hectares by crop type

The decline in use of break crops of peas, beans and oilseed rape is a concern. Integrated Pest Management principles are built on mixed cropping regimes to break pest, weed and disease lifecycles and build resilience in both crops and soils. In addition, growing peas and beans for example, is among the most effective measure in reducing greenhouse gas emissions on farms saving on average 553 kg CO2e (carbon dioxide equivalents) per hectare.

Despite a rise in land use for vegetables and an increasing area returned through census as 'fallow' over the last decade, cereals have continued to occupy 75% of arable land in any given year. (Table 4).

Area of cereals grown as a % of	**2011 ha**	**Av 2018-2020 ha**
All crops including temporary grassland	45%	56%
All crops excluding temporary grassland	76%	75%

Table 4: Percentage of land given over to cereals

Scotland's growers are sowing cereals for the local distilling and malting markets. However, rotational cropping sequences on farms are influenced not only by market demand but also by the associated risk in growing a particular crop in terms of the margins achievable. In England, the dramatic decline in the area of oilseed rape sown is directly attributable to the increasing risk to margins caused by pest damage (flea beetle). To a lesser extent the same is true for Scotland's declining area of oilseed rape; whilst

4. Sugar Beet Overview

climatic differences mitigate the extent of pollen beetle crop damage, the perceived risk deters farmers from either growing the crop at all or influences how much is grown.

In the same way that the ban on noenicitinoids has influenced decisions on the inclusion of oilseed rape in rotations, the loss of the crop desiccant, Diquat, increases the risk of crop loss when harvesting pulses, notably combining peas, and will again influence the farmer's choice of crops. The loss of the ability to desiccate quickly and evenly, especially given Scotland's cooler, later harvesting periods, will have contributed to the decline of pulses as rotation crops over recent years.

A sustainable farming system has diversity of cropping and to have the option, profitably, to use sugar beet into the rotation as a break crop to cereals is undoubtably also of agronomic merit.

Sugar beet grows best on deep fertile soils but is more tolerant of heavier, less fertile soils than potatoes; for this reason, it can provide a valuable break crop on land that might otherwise only be suitable for combinable crops such as wheat. In this instance, beet might be grown one year in four. Where beet is grown in the same rotation as potatoes, it might then be grown one year in six.

A big threat to England's sugar beet production areas that makes a proper crop rotation mandatory is the attack by soil borne nematodes. Although other hosts include fodder beet, mangold, turnip, leafy brassicas and oilseed rape, the risk of nematode damage to the yield of sugar beet newly introduced to Scotland will be very low. However, following good practice, sugar beet should only be grown two years after a beet, brassica or oilseed rape crop was grown on the same land. Sugar beet is part of the Amaranth family of crops and is not a clubroot host.

Rotational Gains of sugar beet

- Environmental benefit from overwintered stubbles (ties in with AECS)
- Allows extra time for grassweed control
- Broadens range of chemistry used across the rotation
- Open canopy in spring can benefit ground-nesting birds
- Returns organic matter to topsoil and deep rooting can improve structure
- Opportunity to add value by grazing sheep on tops after harvest
- Breaks the cycle of pests, diseases, and weeds in combinable crop rotations
- Reduces pressure on grain storage requirements and combine capacity
- Long growing season – benefits from summer rain when other crops do not
- New varieties better at growing for longer in season

Rotational challenges

- Difficult to prepare seedbeds and establish crops when land is cold or wet in spring.
- Young crops vulnerable to dry springs
- Harvesting difficulties and potential soil damage when conditions are wet. Possible damage to tracks/handling areas. Yield penalty on following crops can be considerable
- Limited crop competition against weeds
- Diminishing chemistry available in future
- Needs suitable areas for storage, handling, and loading – often in wet conditions
- Can be tricky to establish a crop after late-lifted beet

4. Sugar Beet Overview

4.2.1 Crop Displacement

An important consideration is to understand which crops are likely to be displaced by sugar beet. During the RISS funded phase a subgroup was formed to discuss this issue. the group members thought it unlikely that sugar beet would displace high value crops such as potatoes and field vegetables, and would potentially displace oilseed rape or cereal crops. Sugar beet potentially adds another break crop to the rotation and it may be possible to grow it in conjunction with oilseed rape. A sugar beet hectarage of 10 – 15k ha is unlikely to have a large impact on cereal markets.

Discussions identified that of the combinable crops the ones likely to undergo displacement would be spring barley and oilseed rape. It was felt that due to price returns wheat would not be diminished in acreage. The soil/land quality requirements for sugar beet mean that, wheat aside, they would compete with spring barley and oilseed rape.

Spring Barley – There is a large spring barley hectarage of 288k Ha in 2018 with an approximate split between feed and malt of 1:1.Depending on conditions at sugar beet harvesting there is anecdotal evidence that following this with spring barley (in a rotation) could benefit spring barley yields.
Oilseed rape - There has been some general dissatisfaction with OSR due to issues like cabbage stem flea beetle damage, followed by larvae damage and the ban on neonicotinoids. However, price has improved markedly in 2021 and it is now producing one of the highest gross margins.
More work needs to be done to investigate the potential impact on other crops.

4.2.2. Adoption of New Arable Crops in Scotland

Sugar beet is a new crop to all but the oldest Scottish arable farmers. It is important to review factors behind new crop adoption and expansion of existing crop hectarages, and the factors behind them. More common has been an expansion of existing crops to other farms, largely potatoes and vegetables. Production of these crops tends to be driven by specialist operations - large farmers or co-ops – who pay farmers a rent to grow these crops on their land. The large operator or co-op generally undertakes all the field work. This arrangement depends on the farmer renting out the land being satisfied that the rent they are paid compares favourably with the financial margin they would have made growing their own crop, plus any benefits that might accrue to the following crop e.g., benefits of a break from cereals or fertility remaining in soil.

4.2.3. New Combinable Crops

There are few examples of widespread adoption of a new crop on the scale we are suggesting for sugar beet. One example is oilseed rape, introduced in the late 1980’s to ensure greater EU self-sufficiency of plant oil. There was widespread adoption because uptake was incentivised through favourable EU hectarage support payments, production required little in the way of specialised equipment and as a cool weather crop it suited the Scottish climate. There are currently 31,800 hectares of oilseed rape grown in Scotland. No other combinable crops have enjoyed such widespread adoption.

A few minor crops, such as linseed, depended on EU support payments, and hectarage dropped away as soon as this support was reduced.

4. Sugar Beet Overview

4.2.5. Scottish Beet Yield and Sugar Content

The NNFCC feasibility study found the average UK sugar beet yields were around 80 t/Ha, with some UK growers achieving yields of over 100 t/Ha. However, Scotland has a cooler and wetter climate at a more northernly latitude and a shorter growing season. This section looks at Scottish farmers experience of growing sugar beet for anaerobic digestion (AD) plants as indicators of likely yields.

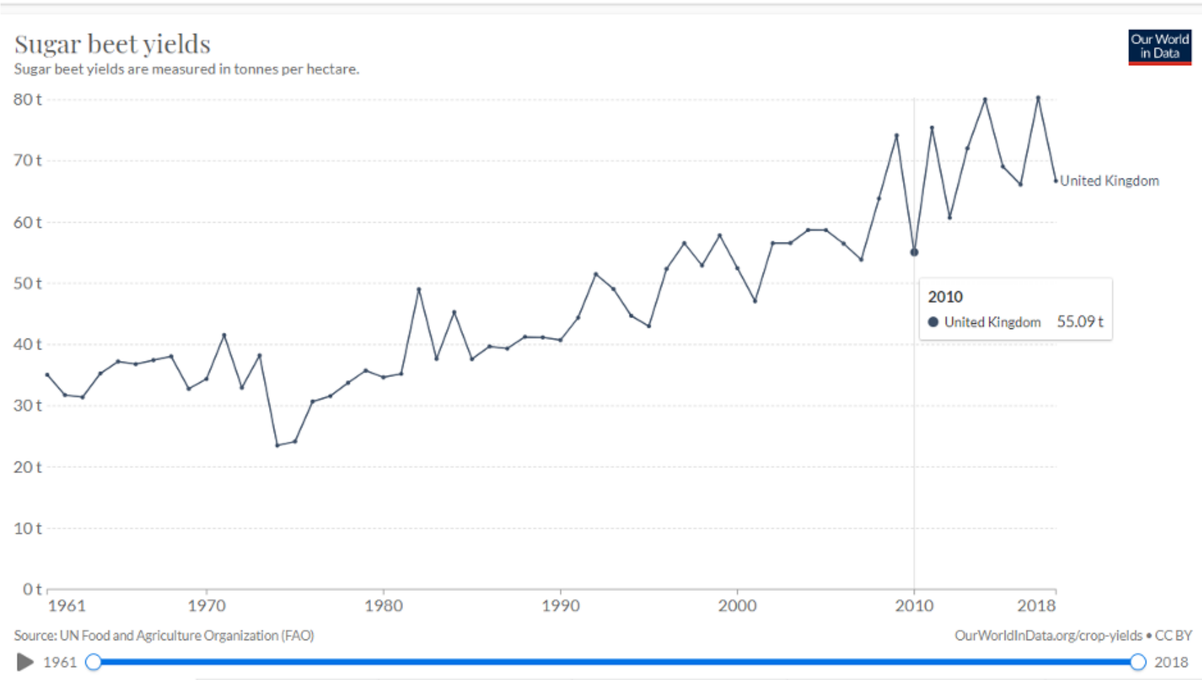

Figure 10: Seasonal variation of sugar beet yields in England

4. Sugar Beet Overview

Trends in English sugar beet yields

English sugar beet yields have increased markedly since the 1970s and have continued to maintain this improvement with no sign of yields tailing off. The graph below shows the trend in sugar beet yields, expressed in tonnes per hectare from 1961 to 2018[94].

Yields of sugar beet can vary significantly from year to year due to climatic factors that affect sowing dates, crop growth and yield harvested. Recent English yields ranged from a high of 83 tonnes per hectare in 2017 to a low of 69 tonnes/ha in 2018[95].

Parameter	Unit	2013	2014	2015	2016	2017	2018	2019
Crop area	kHa	121	117	84	80	107	110	110
Yield	t/Ha	70	80	74	71	83	69	75

Table 5: Yield estimates for the 2020 English crop

2020 proved a very tough year for growing sugar beet. British Sugar estimates that the 2020 crop would be down 10-15% from the five-year average of 75t/ha, with early sugar contents also lower than normal", which suggests an average yield of 63.8 - 67.5 tonnes/hectare following a season that included drought and substantial yield losses from Virus Yellows[96].

94 https://ourworldindata.org/crop-yields
95 https://www.gov.uk/government/statistics/agriculture-in-the-united-kingdom-2019
96 https://www.fwi.co.uk/arable/sugar-beet/british-sugar-sees-sugar-output-drop-more-than-10

4. Sugar Beet Overview

Factor	Impact	Comment
Varietal selection	Significant long-term improvement in sugar beet yields due to improved varieties.	Trend has continued – improved varieties emerging annually. Sugar beet varieties untested in Scottish conditions – will require local trials to identify best varieties and agronomy practice.
Sowing date	Weather window to establish crops in spring	England – March to May, Scotland – April to May. Earlier sowing risks frost damage or bolting, later sowings limit yield in Scotland.
Early growth period	Slow early growth due to cold weather in spring Soil moisture and drought affecting crop growth and yield potential	Slower start to crop growth in Scotland limits potential yield Lower risk of drought impact n crop development in Scotland compared to England
Pests and diseases	Severe impact of Beet Virus Yellows in England in 2020, significantly reducing yield.	Reduced risk of BVY in Scotland? Colder winters may reduce aphid numbers and reduce transmission risk.
Harvest date	Autumn harvest – lower yield, winter harvest – higher yield but greater risk of frost loss.	Crop continues to grow through autumn and winter. There may be more growth in English crops where average soil temperatures are higher than in Scotland.
Wet or harsh winter conditions.	Reduced number of days harvesters can work in fields. Potential loss of crop in field and in temporary storage heaps due to severe frost.	Greater risk in Scotland in higher rainfall areas or when ground is frosted. Higher incidence of frost in Scotland.

Table 6: Factors affecting sugar beet yield in Scotland

Scottish Yields

Records from a 1967 House of Commons debate on the Cupar plant[97] suggest that average yields of the time were 27 tonnes per hectare in Scotland and 37 tonnes per hectare in England. It is likely that there will always be a lower yield in Scotland for reasons outlined in the table above – primarily a shorter growing season and greater risk of harvest losses.

Fodder beet crop has been successfully grown in Scotland for many years for livestock feed, with a surge in interest in the last five years due to new varieties providing higher dry matter yields and enhanced frost resistance. Fodder beet and some sugar beet varieties have been grown as a feedstock for anaerobic digestion (AD) plants, and yield information is shown in following tables. While we have

97 https://api.parliament.uk/historic-hansard/commons/1967/apr/19/sugar-beet-industry-scotland

4. Sugar Beet Overview

evidence of field yields, we lack data from scientific randomised trials.
To address the knowledge gap, the Sugar Beet Working Group established some small-scale trial and demo crops in the spring of 2020, with the trial at James Hutton Institute (JHI), Dundee, and demo crops sited on four farms growing beet for AD plants. On each farm, 0.2 Hectare bags of seed were obtained for five sugar beet varieties.

	Yield of sugar beet variety (tonnes per hectare)					
Farm	BTS 1140	Degas	Eldorana	Haydn	Flixter	Average
Charlesfield	53.72	50.88	54.96	45.2	44.1	49.77
Peace Hill	71.82	71.19	73.3	64.83	60.88	68.4
Stracathro	64.81	65.21	61.26	65.99	57.7	62.99
Savock	62.86	57.96	63.06	54.51	51.22	57.92

Table 7: Demonstration crop trial results 2020

2020 was a difficult season for sugar beet with a dry, cold spring that delayed growth followed by a wet late summer and autumn although crops bulked out reasonably well thereafter. Some virus yellows damage was experienced at Stracathro, but not noted at the other sites. Each demo received a 0.2-hectare pack of seed and was given the fertiliser, herbicide, and fungicide regime of the adjacent farm beet crops. Yields were assessed by weighing trailers on the farm weighbridge. Stracathro and Peacehill demo crops yielded over 60t/ha with Savock not far behind. Charlesfield crops were affected by dry conditions averaging out at close to 50t/ha. There were some varietal differences with Flixter showing the poorest yields across all sites. Farmers would tend to grow only the higher yielding varieties so the average yields may be an underestimate of what would happen in practice.

Stracathro Estates yield results

Stracathro Estates, near Brechin, Angus, have grown both fodder and sugar beet for an AD Plant in recent years. Below is a table showing comparative yields for two varieties each of fodder (FB) and sugar beet (SB), taken at field scale with all harvested beet yields recorded at a weighbridge. These are indicative of the range of yields we might experience on similar land in Angus.

Year	FB - Blizzard	FB - Brick	SB - Tadome	SB – BTS1140
	Field crop yields – tonnes per hectare			
2017	68	72	64	58
2018	73	59	68	65
2019	76	71	72	69

Table 8: Stracathro Estates yield results

4. Sugar Beet Overview

Conclusion

Scottish yields are likely to be lower than the recent average of 75 tonnes/ha in England. This conclusion is based on growers' experience to date, the 2020 demonstration trial results, and our knowledge that the Scottish growing season is shorter than in England largely due to later sowing dates. For the purposes of this study, we assumed a relatively conservative yield of 60 tonnes per hectare. Scottish yields could exceed this figure, and the evidence from growers with AD plants suggests that an average 65 tonnes per hectare should be achievable. However, this is a new crop to be grown on a large scale, and expertise will have to be gained and operational logistics overcome before yields can approach their optimum level. This initial phase could take several years as it is expected that the planted area will increase as more is committed to the crop. The Scottish weather could also impact negatively on a large-scale operation with beet harvest spanning October through to February, and potentially some crop losses due to frost.

4.2.6. Scottish Cooperative

The volume of sugar beet required to manufacture at scale is large and would require a significant number of farms to grow beet to meet the required demand, and this is further complicated by the need for rotations to be taken into consideration. Instead of the bioethanol manufacturing plant operator signing contracts with each individual farm, a better alternative may be to explore the formation of a farming co-op. Co-ops are explored in more detail in Chapter 6.

4.3. Agronomic issues and Virus Threats

This section reviews the potential agronomic threats to growing sugar beet in Scotland, based on knowledge of English crops and Scottish growers experience.

Bolting in beet

Sugar beet should only bolt (run to seed) in its second year as it is a biennial plant, when grown for commercial use it is usually harvested before then. However, in certain scenarios it can "bolt" too early. This can occur when the crop is exposed to low temperatures over a prolonged period of time inducing vernalization. The rule of thumb is that this vernalization period needs to be around 40 days long for the crop to bolt. Control methods can be put in place to limit the bolting risk such as sowing when temperatures are beginning to rise, and our model assumes sowing only commences in April.

Another bolting control method is sowing depth to protect the seed from the air temperature as vernalisation can start before emergence. Variety choice is also a control as there are early sown trial results to show which varieties are more prone to bolting.

Virus Yellows

In recent years Virus Yellows has had a huge impact on English sugar beet growers as there are no immune varieties; some reports from NFU suggest there can be up to 80% yield reductions in infected areas within a field. The virus is transported by aphids, most commonly by the peach potato aphid. Symptoms of this virus include patches of crop yellowing with yellowing between the veins, followed by a thickening of the leaves which then become brittle. In 2020 the sugar beet industry lobbied for an emergency license to use neonicotinoid seed treatments for the 2021 crop but this year the aphid

4. Sugar Beet Overview

population was dramatically reduced because of the cold winter /spring.

Sugar beet weed control

Sugar beet grows slowly in cool conditions and is susceptible to weed competition. For this reason a sequence of three to four herbicide applications are applied to supress weed growth. Recent seasons have seen a reduction in the number of herbicides available. 2021 has been the first year without the herbicide desmediham, which was a key constituent of co-formulated products such as Betanal MaxxPro and Betsana Trio. Applied in a typical three spray programme it made weed control very simple. In its absence, a pre-emergence weed control strategy is likely to become more common.

In summary, sugar beet has few native pests and with good crop management yield losses can be minimised.

4.4. Machinery Requirements

The sugar beet crop requires some specialised equipment that is not used for other crops, notably seed drills, harvesters, trailers and cleaner loaders. This section reviews equipment requirements and workrates based on English systems. The study team have researched and devised a production model that will work in Scottish conditions.

The production model proposed is flexible in so much that land cultivation and preparation ahead of sowing, are tasks that can be carried out either by the farmer/grower or third- party contractor. The same applies for in-crop applications of fertiliser and pesticides, with the default position to use spreaders and sprayers already engaged in applications to other crops on the farm.

The model also assumes that a cooperative (coop) will be developed and this coop would own, and is responsible, for the operation of the machinery required for drilling, harvesting, carting, and loading the beet.

The number of drills and beet harvesters required for these operations are calculated from the number of days available through the autumn, winter and spring for field work and deemed work rates in hectares per day. Standard industry data (SAC Consulting) has been referenced alongside opinion from existing growers of beet and equipment manufacturers to arrive at a realistic investment figure.

Crop establishment

The presumption is that the crop will not be drilled until soil temperatures rise, such that in a typical season, the drilling window will commence in April and conclude by late-May. With an anticipated average of 35 drilling days over this period, and covering an average of 28ha/day, one 18 row drill unit should therefore have the capacity to establish 1000 hectares each spring. The 15,000-ha annual production model therefore requires 15 drill units to service this area.

4. Sugar Beet Overview

Figure 11: 18 row Monosem precision drill working in Lincolnshire – March 2020

Harvesting

The beet lifting campaign will span 5 months starting in October and finishing by the end of February. Each 6-row harvester should have the capacity to lift 10 ha per working day, allowing for travel from field to field and breakdowns. Ground conditions over the 5 months should be dry enough to enable the beet lifters to work 100 of the 150 days of the campaign. On this assumption each 6-row harvester will be expected to lift 1000 ha each season. The 15,000-ha model therefore requires 15 6-row beet harvesters to service this area.

There are many manufacturers across Europe who could supply harvesters with some specialising in sugar beet machinery. The current UK market for self-propelled harvesters is typically 15-20 units per annum but could be as few as 12 for 2021. This is the total between all manufacturers currently selling into the UK market. Due to the relatively low number of beet harvesters in Scotland at the moment it would be wise to choose harvesters where mechanical and parts back-up is readily available. The mechanics of all beet harvesters are broadly the same; a multiple row lifting head feeding into a large bulk hopper that can empty out onto end rigs or into a following trailer. Bulkers on harvesters range from 18-30 tonnes on the most common machines. The larger bulker may mean that the harvester can run to the clamp at the field edge itself, but this will not always be possible.

4. Sugar Beet Overview

Figure 12: Self-propelled 6-row beet harvester unloading into chaser trailer

Carting, cleaning, and loading

Transfer trailers are available that allow beet to be dumped into a clamp or transferred directly to a lorry if conditions are suitable. Some transfer trailers have a built-in cleaning unit meaning that some of the earth and stone is removed when the beet is emptied from the trailer.

Depending on field size, it may be acceptable for harvesters to unload directly onto the field headland without compromising lifting work rates too much, negating the need for a chaser trailer and in effect making the harvesting process a one-man operation. For the purposes of this study, however, 1 chaser trailer is assigned to 2 harvesters given that the 'one-man operation' approach will not be the predominant scenario and it is also likely that 2 harvesters will at times be operating in the same field at the same time.

Clamping is very important as beet may remain on site for a number of days or weeks before being finally transported to the factory. It is important that beet is stacked at a height that is efficient, but not at a height that allows heat to build within the clamp. Up to 2.5 metres is advised. On this basis every square metre of clamped beet will equate to approximately 1 tonne in weight. The top should be level to minimise surface area exposed to frosts and sometimes will need to be sheeted for this reason.

The type of cleaner loader suitable for the hectarage grown in this study loads at 5 tonnes/minute. The unit is not of the self-propelled type, rather it is moved by hitching to a tractor unit.

4. Sugar Beet Overview

Figure 13: Loading and cleaning sugar beet using a static cleaner/loader

One cleaner loader will service each 100 hectares grown and the loading shovel work will be either contracted in or undertaken by the grower.

In summary, for each 1000 hectare block the co-op will have invested in and allocate:

- One 18 row precision beet seed drill
- One 6 row beet harvester
- One 50% share of a chaser trailer
- One cleaner -loader unit

The investment funding required to acquire this equipment is detailed in the Financial Modelling Section below.

4.5. Financial Modelling:

Farm operations

The purpose of this study is to determine a Net Profit Margin from growing Sugar Beet at ex-farm values of £25, £30 and £35/ton. The Margin is the surplus after all costs associated with growing, harvesting, storing, and loading the crop are deducted, when the crop is ready for haulage off the farm. Within this framework the following parameters are set:

- A co-operative acts as an agency in the procurement of inputs (seeds, fertiliser, sprays)
- In-field agronomy is carried out by the co-operative
- For every 1000 hectares grown, the co-operative assigns and operates a seed drill, beet harvester, chaser trailer (50%) and cleaner loader.

4. Sugar Beet Overview

- All other in-field operations (cultivations, fertilising, spraying, loading beet away) are either carried out by the Member or third-party contractor.
- Members are paid on Beet and Sugar Yield achieved
- The co-operative recovers its operational and administration costs through a hectarage fee to Members

The model assumes an average yield of 60t/ha and calculates Net Profit Margins at 3 Sugar Beet price points: £25/ton, £30/ton and £35/ton. (Table 9).

For the purposes of this model, at no point are Basic Payment Scheme values accounted for in these costings. Appendix 1 details all operational costs included in the calculation of Net Profit Margins.

SUGAR BEET MARGINS / TON	**Unit**	**Sugar Beet £25/ ton**	**Sugar Beet £30/ ton**	**Sugar Beet £35/ ton**
Crop area	(ha)	1.00	1.00	1.00
Yield: fresh (t/ha)	(Fr. t/ha)	60.00	60.00	60.00
Yield: straw (t/ ha)	(t/ha)			
Dry matter (%)	(%)	0.22	0.22	0.22
Yield: dry matter (t/ha)	(DM t/ha)	13.20	13.20	13.20
Price: crop (£/t)	(£/t)	25.00	30.00	35.00
Price: straw (£/t)	(£/t)			
OUTPUT (£/ha)	£/ha	1500	1800	2100
£ per ha				£/ha
Seeds	£/ha	231	231	231
Fertiliser	£/ha	234	234	234
Sprays	£/ha	233	233	233
VARIABLE COSTS	£/ha	698	698	698
GROSS MARGIN	£/ha	802	1102	1402
	£/ha	143	143	143
Cultivations	£/ha	141	141	141
In-crop applica-tions	£/ha	331	331	331
Harvesting/cart-ing/loading				

4. Sugar Beet Overview

Co-op annual fee	£/ha	47	47	47
OPERATIONS COST	£/ha	662	662	662
TOTAL COST of PRODUCTION	£/ha	1360	1360	1360
£ per fresh tonne				
TOTAL COST of PRODUCTION	£/t	22.67	22.67	22.67
ENTERPRISE MARGIN	£/t	2.33	7.33	12.33
£ per fresh tonne				
TOTAL COST of PRODUCTION	£/t	22.67	22.67	22.67
ENTERPRISE MARGIN	£/t	2.33	7.33	12.33

Table 9: Profit Margin at £25/ton, £30/ton, and £35/ton

Table 9 indicates that at £35/t sugar beet will return a profit margin of £740/ha. Table 10 illustrates the margin sensitivity to changes in crop yield and price received. (Negative values/ha in red).

Price ex-farm (£/ fresh tonne)	Yield (tonnes/Ha)					
	50	55	60	65	70	75
20	-360	-260	-160	-60	40	140
25	-110	15	140	265	390	515
30	140	290	440	590	740	890
35	390	565	740	915	1090	1265
40	640	840	1040	1240	1440	1640

Table 10: Margin sensitivity to changes in crop yield and price

Cropping Rotations; introducing sugar beet, sequences, and financial gains

There continues to be a dominance of cereals within Scotland's arable rotations (75% cereals 2018-2020); a level influenced partially by the lower margins and higher risks associated with alternative crops such as combinable peas and beans. Weather patterns in Scotland also dissuade growers from other break crops, such as linseed and winter beans, where harvest periods would be too late for subsequent autumn cropping to be established in a timely manner. There will be rotations in place that are solely cereal based (referred to as continuous cereals) although other rotations will include oilseed rape, vegetables, and potatoes.

4. Sugar Beet Overview

Comparison of Enterprise Margins (indicative for 2021) for different arable crops in Scotland

COST OF PRODUCTION DATA		SUGAR BEET			COMBINABLE .ROOT CROPS						
	Unit	Sugar Beet £25/ton	Sugar Beet £30/ton	Sugar Beet £35/ton	Winter wheat	Winter barley	Sp barley (malt)	Oilseed rape	Spring beans	Dry peas	Maincrop Pots Ware
Crop area	(ha)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Yield: fresh (t/ha)	(Fr. t/ha)	60.00	60.00	60.00	9.00	7.60	6.30	3.40	4.00	4.00	50.00
Yield: straw (t/ha)	(t/ha)										
Dry matter (%)	(%)	0.22	0.22	0.22							
Yield : dry matter (t/ha)	(DM t/ha)	13.20	13.20	13.20							
Price : crop (£/t)	(£/t)	25.00	30.00	35.00	167.00	140.00	175.00	475.00	220.00	240.00	167.00
Price: straw (£/t)	(£/t)										
OUTPUT (£/ha)	£/ha	1500	1800	2100	1503	1064	1103	1615	880	960	8350
£ per ha				£/ha				£/ha			
Seeds	£/ha	231	231	231	98	88	80	60	125	134	852
Fertiliser	£/ha	234	234	234	202	188	143	173	50	30	358
Sprays	£/ha	233	233	233	148	97	65	137	101	102	685
VARIABLE COSTS	£/ha	698	698	698	448	373	288	370	276	266	1895
GROSS MARGIN	£/ha	802	1102	1402	1055	691	815	1245	604	694	6455
Cultivations/in crop applications	£/ha	284	284	284	250	220	200	210	190	190	1038
Harvesting/carting/loading	£/ha	331	331	331	175	168	155	98	99	99	577
Co-op annual fee		47	47	47							
Haulage	£/ha										
Drying/cold storage	£/ha	0	0	0	108	46	30	31	36	36	2248
OPERATIONS COST	£/ha	662	662	662	533	433	385	338	324	324	3864
TOTAL COST of PRODUCTION	£/ha	1360	1360	1360	981	806	673	708	600	590	5759
ENTERPRISE MARGIN	£/ha	**140**	**440**	**740**	**522**	**258**	**430**	**907**	**280**	**370**	**2591**
£ per fresh tonne											
TOTAL COST of PRODUCTION	£/t	22.67	22.67	22.67	108.98	106.11	106.77	208.31	150.09	147.59	115.18
ENTERPRISE MARGIN	£/t	2.33	7.33	12.33	58.02	33.89	68.23	266.69	69.91	92.41	51.82

Table 11: Comparison of enterprise margins (source SAC Consulting)

Values in Table 11 are summarised in Table 12. The range between crops is considerable (and will vary from year to year reflecting changes in supply and demand and yields achieved); from winter barley, returning £258/ha, to oilseed rape, returning £907/ha. Area aid payments (Basic Payment Scheme) are excluded from all costings.

4. Sugar Beet Overview

Crop grown	Margin £/ha
Winter barley	£258
Spring legume	£325
Spring barley	£430
Winter wheat	£522
Sugar beet	£740
Oilseed rape	£907

Table 12: Estimated Crop Margins 2021 Harvest and modelled Sugar Beet Margin

Different rotation sequences are illustrated in Table 13 and use the individual crop margins calculated in Figure 14 to demonstrate the variation in average annual returns to the grower arising from each rotation type.

In all rotations it is assumed that oilseed rape crop is preceded by winter barley to facilitate timely drilling.

Rotation type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Average annual margin(£/ha) for each rotation type
A 4 year	spring barley	spring legume	winter wheat	winter wheat			£449
B 4 year	spring barley	winter barley	winter wheat	winter wheat			£433
C 6 year	spring barley	sugar beet	winter wheat	winter wheat	winter barley	spring barley	£483
D 6 year	winter barley	oilseed rape	winter wheat	spring legume	winter wheat	spring barley	£494
E 6 year	sugar beet	winter wheat	winter wheat	spring legume	winter wheat	spring barley	£510
F 6 year	winter barley	oliseed rape	winter wheat	winter wheat	spring barley	spring barley	£511
G 6 year	winter barley	oilseed rape	winter wheat	sugar beet	winter wheat	spring barley	£563

Key
A 1 break crop (spring legume)
B continuous cereals
C 1 break crop (sugar beet)
D 2 break crops (oilseed rape and spring legume)
E 2 break crops (sugar beet and spring legume)
F 1 break crop (oilseed rape)
G 2 break crops (oilseed rape and sugar beet)

Table 13: Rotational cropping options (source SAC Consulting)

4. Sugar Beet Overview

In summary, the best financial outcome is scenario G at £563/ha, which is achieved over a sequence growing both oilseed rape and sugar beet as break crops. Overall, sugar beet's value to farm economic output upon inclusion in a rotation is clearly demonstrated. The data are also described in Figure 14.

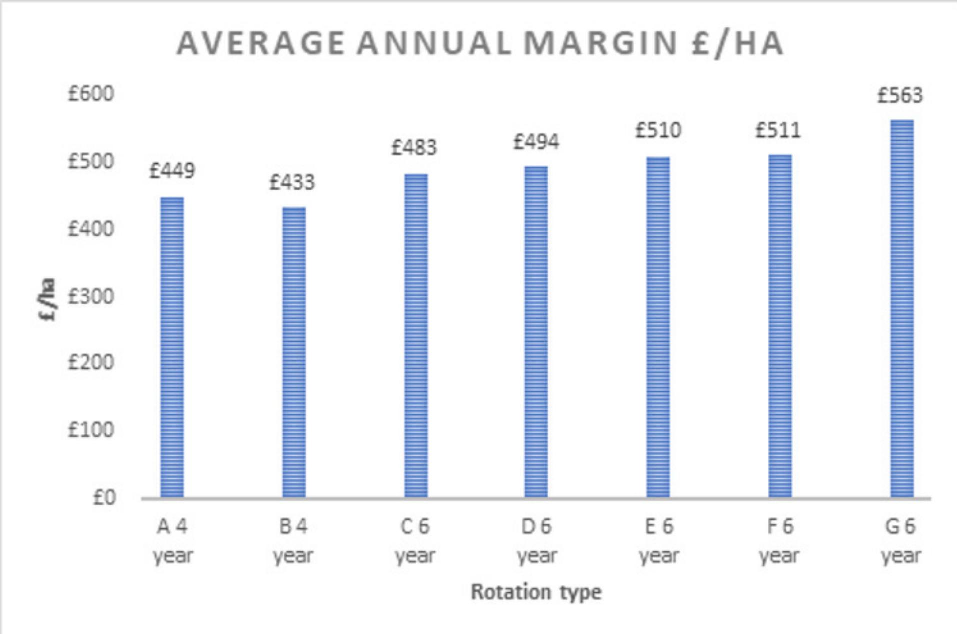

Figure 14: Average annual margin for each rotation type (source SAC Consulting)

4.6. Storage and Cleaning Requirements

In most cases, harvested beet will need to be stored on the farm for a short period before being transported to the processing facility.

Historically in England most growers would harvest their own beet and store it on-farm for long periods, with haulage contractors taking small numbers of regular loads to the factory over the season as the delivery permits allowed. Most farms would have concrete pads strategically placed around their farm on which the beet was stored.
These were often beside a road or suitable hardstanding to allow access to load lorries using cleaner loaders. These beet clamps were often covered with a sheet and/or straw during the winter to protect against frost. The problem with this method is that beet start to deteriorate once out of the ground reducing the sugar levels. Also, in particularly harsh weather, beet would still get frosted again reducing sugar content and adversely affecting the refining process.

With the recent advent of grower groups and contract lifting and haulage, permits are now pooled within these groups allowing for the crop on a farm to be harvested and transported to the factory quickly, with the beet generally not remaining in clamps for more than two weeks on average.

This development has also meant that much of the English beet crop is now stored in short-term clamps on the ground near to a road or hard standing convenient for loading into lorries. It is estimated that around 80% of the crop is now temporarily stored in this way with the remainder either being loaded straight into lorries during harvesting or stored on concrete.

4. Sugar Beet Overview

This in turn has seen the introduction of specialist machinery such as self-propelled cleaner loaders that drive into the clamp and load directly into the lorries, as illustrated in the following image. These machines cost in the region of £400k - £500k each.

Figure 15: Self-propelled cleaner loaders that drive into the clamp and load directly into the lorries

Sugar beet continue to respire after harvesting, reducing the sugar content. Research by the British Beet Research Organisation (BBRO) suggest average losses from beet in a clamp is around 0.1% of total sugar volume per day but by using best practice clamping techniques this can be reduced to just 0.039% per day. Where beet is to be stored on farm the recommendations are that:

- Clamps should be built in open areas to aid ventilation and cooling.
- The clamp should be sited on a firm, well-drained area that is suitable for loading and unloading
- Beet should never be pushed up the face of the clamp as this will break the beet and compact the clamp, reducing ventilation, increase internal heating and increasing sugar loss.

The BBRO recommend three types of clamps depending upon the season, time that the beet is to be stored and the loading method:

Early Season Clamp

Early in the season beet should be in a clamp for no more than a few days. These clamps should not be covered or have retaining walls. Short-term clamps are designed to give maximum surface area and therefore cooling to reduce sugar loss through respiration. Clamps should be made up of individual loads no more than 2m high

Late Season Clamp

Late season, long-term clamps should be no more than 2.5m high with a level surface so there are no frost pockets. Clamps should be built using straw retaining walls. Bales should be placed on pallets with the open-end facing outward to aid ventilation. Only use clamp sheets if the ground temperature is forecast to be below -3^{0}C. Clamp sheets are made of polyfelt which not only offer protection but also allow the beet to breathe.

4. Sugar Beet Overview

A-Shaped Clamp (for self-propelled cleaner-loaders)

Where a self-propelled cleaner-loader is used, clamps should be built in an 'A' shape of the correct width to allow the machine to operate effectively. The beet must be placed on a flat un-rutted surface. Clamps are normally built on the headland, but consideration needs to be given for machinery to access the clamp easily. A-shaped clamps are best built with a harvester or side-delivery trailer rather than a conventional tipping trailer to avoid rutting in the clamp base[98].

However, given the situation in Scotland with narrow rural roads, gateways, and farm tracks, along with generally higher rainfall levels than much of the English beet growing areas, it is likely that in most cases beet growers in Scotland will need to store beet on a hard standing, probably within the farm steading, if there is room, and the beet will then be loaded into lorries using a static cleaner/loader. This may be a much cheaper and more flexible option, better suited to Scottish farming needs.

One advantage of loading lorries from the field boundary in which the beet is grown is that soil from the beet gathered by the cleaner loader will remain in that field. This is important for avoiding the spread of PCN and other pests and diseases if the farm also grows potatoes, something that will be difficult to control if the beet from different fields are mixed at a central area. However, loading from a field boundary into a lorry standing on a road will not be practical in many cases as this would block the public road and many farms are unlikely to have areas of hard standing out with the farm steading.
This may mean that new beet growers in Scotland will have to create or expand existing hard standing areas to cope with storing and loading the volume of beet they grow on their farm.

One problem with storing beet on a central hard standing on a farm is that certain years in the crop rotation the beet fields may be a significant distance from storage area, meaning that two or three tractors and trailers are needed to keep the harvester working efficiently. This need to be considered and planned for before harvesting starts.

Loading lorries with beet stored on a hardstanding area will generally be easier and will stop extra soil being added during the loading process, especially during periods of inclement weather. The lorries are generally loaded using a cleaner loader to prevent as much soil and stones as possible being taken to the factory.

The sugar beet factories in England have large areas of concrete for beet storage in order that they can keep supplies at a level to keep the factories running continually. There is no set volume of beet that each factory has storage capacity for, but the minimum will be enough to keep the factory operating over the Christmas period when there are approximately 3 days when they will receive no deliveries, although the factories all have storage capacity in excess of these volumes

4.7. New Technology and Precision Farming

Originally sugar beet was one of the crops at the forefront of precision farming. The modern beet crop is derived from wild species of beet that possess a natural characteristic where two or more flowers occur as fused clusters to produce multigerm seedballs. When these seedballs were planted, two or more seedlings emerged, generally quite close and often intertwined together. This meant that for many years farmers had to thin the emerging beet seedlings to single, evenly spaced plants using a hand hoe, which require considerable time and labour.

The discovery of monogerm beet seed, along with the development of coatings around individual seed

98 https://bbro.co.uk/media/1210/bbro-advisory-bulletin-no-18-harveststorageupdate.pdf

4. Sugar Beet Overview

during the 1960s – 1970s meant that these seed pellets could be planted using a precision drill and no further thinning was required.

This also meant that weed, pest and disease control could be either combined with the seed pelleting and/or applied with a sprayer to the whole crop post-emergence.

However, the recent banning of certain chemicals on the sugar beet crop means that farmers are having to look for new ways to tackle weeds, pests, and diseases.

Recent rapid developments in new digital technologies are helping to provide a solution: imaging and sensing technology are being used in the development of new inter-row hoes behind tractors and they are also being used in conjunction with AI technology to allow autonomous robots to identify weeds and spot treat them with sprays rather than having to apply them to the whole field.

It is likely that we will start to see autonomous, self-drive farm machinery over the next couple of decades meaning that many jobs such as drilling, and harvesting will require less human input. Combining these with AI and blockchain will also mean that the supply chain will be much more automated and co-ordinated, leading to increased supply chain efficiencies and greater traceability.

In summary, emerging new technologies are likely to have a significant impact on agriculture and food supply chains in the coming years and sugar beet is one of the crops that is likely to be one of the first beneficiaries due to the characteristics of growing the crop and the specificity and delivery requirements of the supply chain.

4.8. Land Availability and Production Considerations

This section investigates production of sugar beet on farm to delivery at the central refinery. It includes an assessment of land availability, growing the crop, machinery requirements, the harvesting process and haulage, and concludes with a section on items relating to farmer uptake.

4.9. Land Availability and Production Calculations

Identifying the amount of land suitable for growing sugar beet is one of the key requirements of this study and an essential precursor to scenario planning the project scale of operation.

Sugar beet is a bulky crop with a high-water content, which imposes limits on its economic transport distance. For reasons of cost and efficiency, production is best focussed in a distinct area within a radius of a central processing plant. In Southeast England, British Sugar obtain their beet supply from fields that are an average of 28 miles distance from a central factory. Note that distance is quoted as an average figure and beet is transported from fields at greater distance. In England there is a large concentration of relatively uniform prime land surrounding each factory. Eastern Scotland has a mosaic of soil series (types) that vary in quality and cannot produce similar tonnages of beet from an average 28-mile radius. The region also has a relatively narrow coastal strip of suitable land, which may either require supply from a wider radius or acceptance of a lower tonnage of beet supply.

4. Sugar Beet Overview

4.9.1. Land Classification Analysis

The NNFCC Feasibility Study 2019[99] assessed land availability using the Scottish Land Classification for Agriculture (LCA) system developed by the Macaulay Institute (now the James Hutton Institute). This is determined by the extent to which the physical characteristics of the land (soil, climate and relief) impose long term restrictions on its use.

The LCA is a seven-class system: Class 1 represents land that has the highest potential flexibility of use whereas Class 7 land is of very limited agricultural value. The LCA system is the official agricultural classification system widely used in Scotland by agriculturalists, planners, estate agents and others as a basis of land valuation.

NNFCC used maps to identify areas of prime land in land class 1, 2 and 3.1, which is suitable for growing a wide range of arable crops and can effectively drain away excess water from rainfall, an important factor for winter harvesting sugar beet. Economic production of sugar beet crops would be possible on land classified as being suitable for arable agriculture under the LCA system (that is land in LCA classes 1, 2 or 3.1).
Land in these classes, is capable of being used to produce a wide range of crops. The climate is favourable, slopes are no greater than 7 degrees, the soils are at least 45 cm deep and are imperfectly drained at worst. The great majority of this land, which is often referred to as prime agricultural land, lies in a near continuous coastal strip in the East of Scotland, from the English border to Inverness. It includes parts of East Lothian, mid and West Lothian, parts of Fife, East Stirlingshire, East Perthshire, Angus, Aberdeenshire and Morayshire and areas around Inverness. Eight percent of the Scottish land area (i.e. 625,800 ha) is classed as being suitable for arable agriculture. Most of this is Class 2 and 3.1 land, with only a very small amount of land in Class 1 (around 0.2% or 4,100 Ha).

It was investigated whether sugar beet could be grown on land of LCA 3.2. High resolution OS maps with LCA overlays were sent to farmers for feedback and this revealed that some Grade 3.2 land could grow, or already grows, beet. Equally there may be fields within LCA 1, 2, 3.1 that are not suitable for sugar beet due to poorly maintained field drains or other factors. On balance, LCA 1, 2, 3.1 land should provide a reasonable estimate of the hectares available.

A caveat needs to be applied when using the LCA data. Some maps have not been updated for many years and detailed GIS analysis of LCA maps has revealed that woodland plantations, roads and railways, new housing developments, some smaller towns and villages, and farm roads, yards and buildings are included as land suitable for agriculture. This study has extracted all sizeable areas of woodland from the prime agricultural land totals by using Nature Scotland's Ancient Woodland dataset & the woodland dataset from Open Street Map. A check using aerial imagery confirmed the accuracy of this approach, which resulted in a 10% reduction of available prime arable land and is consistent for most areas. A further 5% reduction has been deducted from the available prime land area to allow for additional housing, transport infrastructure and farmyards and buildings. Deducting these areas leaves 85% of prime arable land in LCA 1, 2 or 3.1 available for growing sugar beet.

4.9.2. Land Considerations

This study takes the Feasibility study a step further by looking at Land Capability Assessment data in greater detail, by mapping land suitable for sugar beet production around central processing points using GIS analysis. We started with two scenarios:

99 https://www.nnfcc.co.uk/publications/report-sugar-beet-scotland

4. Sugar Beet Overview

1. Mapping available land around a large central refinery at a radius of 30, 40 and 50 miles.
2. Mapping available land around several local hubs in the most promising areas at 10, 20, and 30-miles radius. For this we chose farms that currently run Anaerobic Digestion (AD) plants as many of these already grow energy beet.

Consideration of locations

Central refinery

The greatest concentration of prime land is located in Angus making a north of Tay location the best option for land availability and minimising transport bottlenecks on busy roads. From an agricultural perspective, Dundee would be the best location given that it lies central to prime arable land. It also has some industrial infrastructure and close access to a port for importing alternative product when sugar beet is unavailable. However, from a chemical processing perspective, Grangemouth offers the best location for a processing plant with existing renewable power generation, water treatment, transport logistics including port access, co-location of customers, human capital already available on-site. The downside being its distance from the majority of prime agricultural land. Sugar beet transport economics based on distance and loading/unloading time. Loading time may be more important than distance if onward transport by rail or boat to be considered. Further discussion on this can be found in the transport logistics section (4.9).

Local hub micro-refineries

This study maps available land, at up to 30 miles radius, near AD Plants in six areas - Angus, Fife, Lothians, Borders, Aberdeenshire, and Morayshire. The concept of micro-refining small amounts of sugar beet (small in relation to the tonnage processed in a large central refinery) is not proven, although there are some companies developing the technology. However, Study Team liked the concept and decided to map these areas for future use. Farms with AD Plants were thought most likely to be interested in sugar beet production as they already grow energy sugar beet for their plants, have the growing expertise and could potentially use some sugar beet by-product as a feedstock for AD. AD plant locations have been used purely as examples for this study. Some of these farmers may not wish to join our project, and conversely there may be scope to set up hubs at other locations.

4.9.3. Plant throughput and land availability

Several factors will define the scale of operation required for efficient production and a profitable supply chain. This section assesses the maximum tonnage of sugar beet that could realistically be produced from a defined area of land to feed a central refinery. Sugar beet production is limited by land availability and new land cannot be created.

The closest comparators to this project are the four processing plants run by British Sugar in South-East England and although they are producing a different final product, refined sugar. However, they are growing the same crop and may provide insight to the potential scale of operation in Scotland. These four British Sugar factories have an annual throughput of 1.5 – 2.5 M tonnes.. The British Sugar plants take sugar beet from farms at an average distance of 28 miles from the central processing plant.[100]

To compliment this report, a model has been developed which, among many factors, considers how much prime land is available and whether there is sufficient land in eastern Scotland to produce annual

100 https://www.britishsugar.co.uk

4. Sugar Beet Overview

tonnages of sugar beet at three different levels - 2 million, 1.5 million and 1 million tonnes. Table 14 outlines the hectarage of land required to produce these tonnages, given a relatively conservative average sugar beet yield of 60 tonnes per hectare. This figure is based on the growth trials undertaken in Scotland in 2019 - 2020 and the yields achieved currently from fodder beet yields. Higher yields (up to 75+ tonnes per hectare) can be achieved in Scotland, and the calculations build in a risk factor for achieving this over a large hectarage given a number of planting, agronomic and harvesting variables.

Tonnages of beet and hectares required

Having established the total hectarage required, Land Classification maps were analysed to establish the area of land class 3.1 and above within a 30, 40 or 50-mile radius of Dundee harbour.

Dundee Central Facility	**Radial Distance (miles)**		
Radius from Dundee (miles)	30	40	50
LCA 3.1 and above (hectares)	130808	163298	194358
Beet grown 1 year in 6 (hectares)	21801	27216	32393

Table 14: Rotational land within 3 radial distances of plant

Although there are over 163k hectares of prime arable land within 40 miles of Dundee, crop rotational requirements need to be factored in before we can assess how many hectares are available each year. Only one sixth of this will be available each year if farmers adopt a six- year rotation between sugar beet crops. Rotations are used to minimise the build-up of soil diseases that can arise if land is continuously in one crop and maximise benefits to following crops. The number of hectares identified is described in Table 14.

These calculations measure distances from field to processing plant as the crow flies and actual journeys will be longer and speed of delivery may depend more on closeness to a fast arterial route, or likelihood of bottlenecks in busy places at key times.
Table 15 below shows how the available land in six-year rotation, as shown above, compares to the annual amount of beet required to run 2, 1.5 and 1 million tonne plants, expressed as a percentage.

Plant throughput and available land			
Plant throughput	% Available land required		
Radius from Dundee (miles)	30	40	50
2 million tonnes beet	153%	122%	103%
1.5 million tonnes beet	115%	92%	77%
1.0 million tonnes beet	76%	61%	51%

Table 15: Percentage of available land required for potential refinery capacities

4. Sugar Beet Overview

- A 2 million tonne plant is unrealistic as a feedstock given that it would require 122% of the rotational land to be in beet within a 40-mile radius of Dundee, if it were to only utilise Scottish grown sugar beet. The 1.5 million tonne plant is ambitious, requiring 92% of rotational land within a 40-mile radius of Dundee.
- A 1 million tonne plant is more realistic but remains challenging, with at least 61% of the rotational land required to be in beet within a 40-mile radius.

Note that 61% of available land, refers to one sixth of the land that is within LCA 1, 2 or 3.1, but much of this is used to grow arable crops. The farmers growing these other crops need to be persuaded that sugar beet is a better financial and agronomic option. This will only be achieved by offering an attractive price, long-term contracts to encourage farmer uptake or by offering a more attractive break crop than what they are currently growing.

Available options that would increase the potential volume of bioethanol that could be manufactured include hauling sugar beet from a wider radius (greater than 50 miles); adopting a hub and spoke model, where the sugar is refined to a syrup solution locally and then transported to a central biorefinery to produce bioethanol; or importing some sugar to offset the pressure on Scottish growers.

4.9.4. Radial distances and actual travel distance by road

A 40-mile radius versus a 50-mile radius is more favourable from a transport perspective. However, a proportion of the land available within this 50-mile radius falls south of the Forth and actual travel distance is significantly greater, which is likely to make transport of crops from Mid and East Lothian uneconomic. Haddington is 86 miles and Edinburgh 63 miles distant from Dundee by road. Rosyth, just north of the Forth bridge crossing is 50 miles from Dundee.

Ideally beet would be hauled to a plant situated in the centre of an area with at least 40 miles of largely prime agricultural land in all directions. Eastern Scotland's best land does not conform to this ideal with an angular coastline interrupted by two substantial Firths - Tay and Forth - and much of the radial zone covering the North Sea.

This suggests that calculations should be based on obtaining beet from a 40-mile radius of a central plant. However, beet may be grown and transported from fields that exceed 40 miles from Dundee by road if haulage proves economic.

4.9.5. Mapping prime land at radial distances from potential refinery locations

4.9.5.1. Dundee

Dundee could provide an excellent refinery location from a crop haulage perspective as it sits in the centre of the largest area of prime agricultural land. The refinery could be sited on industrial land close to the port of Dundee.

Table 16 below shows the location of available land in three radial zones from Dundee – 30, 40 and 50 miles as the crow flies. As noted above land south of the Forth has been excluded from calculations as road distances exceed 60 miles to Dundee, which is likely to be too far to transport the crop. Class 1 land is brown, class 2.0 yellow and class 3.1 green.

4. Sugar Beet Overview

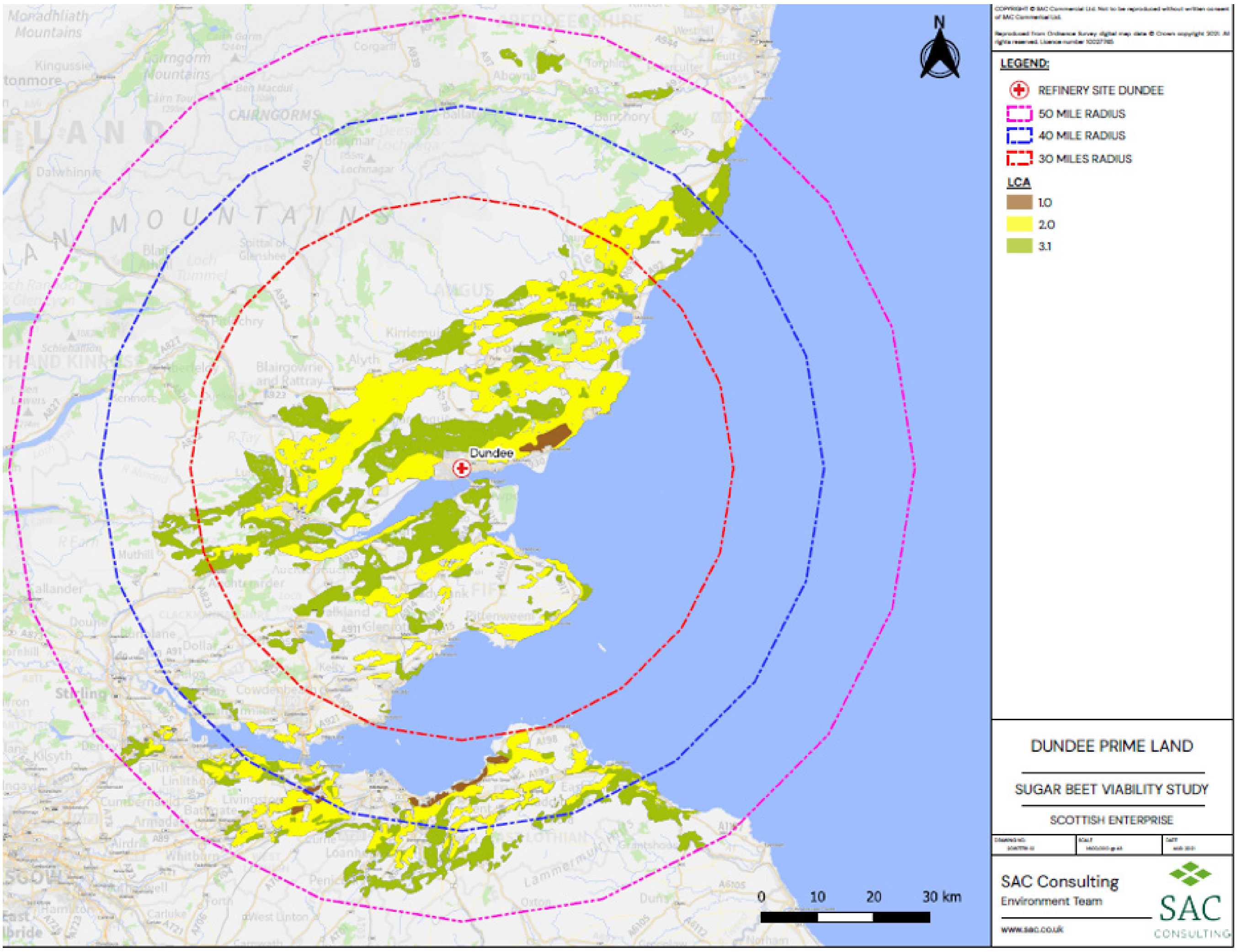

Figure 16 – Land availability by radial distance from Dundee

4.9.5.2. Grangemouth

Grangemouth is absolutely the most compelling location from a chemical manufacturing perspective. The advantages in siting the refinery within the Grangemouth industrial complex include renewable power generation, water treatment, transport logistics including port access, co-location of customers, and human capital. Though Grangemouth lies outside the main area of prime agricultural land; it brings land in the Lothians in to play, much of the beet crop would need to be hauled long distances with additional transport costs and a higher carbon footprint. The map below shows four radial distances with the outer ring 60 miles from the refinery.

4. Sugar Beet Overview

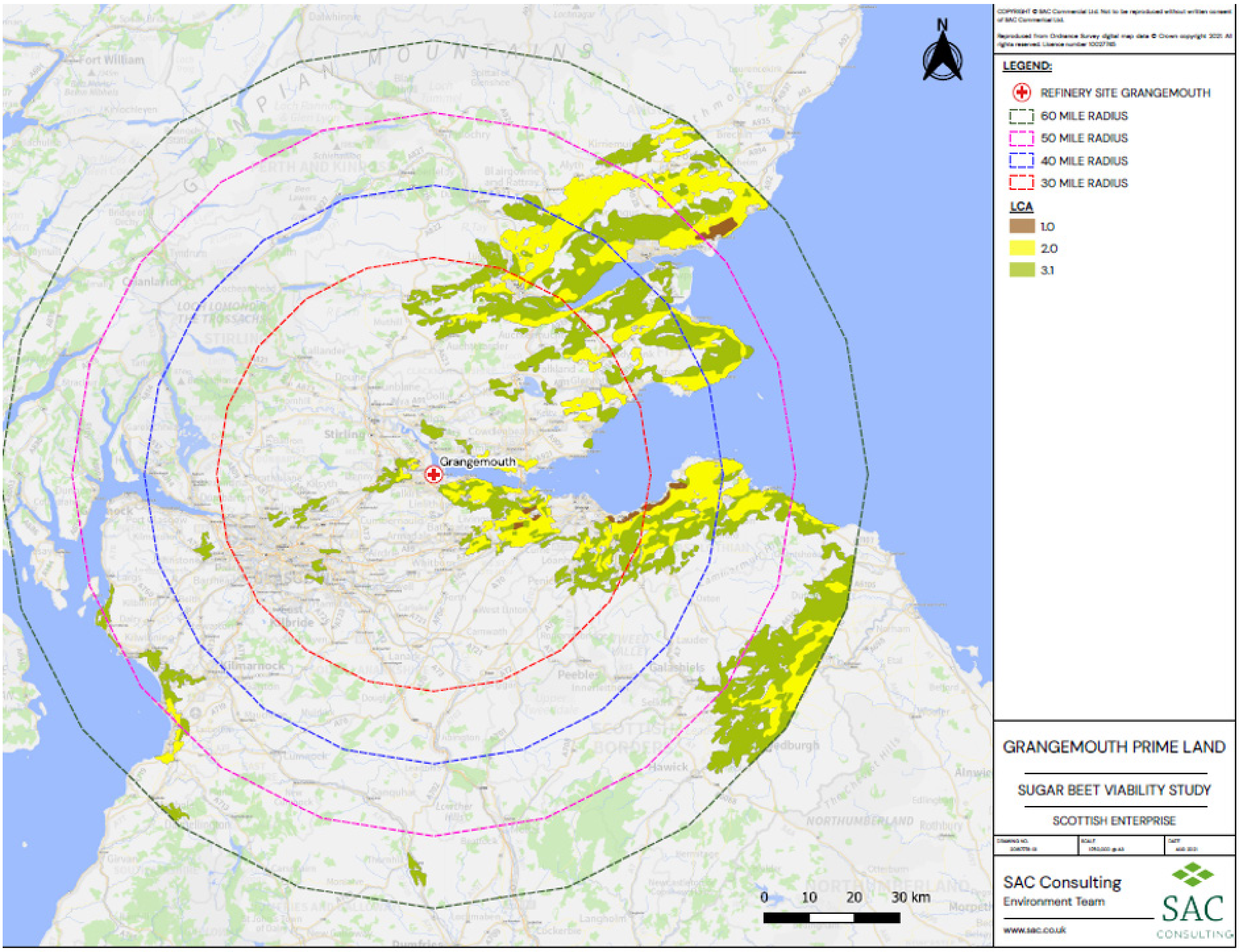

Figure 17 – Land availability by radial distance from Grangemouth

4.9.5.3. Total and rotational land at radial distances from processing facility

Refinery Sites	**LCA 3.1 + ABOVE**			
		Within 50 miles	Within 40 miles	Within 30 miles
		hectares	hectares	hectares
Dundee	All prime land	194,358	163,298	130,808
Grangemouth	All prime land	184,881	132,187	66,269
Dundee	Prime land in rotation	32,393	27,216	21,801
Grangemouth	Prime land in rotation	30,814	22,031	11,045

Table 16: Prime land availability near potential central refinery sites

4. Sugar Beet Overview

The figures confirm that a Dundee refinery would have almost double the beet tonnage of Grangemouth at a 30-mile radius, and 23% or approximately 5k more hectares at a 40-mile radius. The figures become closer at a 50-mile radius, but as mentioned previously, 50 miles 'as the crow flies' is in many cases an underestimate of actual road distance. The greater concentration of beet, the closer Dundee is likely to incur lower haulage charges and a slightly reduced carbon footprint.

4.9.6. Local Hub Micro-refineries

Although this report has looked primarily on the economics of a central bioethanol refinery, the Sugar Beet Working Group was interested in investigating the potential of local production hubs.

Local hubs have appeal for a number of reasons outlined below but are disadvantaged by the fact that this concept has not been trialled before and processing units are not commercially available. Options include:

- Local hubs in addition to a central refinery. For example, adding Lothians or Borders production to the intake from the Dundee 40-mile radial area land.
- Local hubs as an alternative model to a central refinery. For example, a series of 6 local hubs each processing 120,000 tonnes per year, producing a total of 720,000 tonnes of sugar beet.

The map below shows the land available for sugar beet production around some existing AD Plants. These sites have been chosen to demonstrate a geographic distribution and do not represent agreement from AD Plant owners to act as hub points for local production.

4. Sugar Beet Overview

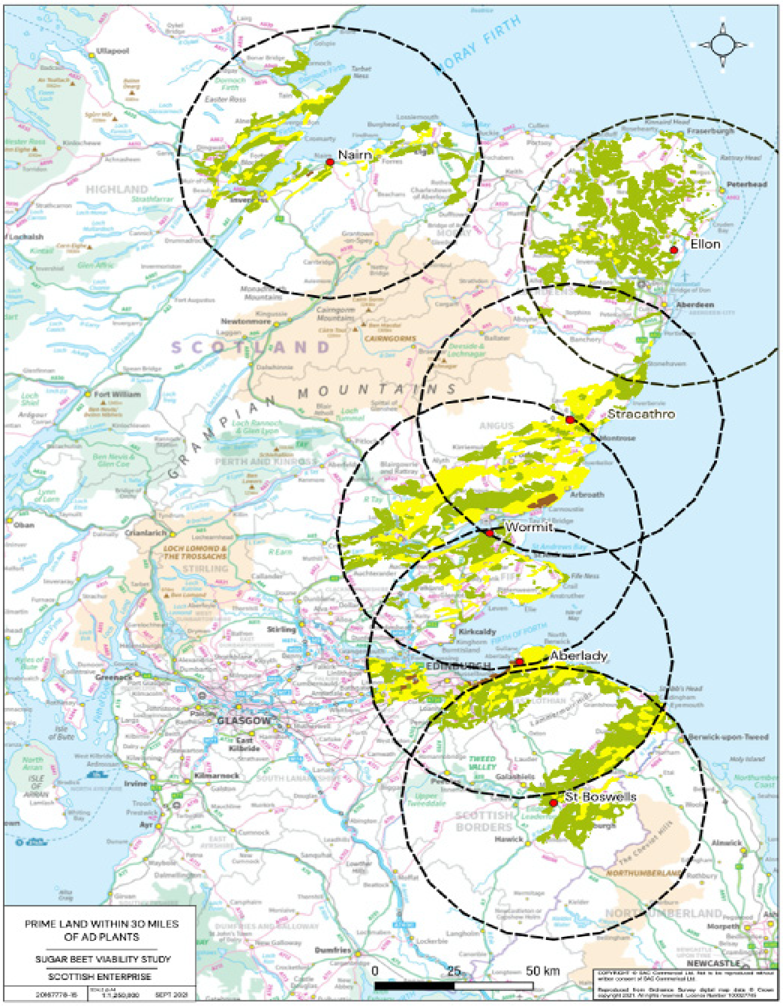

Figure 18– Potential Locations of Regional Hubs

Summary of Local Hub Advantages and Disadvantages

Advantages

- Increases available acreage for growing sugar beet by utilising all favourable areas of prime agricultural land across Scotland.
- Shortens travel distances for harvested beet to the refinery, saving haulage costs and reducing carbon footprint.
- Allows transport of processed sugar in a concentrated syrup form for onward transportation for further processing.
- Reduces road traffic congestion by smaller amounts of traffic to local centres rather than all traffic heading to one central refinery, possibly in an urban location.
- Hubs could be co-located on Anaerobic Digestion plant sites and residue from sugar extraction could form a useful feedstock for AD plants.

4. Sugar Beet Overview

Disadvantages or unknowns

- Sugar beet micro-refining technology is not yet commercially available, although some protypes are in development.
- If Grangemouth were the location of a centralised hub, it has existing capabilities for wastewater treatment though wastewater handling has not been considered.
- Quality control of these hubs would need to be considered to ensure the sugar syrup being produced is of a uniform standard across all of the hub locations.
- Planning consent would be required at multiple sites in rural areas, which can be difficult to obtain consent from councils.

The basic principles behind the idea include setting up local processing hubs that reduce sugar beet transport distance and minimise road traffic. The hubs could be set up within those areas with good beet growing potential. The GIS maps indicate that much of the beet in these areas could be harvested within a radial distance of 15 or 20 miles. Basing the exercise on existing Anaerobic Digestion Plants, LCA data indicates that these hub areas can access a maximum of 5k to 9k ha of rotational land. If 2k ha of sugar beet grown in each hub area, six hubs could produce 12kha or 720,000 tonnes of beet annually. Transport costs for raw sugar beet could be substantially reduced with concentrated sugar syrup transported by lorry for further processing and allow longer journeys to be undertaken from the more distant hubs. Traffic volume would be dispersed around 6 smaller and likely rural hub areas rather than all loads heading to one central refinery destination. The 2k ha is computed on the basis of 40 farms growing 50 hectares each.

Outlying areas of land could potentially be brought into production and hubs could be formed to allow production centred round Easter Ross/Morayshire, Angus (possibly two hubs), Fife, Lothians and Borders. This would give the hub model more land to choose from and could allow smaller groups of farmers, perhaps working in a co-operative, to take a lead in setting up sugar beet hubs in their area.

As part of this study, discussions were had with technology providers who are currently developing modular sugar beet processing units that could process up to 500 tonnes of beet per day, but these are not yet commercially available. Should they become available, a local hub may be able to use two of these units to process 1,000 tonnes of sugar beet per day to produce a concentrated sugar syrup. Consideration of how by-products would be handled at this small scale of operation would need to be considered. These would consist of processing the beet pulp, wastewater, soil, and lime used in the process, which normally comprise a high value percentage of a sugar beet refinery's financial outgoings.

4.9.7. Co-locating processing on AD Plants

Anaerobic Digestion (AD) plants already handle sugar beet, and so in theory they could expand storage and processing space to act as local hubs for their area. Some of the residual product from sugar beet processing could be used as a valuable feedstock for these AD plants.

The table below shows the availability of prime land within a 10, 20 and 30 mile radius of existing anaerobic digestion sites at six potential hub locations.

4. Sugar Beet Overview

Total prime land available	LCA 3.1 + ABOVE		
	Within 10 miles	**Within 20 miles**	**Within 30 miles**
Nairn, Highlands	6,525	36,384	52,087
Ellon, Aberdeenshire	18,017	62,831	97,468
Stracathro, Laurencekirk	26,417	63,208	96,328
Wormit, Fife	30,039	102,481	137,191
Aberlady, Lothians	27,320	47,479	98,506
St Boswells, Borders	25,111	35,208	67,674

Prime land - 1 year in 6 rotation	LCA 3.1 + ABOVE		
	Within 10 miles	**Within 20 miles**	**Within 30 miles**
Nairn, Highlands	1087	6064	8681
Ellon, Aberdeenshire	3003	10472	16245
Stracathro, Laurencekirk	4403	10535	16055
Wormit, Fife	5007	17080	22865
Aberlady, Lothians	4553	7913	16418
St Boswells, Borders	4185	5868	11279

Table 17: The prime land available in a 10, 20 and 30-mile radius of the five potential Hub locations. The top table shows total prime land available and prime land available in a one in six-year rotation.

4.9.7.1. Agricultural Production in Numbers - Farm to Processing Plant

This section summarises the production system from growing the crop, harvesting and transportation to a central refinery described in one table (Table 18). This quantifies the numbers involved for a series of hectares of crop grown.
With suitable land identified a spreadsheet was created to model:

- Suitable land availability within prescribed distances from the plant.
- Frequency of growing sugar beet in a rotation e.g. one year in six.
- Required farmer uptake to meet hectarage targets, expressed as a percentage of available land.
- Average yield assumptions e.g., 60 tonnes per hectare.
- Tonnage raw sugar beet produced per year - providing an idea of scale of operation compared to other UK plants e.g., millions of tonnes of beet processed.
- Potential sowing days – assuming a shorter window than England to reduce frost risk e.g., April and May using standard field working day figures.
- Harvesting days - from October to early March using field working days and farmers experience.
- Machinery – taking the above to calculate the number of harvesters and seed drills required based on hectarages sown or lifted per day with some allowance for road travel.
- Haulage – estimating the number of lorry journeys required per day based on typical lorry capacities.

Table 18 shows output and production parameters for a range of hectares of sugar beet grown. Included is tonnage of beet produced, machinery requirements and percentage of available land required, to help

4. Sugar Beet Overview

assess the feasibility of producing target tonnages of sugar beet for each crop production cycle (April to March). Blue or shaded cells show assumptions made.

	1,000 hectares	10,000 hectares	15,000 hectares	20,000 hectares		
Hectares sugar beet	1,000	10,000	15,000	20,000	UNITS	
Sugar beet yield	60	60	60	60	tonnes per hectare	
Tonnes beet harvested per annum	60,000	600,000	900,000	1,200,000	tonnes beet	Annual tonnage to be processed at central facility
Number harvesting days	100	100	100	100	harvest days	150 day season - how many days crop can be harvested
Harvester work rate	10	10	10	10	hectares per day	6 row harvester allowing for travel between fields and breakdowns
Hectares lifted per day	10	100	150	200	hectares per day	Based on hectares required and harvesting days
Tonnage lifted per day	600	6,000	9,000	12,000	tonnes per day	Total per day based on 100 harvest days
Harvester work rate - 1 machine	10	10	10	10	hectares per day	6 row harvester allowing for travel between fields and breakdowns
Harvesters required	1	10	15	20	Mechanical harvesters	Based on hectares lifted and work rate
Lorry capacity	28	28	28	28	tonnes	
Lorry working days	150	150	150	150	days	Pick up beet from field sides, standings

4. Sugar Beet Overview

Calculated lorry journeys	14	143	214	286	loads per day	At 28 tonnes per load	
Available land within 40 miles	n/a	27,216	27,216	27,216	hectares	Dundee example, 40 miles radius, one sixth of available land	
Percentage of available land required	n/a	37%	55%	73%	one sixth of land LCA class 3.1 and greater	Assuming a 1 year in 6 years rotation	
Hectares sown per available day	29	286	429	571	hectares per day	Planting days per year in April, May	35
Number seed drills	1.2	12	18	24	drills	Hectares drilled per day	24-28

Table 18: Output and production parameters for a range of hectares of sugar beet grown.

4.9.7.2. Conclusions from land availability analysis

These calculations of hectares, tonnages, harvesting and sowing machines, and lorry journeys form the basis of later agricultural production cost calculations.

Assessing the accessible amount of land for sugar beet production, it's unlikely we would achieve 20,000Ha as would require 71% of the rotational land within 40 miles of the central refinery to be sown in sugar beet. Growing 15,000Ha of sugar beet may be achievable but requires 55% of the rotational land in sugar beet, while 10,000Ha requires 37% of the available rotational land. We believe a realistic target lies somewhere between 10,000 and 15,000Ha.

When considering how many farms would be required, there is no typical arable farm size - they come in a variety of sizes. To provide some assessment of the number of farmers who would need to grow sugar beet assumed that larger farms might grow 50Ha, and smaller farms 30Ha of sugar beet each year. A 10,000Ha target would require 200 larger farms or 333 smaller farms to grow sugar beet. A 15,000Ha target would require 300 larger farms or 500 smaller farms to grow sugar beet. There are 584,062Ha of land available in Scotland and over 50,000 agricultural holdings so it would require between 0.6 - 1% of farms in Scotland.[101]

When considering whether 10-15kHa is a realistic target for sugar beet as a rotational crop, we can compare these figures against hectarages of other break crops. In 2020, break crops growing in the Tayside and Fife areas were oilseed rape (9,089ha), potatoes (16,783ha) and field vegetables (13,242ha). Source – Scottish Government June Agricultural Census 2020. However, note that these crops as they can be grown on fields in LCA 3.2 and so there is more available land. Other factors to

101 https://www.gov.scot/publications/results-june-2017-scottish-agriculture-census/pages/3/

4. Sugar Beet Overview

consider around rotational crops can be found in Chapter 3.

When considering how the economics of transportation might influence price, some consideration should be given to the economics of transporting the beet from a wider radius. If the bioethanol plant were to be located in Dundee, then beet could be transported from East Lothian and potentially the Borders to achieve sufficient volumes of beet. If the plant were to be located in Grangemouth, then more sugar beet would be required from Morayshire/Easter Ross and Angus. A different tariff could be applied depending on the sugar beets proximity to the processing site. While it may discourage some growers to receive less for growing beet than growers closer by, it may still be attractive enough for them to decide to grow. A cooperative model could strengthen the appeal as well (Cooperatives are discussed in more detail in Chapter 6).

Alternative options to the 'central refinery' option are a hub and spoke model where it would be possible to increase available acreage for sugar beet growing by utilising all favourable areas of prime agricultural land across Scotland. There could be six hubs based across Scotland in Easter Ross/Morayshire, Angus (possibly two hubs), Fife, Lothians, and Borders. The beet could be processed to sugar syrup on site, which would be much easier and more cost effective to haul than sugar beet. The major downside of the approach is that the technology available for the process is currently at a pre-commercial stage.

The final option is to consider importing some sugar to relieve the pressure on Scottish grower's and to provide protection against lower yielding years. This option is discussed in more detail in Chapter 7.

4.10. The Farmer Uptake Challenge

Farmers will need compelling evidence that a new crop can enhance their returns from arable production. Some of the issues that might be raised include:

- Sugar beet is a new crop for most farmers. Although a Co-op could supply skilled contractors with specialised equipment carrying out key sowing and harvesting operations, some will see this as a leap into the unknown. There will be a focus on risk factors.
- There are two scenarios for land use – land belonging to Co-op members, and land that needs to be rented on an annual basis from other farmers. Rented land introduces an additional cost to production.
- Sugar beet, harvested from October onwards does not lend itself well to establishing a following winter wheat crop, normally one of the higher margin crops in the arable rotation. Farmers will need to consider whether the financial return from sugar beet compensate for this.
- Concerns about damage to soil structure due to post October harvesting, when conditions can be wet, and the impact this might have on following crops.
- Payment for sugar beet not leaving sufficient profit compared to other arable crops.
- Some farmers may be happy with what they are currently doing and see no need to include a new crop on their land.
- Fears that a Co-op might not manage to procure sufficient machinery for specialised operations such as sowing and harvesting the crop.
- Some farmers are naturally reticence to be the first to try something new, instead adopting a "wait and see how others get on" approach before committing to growing sugar beet.

In summary, farmer uptake is crucial to the success of this project. They will require realistic and convincing information to allow them to make a reasoned decision about growing sugar beet as part of the co-operative. Incentives will be required to make the sugar beet price sufficiently attractive for farmers to change their crop rotations.

4. Sugar Beet Overview

4.11. Transport Logistics

Harvested sugar beet requires to be transported from field to processing site either using lorries or tractors and trailers. Bulk transport in lorries is likely to be more efficient for longer journeys given their large load capacity and fast road speed, but there will also be a place for tractors and trailers for shorter journeys. It is interesting to note that the large European sugar business Nordzucker is actively encouraging greater use of lorries as they consider that this form of transport is more efficient than using lower capacity trailers. Sustainability is discussed in more detail in chapter 5.

4.11.1. Lorry Transport

The sugar beet crop harvesting season is likely to span October and February with the crop either stacked at the side of fields, or on a hard standing near the field, for loading into lorries using cleaner loaders that remove excess soil and stones. Sugar beet can be stored in clamps at the side of the field for several days before loading, provided that severe frost can be avoided. Lack of hard standings in field, and impracticality of loading lorries parked on the road over field boundaries, makes it more likely that hard standings at farm steadings will be used for temporary storage.

Phone calls to a three Angus based hauliers indicated “definite interest” in transporting the crop to a central refinery. These operators had small fleets of bulk tipper lorries and estimated that 4-6 lorries might be available from their current fleet, with each lorry making 3-4 pickups per day depending on distance from the plant and loading and unloading time. The typical payload of bulk tippers in the area is 28-29 tonnes.

Haulage companies would consider in investing in more lorries if winter work could be guaranteed. Rough pricing indicated a rate of £5-£7 per tonne transported within a 40-mile radius of a processing plant.

In England the maximum distance to transport beet from farm to factory is between 40-50miles depending upon the quality and type of road network although a small number of growers do operate at greater distances where they are close to a major road network. Most haulage contractors would seek to make 3-4 deliveries per lorry per day from the farm to the factory.

British Sugar have an established Beet Delivery Service (BDS) for farmers that involves contract procurement from haulage companies. British Sugar manage the BDS and allocate approved contractors to clean, load and deliver grower’s beet and offer to co-ordinate harvesting services. During the 2019/20 crop harvest, 30 BDS contractors provided their services.

4.11.2. Tractor and trailer transport

The experience of English growers is that it is important to ensure that the harvesting, loading, and transport systems are balanced to avoid bottlenecks and to keep the operation running as efficiently as possible.

In the field, trailers used to collect the beet from the harvester need to match the capacity of the harvester’s tank and if the beet are being taken straight from the field to the factory by lorry, the cleaner loader needs to operate at the same rate as the beet arrives from the harvester. One English grower that has a harvester with a 26-tonne tank, uses a 26-tonne trailer pulled by a 300+hp tractor to take beet from the harvester but if it must travel more than around half a mile to empty then a second tractor and

4. Sugar Beet Overview

trailer may well be required to prevent the harvester from having to wait to unload.

Tractors and high-capacity trailers may also be a preferred option to take beet to the central refinery or local hob. This is only really viable within a certain distance of the processing facility, (i.e., approx. 10 miles but factors such as the road network and trailer capacities and numbers will also determine whether this is the most efficient means of delivery.)

4.11.3. Rail Transport

The Cupar Sugar Beet factory that operated up to 1972 was heavily dependent on rail deliveries backed by government transport subsidies. This saw beet being transported to Cupar from as far north as the Black Isle and as far south as Northumberland. It relied on an extensive railway network passing through many small towns, before much of the network was closed following the Beeching rail re-organisation from the mid 1960's. Haulage to the railheads is likely to have been a labour-intensive operation with beet unloaded from trailers and reloaded on to railway trucks. However, the Cupar operation was efficient from an unloading aspect as a branch rail ran straight to the refinery.

A rail network transporting beet direct to a refinery that reduces pressure on roads is a great objective that is unlikely to be feasible without rail upgrading and an integrated containerised method of haulage that links road and rail. It is unlikely that beet could be economically transported to a Dundee refinery by rail given our limited railway network and the requirement to haul beet in stages by road to a railhead then by rail to the nearest station, then presumably by lorry to the refinery.

Haulage involves both travel and loading/unloading time and the latter can greatly affect delivery times particularly when there are delays. Sugar beet plants try to avoid double handling during transport, which makes road plus rail transport appear less attractive.
The East Coast main line runs along the coastal edge of the main beet growing area in Angus[102].

4.12. Feedstock Crops for Anaerobic Digestion Plants

A recent example involves growing crops as feedstocks for Anaerobic Digestion plants producing biogas, including energy sugar beet and forage rye. Hectarage is limited as few businesses had the capital required to set up plants and the tenacity to apply for funding through Government Feed in Tariff (FIT) support. There are approximately 60 AD plants established in Scotland and a proportion, mainly on the east coast, using beet and rye, while others use largely grass silage and other materials. AD plants generally draw their feedstocks from the home farm and others in the local vicinity. They have been able to offer other farmers attractive prices to either grow beet and rye or have paid these farmers rent to use their fields. This is a relevant example as AD plant operators adapted quickly to growing energy sugar beet and have been able to obtain supply from other farmers thanks to attractive support payments. Several farmers interested in growing sugar beet already grow the crop for AD plants.

4.13. Land Rental

While much of the sugar beet may be grown on land belonging to farmer members committed to the cooperative, a significant amount of additional land will be required from non members farms if we are to hit targeted tonnage. This land will need to be rented on an annual basis. This type of arrangement

102 https://www.thetrainline.com/train-companies/national-rail/national-rail-map?gclid=2c311002a02613ea9aae71248096ea3d&gclsrc=3p.ds&&cm=0p2b&msclkid=2c311002a02613ea9aae71248096ea3d

4. Sugar Beet Overview

is used for growing potato crops where long rotations are required to minimise pest and disease risk, and land rental is typically £1000 to £1500 per hectare in Angus where there is strong competition for potato land. A new crop like sugar beet should be less competitive, with a wider range of suitable land to choose from as there is no historic soil pest or disease burden. The price is likely to be set by the marketplace and farmers view of how much rent they require to provide similar or better profitability than their current crop mix, adjusted for the perceived benefit of the break crop on the performance of subsequent crops. It is difficult to predict rent values but as an example if sugar beet rent was £500 per hectare this would add £8.33 to the cost of each tonne produced, and £12.50 per tonne at a rent of £750 per hectare.

5.Carbon Accounting, Sustainability and Societal Impact

The net-zero targets set by Scottish Government by 2045 are an important driver for the introduction of sugar beet as an alternative feedstock to fossil-based carbon. Grangemouth is responsible for around 10% of Scottish CO_2 emissions[103] . Sugar beet as a feedstock can offer a sustainable solution for the manufacturing of a range of end products and help achieve the greening of Scotland's chemical industry whilst safeguarding it into the future towards the achievement of net zero targets.

An important aspect to understand when considering this project is the carbon saved by the reshoring of a Scottish sugar supply chain, the overall impact it will have on sustainability and the wider societal benefits.

5.1. Carbon Accounting

5.1.1. Carbon Footprint of Bioethanol

Carbon saved in the supply chain

The following table outlines the CO_2 captured at the Crop Energies AG site and based on this figure, the CO_2 captured at a 170M litre Scottish bioethanol facility has been calculated:

Site	Scale (million litres)	CO2 (e) Captured (k Te)
Crop Energies AG	420	750
Scottish Bioethanol Plant	170	275

Table 19: Carbon savings in supply chain

The calculation above shows that the Scottish bioethanol facility would capture 275,000 tonnes of CO2 equivalent, which is equates to the removal of almost 60,000 cars from the road per annum.

Carbon saved (transport only)

The benefit of local bioethanol production means that Scotland would no longer be reliant on importing bioethanol . Currently Scotland imports bioethanol from the Champagne-Ardenne region in France. The carbon savings for this have been calculated and 6,653 Te of CO2 are saved per annum. The assumptions behind this calculation can be found in Table 20:

103 https://www.thecourier.co.uk/fp/business-environment/business/2462872/firth-of-forth-net-zero-hub-key-to-achieving-climate-goals/

5.Carbon Accounting, Sustainability and Societal Impact

Assumption	Value
Hauled by road (Champagne-Ardenne to Grangemouth)	Distance – 870 miles
Load capacity per tanker	40,000 litres (38 tonnes)
Volume needed to satisfy annual demand	50M litres
Loads per annum	1250
'Tonne miles'	41,325,000
CO_2 per tonne mile	161g CO2 [104]
Total CO_2 emitted	6,653 Te

Table 20: Assumptions for CO2 savings

A typical passenger vehicle emits 4.6Te CO_2 per annum[105] .If Scotland were to switch from importing bioethanol to using a domestic supply chain, this would be the equivalent of removing 1447 cars off the road per year.

Total carbon saved

The combined savings of a domestic supply and the transport emissions saved could capture over 280,000 tonnes of CO2 equivalent from the atmosphere, when looking at the supply chain emissions associated with bioethanol production. This is the same as removing almost 61,000 cars off the road per year.

5.1.2. Carbon Accounting Farming

Carbon in farming

Reducing Greenhouse Gas (GHG) emissions from agriculture is essential for Scotland to meet its carbon reduction commitments and to improve farm efficiency and profitability. Before any improvements can be made it is necessary to establish a baseline of farm performance and resource use efficiency.

SAC Consulting Agrecalc© is the UK's leading Agricultural Resource Efficiency Calculator that estimates the type, source and extent of GHG emissions produced from a whole farm, individual farm enterprises and products. It has over 2,500 users across the UK and this number is growing rapidly as governments, retailers, commercial farm businesses and other farming industry stakeholders want to measure and mitigate agricultural emissions.

104 https://business.edf.org/insights/green-freight-math-how-to-calculate-emissions-for-a-truck-move/
105 https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

5.Carbon Accounting, Sustainability and Societal Impact

The three main GHGs assessed by Agrecalc© and their sources include:

1. Nitrous oxide (N_2O), released during the application of synthetic and organic fertilisers to the soil, from urine deposition by grazing animals and from crop residues.
2. Methane (CH_4), produced as a natural by-product of enteric fermentation during ruminant digestion and from management of organic manure.
3. Carbon dioxide (CO_2), produced through burning fossil fuels to produce energy, embedded in purchased inputs and disposal of waste.

Agrecalc© calculates emissions from the above sources up to the farm gate, including emissions associated with purchased inputs. Any emissions that arise after outputs have left the farm are not included. Calculated emissions are typically displayed in terms of CO_2e (CO_2 equivalents) as an emissions intensity (i.e., CO_2e per unit of output), commonly known as a carbon footprint. Presenting emissions in this way allows comparisons to be made with other farms or enterprises and allows farm production to be taken into account. Farms with a low carbon footprint are generally the most efficient. Agrecalc© benchmarks carbon footprint results against similar enterprises, this process highlights areas where improvements can be made potentially helping to improve the efficiency of a farm business.

On an industry scale, Agrecalc© provides the capabilities and services to identify optimum mitigation options, develop informed government strategies, and support the farming industry to reduce emissions and increase efficiency, with potential for scenario modelling and monitoring services.

Carbon footprints of individual arable crops

The Agrecalc© programme was used to identify the relative carbon footprint values of sugar beet and the other individual crops listed within the arable rotations modelled in the project. The calculation models the growing of 10 hectares of each of the following crops:

- Sugar beet
- Winter wheat
- Winter barley
- Spring barley
- Oilseed rape
- Spring beans
- Spring peas

The same values used to compute the Enterprise Margins were entered to calculate the carbon footprints for each of the crops. Results are summarised in Table 21 (full details in Appendix 6).

5.Carbon Accounting, Sustainability and Societal Impact

		Whole farm	Feed wheat	Feed winter barley	Malting spring barley	Oilseed rape	Field beans	Field peas	Sugar beet
		kg CO_2e							
Total CO_2 emissions from farming (inc. Soil Carbon)		238,372	45,628	42,922	36,734	42,107	15,689	15,701	39,592
Emissions per hectare (inc. Soil Carbon)	(kg CO_2e/ ha)	3,405	4,563	4,292	3,673	4,211	1,569	1,570	3,959
	($KgCO_2e$/ kg crop)		0.51	0.56	0.58	1.24	0.39	0.39	0.07

Table 21: CO_2 Emissions by crop type

In summary, the analysis shows that, for each kilogram of crop produced, sugar beet has a carbon footprint ($kgCO_2e$) 87% lower than the cereals, 94% lower than oilseed rape and 82% lower than pulses. When expressed by area, a hectare of sugar beet has a carbon footprint value greater than a hectare of pulses and lower than a hectare of either cereals or oilseeds.

5.1.3. Carbon Savings and Carbon Price

The NNFCC report calculated that 55.5 gCO_2(e) MJ would be saved in comparison to a traditional refinery at a French sugar beet ethanol plant. We would expect a Scottish plant would have similar savings and have used this figure to calculate the overall savings per annum (table 22) and to calculate an associated carbon price (table 23).

Further work has been undertaken to calculate the carbon savings (tonnes equivalent), using the value 55.5 gCO_2(e) MJ and based on low, medium, and high energy requirements. Using the medium energy requirement, (Table 22) an associated carbon price has been calculated, based on potential carbon prices per tonne of CO_2. (Table 23)[106] [107] .

Energy (MJ)	Carbon saving (gCO_2e/MJ)
3,146,598,000 (low)	174,636
3,375,197,000 (medium)	187,323
3,603,796,000 (high)	200,011

Table 22: Carbon savings (gCO_2e/MJ))

106 https://ember-climate.org/data/carbon-price-viewer/
107 https://ec.europa.eu/clima/policies/ets_en

5.Carbon Accounting, Sustainability and Societal Impact

To calculate the carbon price, we have assumed the medium energy requirement, and we have calculated the carbon saving based on three potential carbon prices per tonne of CO_2 (£25, £50, and £100). This price is variable but currently the carbon price is £74 a tonne in the UK[108].

Carbon Price (£) per tonne CO_2	Carbon Savings (£)
25	4,683,086
50	9,366,172
75	14,049,225
100	18,732,343

Table 23: Carbon savings (£) based on carbon per tonne

Based on today's carbon price of £74 and assuming the medium energy requirement, £13,861,902 would be the carbon price saved.

5.2. Sustainability

The purpose of this analysis is to identify sustainability parameters that could be valued by stakeholders in the Sugar Beet Project including farmers, the Co-op, investors, government, and the general public. It must also address the climate change agenda and respect the natural environment and biodiversity.

Review of Sugar beet processing companies' sustainability statements

Nordzucker, based in Germany but operating across Europe and Australia is an international company producing both sugar beet and cane for sugar production[109]. The following text provides a useful case study for sugar beet sustainability.

They have recently produced a Sustainability Strategy 2030 covering their entire supply chain, based on four pillars: People Focus, Sustainable Sourcing including Beet Growing, Sustainable Production and Sustainable Products. These four pillars include a wide range of commitments and actions on issues such as climate change, ecological agriculture, sustainable supply chains and take into account changing expectations of consumers, employees, and other stakeholders. Their Sustainability Strategy 2030 can be found in the latest Annual Report[110].

Nordzucker describe sugar beet as "A naturally sustainable and environmentally friendly Crop." This assertion is based on benefits to soil health and farm rotations. "It has a deep root system that is good for the soil structure in crop rotation. Sugar beet makes good use of available nutrients and needs less nitrogen fertiliser than most other crops grown in the sugar beet areas. Sugar beet continues to grow in the autumn when other crops are already harvested and keeps absorbing nitrogen from the soil, reducing the risk of nitrogen leakage."

Growers follow "national Integrated Pest Management (IPM) to avoid unnecessary applications of plant protection products and act according to the following guidelines: 1) Observe and monitor for pest and

108 https://ember-climate.org/data/carbon-price-viewer/
109 https://sustainability.nordzucker.com/growing-sourcing/growing/sugar-beet-sustainability-through-partnership/
110 https://www.nordzucker.com/en/wp-content/uploads/2021/05/Annual_Report_2020_21_EN.pdf.pdf

5.Carbon Accounting, Sustainability and Societal Impact

diseases, 2) Assess potential alternatives, e.g., naturally occurring beneficial insects already in the field, 3) act when a clearly defined threshold has been reached and no alternative is applicable. Our growers are here supported by national research institutions through seasonal monitoring."

Proximity to factories is also quoted as a sustainability measure – "The sugar beet is grown on fertile soils suited for beet growing and close to our sugar factories." The company has assessed the carbon footprint of all of its transport logistics, the bulk of which are transporting the crop from field to factory. It is interesting that they have focussed on travel distances reducing lorry weights, and the proportion of crop transported by lorry. "Transporting sugar beets from field to factory from September until January is a logistical task. In Nordzucker Group, in 2016, 86% of the beets were transported by truck instead of tractors. An increase by 6% since 2013. Switching to trucks has resulted in a higher load per truck and therefore reduced the amounts of transports on the road. On average trucks can transport on average 28,9 tons, while tractors carry 21,2 tons. In Nordzucker Group the average distance for our beet transports from farm to factory is 46 km."

Much of the case for sustainability of sugar beet production centres around the rapid advances in plant breeding that have allowed enhanced yields at the same time as reducing nitrogen inputs. Nordzucker stresses the importance of an effective R&D programme that maximises crop production efficiency. "One way we support farming sustainability is through our work in agricultural research and development. When new knowledge becomes available that could lead to improvements in beet farming – for example, by using less fertiliser or increasing production efficiency – we share this knowledge directly with our growers. In this way we can work together to improve farming practices while further strengthening our relationships with growers.

Field research into seed variety trials, innovative growing techniques and pest and disease management is carried out by our partners in Germany (ARGE Nord), Denmark/Sweden (Nordic Beet Research-NBR) and Finland (SJT) and at the Institute for Sugar Beet research (IFZ) at the University of Göttingen, Germany. Additionally, we are active in other research projects and sugar beet societies like the International Institute of sugar beet research (IIRB).

It is impressive to see that "Since 2010 Nitrogen fertiliser application in German beet growing has dropped from 11 to 8.7 kg/t we now need much less nitrogen to produce a tonne of sugar."

5.2.1. Farm Rotation Benefits, Soil Health, Structure and Sequestration

Sugar beet acts as a 'break' crop in the rotation, and this means it provides a break or a rest from the more intensively farmed cereal crops that dominate most arable rotations.
A break crop is sown to provide diversity to help reduce disease, pest and weed levels and improve soil health. As a break crop, sugar beet 'breaks' the cycle of many pests, weeds, and diseases, and without this, these threats could increase and ultimately could mean the land is unsuitable for growing some crops. Having sugar beet as break crop also reduces the need for pesticides.

The large amount of organic material returned to the soil by the tops of the sugar beet after harvesting also helps build up soil carbon and organic matter reserves - an essential part to the healthy functioning of the soil and of agronomic value to subsequent crops. The average increase in winter wheat yield following break crops in northern Europe has been estimated at 24%, reinforcing the value of a break crop[111].

111 https://www.researchgate.net/publication/222578061_Break_crop_benefits_in_temperate_wheat_production

5.Carbon Accounting, Sustainability and Societal Impact

Growers often also take the opportunity to grow winter cover crops before drilling their beet. Cover crops have been shown to have a significantly positive effect on soil health. For example, British Beet Research Organisation (BBRO) cover crop trials have found that soils tend to be drier, less susceptible to compaction, earthworm populations are higher, the crops help to conserve and add nitrogen to the soil and their roots helps improve soil structure[112]. Existing growers of sugar beet are very aware of the need to minimise soil damage and compaction as this reduces the performance of their crops. The co-operative agronomists would work closely with growers to provide advice on this throughout the sugar beet campaign. Machinery designers are also very aware of the importance of protecting the soil and developments in technology such as weight reduction and tyre technology and configuration are key design features of modern sugar beet harvesters.
As well as managing the sugar beet harvester, the management of the trailers used to move the beet is just as important and controlling the movement of these within the field is another integral part of how growers manage their soils.

Growers also manage the risk of soil damage by selecting fields carefully in relation to their harvest date. For example, targeting the heavier land with higher clay content for early harvesting when soils are more likely to be drier and less prone to damage and using the lighter sandy soils for later harvesting. Harvesters and cleaner loaders are increasingly effective in removing the soil from the sugar beet during harvesting and increasingly sophisticated cleaning systems are being employed to remove soil on the harvester, all of which minimises soil loss from the field

5.3. Societal Benefits

5.3.1 Job Creation

5.3.1.1. Jobs Created at Bioethanol Plant

The reshoring of a supply chain and the creation of an entirely new industry in Scotland will have positive economic and societal impacts. When reviewing other comparable plants, for example Vivergo, employs 80 directly to run the plant but also supports 1,000 additional jobs through its supply chain.

The creation of a new bioethanol plant will not only support direct high-value, on-site jobs but also support and create jobs throughout the entire supply chain. To determine the number of direct jobs created, depending on the size of the plant, a figure of £0.128 per litre of ethanol equivalent was used and the assumption that each person per year would cost £100,000. Table 24 below shows the direct, high value jobs created at the plant based on the volume of ethanol it produces annually. It should also be noted that considerably more indirect jobs would be created through the supply chain, depending on ethanol demand and the volume of sugar beet grown.

Ethanol Capacity	Direct Jobs Created
100M litres at 85% capacity	32
200M litres at 85% capacity	52
400M litres at 85% capacity	78

Table 24: Direct jobs created by ethanol plant capacity

112 https://bbro.co.uk/our-news-opinions/our-opinions/opinions-2019/cover-crops-role-in-soil-management/)

5.Carbon Accounting, Sustainability and Societal Impact

5.3.1.2. Agricultural Jobs Created

There are 67,000 people directly employed in agriculture in Scotland – this represents around 8% of the rural workforce. Agriculture is the third largest employer is Scotland after the service and public sectors[113]. To meet 100% of Scottish bioethanol demand, approximately 300-500 farms will be required to grow sugar beet which accounts for between 0.6-1% of Scotland's farms. Based on these figures, this project could generate between 402-670 additional direct jobs in agriculture. Furthermore, seasonal jobs would be created from this project. In 2017 the Scottish Government conservatively estimated there were 9,255 seasonal migrant workers engaged in Scottish agriculture, based on this figure between 56-93 season jobs could be created through this project.

5.3.1.3. Logistics Jobs

Additional jobs will be created through logistics as the beet will need to be transported from the field for processing. Depending on how the beet is transported, it will create additional jobs for lorry and/or train drivers.

5.3.1.4. Jobs Potentially Safeguard

The development of a new sustainable feedstock would help safeguard some of the 11,000 existing jobs[114] in the chemical industry. Grangemouth's petrochemicals site is home to most of Scotland's chemical manufacturers and its sole refinery. These companies support many jobs, in particular, INEOS and Petroineos who directly employ 1,850[115] [116], alone and many indirectly through supply chain jobs, logistics and the employment of local contractors. Currently these sites are highly reliant on fossil carbon for fuel production and the manufacturing of polyethylene and its derivatives. Scotland has a growing bioeconomy, and many industries are adopting industrial biotechnology (IB) processes to help them to increase their sustainability and help achieve their net-zero aspirations. The IB industry has increased from a £189M turnover and 43 companies in Scotland in 2012 to a £749M turnover and 130 IB active companies in just 7 years to 2019 and it continues to grow[117]. Many IB companies could use sugar beet as a sustainable feedstock to manufacture biofuels, bioplastics, pharmaceuticals, and chemicals. Sugar could also be used as a feedstock for fermentation.

As Scotland moves closer to its net zero targets, manufacturing industries that are currently reliant on fossil carbon will adopt need to adopt alternative, net-zero manufacturing processes. The introduction of sugar beet can help in safeguard these industries as Scotland moves towards its net-zero targets as well as creating additional direct and indirect jobs for locals.

The Scottish Government has recognised the importance of transitioning jobs to green jobs, in 2020 the Scottish Government published its annual Programme for Government 'Protecting Scotland, Renewing Scotland' where it set out the importance of green jobs for the future of Scotland and have committed £100m over the next 5 years for a Green Jobs Fund which is managed by Scottish Enterprise[118].

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113 https://www.nfus.org.uk/farming-facts.aspx
114 https://www.scottish-enterprise.com/learning-zone/research-and-publications/components-folder/research-and-publications-listings/scotlands-chemical-sciences-facts
115 https://www.ineos.com/sites/grangemouth/about/
116 https://www.petroineos.com/refining/grangemouth/
117 https://www.lifesciencesscotland.com/supporting-strategies/national-plan-industrial-biotechnology
118 https://www.gov.scot/publications/protecting-scotland-renewing-scotland-governments-programme-scotland-2020-2021/documents/

5.Carbon Accounting, Sustainability and Societal Impact

5.3.2. Deprivation and Rural Area Consideration

5.3.2.1. Grangemouth

The Central Belt is Scotland's most densely populated region (~3M). While it hosts research excellence, multinationals, and SMEs, it also encompasses some of Europe's most deprived areas, including Falkirk. Falkirk is home to the Grangemouth petrochemicals site, which has ambitious plans to become an international, biobased manufacturing campus.

In 2020, the Scottish Government published the Scottish Index of Multiple Deprivation (SIMD)[119]. The SIMD is a tool to identify areas of multiple deprivation in Scotland. Each of Scotland's 6,976 data zones are ranked from 1 to 6,976, with 1 being the most deprived and 6,976 being the least. There are 214 data zones in Falkirk and 35 of these falls in the worst 20% of deprivation in Scotland. 15% of Falkirk's residents live in the 20% most deprived areas in Scotland[120].

5.3.2.2. Dundee

Dundee is Scotland's fourth largest city, in the North-East of Scotland with a population of around 150,000. Dundee is also home to some of Scotland's most deprived neighbourhoods. The SIMD Tool identifies that Dundee City Is the fifth most deprived area in Scotland[121] with 38% of data zones living in deprived areas.

5.3.3. Conclusions

In summary, at least 815 additional jobs could be created directly through this project and others will be created through the supply chain and logistics. Additionally, the development of a new sustainable feedstock would help safeguard existing jobs in the chemical industry and create new jobs in Scotland's biotechnology sector. Many of these jobs will be created in rural areas and some of the most deprived areas in Scotland. It is envisaged that Grangemouth is likely the best site for a central bioethanol facility given its location, logistics, utilities and COMAH accreditation.

The bioethanol plant would create at least 52 direct high-value jobs and additional jobs would be created. The introduction of a new sustainable feedstock will help to safeguard chemical jobs in Scotland and create new biotechnology jobs through new product development.

As well as creating jobs at the bioethanol facility, rural farming jobs would be created through the growth and harvesting of sugar beet. This project could generate up to 763 (direct and seasonal) jobs for the Scottish agricultural sector.

119 https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/
120 https://www.falkirk.gov.uk/services/council-democracy/statistics-census/docs/simd/Scottish%20Index%20of%20Multiple%20Deprivation%20Report%202020.pdf?v=202001281540
121 https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/

5.Carbon Accounting, Sustainability and Societal Impact

To generate sufficient volumes of sugar to meet Scottish bioethanol demand, hundreds of farms will be required to grow sugar beet. The bioethanol manufacturer could sign individual contracts with each grower but this model is time consuming and complex. There are other models which could be explored which may make the process much easier. To create a viable supply chain for sugar beet as an energy crop, farmers may choose to work together to grow, harvest and transport the beet to the biorefinery - whether this is located at a single central location or smaller hubs. One mechanism could be through forming a farmer producer co-op, a well-established and successful approach of modern farming. This Chapter explores how co-ops work and how they might benefit wider adoption of the growth of sugar beet across Scotland. It also explores what obstacles that a co-op model may present. The experiences from sugar beet co-ops operating in France and corn bioethanol co-ops in the United States are also reviewed.

6.Co-operative Structure

6.1. What is co-operation?

Co-operation is a voluntary association of farmers, other rural businesses and communities working together to achieve a commercial objective, which they cannot achieve independently and individually. Through co-operation, members help themselves, pro-actively taking responsibility for generating value and sustainable services in which they have a common purpose.

Today, the Scottish farm co-op movement involves some 60 independent co-ops, owned by over 22,400 members, with a combined turnover £1.3bn, employing over 1,200 people (SAOS 2021). Co-ops are active in all sectors of Scottish agriculture, including; dairy, pigs, cattle & sheep, cereals, potatoes, soft fruit, vegetables, renewable energy, timber and shellfish. There is also the full range of co-op types operating in Scotland, these include, marketing co-ops, input supply co-ops, specialist service co-ops, Business Rings and multi-purpose co-ops. The co-op business model is mainstream and working in all parts of the Scottish economy.

6.1.1. The Co-op business model

The co-op business model is a unique form of business structure. A co-op differs from an investor-owned business in some key aspects and principles, namely:

- The primary purpose of a co-op is to capture and return value for members through their use of its facilities and services. Return on capital invested in the co-op, although important, is not the main purpose and is not the primary success measure for members. Farmers measure the effectiveness of their co-ops by the profitability of their farm businesses, achieved by participation in their co-ops.
- The basis of control in a co-op is not based on the number of shares purchased. Voting is democratic through one member one vote, irrespective of size of business. The principal governing control in a co-op is equity.
- Although farm co-ops have to be commercial businesses, primarily they are about the association of people, rather than capital, as in the alternative investor-owned model.
- Co-ops have multiple bottom lines, simultaneously serving both an economic and a social purpose. Members are both the 'owners' and 'customers' of the co-op.
- Investment and benefit are in proportion to the use of the co-op's services. Those making more use of the co-op contribute more towards the capital requirements – usually based per head, tonne, or hectare of commitment. If there is a surplus for distribution at the end of the year, it would be distributed on the contribution of the commitment from each member. The principal for capital commitment and surplus distribution is equitability.
- Co-ops are limited liability entities, normally constituted and registered under the 'Cooperative and Community Benefit Societies Act' with the Financial Conduct Authority (FCA) rather than under the Companies Act at Companies House.
- Farmer financial investment in the co-op can be either in the form of shares or loans. Under co-op law, shares can be 'withdrawable' or 'non withdrawable'. It is up for each co-op to decide the mix of shares and loans that meets its needs, and the terms and conditions under which commitment of capital takes place, including the exit terms.

6.1.2. Why co-operation?

The rationale for the formation of farm co-ops is well evidenced. For farmer producers, the main benefits of co-operation are:

6.Co-operative Structure

- Leadership to make things happen.
- Reduced costs – through economies of scale and collective purchasing
- Improved bargaining power – keeping the market fair
- Obtaining access to markets
- Saving time and taking hassle away – farmers are increasingly time constrained
- Route to manage risk and volatility – through the pooling of risk
- Training and knowledge transfer exchange (KTE) to improve members' performance
- Supports rural communities – surplus (profit) is retained in the farming community and not leaked away to external shareholders

Co-ops are a better way of doing business because they empower individuals through participation and ownership. This makes them more engaging, productive, and more relevant. Democratic member participation is seen as one of the co-op sector's most valuable resources, a source of competitive advantage, and a major part of what characterises a co-op.

One of the primary roles of a producer co-op is to tackle the imbalance in bargaining power in the food and drink supply chains. The continued consolidation of processing, manufacturers and retail businesses means increasingly multi-national companies exploit their dominance resulting in farmer producers being weak price takers.

6.1.3. The alternative to a Producer Co-op

The alternative to forming a producer co-op is simply to leave it to the supply chain. The sugar beet biorefinery as the customer, would have to take on the role of organising and communicating with all the individual farmer producers. This could be characterised as the traditional model between a 'customer' and 'supplier', which there are many examples in UK agriculture. The downside of this model is that it can lead to low trust between both parties, ending up as a transactional relationship based on price. The relative power between both parties is the key determining factor in the relationship. The biorefinery as the customer, has to undertake the accumulator role, dealing with hundreds of individual farm producers. This is very inefficient leading to higher transaction costs and a loss of competitiveness. The alignment of interests between the biorefinery plant operator and farmers can be difficult.

Through the benefits of economies of scale, co-operation allows the efficient use of capital, so that the purchase for specialised field equipment can be optimised. Co-operation also allows risk to be pooled across all farmer members, which helps encourage involvement. The speed of uptake in terms of farmers growing sugar beet would most likely be slower if there was no producer co-op involved. In conclusion, forming a producer co-op to lead farmers is not the only business structure but it is by far the optimal model to help ensure farmer involvement, and that the proposed biorefinery plant is competitive and sustainable.

6.1.4. Adopting a collaborative supply chain approach

If the proposed biorefinery processing plant is to be successful, it must work collaboratively with farmer growers and their co-op in the supply chain. Collaborative supply chains have developed in many industries over the last 50-years and have been shown to increase competitiveness overall. Collaboration means working in partnership towards a shared goal, typically over the medium to long term. Businesses must be competitive, but there are always situations where co-operating with others makes more business sense - for example, bringing cost savings or adding value. The critical element is working with partners in the supply chain for mutual benefit.

6.Co-operative Structure

The challenge is to move away from the traditional transactional supply chain which are common in the food and drink sector, to one that works collaboratively, where partners work closely together to meet shared objectives. These objectives are typically focused on improving efficiency, reducing waste, improving customer service, and tackling specific aspects of supply chain performance for the benefit of all partners in the supply chain.

The benefits to be gained from greater levels of supply chain collaboration are well documented and ultimately lead to higher performing networks of businesses that are more innovative, forward looking, leaner, better able to manage risk, less error prone, and more responsive to customer demands. By developing a culture of agility, rather than reactivity within businesses and supply chains, the response to market demand can be more rapidly and effectively delivered, and the impact of supply chain shocks reduced.

6.1.5. Selling the co-op advantage to farmer growers

It is important to acknowledge that not all farmers are enthusiastic about co-operation. Simply forming a new producer co-op doesn't automatically ensure farmer growers would join. Although the benefits of co-operation are well evidenced, research shows that approx. a third of Scottish farmers are a member of a formal co-op (Why Research, 2016). This is in stark contrast to agriculture in mainland Europe and North America, where farm co-ops are dominant with participation rates typically of 50-70%.

One of the main reasons for the lower participation rate in farm co-operation in the UK is simply down to agri-policy. Following the second World War, the UK had statutory marketing boards so there was less need for co-operation. While in the rest of Europe, governments adopted a different policy, relying on co-ops to help rebuild their agriculture, infrastructure and develop markets. It is only when statutory marketing boards were de-regulated in the UK (during the 1980's), that there was a need for co-operation.

Another reason cited for lower co-op participation rates in the UK is that structurally, farm businesses are significantly larger here than in mainland Europe, so arguably more able to work independently.

It is also acknowledged that the benefits of co-operation are not guaranteed. Co-ops have to compete in an increasingly competitive market environment. Many competitors see farmer co-operation as a threat and will aggressively pursue strategies to weaken or prevent co-operation. Co-op success will depend on the quality and competence of the board and management, and the strategies that are developed. There have also been a small number of high-profile failures amongst co-op business in the past. The risk of co-op failure is often cited as a reason for some farmers not to join a co-op. This concern while genuine, doesn't recognise that the failure rate of co-ops is actually half that of other business structures (Co-ops UK 2020). Co-ops are resilient. They are almost twice as likely to survive the early years of existence when compared to other start-up businesses.

In summary, it is important to acknowledge that there will be resistance amongst some farmers to join a producer co-op. This needs to be tackled head on. Effective communication will be required supported by a clear business plan showing the benefits of joining the co-op. A prospectus needs to be produced which would provide interested farmers with all the necessary information to make an informed decision on whether to join or not. Experience shows that to successfully form a new co-op, prominent farm leaders are required to ensure a positive reception amongst the farming community.

6.Co-operative Structure

6.2. Case Study of a Producer Co-op

Although every co-op is different, the following case study illustrates how a producer co-op operates and the activities conducted for member benefit.

Scottish Borders Produce (SBP) is a successful farmer producer co-op (formed 1972) with 90 members, who collectively grow 2,800ha of vining peas, producing 13,000t of peas. All its growers lie within 30 miles of the modern processing, cold storage and packing facilities at Eyemouth, in the Scottish Borders. This ensures that they freeze the peas grown within 150 minutes of harvest, to meet industry standards for premium quality. Key to success is SPB's collaborative partnership with Eyemouth Freezers, which was supported by investment from both SBP and individual members. At the freezer plant the peas are packed into own-brand packaging for UK supermarket customers and transported to their distribution centres, minimising the carbon footprint.

SBP have a very simple model. Effectively, they rent the land for pea growing and organise all the field work to be done. The co-op treats the whole area grown as one owner. The aim is to maximise the production from 2,800ha of peas, to schedule delivery to the freezer plant, so as to optimise the processing plant's intake (measured by tonnes/hour). This is the key metric to hit the quality standard of 150 minutes from harvest to frozen.

Flexibility is a key aspect of SBP's success. Members can choose whether to grow 'funded peas' or to simply to rent the land to the co-op. The average is 60% funded crop, with the balance (40%) on a straight rent. It's all to do with risk and reward. The rented option brings a guaranteed income (currently £330/ha), while the 'funded' option, requires a contribution to the annual growing costs but the returns are potential higher (normally £500/ha).

In addition, members can elect to do some of the field work or not. The majority of member growers do their own ploughing, cultivation, sowing and spraying. This allows growers to earn additional income above the rented land price.

One of the advantages of peas, it is seen as a very attractive option for arable farmers as a great break crop for cereals. As a pulse crop, they enhance soil health by introducing a natural source of nitrogen which is stored in the soil and drawn down gradually by subsequent crops. Soil structure is also improved due to the ability to use min-till establishment rather than plough for the subsequent crop (normally wheat). Wheat yields following peas are consistently +1t/ha higher with a lower nitrogen requirement. Vining peas also have the advantage of being early harvested (June – Sept) allowing early sowing of the subsequent crop.

Members, like the ease of it all. They are able to introduce peas into their arable rotation, without the need of extra work, staff or machinery. All aspects of the process are undertaken on their behalf by SBP's experienced professional team, from crop establishment, agronomy, harvesting, to haulage, processing and marketing, without the need for additional overheads or equipment.

By adopting a flexible approach, SBP also allow non-members to rent land to the co-op, which is a good route to expand the area of peas grown. Experience also shows that many of the "renters" transition over time to become full members. Membership only costs £150 for one share in the co-op.

6.Co-operative Structure

SBP activities include:
- Provide the leadership to co-ordinate growers
- Plan and schedule all the growing, planting and agronomy of the crop
- Collectively purchase the seed, agrochemicals and agronomy service on members' behalf
- Schedule the harvesting of the peas
- Own the specialised pea viners and loaders
- Organise and manage the logistics from field to freezer via a contractor
- Carry out co-ordinated field-trials to improve pea production
- Provide knowledge transfer (KT) activities to help members improve their performance
- Collective marketing the peas and work in partnership with Eyemouth Freezer
- Pooling the risk, de-risking the operations for both growers and the processor
- Handling all the payments and distribution of funds.

Like sugar beet production, pea vining is a seasonal business. Through growers working together via a co-op, the business is very efficient and competitive. SBP has a £8M throughput, but is a lean business only employing two full-time staff and 20 seasonal staff.

A feature of vining peas is the key requirement to achieve the 150 minutes quality specification. Invariably, this means some members' crops are not harvested (bypassed crop varies by season). This pooling of risk and payment is important aspect of the business. Members enjoy full transparency of the figures and trust their co-op to act honestly and fairly across the membership. The business is governed by 8 farmer directors who are elected by the members to represent them.

The EU Fresh Fruit and Vegetable Aid Scheme

One of the advantages peas enjoy is it is eligible for grant support through the EU's "Fresh Fruit and Vegetable Aid Scheme".[122]

The scheme was set up to strengthen farmer growers' position in the supply chain in the face of increasing concentration of buyer power. To be eligible for support, growers must form a single producer organisation – a co-op business. Co-ops then have to submit a 3-5 year 'Operational Programme' that meet the scheme's criteria to be accepted. In return, there is a 50% grant for eligible activities up to a cap of 4.1% of the co-op's marketable turnover less haulage costs.

The Operational Programme can fund work in the following areas:
- Production efficiencies
- Improving or maintaining product quality
- Improving marketing
- Research and experimental production
- Training and advisory services
- Environmental actions

In practice, this means the specialist equipment, new technology, staff cost, research trials and KT activities are all eligible for grant support. In effect, the cost of specialist pea viners is reduced by half through grant support. In the UK, the scheme is managed by the Rural Payment Agency. Although the UK has now left the EU, the scheme is considered so successful in driving change, Scottish Government have committed to continue its support in the future. Being eligible for the Fresh Fruit and Vegetable Aid Scheme is a major advantage for SBP and its members.

122 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/668582/FVSG1_v8.0_dec_17.pdf

6.Co-operative Structure

Extending the Fruit and Veg Aid Scheme to include sugar beet would provide a major boost to the viability of the proposed producer co-op. This is an issue that needs to be raised with Scottish Government.

6.2.1. The Proposed Producer Co-op's Role

The role of the co-op in the proposed biorefinery plant is to provide the leadership and co-ordination of farmer growers and to work collaboratively with the supply chain partners. For the proposal to be successful, it must be an internationally competitive and sustainable business. If that is to be achieved, one of the best ways is through the formation of a producer co-op. As described earlier, farmers are used to working with co-ops. There is a degree of trust there to ensure their interests are safeguarded and that they can influence the co-op's operations and strategy.

6.2.2. The Producer Co-op's purpose

The purpose of the proposed producer co-op is critical. Having a common purpose that allows farmer producers to coalesce behind and support is essential. Clarity of purpose is also critical for the successful management and governance of the business.

The precise operations and services provided by the producer co-op have to be finalised, but are likely to include:

- To provide the leadership for farmer growers, to ensure things happen
- To optimise the production and supply of sugar beet by managing members' land bank as one entity, whilst ensuring equity and fairness to all members
- To co-ordinate and plan members sugar beet production to meet customer needs and specification. Managing the supply:demand relationship
- To develop a best practice "blue-print" for the production of sugar beet in Scotland
- To negotiate the purchase the necessary inputs for sugar beet production, where the benefits of collective purchasing are worthwhile e.g. seed and agrochemicals
- To tender for a specialist agronomy support service for members (3-year contract)
- To undertake (or commission) co-ordinated variety and agronomy field-trials to improve the sustainability and performance of sugar beet production in Scotland
- To undertake a range of knowledge transfer exchange (KTE) activities as a route to improve the technical and financial performance of grower members. This normally involves the gathering and analysis of data to provide members with benchmarked data to show areas of strengths and weaknesses to improve.
- To manage and deliver an efficient and effective sugar beet harvesting service for members. Ensuring the effective utilisation of machinery capacity to provide an economic cost-effective harvesting service
- To organise the logistics with respect to the delivery of the sugar beet harvested from field to factory
- To market the sugar beet produced by members to long-term customers for best advantage
- To develop long-term relationships and work collaboratively with supply chain partners
- In general, to ensure the production of sugar beet and the various processing of sugar beet derived products is successful and efficient as possible.

6.2.3. Members Agreement and Contracts

A members' agreement is essentially a legal contract between the co-op and individual members who use the co-op's services. It specifies the obligations and responsibilities for both parties. Each member receives their own copy with their name in the document, which both parties sign to indicate their acceptance to follow the terms and conditions outlined in the contract. Having members read through and understand the members agreement also helps keep them accountable and understand their obligation for the future success of their co-op.

There are no set rules when it comes to creating a members' agreement. Every co-op is different, so their agreements are highly customized to their needs. The membership agreement should cover all the specifics for items such as annual fees, obligations, restrictions, privacy, exit arrangements and liability claim exemptions to protect each party.

6.2.4. Securing long-term commitment

The key requirement for any investor in a processing plant is securing a long-term commitment for its feedstock – in this case, sugar beet. Without that, an investor would be unable to proceed with the development, the risk is too great. Securing long-term farmer grower commitment is not easy. The most obvious example in agriculture is in the anaerobic digester (AD) sector. Through the provision of 20-year Feed in Tariffs (FIT) payments, which are index linked to rise with inflation, farmers have the confidence to commit to provide long-term agreements to supply appropriate feedstock (normally winter rye or grass silage) to the AD plant. A similar government backed scheme would be required to provide the necessary confidence to both the plant operators and growers supplying the beet feedstock.

For example, the French co-op Cristal Union commit their member growers to an initial 10-year contract. Thereafter, members commit to 5-year contracts. Cristal Union is able to secure this commitment from members due to a number of reasons:

- The co-op owns the added-value downstream processing operations, so the plant belongs to the members. The co-op has built up a proven track record over time.
- Sugar beet has successfully been grown in France for over 100-years. It grows well in France with high yields and is part of a farm's normal rotation.
- Having been in operation for many years, the co-op has generated reserves from annual profits to build a balance sheet to support capital investment.
- Over the long-term, members would expect to get a better price for their sugar beet compared if they simply were a grower for a private company. They get a share of the profits generated by the plant.
- The returns from sugar beet make it one of most popular and profitable crops for arable farmers
- In effect, Cristal Union acts as new generation co-op. Members have to invest capital in the plant in the form of a loan which ties in commitment. Currently the investment is €12 per tonne (in the past it has been as high as €20 per tonne). At an average yield of 80t/ha, this equates to nearly €1,000/ha. With the average size of member having 15ha of sugar beet, means a loan commitment of €15,000.
- The loan is only repayable when the member leaves the co-op at the end of the contract.

6.3. Raising Capital Funds through Coop

All businesses require at least a minimal level of capital to get started. This usually comes in the form of share capital invested by the founding members of the business. The central issue in financing co-ops revolves around making efficient use of any capital which is invested in the enterprise and at the same time retaining control in hands of the members so that the co-op can pursue its purpose.

The general purpose for raising capital is to introduce, maintain or improve benefits and services to

6.Co-operative Structure

members, which have to be run profitably. A co-op should therefore have a clear purpose and strategy for raising capital and appropriate financial controls and transparency to provide potential investors with confidence.

In this situation, the proposed producer co-op requires capital to provide cash flow to get the business off the ground, to cover all the legal and professional fees and to fund the machinery and equipment required by the business.

6.3.1. Common sources of funds

Commonly used courses of finance by co-op start-ups include:

- Member share capital
- Member loans
- Grant funding
- External loans/lease
- Creditor finance

Once the business is up and running there is an on-going requirement to re-invest in new and more efficient assets, finance working capital and maintain an appropriate level of reserves within the co-op in proportion to the risks involved. The most appropriate capital structure for the co-op will depend on the type of business the co-op is involved in, the level of capital required and the attitude of the members. Ideally, the members of the co-op in will provide the entire capital requirement, investing in proportion to the use they make of the co-op's services. In reality, the greater the level of capital required, the more likely the members will be unable to provide all of the capital, thus requiring external sources to be found.

Finance From Members

As already highlighted, members must provide the risk bearing capital for the core enterprise of a co-op and there are several methods of raising finance from members, often used in combination with each other. The sources are as follows:

Members Share Capital

Members are almost universally required to purchase a minimum level of shares upon joining a co-op, although these may be paid over a period of time. The Rules determine the circumstances in which shares may or may not be withdrawn ('sold' back to the co-op) or transferred (to another member). The Rules of the co-op also set out the value of each share and this is fixed for the life of the investment.

Co-op legislation imposes a maximum withdrawable shareholding of £100,000 for any individual co-op member. This can be restrictive when trying to raise additional capital from members. UK agricultural co-ops are often under-capitalised, particularly in comparison to agricultural co-ops in key competitor countries. Note, there is no maximum level of shareholding under company law.

Unlike a company, voting power is not in proportion to capital shareholding but by one member one vote. Share capital in a co-op can be rewarded through the payment of interest. This is paid at a rate decided by the Board, which should be in line with the market rate at that time, and within the limits stated by the co-op's rules.

6.Co-operative Structure

Member Loans

Loans from members are often the most significant source of capital for a co-op as there are no limits to the value of loans that can be made. Loans may be fixed term or repayable after giving a fixed period of notice and may or may not be interest bearing. Loans in the form of compulsory "qualification loans" may be required from members, and would be in proportion to their committed throughput with the Society.

Capital Levy

Capital retentions may be levied by way of a charge on members' throughput. These are usually applied at a rate per tonne, e.g. £2 per tonne. These are then credited to an individual members' capital or loan account. It would be normal for an Agreement to be in place between the member and their co-op for the capital account and the Agreement to include repayment or transfer terms.

Bonds

Bonds may be issued by the co-op to individual members who provide capital for a fixed period at an agreed rate of interest. Bonds are repaid to the member upon a set notice period or at the end of the period agreed at the date of issue of the bond.

Retained Profits

There are a number of ways in which retained profits can be allocated and used as capital for the co-op. Annual surplus /profits can be allocated to general reserves so that the capital is allocated to the co-op as a whole and not to a specific member. This can be a cost effective source of capital as it is not interest bearing, however, a balance must be made between the requirement for capital and the need for the co-op to provide services at a competitive rate. Many co-ops prefer to build general reserves as a capital source because it is 'permanent' capital to the co-op, as it does not need to be repaid when members leave the co-op.

Revolving Funds

Revolving funds are used and involve allocating profit to, or retentions from, individual members in line with their usage of the co-op. The investment allocated in a particular year remains in the co-op for a set period of time (e.g. 3-years) when it is repaid to members, to be replaced with the subsequent allocation. This type of capital is relatively fixed and is increasingly commonly used to provide the co-op with cashflow. Again, tax is due by the member on any profit allocation at the time the allocation is made rather than when the fund is paid to the member, therefore most revolving funds are based on retention of levy rather than an allocation of profit.

6.3.2. External (Non-Member) Finance

There is a wide variety of external sources of finance, namely:

- Bank Finance. This can be in the form of either overdraft or fixed term loans (secured by the co-op's assets, debtors and member guarantees).
- Preference Shares. Non-voting preference shares may be issued to members and non-members alike. A preference share would normally be paid a (higher) rate of interest every year in contrast to an

6.Co-operative Structure

ordinary share that may not be paid interest at all.

- Loans and Bonds. Loans or bonds from non-members can be agreed at the same or different rates to members.
- Creditors. As in any business, securing preferential credit terms from suppliers can provide a cost-effective source of finance for co-ops, and is particularly useful in a start-up situation.

6.4. Forming a new co-op

Starting a new co-op is only slightly different to starting any other business. The same basic rules must be followed, but some additional steps are needed because a group is involved in reaching decisions in the conception, planning and launch.

The following diagram shows the key steps in the process of establishing a new co-op. It requires a step approach, there are no short cuts and its important founding farmer members all participate in the process. It takes time to form a new co-op, typically 6-month to a year. There are no short-cuts, the process cannot be rushed.

Figure 19: Steps in the process in the formation of a new co-op

6.Co-operative Structure

6.4.1 Governance Model

What is governance and why is it important?

Agricultural co-ops are legal entities in which farmers work together to achieve some commercial objective that they cannot achieve working independently of each other.
Key to the success of the model is governance. Governance concerns the way co-ops are directed and controlled and is therefore central to the work of the co-op board. Effective governance is the number one critical success factor for any co-op or business. Governance also provides a structure to guide management and the board on how to run the business. It ensures there are appropriate decision-making processes and controls in place to protect the interests of members and stakeholders (staff, lenders, suppliers and customers).

A neglect of governance weakens the framework of accountability and carries multiple risks to the business and its strategy over time. Conversely, good governance supports the co-op board in its task of creating and maintaining a strong and sustainable business. The co-op sector has therefore long recognised the value of good governance practice.

6.4.2. The Governance of the proposed Producer Co-op

Co-ops UK have produced a guide to the key elements of effective board governance and best practice: "Co-operative Corporate Governance Code"[123] . The code is designed to assist boards in carrying out their governance role and to provide a measure of accountability and assurance to members.

The proposed producer co-op will be governed by a board of directors, whose main purpose is to ensure the co-op's future commercial success by collectively directing its affairs, while meeting the appropriate interests of members and supply chain partners. Members of the board are elected and appointed by the members to represent their interest and ensure the successful guardianship of the business.

To have effective co-op governance directors require a clear understanding of their role both individually and collectively as a board, and they need knowledge of good board practice. One of the main responsibilities of a board is to establish the co-op's purpose and future vision, to set clear business objectives and to develop a strategy for their achievement. The co-op would also employ appropriate professional management and operational staff.

Critical for effective governance is having a written set of policies and practices that clearly explain the role and responsibilities of senior management and the board and how decision are made. It is said that good boards are created by good chairs. It is the chair who must ensure that there are policies and practices in operation which ensure that the board fulfils its responsibilities. The chair is responsible for creating the conditions for good board and individual director effectiveness. Good governance ensures that the board is composed of the most effective and appropriately qualified and experienced persons to direct the business.

6.5. Sugar Beet in France

France has 23,500 sugar beet growers, with 423,00Ha producing 34MT, and 25 sugar beet processing plant. It is the second largest sugar beet producer in world (next to Russia) having grown sugar beet for

123 https://www.uk.coop/resources/co-operative-corporate-governance-code

6.Co-operative Structure

over a century ago. It also enjoys some of the highest yields in the world, averaging 88 t/ha and 13.7t of sugar. Sugar beet in France is dominated by two farmer co-ops, Tereos and Cristal Union who both own downstream added-value processing.

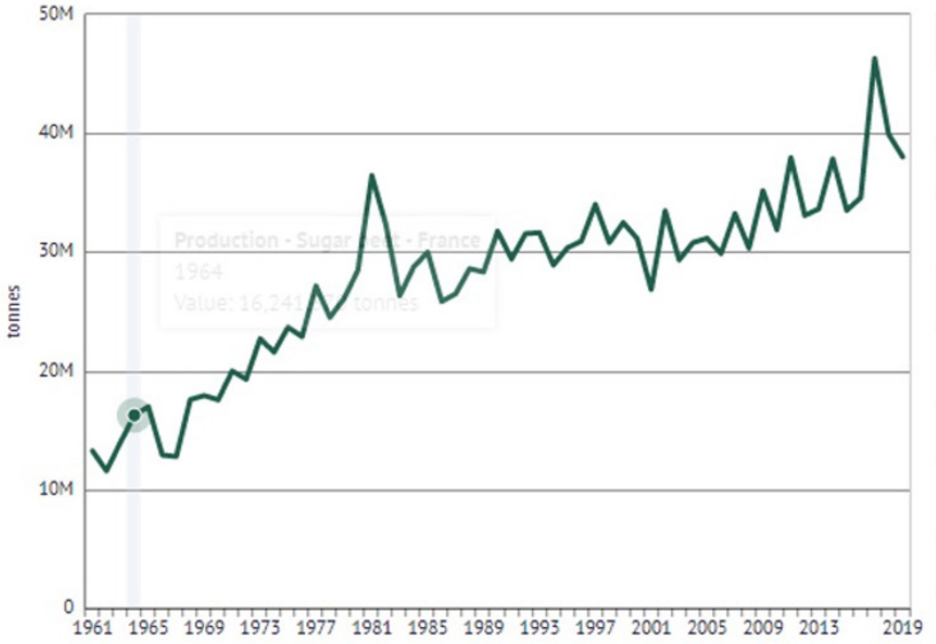

Figure 20: Annual sugar beet yields in France

The EU sugar sector is regulated by the Common Agricultural Policy (CAP) which focuses on aligning EU production with global markets as described within the previous NNFCC report in June 2019. Section three within this report 'Sugar Policy in Europe' describes why the sugar production quotas ended (Sept'17), and how that has helped growers in France become more market driven, allowing exploration and fulfilment of alternative markets around the world to be met with limited constraints. Although the EU is in deficit of sugar, and relies on imports to fulfil requirements, the EU sugar market is protected by high tariff agreements with regards to importing and exporting sugar to give security and reassurance to producers and processors in the country.

		2019	2018	2017
1	Russian Federation	54,350,115	42,065,957	51,913,442
2	France	38,024,390	39,914,030	46,300,141
3	Germany	29,728,300	26,191,400	34,059,900
4	United States of Ameri...	25,945,480	30,192,920	32,039,040
5	Turkey	18,085,528	17,436,100	21,149,020

Figure 21: Highest global sugar beet yields[124]

124 https://knoema.com/atlas/topics/Agriculture/Crops-Production-Quantity-tonnes/Sugar-beet-production

6.Co-operative Structure

6.5.1 Cristal Union - background

Cristal Union is owned and controlled by 9,000 member growers. It is the second largest sugar beet co-op in France, accounting for circa 45% of France's beet production. Established in 2000, Cristal Union was formed from the merger of three sugar beet co-ops prior to the time when the EU Sugar Regime was changing with the threatened demise of quotes. With a long, history and appreciation for how co-ops work and what their role was, the consolidation of these three co-op businesses gave their members increased scale and strength in the market to develop to where they are today; growing and processing 160,000ha of sugar beet per annum. The co-op employs approx. 2000 staff with a turnover of €1.7bn (2020/21).

In total, Cristal Union (CU) operates ten sugar beet processing plants eight are sugar plants and two bioethanol distilleries. Their plants and operations are all located in the North of France. The main added-value product produced is sugar which makes up two thirds of the business. The majority of sugar sales (90%) are B2B, to food and drink companies such as Nestle and Danone. Only 10% of the sugar is branded and sold direct to consumers. The co-op also produces a range of other products including bioethanol, alcohol and gels, nutrition and pharmaceuticals, animal feeds, perfumes and cosmetics.

6.5.2 Members' Obligations

Commitment to the co-op and production is one of the most important aspects of membership the grower is signing up to. With an initial ten-year contract, reducing to five years thereafter (or the chance to exit), growers have an obligation to deliver a set tonnage per annum with the current investment of €12 per tonne. This is the form of a loan to the co-op. The investment is paid in full in the first year of membership, unless the member is a young farmer (<40 years old), in which case payment can be set over a five-year period. This investment from members provides the co-op leverage to borrow from the bank, to help fund growth and reinvestment.

A member's tonnage commitment is calculated from averaging the previous three years production. In theory, penalties can apply if a member fails to meet their tonnage obligation, however, in practice that is not usually applied, as the co-op can balance supply over the whole membership.

A member can only break their 10-year agreement under exceptional circumstances, for example, for health reasons or selling the farm. The final decision, however, is always at the discretion of the board. If a member decides to leave the co-op during contract renewal, they will get their initial investment returned. This is typically paid in one lump sum.

As normal, grower members generally come from a catchment area up to 40km of the processing plant to ensure competitive logistics. The geographical spread of processing sites and members across France allows climatic diversity which supports a steady supply of sugar beet production.

6.Co-operative Structure

Figure 22: Cristal Union locations in France[125]

Members are paid in two or three tranches. Payment one is 50% of the beet price in November during harvest, the second at the end of the season in March, a third final bonus payment is at the year-end (June), depending on the overall co-op's performance.

6.5.3. Supporting Members

Cristal Union plays a key part in almost every step of the beet growing process. The one area the co-op does not get involved in is in field operations. There are well established agricultural contractors and Machinery Rings who own the specialist equipment to provide that service. Harvest starts mid-September and runs to the end of December, depending on weather conditions. France has a shorter harvest than the UK due to frost; normally 100-120 days, compared to 150-days in the UK. Frost is a major issue and the later the harvest the greater the requirement for on-farm storage. By December, growers are obligated to protect the beet for weather conditions. Around 40% of the crop is stored on farm during harvest, which allows for the following wheat crop to be planted to maintain a good crop rotation.

Growers all get a share the delivery slots so will get some of their crop harvested early and the balance harvested and delivered later in the winter. Growers are normally allocated three deliveries to the plant closest to them, twice in the Autumn, and once in winter for stored crop. These slots are allocated equally to ensure fairness across the membership.

Cristal Union also has its own dedicated agronomy team, who support members with technical agronomy

125 https://www.cristal-union.fr/en-bref/

advice, and who also conduct crop agronomy trials. CU also undertake some collective purchasing of inputs, particularly seed. Around 90% of members purchase their seed requirements from the co-op, giving the business control over preferred varieties and quality of seed. There is, however, no obligation to purchase seed from the co-op. Some plant protection chemicals are also sold, although being a highly competitive market, there are many providers in the market and good competition. The co-op would play a more active role if there was evidence of market failure in procuring inputs.

6.5.4. Why are French bioethanol plants profitable?

One of the questions tackled through the interviews with French colleagues is, why are French bioethanol plants successful when UK bioethanol plants all have had a chequered history? The following provides some of the explanation:

- Most of the French bioethanol plants are co-ops – so have committed grower members who take a long-term view.
- The price paid for the sugar beet depends on what they can afford – members own the plant.
- French bioethanol plants are not exposed to global cereal commodity markets as UK plants. They have a secure supply of feedstock through the long-term commitment (10-years) from members.
- Having both sugar and alcohol plants means the co-op has the flexibility to switch production as required. There is some cross-support when needed. It is the overall business performance that determines the price grower members receive for the beet feedstock
- French plants are also involved in a broad range of markets, some of which are added-value (sugar, pharma, alcohol gels, alcohol, cosmetics and animal feeds)
- The importance of the Regulatorily Framework for the biofuel market can't be overstated. In France, they have had the equivalent of the RTFO since 2010. It is this which created the new market for bioethanol. They also enjoy tax reductions for biofuel use. The demand for bioethanol in France is growing, having had E10 blends for years and significant export markets.
- The French government is very supportive to French farmers and domestic markets. It also about fuel security, which again is very important to France.
- Domestic biofuel markets within the EU are protected by import tariffs. Without this French bioethanol couldn't compete with US Maize bioethanol. (USA is the main competitor in the world for bioethanol). It was reported that the US can produce bioethanol considerably cheaper from GM Maize (nearly 1/2 the price of France growers!). EU research showed that EU imports of bioethanol increased by more than 500% between 2017 and 2019, while EU consumption of renewable ethanol for fuel increased by only 10% over the period. At the time, France claimed imports undercut the prices of EU producers by an average 15%.

6.5.5. Key learning for a potential Scottish Bioethanol plant

There is much to be learned through the analysis of the success of French sugar beet co-ops:

- Scale is important. At the proposed 1MT scale, any bioethanol plant is marginal. It would incur a high level of fixed costs, impacting on the overall competitiveness. All the French processing plants are significantly larger – at three times.
- A sugar processing plant has to be commercially driven,. having two distinct markets (sugar and ethanol) gives the business more resilience by spreading risk. It can switch production between sugar for the consumer market or bioethanol for the transport fuel market as the relative economics / prices dictate.
- The various by-products are also important in the mix. Their contribution to the overall business viability and competitiveness is critical. It would be impossible to justify building a plant dedicated

6.Co-operative Structure

solely for alcohol / bioethanol. A sugar beet plant which is dedicated to one by-product means there is a high level of risk.

- There is a big risk for sugar beet production in the UK since leaving the EU. This means the UK government now determines policy and whether to control imports of sugar / bioethanol into the UK. Exposure to international trade could undermine UK production, from competition from sugar and bioethanol from the USA and Brazil.

6.6. Review of the US Corn Bioethanol Co-ops

6.6.1. Background

The United States are the world's largest producer of bioethanol, at over 13.9bn US Gallons in 2020 (15.8bn, 2019). That is over half of global ethanol production. Together, the U.S. and Brazil produce 84% of global production. The U.S. Department of Energy identify that the vast majority (94%) of their production is from corn, while Brazil primarily uses sugarcane[126].

Ethanol imports to the U.S. are relatively low at c.200m US Gallons while exports have steadily increased over the last 10 years to c.1.4bn US Gallons (10% of total production). Their top five ethanol export markets in 2020 were Canada (25%), Brazil (15%), India (15%), South Korea (8%) and EU (8%). The sector hopes that a slow unrolling of the high-profile trade war with China also offers significant growth potential.

The scale and makeup of this sector is complex. Its contribution to national GDP is around US$ 40bn or 3 times higher than the total UK agricultural output in 2020. Corn is the U.S. largest crop with around 37m ha planted according to U.S. Department of Agriculture (USDA) figures, 2019. Some 40% of total plantings are now for ethanol production, which is equivalent to 2.5 times more than the total agricultural area in Scotland.

The U.S. ethanol market has expanded rapidly, corn plantings have increased by some 6m ha in 30 years. Output has increased from 175m in 1980 to 17bn US Gallon capacity over the last 20 years, to 2020. The number of biorefineries has increased from 56 to 208, predominantly using the dry mill process. Average production capacity per plant has more than doubled to 84m US Gallons (318m litres) per annum over the same period.

Furthermore, whilst corn is grown in most U.S. States, production is particularly concentrated within the states of Illinois, Iowa, Indiana, eastern portions of South Dakota and Nebraska, Missouri, western Kentucky and Ohio. Illinois and Iowa are the top corn producing states and typically account for about 33% of the national crop. Its concentration within the mid-west (States where agriculture is also a large contributor to the economy) makes corn ethanol production politically highly important. There is sizeable support and lobbying capacity within federal and state government.

Resulting coproducts include over 33m metric tons of distillers grains, maize gluten feed or meal. These are valuable protein-rich substitutes for corn, soybean meal, and other ingredients used to livestock feeds, with a third being exported worldwide. Additionally, biorefineries extracted 1.5bn kilos of corn distillers oil, a USD 940 million market that underpins production of biodiesel and animal feed. In 2020 also saw surplus and certified biorefinery capacity used to produce hand sanitiser and additional valuable levels of CO2. The ethanol industry produces some 40% of U.S. CO_2 requirements.

126 https://afdc.energy.gov/fuels/ethanol_fuel_basics.html

6.Co-operative Structure

6.6.2. Stimulus for growth in the USA

The increase in production was largely a result of legislation that mandated the nation's supply of transportation fuel to contain specified quantities of renewable fuel(s). The Energy Independence and Security Act of 2007 provides the legal framework for the Renewable Fuel Standard (RFS). The RFS is similar in function to the UK Renewable Transport Fuel Obligation (RTFO). Corn ethanol's mandate scaled-up rapidly from 9bn in 2008 to 15bn US Gallons by 2015 and holds constant to 2022. The balance to 36bn US Gallon (60%), by 2022, is targeted from advanced or cellulosic biofuels.

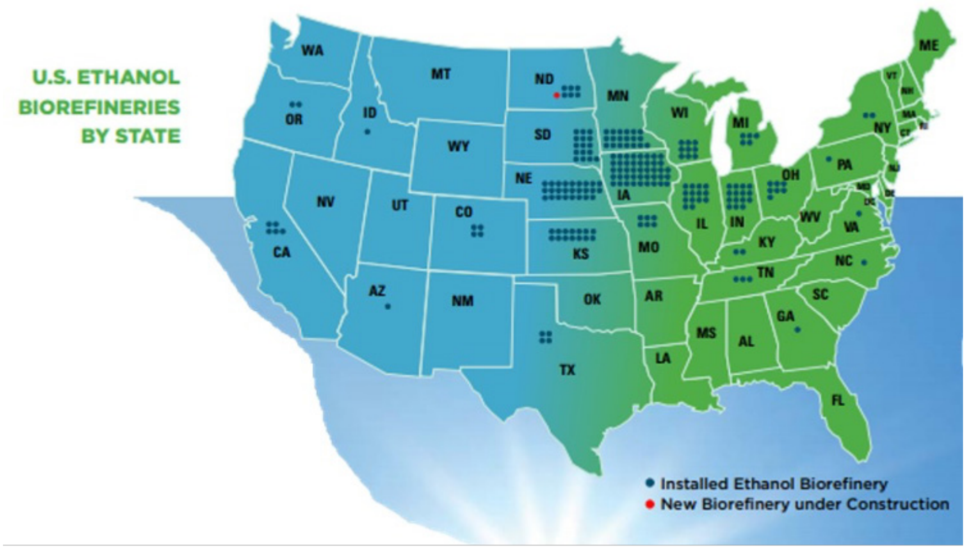

Figure 23: US Ethanol biorefineries by State

6.Co-operative Structure

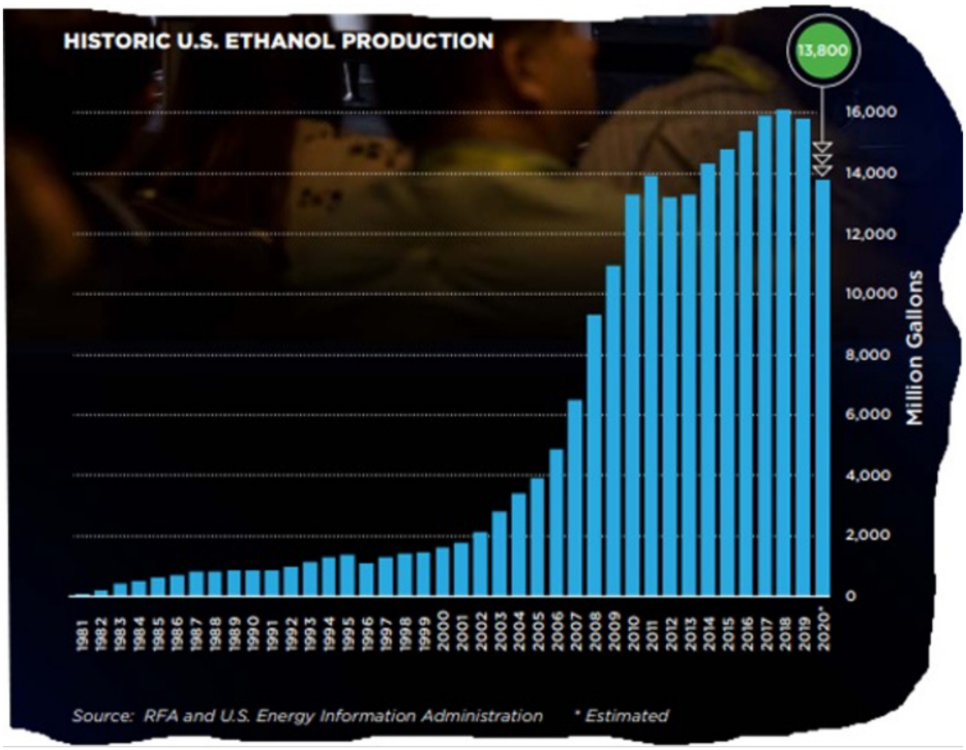

Figure 24: US annual ethanol production

Various mechanisms have been / are used to support the sector. These include tax incentives (included for blenders and refiners), fuel station biodiesel tax credits (effecting corn oil demand), import tariff protection, infrastructure subsidies, and a government mandate, RFS[127]. Furthermore, the Farm Bill sees further support, including trade programs, and commodity and crop insurance supports for corn and ethanol blender pumps. These combined measures have a significant benefit to corn demand[128].

6.6.3. Environmental benefit

The original Act was passed with the intention of reducing reliance on foreign oil imports. A contributing policy enabler was a coinciding slump in domestic corn prices. But with the advent of economic shale oil extraction making the U.S the largest oil producer in the world and a net exporter over the last 5-years (20% of the global production, per the U.S. Energy Information Administration) greater emphasis is now placed on environmental benefits. According to the U.S. Department of Energy, more than 98% of U.S. gasoline (petrol) contains ethanol, typically E10 (10% ethanol, 90% gasoline [petrol]).

There is some contention over the true environmental advantage of corn ethanol due to its influence on world food and feed markets and impacts on land use change. Some 90% of land brought into corn production was prairie pasture, suggesting biodiversity loss. A full life-cycle-analysis for corn ethanol, however, was commissioned by the U.S. Environmental Protection Agency (EPA), which concluded that in 2022, the emissions profile of a unit of corn ethanol from a new natural gas-powered refinery would be 1% lower than the emissions profile of an energy-equivalent quantity of 'average' gasoline in 2005[129]. Some research indicates the benefit could be even greater, with opportunity to further improve its credentials. This is being used to demonstrate marketing advantage for exports.

127 https://www.taxpayer.net/wp-content/uploads/2021/05/TCS-Biofuels-Subsidies-Report.pdf
128 https://ethanolrfa.org/wp-content/uploads/2021/02/RFA_Outlook_2021_fin_low.pdf
129 https://www.eesi.org/files/420r10006.pdf

6.Co-operative Structure

Whilst significant technological developments have improved biorefinery efficiency, it is also evident from the National Corn Growers Sustainability Report 2021[130] that major efficiencies have also been obtained on farm. Over the last 35 years to 2015, crop yields have increased by 61%; there has been a 41% reduction in the land required to produce a bushel of corn; a 58% reduction in soil loss per acre; 46% reduction in irrigation water; and further advances are being made. The report states that the U.S. attributes 33% of the worlds corn on only 10% of the land area dedicated to corn production. The biggest recognised contributing factor in delivering these gains has been adoption of Genetically Modified seed that is more competitive against weeds and tolerant to cover crops and reduced or no-till methods.

6.6.4. Economics

Critics argue that the RFS is protectionist, creates complacency, and has done little to improve rural prosperity, with farm bankruptcies on the rise. If the ethanol mandate and import tariff protection was removed, the ethanol industry (including upstream growers) would be in major difficulty, and it remains vulnerable to political will.

There is industry expectation, however, that the new Administration and Congress is anticipated to focus more heavily on reducing carbon emissions and provide new market opportunities for bioethanol in the US and as a major export. The industry is also lobbying for wider rollout of other blends, E15 and flex fuels such as E85. This would further stimulate domestic demand. E85 contains between 51% and 83% ethanol by volume. Some biorefineries are also increasingly concentrating on alternative higher value markets such as industrial products and cosmetics.

Modelling work from Iowa State University indicates significant volatility in biorefinery margins that is largely due to the cost of grain resulting from weather impacts on plantings or yield. It is also a maturing market, finding equilibrium between supply and demand. And whilst there have been significant opportunities for profit, speculative investment in anticipation of favourable legislative change was not without risk. This is heightened with expansion into more marginal cropping areas; some of those plants have succumbed to a difficult Covid-19 trading period.

The Federal Trade Commission 2019 Report on Ethanol Market Concentration[131] identifies there is sufficient capacity to ensure no individual player has uncompetitive influence over the corn market. However, it is also true that the further a grower or refiner is from their marketplace the lower the choice, greater the transport costs, and greater the importance of strong supply chain relationships – something more easily formed within a co-operative.

6.6.5. New Generation Co-ops

The New generation Co-operatives (NGCs) structure became common in north America with the establishment of legislation in the 1990's that was attractive to producers especially when commodity prices were too low to sustain profitable farm operations. NGCs enabled farmer producers to raise capital and invest in downstream value-added processing as a route to improve the prices for farm produce. NGCs created tradable co-op shares ("deliverable rights") moving the traditional co-op model closer to a PLC model, where the co-op share price can move up or down. NGCs are in effect closed co-ops. The only way a farmer member can increase his/her produce delivered to the NGC is by purchasing

130 https://dt176nijwh14e.cloudfront.net/file/392/NCGA%20Sustainability%20Report_final_digital_07_29_21.pdf

131 https://www.ftc.gov/system/files/documents/reports/2019-report-ethanol-market-concentration/p063000_ethanol_report_2019.pdf

6.Co-operative Structure

more deliverable rights from a fellow member. The value of the shares /deliverable rights can move up or down depending on the performance of the NGC. It also allows a farmer an exit from the co-op, as he /she can sell their deliverable rights in the future. In a traditional co-op, the value of the co-op share remains the same.

NGCs maintain many traditional characteristics of producer co-ops including one member one vote, patronage-based distribution of profit, and being member-owned and controlled. Many marketing co-ops already restrict membership to manage volume and quality on behalf of the collective and their customers but NGCs take this further by selling shares carrying 'delivery rights' to raise required capital. Membership tends to be set at a low or nominal price, like a traditional co-operative, but a pre-established number of delivery rights is set at a price sufficient to generate capital requirements. The goal would be to ensure delivery right shares amount to at least 50% of equity. The actual process of establishing the NGC is otherwise very similar to that of a more traditional producer co-operative.

Delivery rights allow members to market their production to the co-operative, with a percentage of the sales value retained by the co-op for reinvestment. The co-op will only sell the number of 'delivery rights' required to meet processing needs. Similarly, it is not possible to deliver more than a producer's number of delivery rights. One of the big advantages of the NGC model is that it de-risks the supply of feedstock to the processing plant. Members have a legal obligation to deliver the tonnage specified.

It is a two-way contract for members to deliver requirements and the co-op to accept the agreed amount. There is no obligation to fully commit to the co-operative. A fundamental difference with NGC's over traditional co-ops is in risk management for members. If the quantity or quality of the goods does not meet the NGC's standards, the grower will be required to purchase goods from another grower to fulfil their commitment. The grower is otherwise responsible for paying any difference that the NGC pays to fill the requirement.

NGC contract issues to members is based on a pre-agreed price. In addition to contracted supply, the NGC may venture into the open market through a mix of futures and options to hedge their position and provide any balancing supplies. Similarly, a grower may sell non-contracted grain on the futures market. They may do this directly but more likely via a trader or their local 'Elevator' (co-operative or private grain storage facility). NGC's usually manage the flow of the raw product to their facilities by establishing delivery schedules for each member. These schedules require members to fulfil their annual delivery obligation in instalments spaced throughout the year. This limits co-op owned (capital intensive) or leased (operationally expensive) storage requirements.

Return on capital - Members receive their share of the NGC's surplus, which is proportionate to the number of delivery rights held. Their capital investment serves to create a more profitable "home" for their respective farm's production than would otherwise be available. These delivery rights (shares) are tradeable at a price determined by the market assuming strong demand[132]. The value of shares can go down as well as up based on the cooperative's performance. They are not, however, redeemable by the NGC. Typically, a grower-member can choose to transfer or sell their shares to other members, pending approval from the board, but they do not have the automatic right to sell to non-members.

6.6.6. Influence of the grower

Corporations (investor-owned) businesses would typically only invest in ethanol production because it promises to be profitable. Conversely, NGCs are more likely to tolerate lower plant profitability because

132 https://indexarticles.com/business/rural-cooperatives/why-choice-of-trading-rules-matters-for-new-generation-co-op-stockholders/

6.Co-operative Structure

grower-owners retains the advantage of diversifying income streams and, therefore, exposure to the corn market. When corn prices are high, members see a direct benefit on grain sales, whereas when corn prices are low demand for ethanol often improves along with the return from biorefining.

The National Corn Growers Association (NCGA) Economic Impacts on the Farm Community of Cooperative Ownership of Ethanol Production 2006[133] study concludes that "since a farmer-owned co-operative ethanol plant is literally a member of the community, the full contribution to the local economy is likely to be as much as 56% larger than the impact of an absentee-owned corporate plant". This report, written over 15-years ago, also notes a decline in opportunities for farmers and other locals to invest in plants being constructed in their communities.

There remains a number of successful NGC owned biorefineries across the mid-west but numbers have reduced. An influx of private equity to exploit projected financial surpluses within a new market, underpinned by Government mandate, now sees much greater nuances in biorefinery ownership and control. Many ethanol plants have become Limited liability companies (LLCs) or LLPs that are only partially owned by the NGC. Some NGCs have gone a step further and chosen to convert to a non-co-op business. Another possibility, that does not require outside investment, is to allow distant farmer producers to arrange for delivery of corn through co-operating grain elevators. This practice is currently used by some NGCs to expand and de-risk the area they source corn.

Note, that there are alternative structures that are sometimes classified under the broad term of, but are not strictly, NGCs. These include co-operatives that accept private or public equity. This can be done outside the co-operative structure, e.g. establishment of a joint venture. Alternatively, in north America, investor-share co-ops issue and reward on investment shares as well as patronage. Farmer controlled businesses can provide a similar model in the UK.

6.6.7. Lessons Learned from the US Corn Co-ops

Political support – Unwavering commitment to the RFS, combined with import tariff protection, export promotion, tax incentives, crop insurance, and other stimulus provide both direct and indirect support to the sector. This instils investor confidence to commit the necessary capital required to deliver on policy objectives.

Accompanying programmes - Irrespective of production gains attributable to GMOs, significant resource has been directed to breeding programmes and research to improve yield, and lower production costs. This supports business and environmental efficiency. Similarly, federal and state support can minimise transport infrastructure limitations. For example, funding is anticipated for constructing new locks along the Mississippi river. More than 60% of the nation's corn and soybeans are transported on the river. The use of barges for corn transportation is considered some x4 more fuel efficient than road transportation.

A risk management tool - U.S. biorefineries and growers alike require an often-complex mix of contracts, futures and options to hedge against market volatility. A highlighted advantage of co-operatives is a higher tolerance for short-term market performance as added-value investments diversify a growers income portfolio.

New generation co-ops - A limited ability to raise capital can be a weakness of traditional co-operatives. It is partly alleviated by the adoption of the NGC model, where capital requirements are moderate. The increased scale of biorefineries and sophistication has significantly increased capital requirements that has often forced a change in business model. It would, however, be a good model for growing and

133 https://energy.agwired.com/2006/09/12/locally-owned-plants-better-for-local-economies/

6.Co-operative Structure

coordinating supplies.

Don't forget biodiversity - Whilst the emphasis has been on lowering GHG emissions, resulting land use change means a more holistic approach is required to circumvent pressure on natural habitat.

Alternative markets - After rapid expansion, corn ethanol is now considered a mature market. It is now searching for a balance between supply and demand that risks leaving more marginal refineries vulnerable. The market is also volatile and exposed to political will. The most obvious and near-term answer would be to stimulate additional domestic demand followed by ensuring stable export markets. Whilst it remains niche, there is growing interest in alternative higher value markets.

The weather - A major reason for corn ethanol refinery margin volatility is the unpredictability of the weather, resulting yields, and purchase price of corn. Biorefineries try to mitigate that by using the futures market and reducing reliance on sourcing from any single geographical area but this can only have a small benefit since most plants have a similar strategy. Some mechanism to tolerate lower than projected contract volumes will be worth considering within any plant commissioned in Scotland.

7. Investment and Funding

7.1. Financial Costings

IBioIC have used their expertise in the field of bioethanol production to develop an interactive financial tool to assess a range of different sized bioethanol plants. This model quickly and accurately calculates the annual net profit based on real time input of raw materials, transportation, operating costs and the sales price of ethanol and associated co-products. A snapshot of forecast annual revenues and an evaluation of the revenue stream versus the capital investment required is efficiently produced. Based on the amount of ethanol to be produced the model also calculates what tonnage of raw material is required and how much land would be required to produce this. If an alternative feedstock to sugar beet (or a mixture of feedstocks) is to be used it could also generate this information.

We used our financial model to evaluate the potential of three different sizes of bioethanol plants: 100 million litre (Scenario A), 200 million litre (Scenario B) and 400 million litre (Scenario C).

Assumptions made in relation to the model can be found in section 7.1.2 below.

100M Litre Plant

Scenario A: 100 million litre plant at 85% capacity. All sugar beet as raw material.

Key metrics			Capex		100,000,000
Ethanol required	85,000,000	litres			15
Beet required	812,017	Fresh tonnes	**Plant revenue**	**£**	**80,211,795**
Land cultivated	13,534	Hectares	Bioethanol	£	49,300,000
% of growing area	2.2	%	Beet pulp as animal feed	£	12,448,219
Co-Products			Topsoil	£	2,030,042
Pulp	56,841	Tonnes	Stones	£	6,902
Topsoil	40,601	Tonnes	Spent lime	£	974,420
Stones	1,380	Tonnes	CO_2	£	877,681
Spent lime	32,481	Tonnes	Biogas	£	12,447,830
CO2	87,768	Tonnes	Digestate as fertiliser	£	2,126,700
Vinasse	472,600	Tonnes	**Expenditure**	**£**	**65,449,652**
Biogas	51,607,920	m3	Raw materials	£	33,954,370
Digestate	425,340	Tonnes	Utilities	£	7,855,072
Utilities			Labour	£	3,120,000
Electricity	15,022,313	kWh	Fixed costs	£	11,030,334
Process heat	74,209,323	kWh	Depreciation *(straightline)*	£	6,656,667
Natural gas (assuming 60% efficienc	123,682,205	kWh	Cost of finance	£	9,489,876
			Profit	**£**	**14,762,143**
			Total cash inflows	**£**	**221,432,143**
			NPV of cashflows	**£**	**153,225,995**
			Initial investment	**£**	**100,000,000**

Figure 25: Modelling of 100M litre plant operating at 85% capacity - source IBioIC

7. Investment and Funding

200M Litre Plant

Figure 26: Modelling of 200M litre plant operating at 85% capacity - source IBioIC

Scenario B: 200 million litre plant at 85% capacity. All sugar beet as raw material.					
Key metrics			**Capex**		200,000,000
Ethanol required	170,000,000	litres			15
Beet required	1,624,034	Fresh tonnes	**Plant revenue**	£	**160,423,590**
Land cultivated	27,067	Hectares	Bioethanol	£	98,600,000
% of growing area	4.3	%	Beet pulp as animal feed	£	24,896,438
Co-Products			Topsoil	£	4,060,085
Pulp	113,682	Tonnes	Stones	£	13,804
Topsoil	81,202	Tonnes	Spent lime	£	1,948,841
Stones	2,761	Tonnes	CO_2	£	1,755,361
Spent lime	64,961	Tonnes	Biogas	£	24,895,661
CO2	175,536	Tonnes	Digestate as fertiliser	£	4,253,400
Vinasse	945,200	Tonnes	**Expenditure**	£	**136,216,167**
Biogas	103,215,840	m3	Raw materials	£	74,404,875
Digestate	850,680	Tonnes	Utilities	£	15,710,144
Utilities			Labour	£	5,200,000
Electricity	30,044,626	kWh	Fixed costs	£	22,060,668
Process heat	148,418,646	kWh	Depreciation *(straightline)*	£	13,311,333
Natural gas (assuming 60% efficienc	247,364,410	kWh	Cost of finance	£	18,840,480
			Profit	**£**	**24,207,422**
			Total cash inflows	**£**	**363,111,337**
			NPV of cashflows	**£**	**251,264,767**
			Initial investment	**£**	**200,000,000**

400M Litre Plant

Scenario C: 400 million litre plant at 85% capacity. All sugar beet as raw material.					
Key metrics			**Capex**		300,000,000
Ethanol required	340,000,000	litres			15
Beet required	3,248,068	Fresh tonnes	**Plant revenue**	£	**320,847,180**
Land cultivated	54,134	Hectares	Bioethanol	£	197,200,000
% of growing area	8.7	%	Beet pulp as animal feed	£	49,792,877
Co-Products			Topsoil	£	8,120,169
Pulp	227,365	Tonnes	Stones	£	27,609
Topsoil	162,403	Tonnes	Spent lime	£	3,897,681
Stones	5,522	Tonnes	CO_2	£	3,510,723
Spent lime	129,923	Tonnes	Biogas	£	49,791,321
CO2	351,072	Tonnes	Digestate as fertiliser	£	8,506,800
Vinasse	1,890,400	Tonnes	**Expenditure**	£	**284,772,602**
Biogas	206,431,680	m3	Raw materials	£	173,170,258
Digestate	1,701,360	Tonnes	Utilities	£	31,420,288
Utilities			Labour	£	7,800,000
Electricity	60,089,251	kWh	Fixed costs	£	44,121,336
Process heat	296,837,292	kWh	Depreciation *(straightline)*	£	19,966,667
Natural gas (assuming 60% efficiency)	494,728,820	kWh	Cost of finance	£	28,260,720
			Profit	**£**	**36,074,578**
			Total cash inflows	**£**	**541,118,665**
			NPV of cashflows	**£**	**374,441,780**
			Initial investment	**£**	**300,000,000**

Figure 27: Modelling of 400M litre plant operating at 85% capacity - source IBioIC

7. Investment and Funding

The above financial model shows that it would be profitable to use solely sugar beet in the bioethanol production process.

As sugar beet is seasonal the processing plant would need to produce sugar syrup for use over the whole year. As the amount of sugar beet increases then so would the cost of transportation from farms to the plant, and this has been included in the above. The possibility of using imported sugar for up to 50% of the process has also been modeled. Using imported sugar would incur lower labour costs and utility costs, though the cost of the sugar and lower by-product revenues results in a negative NPV.

7.1.2. Assumptions

We assume the following for our model:

- 15 year time period measure as most governing and private institutions make decisions based on the payback of investment over increments of time, at least equal to or greater than 10 years for research involving long-term energy and fuel projects.
- An Interest/Discount rate of 5% over a period of 15 years, as is assumed for most studies of this nature.
- We also assume the salvage value of the project is £500K for a 400 million litre plant and £330K for a 200 million litre plant and £150K for a 100 million litre plant.
- We assume a fixed increasing demand for biofuels based on population and fuel consumption growth, which allows us to produce a general picture of the feasibility of biofuels on a large scale and is based on government mandated consumption.
- We depreciate PP&E using the Straight Line Method (SLN).
- The model begins at year one; however, due to typical start-up and setup costs of a development project, it is assumed that these costs occur in year zero with a full year of operation in year one.
- Adequate land expansion for expansion of biofuel production, which will enable the use of this model to multiple situations.
- The model is scaled down to calculate the viability of a single value, which will allow us to multiply the result to estimate the national costs and benefits and generalize it to other situations.
- Biofuel sale prices and by product sale prices remain fixed, as are energy costs and raw materials.

7.1.3. Capital Expenditure

For our model we looked at comparatively sized UK operations. These typically had capital investment of £300 million for a 400 million litre capacity plant and £200 million for a 200 million litre plant and £100 million for a 100 million litre plant. We assume a £300M of debt repaid equally over 180 months with a 5% interest charge. This makes a total loan repayment of £423.9 million. With the same interest and repayment term for a 200 million litre plant total loan repayment is £282.6 million and £142.3 million for a 100 million litre plant.

7.1.4. Operating Costs

We have used the above report findings to determine yield and price per tonne of sugar beet to calculate the cost of raw materials to a bioethanol plant plus transportation costs. Labour is based on comparable sized plants based in the UK. Utilities and fixed costs are based on the NNFCC report as a price per litre of ethanol produced.

7. Investment and Funding

7.1.5. Cashflow

Our model shows that a 100/200/400 million litre plant operating at 85% efficiency = 85/170/340 million litres of bioethanol production per year. Based on the conservative sale prices for bioethanol and associated by-products, versus the costs of production and finance, there is a positive cash inflow for each year of operation over the 15-year lifecycle of the investment of:

- £14.8 million Scenario A
- £24.2 million Scenario B
- £35.8 million Scenario C

7.1.6. Investment Appraisal and Payback

Net Present Value (NPV) can be computed as the average discounted net cash inflows minus the average discounted net cash outflows less the Setup costs. The NPV model is a good model to show the projected value of an investment from a variety of fixed costs over a period, which are discounted back to the present. In the context of this paper, the projected value of an investment in a biofuels plant can be modelled using NPV analysis to evaluate whether the investment is attractive to prospective investors. The NPV results for biofuels can be contrasted with the same values from other renewable energy sources.

A project is deemed economically feasible if the NPV value is greater than zero. A NPV value of 0 does not confer any benefit; however, this result would not be optimal in the context of this paper. Negative NPV values indicate that the project would incur a net loss and the investment should not proceed. The value of the NPV, or the output variable, will determine the economic viability of the proposed project or plant. For economic efficiency to be achieved, the option that generates the maximum NPV must be selected.

From our model the NPV of future cash inflows of Scenario A is £153.2 million which is positive based on a £100 million capital investment for a 100 million litre capacity plant. NPV of future cash inflows of Scenario B is £251.3 million which is positive based on a £200 million capital investment for a 200 million litre capacity plant. NPV of future cash inflows of Scenario C is £374.4 million which is positive based on a £300 million capital investment for a 400 million litre capacity plant.

7.1.7. Risk

From analysis of comparable UK bioethanol plants and of plants in other western countries there are three main risks involved:

1. cost of raw materials;
2. value of bioethanol and by-products; and,
3. plant capacity and operation.

Failed UK operations never produced bioethanol at near maximum capacity and had numerous production issues which suspended operation for many months at a time. They used wheat as raw material which had a more volatile and higher input price, and less by-product value. At the time, demand for ethanol was also lower, as were ethanol prices. This led to the plants failing to cover their operation costs and accumulating financial losses.

7. Investment and Funding

7.1.8. Sensitivity Analysis

Our model shows that it can be profitable to use sugar beet to produce bioethanol. The main drivers are input cost of raw materials and the output price for ethanol and related by-products. These variables have been tested and show that the plant can remain profitable within a wide range of cost/revenue values provided production can remain near capacity. Sugar costs are too high and have been too volatile over the past year to provide an alternative raw material for the process, however other feedstocks could be used as producers ramp up sugar beet growth.

Key factors affecting the overall economic viability of beet to ethanol in Scotland include:

Factor	Unit	Lower	Upper	Typical assumption
Beet yield	Tonnes / ha	50	90	60
Price paid to farmers	£ / te	27	35	33
Ethanol price	£ / L	0.40	0.70	0.6
Discount rate for NPV model	%	2.5	10	5
Scale (ethanol volume)	M litres	150	400	300
Fraction imported sugar	% of sugar input	0	50	-

Table 25: Key factors affecting the economic viability of beet in Scotland

In summary, a model was developed as part of this study to take into account the full economic costings from the farm to the bioethanol plant. While all scales investigated (100M, 200M and 400M litres) have been shown to be profitable, we have concluded that the optimal size for Scotland would be a 200 million litre plant, making 170 million litres of bioethanol a year. An investment of £200m would be required and it would generate £24M profit per annum.

7.2. Financing

Significant private and or/public investment will be required to enable this project to progress. There are many different options available which will be explored further in this section.

7.2.1. Public Investment

7.2.1.1 Scottish Funding and Support

Grants

The Scottish public investment landscape offers a range of grants at different interventions, most Scottish grants are offered to support early-stage R&D and could be beneficial for any novel R&D

7. Investment and Funding

processes being developed, for example further development of micro-processing hubs. There are some grants that support larger projects to take them to a commercial stage and support job creation and green jobs.

Scottish Enterprise have recently moved to a calls-based approach for their grant funding[134]. They offer a wide range of support for projects and some calls that could be beneficial for this project can be found in Appendix 7. Zero Waste Scotland operate in a similar way to Scottish Enterprise and details of the relevant grants they offer can also be found in Appendix 7.

Loans

Scottish Enterprise

Scottish Loan Scheme

The Scottish Loan Scheme can provide a loan funding of £250,000 - £2 million to growth focused Scottish companies that have a viable business plan and a clear ability to repay the debt.

Loan can be used for a variety of purposes including:

- Working Capital
- Capital Expenditure
- Growth Funding
- International Expansion
- Marketing Investment[135]

Discussions were had with the Scottish Investment Bank (SIB) who thought given the scale of the project, it might be of interest to the Scottish National Investment Bank (SNIB).

Debt Financing and other support

Scottish National Investment Bank

The Scottish National Investment Bank opened for business in November 2020. It is the first mission-oriented investment Bank in the UK[136].

The Bank will:
- address key societal challenges
- shape future markets
- spark innovation
- deliver a range of environmental, social, and economic returns

It will do this through the long-term missions Scottish Ministers have set for it. The mission-led approach is crucial, allowing the Bank to address social challenges as it invests in economic opportunities.
The Bank's aims and objectives are aligned with Scotland Economic Strategy. The Bank has the potential to transform Scotland's economy, providing patient and growth capital (debt and equity) for businesses

134 https://www.scottish-enterprise.com/support-for-businesses/funding-and-grants/business-grants
135 https://www.scottish-enterprise.com/support-for-businesses/funding-and-grants/accessing-finance-and-attracting-investment/scottish-loan-scheme
136 https://www.gov.scot/policies/economic-growth/scottish-national-investment-bank/

7. Investment and Funding

and projects across Scotland and catalysing private sector investment.

Scottish Government have committed £2 billion to capitalise the Bank. It is clear there is a need for a Bank with ambition and vision - to address Scotland's economic priorities - in a sustainable, inclusive, and ethical way. The Bank will provide a source of long-term finance which – in partnership with the private sector – can invest in ambitious companies and low carbon infrastructure. This investment is key to supporting Scotland's transition to a net-zero future.

The Bank hold to the principles of equality, transparency, diversity, and inclusion. The way the Bank operates will define it as an ethical, inclusive, and trusted institution.
The three missions of the Bank are:

- achieving a Just Transition to net zero carbon emissions by 2045
- extending equality of opportunity through improving places by 2040
- harnessing innovation to enable our people to flourish by 2040

This project aligns well with the missions of SNIB, it could be a strategic project for Scotland where SNIB could support its development in a number of different ways depending on how it is taken forward. We have recommended prices for sugar beet and ethanol that we think could satisfy the entire supply chain, however, it may be there is a shortfall due to market fluctuations and other factors and SNIB could plug this gap to ensure the success of the project. Also due to the changeable market conditions this could be viewed as a risky project by investors so SNIB could underwrite a certain value to protect against the market and any poor sugar beet yield years.

SNIB could also provide support through loans and/or debt financing to the bioethanol operator to ensure the success of the project and attract inward investment into Scotland.

7.2.1.2. UK Funding and Support

UKRI

UK Research and Innovation (UKRI) is the national funding agency investing in science and research in the UK. Operating across the whole of the UK with a combined budget of more than £6 billion, UKRI brings together the 7 Research Councils, Innovate UK, and Research England[137].

UKRI runs on a calls-based process, the calls are regular and varied and Innovate UK calls are likely to be the most relevant to this project, given their scale and relevance to industry[138].

Feed-in Tariffs (FIT) scheme is a government programme designed to promote the uptake of renewable and low-carbon electricity generation technologies. Introduced in April 2010, the scheme requires participating licensed electricity suppliers to make payments on both generation and export from eligible installations. The scheme has been very successful and closed to new applicants on 1 April 2019.[139]

The FIT scheme is available to anyone who has installed one of the following technology types up to a capacity of 5MW or 2kW for CHP:

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137 https://www.gov.uk/government/organisations/uk-research-and-innovation
138 https://www.ukri.org/opportunity/page/3/?filter_council%5B0%5D=822&filter_status%5B0%5D=open&filter_status%5B1%5D=upcoming&filter_order=publication_date&filter_submitted=true
139 https://www.ofgem.gov.uk/environmental-and-social-schemes/feed-tariffs-fit

7. Investment and Funding

- Solar photovoltaic (solar PV)
- Wind
- Micro combined heat and power (CHP)
- Hydro
- Anaerobic Digestion (AD)

In the case of anaerobic digestion there are existing growers in Scotland growing energy beet to feed into an anaerobic digester. Given the success of FIT payments for the adoption of renewable and low carbon energy, perhaps a similar payment be introduced to encourage the adoption of sustainable manufacturing. This would help to ensure the decarbonisation of manufacturing industries towards net-zero targets.

7.2.1.3. European Funding

Horizon Europe

Horizon Europe is the EU's key funding programme for research and innovation with a budget of €95.5 billion.

It tackles climate change, helps to achieve the UN's Sustainable Development Goals, and boosts the EU's competitiveness and growth.

The programme facilitates collaboration and strengthens the impact of research and innovation in developing, supporting, and implementing EU policies while tackling global challenges. It supports creating and better dispersing of excellent knowledge and technologies.

It creates jobs, fully engages the EU's talent pool, boosts economic growth, promotes industrial competitiveness, and optimises investment impact within a strengthened European Research Area. Legal entities from the EU and associated countries can participate[140].

Horizon Europe also operates on a calls-based system with frequent calls open, for most calls a consortia with several European partners must be formed as the project team.

7.3. Private Investment

There has been significant investment activity in the bioeconomy and in biotechnology in recent times. This is likely driven by a number of factors including the Government's net-zero targets, global multinationals adopting sustainability drivers and policies and the global pandemic. Indeed, unlike most industries in these challenging times, biotechnology is experiencing a high. Between 2019 –2020, biotechnology saw double-digit annual growth in fundraising from venture capitalists (VCs) and deals such as partnerships, co-developments and joint ventures, and triple digit growth in IPOs[141].

Investors have recognised the increasing importance of the green economy and the key part it plays in addressing environmental objectives. Data shows that the green economy is represented by more than 3,000 global listed companies with a $4 trillion USD market cap opportunity. More specifically in the area

140 https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
141 https://www.mckinsey.com/industries/life-sciences/our-insights/whats-ahead-for-biotech-another-wave-or-low-tide

7. Investment and Funding

of investment into biofuels there has been significant investment both nationally and internationally[142].

Global investments in biofuel technologies in 2019 were around $3 billion USD and global investments in biomass and waste-to-energy technologies were $11.2 billion USD[143] , which demonstrates a strong appetite for investment in this area. In Scotland, there has been recent investment in novel biofuel technologies, an example of this is Celtic Renewables.

Celtic Renewables

Celtic Renewables' patented low-carbon technology converts unwanted, low-value biological material into high-value, low-carbon sustainable chemicals & advanced biofuel. The company – winners of the "Most Innovative Biotech SME in Europe" award in the EU parliament –are currently constructing Scotland's first biorefinery, which will produce 1M litres of sustainable low-carbon chemicals, including ethanol and butanol, annually that will displace fossil-fuel equivalents across a broad range of markets from cosmetics to fuel. Celtic Renewables recently completed one of the most successful and high-profile Crowd raises by any Scottish company, focusing global media attention on Scotland's biotech sector and raising over £3.5m of new investment on top of the £30m that the company secured to bring the technology from university innovation to industrial operation. With ambitious plans for full scale deployment in Scotland and around the world - to penetrate a biochemicals market set to be worth over £130bn by 2025 - Celtic Renewables is poised to play a pivotal role in Scotland's carbon transition to net-zero and growing a bioeconomy.

142 https://www.ftserussell.com/research/investing-green-economy-sizing-opportunity
143 https://www.statista.com/statistics/186825/global-investment-in-biofuel-technology-since-2004/

8. Conclusions

Background and demand

This project attempted to understand the factors that would contribute to a viable bio-based supply chain in Scotland - from farm to refinery - to re-shore production of bioethanol and replace imported ethanol for blending into petrol in Grangemouth.

UK demand for bioethanol is 1.7Bn Litres and current UK capacity for domestic production is around 900M litres (Crop Energies AG formally Ensus, Vivergo) derived predominantly from wheat. A previous study showed that demand for ethanol in Scotland will reach at least 145M litres by 2021 to supply E10 mandated fuel and that a larger biorefinery plant producing at least 170M litres would be more economically viable.

In this project, a detailed cost model was created to estimate the return on investment (ROI) of a new Scottish bioethanol facility. The model also looked to assess the likely return per hectare for sugar beet on Scottish farms, compared to other crops, to make the crop attractive to farmers. The wider social, political and agronomic benefits of the entire sugar beet to bioethanol value chain was also explored.

Location for a bioethanol plant

From an agricultural perspective, considering land of a suitable classification (3.1 and above), a site in Dundee would be the optimal location; with the most suitable land for growing sugar beet within a short distance (less than 50 miles) from central Dundee.

However, the existing infrastructure at Grangemouth for chemicals production and oil refining (i.e. renewable power generation, water treatment, transport logistics including port access, co-location of customers and human capital) is likely to outweigh the benefits of any green field site elsewhere. However, a Scottish bioethanol facility at Grangemouth requires longer haulage distances than is currently seen in France or in the south of England. One solution could be to offer farmers different prices for beet to account for the higher costs incurred for longer distance haulage. Haulage from within a 50 miles radius would be around £6 per tonne, whereas haulage from outside this distance would be higher; the price offered for beet would need to offset this differential.

Scale – agriculture

Land in Scotland suitable for growing sugar beet (grade 3.1 and above) is distributed down the East Coast margins. A detailed assessment of land availability showed that 194,358 hectares of suitable land is available within 50 miles of Dundee and 184,881 hectares within 50 miles of Grangemouth. The calculations are also ‘as the crow flies’ so the reality is that transport by road would be longer in some cases requiring transport across Tay and Forth.

Assuming a yield of 60 tonnes per hectare, and taking crop rotation into account, the analysis suggests that the total sugar beet available would be sufficient to supply a 1 million tonne capacity bioethanol plant in the first instance with the potential to increase farmer adoption if the distance of transport is increased and as the project develops and starts to de-risk the growth of a new crop for farmers.

Aside from the financial incentives of growing a valuable crop, sugar beet also offers farmers a new break crop to introduce into their rotations, which helps with pest control, improves soil quality and may enhance biodiversity.

8. Conclusions

Scale of Bioethanol Plant

The financial model shows that a scale of 100M – 400M litres are viable. The model had all scales operating at an 85% capacity as this is the most realistic scenario as existing bioethanol plants don't run at a 100% capacity. Due to economies for scale, the larger the plant, the more profit it will generate. Scotland is limited by its available arable land and could produce around 100M tonnes of sugar beet within a 50-mile radius of a central bioethanol facility, which would generate around 110M litres of ethanol. More ethanol could be produced if it were to be sourced from a wider radius but a longer haulage would increase the costs.

The increased haulage costs have been taken into account for the 200M litres scale and the analysis shows that this would be financially viable. To meet the demand of a 400-litre plant, we modelled importing sugar but this resulted in a negative net profit value (NPV) and would not be financially viable due to the high costs associated with this option. Therefore, we recommend a 100-200 litre scale facility based on our analysis, with a 200M litre facility operating at 85% and producing around 170M litres per annum being optimal as this will meet Scottish E10 demand and leave a small surplus for chemical and IB processes.

Operating model – Farmer Co-Operatives

The formation of a grower's co-op for beet would be beneficial to farmers and the end user and they are well tried-and-tested models. The development of a co-op enables shared risk for growers and offers multiple benefit such sharing the burden of needs such as extra work, staff or machinery for new crops. All aspects of the process will be undertaken on their behalf by an experienced professional team, from crop establishment, agronomy, harvesting, to haulage, processing, and marketing, without the need for additional overheads or equipment. The development of a coop can also increase efficiency, with the shared responsibility of increasing profit margins. Potential plant operators stated that a coop was necessary to simplify the contracts and logistics of the supply chain. This project studied and met with existing coops in Scotland, France and the US. Various operating models were studied, and a structure has been proposed for a potential sugar-beet growers co-operative. While a third of Scottish farmers are part of a cooperative, not all farmers will necessarily be keen to join one but farmer focus groups could be used to share evidence of their success and increase participation in the co-operative.

Operating model – Bioethanol centralised or 'hub and spoke' plant

To optimise return on capital, the project sought methodologies for distributed processing of beet to a storable sugar syrup (or equivalent) either on farm or in a number of local hubs which then ship to a central facility for conversion to ethanol. Shipping the concentrate to a single location for conversion to ethanol reduces haulage weight by approximately 50% and is logistically simpler to operate (liquid tanker vs solid beet in trailers).

The project team was unable to find any examples of such an operating model (except potentially movement of syrup between existing sugar production facilities to ethanol production in France). Neither was the team able to identify any established technology to enable creation of a "hub and spoke" model.

Consequently, this project has focused on a simpler centralised model with all beet shipped from farm to processing facility which is the typical operating model worldwide. This model can be readily adapted as new distributed technologies for beet to sugar syrup are developed in future. The advantages created by reduced shipping (cost and emissions) can be balanced against cost of capital for distributed facilities.

8. Conclusions

Specifically, it could enable locations which are "out-of-range" to join the production coop. As sugar beet agriculture is established the plant will be required to operate from imported sugar.

Economic viability

Two separate cost models were created to determine economic viability:

1. An agricultural model: created to calculate the return per hectare for famers growing beet and compared to other crops which may form part of the rotation. At a beet price of £30-35/Te paid to farmers, beet is a rewarding option. This is significantly higher than the NFU/British Sugar agreed price for 2021, which was £20.30/Te137 but closer to the futures market price for beet (which is £27/Te)138 operated by Czarnikow Group Limited for farmers with British Sugar contracts.

2. A cost model: developed to calculate the Net Present Value of an investment in a plant to convert beet to ethanol. The model contains inputs from the agricultural model (beet price, haulage cost) and other variable and fixed costs (all raw materials, labour, capital, utilities). Ethanol accounts for <60% of the plant revenue with biogas and feed making up most of the remainder.

Carbon accounting

The carbon savings for on-shoring bioethanol from sugar beet have been calculated and 280,000 Te equivalent of CO2 are saved per annum, this equates to the removal of nearly 61,000 cars from the road a year.

Per kilogram of crop produced, sugar beet has a carbon footprint (kgCO2e) 87% lower than the cereals, 94% lower than oilseed rape and 82% lower than pulses. When expressed by area, a hectare of sugar beet has a carbon footprint value greater than a hectare of pulses and lower than a hectare of either cereals or oilseeds.

The daily carbon price in the UK fluctuates but a reasonable estimation is between £50-£100 per tonne equivalent of carbon. Therefore, the estimated monetary value of carbon saved by this project per year is estimated to be £9.4M - £18.7M.

8. Conclusions

SWOT Analysis

Strengths	Weakenesses
▪ Scotland is able to grow sugar beet at sufficient yields to be viable as the basis of a sugar supply chain ▪ Scotland has an existing chemicals industry ▪ Scotland is home to an oil refinery	▪ Scotland is a small country and has limited prime land available for sugar beet growth ▪ Scotland doesn't currently manufacture bioethanol for industrial uses

Opportunities	Threats
▪ Net zero drivers have presented an opportunity to introduce a scalable, sustainable feedstock for manufacturing a range of end products ▪ E10 has been introduced and doubles the UK demand for bioethanol	▪ Post Brexit trade deals could encourage bioethanol to be imported (North and South America) ▪ Delaying the development of a sustainable feedstock to service the Scottish chemicals sector could result in losing the entire sector once net-zero comes into force in 2045

Final Conclusions

From this study we can conclude that Scotland can grow enough sugar beet to manufacture its own bioethanol. The land lies down margins of the East coast of Scotland and with the correct pricing, farmers will likely be interested in adopting sugar beet as a new break crop. A centralised bioethanol plant is the most ideal model, the possibility of 'hub and spoke' model has been explored as part of this study but currently the infrastructure and technology are not yet available commercially to make it a viable option.

From an analysis of available land and existing infrastructure, Dundee or Grangemouth are both credible locations. Dundee is more attractive form an agricultural perspective as more arable land is available within a 50-mile radius. Grangemouth is a better fit from an industrial perspective with access to renewable power generation, water treatment, transport logistics - including port access, co-location of customers and human capital due to existing chemicals and oil refining capabilities on site. Some price differential could be considered to haul beet longer distances if Grangemouth was the chosen site.
A model was developed as part of this study to take into account the full economic costings from the

8. Conclusions

farm to the bioethanol plant. We have concluded that the optimal size for Scotland would be a 200 million litre plant, making 170 million litres of bioethanol a year. An investment of £200m would be required and it would generate £24M profit per annum. If a carbon tax were to be introduced, an additional profit of between £9.4-£18.7M would be generated per year.

The further benefits of this project to Scotland include the generation of at least 815 additional jobs, many of which will be created in rural and/or deprived areas. From an agronomy perspective, a break crop is sown to provide diversity to help reduce disease, pest and weed levels and improve soil health. As a break crop, sugar beet 'breaks' the cycle of many pests, weeds and diseases, and without this, these threats could increase and ultimately could mean the land is unsuitable for growing some crops. Having sugar beet as break crop also reduces the need for pesticides. The carbon saved from moving from importing bioethanol to manufacturing it locally is over 280,000 tonnes of CO2 equivalent per annum which equates to taking nearly 61,000 cars off the road in Scotland per year. This will also result in greater fuel security for the country and provide an opportunity to develop the Scottish bioecomony and a just transition for the Scottish chemicals sector towards the Net-Zero targets set for 2045.

Next Steps

Based on the findings of this report, a number of next steps have been suggested:

- Undertake a full engineering study of the bioethanol plant to fully understand all of the capital expenditure and operational expenditure associated with the project.
- Develop a campaign to attract inward investment and/or bioethanol plant operators to Scotland.
- Hold farmer focus groups to disseminate the project, address questions and increase adoption of sugar beet growth.
- Develop a Cooperative structure.
- Explore public sector support options.
- Explore the development of Government subsidies and incentives to drive the project forward at both a Scottish and UK level.

Appendices

Appendix 1 - Full Press Coverage

The project has garnered significant press coverage to date. IBioIC placed an exclusive in The Times '*Reintroduction of sugar beet to Scotland takes a significant step forward'*[144] that centred on the new funding from Scottish Enterprise for the sugar beet project. The full release that went to media is available to read on the IBioIC website[145], and included quotes from IBioIC Scottish Enterprise, SAC Consulting and SAOS.

The sugar beet project took a large step forward in terms of media activity, with a total of 20 pieces of news coverage across print and online media in a wide range of publications across UK & Scottish national press, local & regional publications, and agricultural & other trades.

The placement in The Times is a definitive milestone for IBioIC and industrial biotechnology, being placed in a UK publication is traditionally very difficult when the story is a Scotland only focus, with this achievement detailing the influence of energy crops on the UK stage.

The story has done incredibly well across a variety of national, local, regional and trade publications:

- UK Nationals: The Times
- Scottish Nationals: The National[146] and The Herald (in print) and The Herald online[147]
- Farming and Agricultural trade publications: Agronomist & Arable Farmer[148], Agriland[149], Farming Online[150], The Scottish Farmer[151], Farming Scotland (online)[152], Farming Scotland (in print maga zine), AgriTrade News[153] , Food & Agribusiness (EU Agri trade publication).
- Local and regional publications: The Courier online[154] and in-print, Press & Journal online[155] and in-print, Grampian online[156]
- Biotech & environmental publications: Envirotec Magazine[157], Biofuels International [158], Agro & Chemistry[159]

The full press release and pictures can be found in Appendix 1.

144 https://www.thetimes.co.uk/article/sugar-beet-plan-aims-to-grow-greener-fuel-tcspfhd87
145 https://www.ibioic.com/news-database/re-introduction-of-sugar-beet-to-scotland-takes-significant-step-forward
146 https://www.thenational.scot/news/19370754.sugar-beet-boost-scotlands-green-economy/
147 https://www.heraldscotland.com/business_hq/19372923.cash-boost-project-reintroduce-sugar-beet-production-scotland/
148 https://www.aafarmer.co.uk/agronomy/re-introduction-of-sugar-beet-to-scotland-takes-significant-step-forward.html
149 https://www.agriland.co.uk/farming-news/sugar-beet-set-to-make-a-comeback-in-scotland/
150 https://farming.co.uk/news/re-introduction-of-sugar-beet-to-scotland-takes-significant-step-forward
151 https://www.thescottishfarmer.co.uk/news/19376214.scottish-bioeconomy-built-sugar-beet/
152 https://issuu.com/atholedesign/docs/farmingscotlandmag_august_2021
153 https://agritradenews.co.uk/become-an-agritrade-news-subscriber-to-read/?code=100020
154 https://www.thecourier.co.uk/fp/business-environment/farming/2315404/cash-injection-secured-for-sugar-beet-pilot/
155 https://www.pressandjournal.co.uk/fp/farming/3240928/cash-injection-secured-for-sugar-beet-pilot/
156 https://www.grampianonline.co.uk/news/pilot-project-looks-at-growing-sugar-beet-242092/
157 https://envirotecmagazine.com/2021/06/14/re-introduction-of-sugar-beet-to-scotland-takes-significant-step-forward/
158 https://biofuels-news.com/news/sugar-beet-trials-in-scotland-could-pave-way-for-new-bioefinery/
159 https://www.agro-chemistry.com/news/scotland-re-introduces-sugar-beet-to-develop-the-bio-economy/

Appendices

FULL PRESS RELEASE & PICTURES

Re-introduction of sugar beet to Scotland takes significant step forward

Crop harvested for first time in 50 years will support development of a bioeconomy in Scotland

14 June 2021

The re-introduction of sugar beet production to Scotland – a move that could support national climate change targets, create green jobs, and unlock new economic opportunities – has taken a significant step forward after the pilot project laying its foundations received new funding.

With the first successful crop in half a century harvested earlier this year, the consortium behind the sugar beet initiative – which includes the Industrial Biotechnology Innovation Centre (IBioIC), SAC Consulting, and Scottish Agricultural Organisation Society (SAOS) – has secured a funding boost from Scottish Enterprise to 3 its potential environmental, societal, and economic impact.

The study will examine the widespread benefits that are expected to follow on from the crop's return to Scotland. Sugar beet is seen as a key building block for the development of sustainable supply chains and a 'bioeconomy', which uses natural materials instead of petrochemical compounds in manufacturing.

A local source of sugar beet could pave the way for the development of an ethanol-producing biorefinery in Grangemouth – the hub of Scotland's chemicals and petrochemical processing industries – and later support a fully functioning bio-based chemicals industry.

Sugar beet can be used in the production of ethanol as a natural and sustainable[1] substitute for petroleum-based chemicals used in a range of household goods, as well as antibiotics and therapeutic proteins. Demand for ethanol in Scotland is expected to double in the coming years to more than 100 million litres, yet all the country's supply is currently imported from Europe.

Ian Archer, technical director at IBioIC, said: "Growing sugar beet in Scotland once again is a huge opportunity to re-invent the economy, build sustainability into manufacturing supply chains, and secure jobs for the future. Many of the biggest consumer goods manufacturers have committed to net-zero caron targets over the next two decades and a big part of that drive will be replacing the use of petrochemicals with natural materials.

"You cannot have a chemicals industry without a feedstock and to retain the sector in Scotland we need a local supply and the supply chains that follow. In northern Europe, that crop is sugar beet and growing it for ethanol production will not only diversify farmers' income stream but could allow them to be part of a green alternative to fossil fuels.

"Bio-based manufacturing shares many skills with using traditional chemicals and given the direction of travel in the industry, transitioning towards this approach could secure and create jobs in Scotland. It is almost inevitable that we need to change the way we produce goods if we are going to compete in global supply chains and secure a future for the domestic market.

"We have made huge progress in the last year that has taken the concept of a bio-economy based on sugar beet production from a nice idea to the harvesting of the first yield in 50 years and the outline of how a farming co-operative would be structured. This next step should confirm what we already know, with data to support the rage of benefits associated with growing sugar beet."

Appendices

Andrew Henderson of Scottish Enterprise's advanced manufacturing team said: "This is a hugely exciting project which could yield transformational outcomes for businesses.
"Our funding will help unlock a vital next step for this project to support sustainable fuel and chemicals production through biotechnology, and ultimately create new jobs and investment to strengthen communities across Scotland.
"Sugar beet production can also help deliver our green economic recovery and transition to a net zero economy, through benefits like better air quality via carbon capture, and enhanced quality of soil."

Jim Booth, Head of Co-op Development at SAOS, commented: "The re-introduction of sugar beet represents an exciting opportunity for farmers. If the proposal is to get off the ground, the only way to get farmer growers involved is through co-operation. Creating a producer co-op means the production, crop management, harvesting, marketing and delivery is optimised, safeguarding grower returns, and importantly ensuring a collaborative supply chain approach."

Iain Riddell of SAC Consulting added: "We welcome the Viability Study funding, which gives our Sugar Beet Working Group the opportunity to further investigate agronomy, harvesting logistics, refining and by products, and most importantly, the investment required and support mechanisms that could credit sugar beet growers for their contribution to industrial carbon savings that help achieve Scotland's Net Zero targets. We are confident we can grow and harvest sugar beet on better land in the East of Scotland with group members already growing it for use in AD Plants and are exploring the potential of localised micro-processing plants as an option for onward transportation of concentrated sugar syrup rather than the bulky sugar beet crop. Much will depend on government support, investor interest and the offer of long-term contracts that encourage farmers to commit to growing the crop".

- ENDS -

[1] Traditionally produced oil-based polyethylene used in plastics emits around two tonnes of CO_2 for every tonne produced. By comparison, plastics made from bio-based polyethylene sequester more than two tonnes of CO_2 for every tonne created.

Appendices

Appendix 2 – Legislation, policy & guidance of note

Additional Policy commentary of note

Green investment

The Green Investment Portfolio[160] was launched in 2020. It promotes market-ready projects that will help Scotland transition to net-zero and are seeking private capital. The Programme for Government included a commitment to add to this to bring investment proposals worth £3bn to the market by 2022. The government also outlined plans to take forward a Green Market Solutions Programme to stimulate private sector investment into major projects and new technologies, take forward a Green Growth Accelerator and explore the creation of a new green industrial catalyst fund to support investment and resilience in the green industrial sector.

Co-operatives

In 2018 the First Minister confirmed the establishment of 'Scotland for EO[161]', which aimed to increase the number of employee and worker-owned businesses from around 100 to 500 by 2030. The Programme for Government[162] includes a commitment to support businesses with alternative ownership models, including cooperatives and social enterprises.

A Future Strategy for Scottish Agriculture: Final Report by the Scottish Government's Agriculture Champions, published in 2018[163], includes several recommendations based on collaboration. It emphasises the importance of farmers grasping the benefits of working collaboratively, including "strengthening their arm in the supply chain". The report also suggests future agriculture schemes should include collaboration and collaboration should be encouraged in the area of collective purchasing, to reduce costs. Recommendation is also made that collaboration should be embedded in training and business practices and the government should continue to provide grants towards collaborative capital investment.

Co-operative Development Scotland is an arm of Scotland's enterprise agencies supporting company growth and co-operative business models[164].

Supply Chain Innovation

The Scottish Government consulted on Making Scotland's Future: A Recovery Plan for Manufacturing[165] and presented the findings of this in March 2021[166]. The consultation included mention of the need

160 https://www.gov.scot/news/green-investment-portfolio-launched/
161 https://www.gov.scot/news/new-leadership-group-for-employee-ownership/
162 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/09/fairer-greener-scotland-programme-government-2021-22/documents/fairer-greener-scotland-programme-government-2021-22/fairer-greener-scotland-programme-government-2021-22/govscot%3Adocument/fairer-greener-scotland-programme-government-2021-22.pdf
163 https://www.gov.scot/publications/future-strategy-scottish-agriculture-final-report-scottish-governments-agriculture-champions/
164 https://www.scottish-enterprise.com/our-organisation/about-us/who-we-work-with/co-operative-development-scotland
165 https://www.gov.scot/publications/making-scotlands-future-recovery-plan-manufacturing-draft-consultation/pages/5/
166 https://www.gov.scot/publications/making-scotlands-future-recovery-plan-manufacturing-consulta-

Appendices

to revitalise Scottish supply chains and provided a list of immediate actions that were required. The SNP manifesto includes a pledge to invest £26m to support the development of robust supply chains in low carbon industries through the Low Carbon Infrastructure Challenge Fund. The Programme for Government[167] states work will continue to build on the Supply Chains Development Programme, including ensuring infrastructure investment is a priority of this and embedding Fair Work First, climate and local economic considerations in more contracts and grants.

Rural innovation post Brexit

The Scottish Rural Development Programme (SRDP)[168], delivering Pillar 2 of the EU Common Agricultural Policy (CAP) originally ran from 2014-2020. The programme was approved by the European Commission in May 2015 and had a budget of over £1.3bn to deliver priorities. The purpose of the programme was to help achieve sustainable economic growth.

After the UK voted to leave the EU in 2016, the Scottish Government said it was committed to continuing to support the rural economy. In 2018, the Scottish Government set out its proposals for future agriculture funding until 2024 in its consultation Stability and Simplicity. This document proposed continuing most CAP schemes in this period. The Future Agricultural Funding Policy Delivery Group will take forward the recommendations from this consultation and deliver the transition for the rural economy.

Since then, the powers of the Agriculture (Retained EU Law and Data) (Scotland) Act have been used to "enable the continued operation of current CAP schemes and policies" from 1 January 2021. This legislation "is not intended to represent a major policy shift but rather streamlining existing policy". On 1 January 2021 the Scottish Government published Scottish Rural Development Programme – domestic: programme 2021[169] which approved programme document continues the extension of Pillar 2 funds across the transition period into a new programme.

The Scottish Rural Development Programme has a series of funding streams, the majority of which will continue until 2024.

The Knowledge Transfer and Innovation Fund[170] was delivered through the Scottish Rural Development Programme (SRDP) 2014-20. The scheme funded eligible innovation projects under the European Innovation Partnership. The Scottish Rural Development Programme - domestic: programme 2021[171] highlights the Scottish Government's commitment to knowledge exchange in the rural sector. The 2021-

tion-summary-march-2021/

167 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/09/fairer-greener-scotland-programme-government-2021-22/documents/fairer-greener-scotland-programme-government-2021-22/fairer-greener-scotland-programme-government-2021-22/govscot%3Adocument/fairer-greener-scotland-programme-government-2021-22.pdf

168 https://www.ruralpayments.org/publicsite/futures/topics/customer-services/common-agricultural-policy/scottish-rural-development-programme/

169 https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2020/12/scottish-rural-development-programme---domestic-programme-2021/documents/scottish-rural-development-programme---domestic-programme-2021/scottish-rural-development-programme---domestic-programme-2021/govscot%3Adocument/SRDP%2BProgramme%2BDocument%2B%2528Domestic%2529%2BJan%2B2021.pdf

170 https://www.ruralpayments.org/publicsite/futures/topics/all-schemes/knowledge-transfer-and-innovation-fund/knowledge-transfer-and-innovation-fund-full-guidance/

171 https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2020/12/scottish-rural-development-programme---domestic-programme-2021/documents/scottish-rural-development-programme---domestic-programme-2021/scottish-rural-development-programme---domestic-programme-

Appendices

22 Budget committed to continuing this fund[172].

The Rural Innovation Support Service (RISS), financed by the Scottish Rural Development Programme, was launched in February 2018, and ran until March 2021[173]. The service provided professional support to farmers interested in trying new things by connecting them with a facilitator to help develop the idea.

In November 2020, the Scottish Government published an Evaluation of the Scottish Rural Network which suggested the SRN had contributed to innovation through engagement with European networks and the creation of the Rural Innovation Support Service[174]. Recommendations are made on the role a future network could play in pursuing rural development, these include clarifying the network's intervention logic, improved co-ordination internally, more regular reporting on activities, more inclusive goal setting, making the broader rural network more visible, adopting a membership structure, expanding delivery methods and following-up impact evaluation.

The Scottish Government's 2021-22 Budget pledges continued Scottish Government support for "agricultural transformation". The government will assist the sector to reduce emissions and improve efficiency through the £40m Agriculture Transformation Fund. Other sources of funding include the pilot Sustainable Agricultural Capital Grants Scheme and the continuation of previously successful schemes such as the Farm Advisory Service, Knowledge Transfer and Innovation Fund and Farming for a Better Climate.

The Programme for Government[175] includes plans to launch a £20m Rural Entrepreneur Fund in the coming financial year, providing grants of up to £10,000 to support the creation of new businesses, or the relocation of existing businesses.

Scottish Legislation

RENEWABLES

- Renewables Obligation (Scotland) Order 2009
- The Renewables Obligation (Scotland) Amendment Order 2018
- Climate Change (Scotland) Act 2009
- Climate Change (Emissions Reduction Targets) (Scotland) Bill

SOILS

- Forestry and Land Management (Scotland) Act (2018)
- The Water Environment (Miscellaneous) (Scotland) Regulations (2017)
- Land Reform (Scotland) Act (2016)
- The Pollution Prevention and Control (Scotland) Regulations (2012)
- Historic Environment (Amendment) (Scotland) Act (2011)
- Waste Management Licensing (Scotland) Regulations (2011)
- Wildlife and Natural Environment (Scotland) Act (2011)

172 https://www.gov.scot/publications/scottish-budget-2021-22/
173 https://www.innovativefarmers.org/welcometoriss
174 https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/11/evaluation-scottish-rural-network/documents/evaluation-scottish-rural-network/evaluation-scottish-rural-network/govscot%3Adocument/evaluation-scottish-rural-network.pdf
175 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/09/fairer-greener-scotland-programme-government-2021-22/documents/fairer-greener-scotland-programme-government-2021-22/fairer-greener-scotland-programme-government-2021-22/govscot%3Adocument/fairer-greener-scotland-programme-government-2021-22.pdf

Appendices

- The Water Environment (Controlled Activities) (Scotland) Regulations (2011)
- The Environmental Liability Regulations (Scotland) (2009)
- Climate Change (Scotland) Act (2009)
- Flood Risk Management (Scotland) Act (2009)
- Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations (2008)
- Radioactive Contaminated Land (Scotland) (Amendments) Regulations (2007)
- Planning etc. (Scotland) Act (2006)
- The Contaminated Land (Scotland) Regulations (2005) & Statutory Guidance SE/2006/44
- Environmental Assessment (Scotland) Act (2005)
- Nature Conservation Scotland (Act) (2004)
- Water Environment and Water Services (Scotland) Act (2003)
- Landfill (Scotland) Regulations (2003) (and later amendments)
- Conservation (Natural Habitats, &c.) Regulations (1994)
- Radioactive Substances Act (1993)
- Sludge (Use in Agriculture) Regulations (1989 and later amendments)
- Plant Health (Official Controls and Miscellaneous Provisions) (Scotland) Regulations 2019

CO-OPERATIVES
- Community Empowerment (Scotland) Act 2015
- Land Reform (Scotland) Act 2016

AGRICULTURE
- Agriculture (Retained EU Law and Data) (Scotland) Act
- The Rural Development (EU Exit) (Scotland) (Amendment) Regulations 2020

Scottish Policy & Guidance

GENERAL
- Programme for Government 2021-22
- The Environment Strategy for Scotland: vision and outcomes
- Infrastructure Investment Plan for Scotland 2021-2022 to 2025-2026
- Fourth National Planning Framework: position statement
- The refreshed Economic Action Plan 2019-20 was launched in January 2020. Headline actions included 50% of energy needs being met by renewables by 2030, delivering the Green Investment Portfolio and investing £2m to expand zero carbon mobility. A commitment is made to use the expertise of businesses and the private sector to speed up the development of new greener technologies in collaboration with colleges, universities, innovation centres and research institutes.

CIRCULAR ECONOMY
- Making Things Last: A Circular Economy Strategy for Scotland

GREEN RECOVERY
- Towards a Robust, Resilient Wellbeing Economy for Scotland: Report of the Advisory Group on Economic Recovery
- Economic Recovery Implementation Plan: Scottish Government response to the Advisory Group on Economic Recovery

FUELS/BIOFUELS
- Scottish Energy Strategy
- Bioenergy: update - March 2021

Appendices

- The Biorefinery Roadmap for Scotland

RENEWABLES
- Agri-renewables strategy for Scotland
- Scottish Energy Strategy
- Cleaner Air for Scotland 2 - Towards a Better Place for Everyone

SUPPLY CHAIN
- Making Scotland's Future - recovery plan for manufacturing - draft: consultation

RURAL INNOVATION
- Evaluation of the Scottish Rural Network
- Scottish Rural Development Programme - domestic: programme 2021
- Stability and Simplicity

AGRICULTURE
- Stability and Simplicity
- A Future Strategy for Scottish Agriculture: Final Report by the Scottish Government's Agriculture Champions
- Scotland's Third Land Use Strategy
- Land use - getting the best from our land: strategy 2021 to 2026

SOILS/CROPS
- Scotland's Forestry Strategy 2019-2029 (2019)
- Climate Change Plan: third report on proposals and policies 2018-2032 (RPP3) (2018)
- The Muirburn Code (2017)
- Valuing Your Soils (2016)
- Land Use Strategy (2016)
- Historic Environment Scotland Policy Statement (2016)
- National Peatland Plan (2015)
- Common Agricultural Policy in Scotland (2015)
- Flood Risk Management Strategies (2015)
- Natural Flood Management Handbook (2015)
- River Basin Management Plans (2015)
- Guidance on suitable organic material applications for land restoration and improvement (2015)
- Scottish Rural Development Plans (2014-2020)
- Scottish Planning Policy (2014)
- National Planning Framework 3 (2014)
- Scottish Climate Change Adaptation Programme (SCCAP) (2014)
- 2020 Route map for renewable energy in Scotland- update (2013)
- 2020 Challenge for Scotland's Biodiversity (2013)
- Strategic Environmental Assessment Guidance (2013)
- Management of Carbon-Rich Soils (2010)
- Scotland's Zero Waste Plan (2010)
- Planning Advice Note 33 (Development of Contaminated land)
- Scottish Soil Framework (2009)
- Scottish Forestry Strategy (and implementation Plan) (2006)
- Scottish Plant Health Strategy

Appendices

CHEMICALS
- Shaping Scotland's Economy: Scotland's Inward Investment Plan

BIOECONOMY
- National Plan for Industrial Biotechnology

JUST TRANSITION
- Just Transition Commission: A national mission for a fairer, greener Scotland
- Just Transition - A Fairer, Greener Scotland: Scottish Government response

CO-OPERATIVES
- A Future Strategy for Scottish Agriculture: Final Report by the Scottish Government's Agriculture Champions

Scottish Codes of Practice

SOILS
- Good practice during wind farm construction (2015)
- Code of practice for the use of sludge, compost, and other organic materials for land reclamation (2010)
- Prevention of Environmental Pollution from Agricultural Activity (PEPFAA) Code (Voluntary code of practice) (2005)

Funding policy themes

RESEARCH
- Environment, natural resources, and agriculture research: strategy 2022 to 2027

GREEN RECOVERY
- Community Climate Asset Fund (Currently closed to applications)

RENEWABLES
- Community and Renewable Energy Scheme (CARES)
- Resource Efficient Scotland
- Energy Investment Fund

AGRICULTURE
- Agri-Environment Climate Scheme
- Sustainable Agriculture Capital Grant Scheme (SACGS) (Currently closed to applications)
- Knowledge Transfer and Innovation Fund (KTIF)
- LEADER

UK legislation

SOILS
- The Control of Pesticides (Amendment) Regulations (1997)
- Environmental Protection Act – Part IIA: Contaminated Land (1990)

Appendices

CHEMICALS
- The REACH etc. (Amendment etc.) (EU Exit) Regulations 2020
- The REACH etc. (Amendment etc.) (EU Exit) (No. 3) Regulations 2019
- The REACH etc. (Amendment etc.) (EU Exit) (No. 2) Regulations 2019
- The REACH etc. (Amendment etc.) (EU Exit) Regulations 2019

UK policy/guidance

CIRCULAR ECONOMY
- Circular Economy Package policy statement

FUELS/BIOFUELS
- Clean Growth Strategy
- Energy White Paper

RENEWABLES
- Contracts for Difference (CfD) scheme
- UK Renewable Energy Roadmap
- The Ten Point Plan for a Green Industrial Revolution
- Energy White Paper

SOILS/CROPS
- UK Forestry Standard (2017)
- Woodland Carbon Code (2011)
- Code of Practice for the agricultural use of sewage sludge (2001)
- BS 10175 Code of Practice for the Investigation of Potentially Contaminated Sites
- Plant Biosecurity Strategy for Great Britain

BIOECONOMY
- Growing the bioeconomy: a national bioeconomy strategy to 2030

EU policy & guidance

GENERAL
- European Green Deal
- Industrial Strategy
- Plastics strategy
- Zero pollution action plan

CIRCULAR ECONOMY
- EU Circular Economy Action Plan

GREEN RECOVERY
- Recovery and Resilience Facility
- European Green Deal

SOILS
- Common Agricultural Policy (2013)
- EU Biodiversity Strategy (2011)
- Thematic Strategy for Soil Protection (2006)

Appendices

CHEMICALS

- Chemicals strategy

COOPERATIVES

- Support for Farmers' Cooperatives
- Communication on the promotion of co-operative societies in Europe

EU directives

SOILS

- EU Industrial Emissions Directive (2010)
- Waste Framework Directive (2008)
- Floods Directive (2007)
- Groundwater Daughter Directive (2006)
- Environmental Liability Directive (2004)
- National Emissions Ceiling Directive (2001)
- Strategic Environmental Assessment (2001)
- Water Framework Directive (2000)
- Landfill Directive (1999)
- Habitats Directive (1992)
- Urban Waste Water Treatment Directive (1991)
- Sludge Directive (1986)

Scottish Rural Development Funds

- Agri-Environment Climate Scheme
- Forestry Grant Scheme
- Less Favoured Area Support Scheme
- Crofting Agricultural Grant Scheme
- Small Farms Agricultural Grant Scheme
- New Entrants Capital Grant Scheme
- New Entrants Start-Up Grant Scheme
- Young Farmers Start-Up Grant Scheme
- Environmental Co-operation Action Fund
- Food Processing, Marketing and Co-operation
- Knowledge Transfer and Innovation Fund
- Beef Efficiency Scheme
- LEADER
- Broadband

Appendices

Appendix 3 - Key economic influencers & supporters

SCDI's Manifesto for Clean Growth[176] identifies seven opportunities and 21 priority actions related to clean growth in Scotland. These include:

Transforming Industry – establishing world-leading circular and bio-economies to transform and decarbonise industry to boost innovation, protect jobs and create green jobs.

- Recommendations on this include the UK and Scottish governments backing biotechnological innovation which supports industry to decarbonise, transform Grangemouth into a biorefinery and protect jobs through public investment, innovation, incentives, and innovation support.

Clean Energy Innovation World Leader – building on existing energy expertise to maximise renewable energy generation and flexible storage, pioneer CCUS and build a hydrogen economy.

- Recommendations on this include industry working with the Scottish Government to build an internationally competitive domestic supply chain for renewable energy manufacturing and related services and increase local content in equipment and people.

Close the Investment Gap – delivering a green stimulus, unlock green finance and recognise climate risks to fund the transition to Net Zero, deliver co-benefits for society, economy and environment and establish Scotland as a world leader in ethical, responsible, and sustainable investment.

- Recommendations on this include UK Government and Scottish governments should scale-up public investment funded through additional affordable borrowing and taxation of carbon emissions to deliver a large-scale green stimulus; UK Government working with industry and devolved administrations to agree a new carbon pricing mechanism which aligns with Net Zero.

Nature-Rich Future – including transforming agriculture

- Recommendations on this include the Scottish Government proposing a new system of farm support payments which protect and restores biodiversity, support innovative and sustainable food production, and is aligned with expanded and strengthened advisory services for farmers and crofters.

176 https://www.scdi.org.uk/wp-content/uploads/SCDI-Manifesto-for-Clean-Growth-2020.pdf

Appendices

Appendix 4 - Operational costs to derive Net Profit Margin

Individual operation costs

Operation		SAC referenced data	NAAC referenced data	Values applied
Ploughing (F)	(£/ha)	68.07	67.09	67.09
Cultivating (F)	(£/ha)	40.87	56.64	56.64
Rolling (F)	(£/ha)	11.59	19.25	19.25
		120.52	142.98	142.98
Sowing (co-op)	(£/ha)	29.19	61.25	36.57
Spraying (F)	(£/ha)	40.31	55.56	55.56
Fertiliser (F)	(£/ha)	39.45	49.60	49.60
	(£/ha)	108.95	166.41	141.73
Beet lifting (co-op)	(£/ha)	252.15	238.00	242.40
Beet carting loading (co-op)	(£/ha)	87.92*	31.44*	88.50
Total lifting, carting, loading	(£/ha)	340.08	269.44	330.90
All operation cost	(£/ha)	569.56	578.83	615.61

*carting only

SAC: Scottish Agricultural Consulting
NAAC: National Association Agricultural Contractors
(F) Farmer /grower

Appendices

Appendix 5 - Calculation of equipment operational costs

Operational cost of drill	£/ 1000 ha	£/ ha
18 row drill New value £85,000. Life 8 years		
Tractor + driver + fuel £380/day 42 days 24ha/day	15,960	15.96
Lease/purchase cost on £85,000 +2%. Annual charge	10,837	10.84
Repairs spares 11.5% purchase price	9,775	9.78
Total annual ownership and operating cost	36,572	36.57

Operational cost of harvester	£/ 1000 ha	£/ ha
6 row beet harvester New value £480,000. Life 4 yrs		
Driver £180/day 100 harvesting days	18,000	18.00
Fuel for harvester 49l/ha at 55p/l	18,000	18.00
Annual lease/purchase charge on £480,000 +2%. Annual charge	122,400	122.40
Repairs spares 17.5% purchase price	84,000	84.00
Total annual ownership and operating cost	242,400	242.40

Operational cost of carting, cleaning, loading	£/ 1000 ha	£/ ha
1 Chaser unit £120,000 per 2000ha		
1 CTM 9000 Cleaner loader £67,000 per 1000ha		
Tractor (big) + man carting off harvester £40/hr + fuel £10/hr = £400 per day	40,000	40.00
JCB loader hire + man 5ton/min (60,000 tons 200 hrs) £42/hr +20% downtime	10,800	10.80
Purchase charge on £127,000 +2%. Life 8 years	16,192	16.19
Repairs spares 11.5% purchase price	21,505	21.51
Total annual ownership and operating cost	88,497	88.50

Appendices

Appendix 6 - Detailed emissions by source by crop type

		Whole Farm	Feed wheat	Feed winter barley	Malting spring barley	Oilseed rape	Field beans	Field peas	Sugar beet
		kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e	kg CO_2e
CARBON DIOXIDE									
Direct Emissions	**Diesel** [1]	20,394	3,020	2,835	2,678	2,587	2,482	2,482	4,310
	Electricity [1]	0	0	0	0	0	0	0	0
	Other fuels [1]	0	0	0	0	0	0	0	0
	Renewable electricity [1]	0	0	0	0	0	0	0	0
	Renewable heat [1]	0	0	0	0	0	0	0	0
	Direct CO_2	**20,394**	**3,020**	**2,835**	**2,678**	**2,587**	**2,482**	**2,482**	**4,310**
Direct & Indirect emissions (embedded in purchased inputs)	**Fertiliser**	72,869	16,916	15,493	11,450	15,795	1,443	898	10,874
	Lime	0	0	0	0	0	0	0	0
	Biochar	0	0	0	0	0	0	0	0
	Feed	0	0	0	0	0	0	0	0
	Bedding	0	0	0	0	0	0	0	0
	Pesticides	251	30	30	30	32	49	49	33
	Waste plastic / packaging	0	0	0	0	0	0	0	0
	Disposal of carcasses	0	0	0	0	0	0	0	0
	Transport	0	0	0	0	0	0	0	0
	Indirect CO_2 (inc. Biochar)	**73,120**	**16,946**	**15,523**	**11,480**	**15,826**	**1,492**	**947**	**10,906**
	Total CO_2 from energy & waste (inc. Biochar)	**93,514**	**19,966**	**18,358**	**14,158**	**18,413**	**3,974**	**3,429**	**15,217**
METHANE									
Enteric	**Fermentation (feed digestion)**	0	0	0	0	0	0	0	0
	Manure mgmt	0	0	0	0	0	0	0	0
	Total CO_{2e} from methane	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
NITROUS OXIDE									
Volatilisation, leaching & run-off	**Inorganic and imported organic manure input to soil**	50,017	12,199	10,978	7,929	12,199	0	0	6,713
	Grazing deposition, manure management and organic manure input to soil	0	0	0	0	0	0	0	0
Vegetation, stubble & roots	**Crop N residues**	21,566	2,995	3,118	4,179	1,027	1,248	1,804	7,195
	Total CO_{2e} from nitrous oxide	**71,583**	**15,194**	**14,096**	**12,108**	**13,226**	**1,248**	**1,804**	**13,908**
Total CO_{2e} emissions from farming		**165,097**	**35,160**	**32,454**	**26,266**	**31,639**	**5,221**	**5,233**	**29,124**
CARBON SEQUESTRATION									
	Soil carbon	73,275	10,468	10,468	10,468	10,468	10,468	10,468	10,468
	Biochar	0	0	0	0	0	0	0	0
	Total CO_{2e} from soil carbon sequestration	**73,275**	**10,468**	**10,468**	**10,468**	**10,468**	**10,468**	**10,468**	**10,468**
Total CO_{2e} emissions from farming (inc. Soil Carbon)		**238,372**	**45,628**	**42,922**	**36,734**	**42,107**	**15,689**	**15,701**	**39,592**
Sequestration by forestry	**(kg CO_{2e})**	0							
Net emissions from land use (inc SoilCarbon)		**238,372**							
Whole farm CO_2e emissions per kg of farm output (inc. Soil Carbon)	**(KgCO_2e/kg output)** [2]	**0.25**							

Appendices

		Whole Farm	Feed wheat	Feed winter barley	Malting spring barley	Oilseed rape	Field beans	Field peas	Sugar beet
Product CO_2e emissions									
Meat (inc. Soil Carbon)	Total $KgCO_2e$								
	($KgCO_2e$/kg lwt)								
	($KgCO_2e$/kg dwt)								
Wool (inc. Soil Carbon)	Total $KgCO_2e$								
	($KgCO_2e$/kg wool)								
Milk (inc. Soil Carbon)	Total $KgCO_2e$								
	($KgCO_2e$/kg FPC milk) [3]								
Eggs (inc. Soil Carbon)	Total $KgCO_2e$								
	($KgCO_2e$/kg eggs)								
Forage, grain, seeds, roots (inc. Soil Carbon)	Total $KgCO_2e$		45,628	42,922	36,734	42,107	15,689	15,701	39,592
	($KgCO_2e$/kg crop)		0.51	0.56	0.58	1.24	0.39	0.39	0.07
Straw (inc. Soil Carbon)	Total $KgCO_2e$		0	0	0	0	0	0	
	($KgCO_2e$/kg straw)		0	0	0	0	0	0	
Emissions per LU equivalent (inc. Soil Carbon)	($KgCO_2e$/LU)	0							
Emissions per hectare (inc. Soil Carbon)	($KgCO_2e$/ha)	3,405	4,563	4,292	3,673	4,211	1,569	1,570	3,959
Farm and enterprise output	(Kg)	943,000	90,000	76,000	63,000	34,000	40,000	40,000	600,000

Appendices

Appendix 7 – Scottish Grants

Scottish Enterprise

Low Carbon Manufacturing Challenge Fund

£26 million in total is available with a kick-off round of £500k which opens later this year. The Low Carbon Manufacturing Challenge Fund (LCMCF) is to support the manufacturing sector to develop new products and processes. It will allow manufacturers (and their supply chains) to participate in (or create new) low carbon markets or to provide significantly lower carbon products for existing markets.

R&D Grants

The value is TBD, and the call is likely to open in October 2021. It's a general call for capital expenditure investment that fits into Scottish Enterprise's National Programmes, Net Zero and Place agendas.

Capital Investment

Similarly, to the R&D grant, the value is TBD, and the call is likely to open in October 2021. It's a general call for capital expenditure investment that fits into Scottish Enterprise's National Programmes, Net Zero and Place agendas.

Zero Waste Scotland

Circular Economy Investment Fund

Zero Wate Scotland (ZWS) are investing £18 million as grant funding to small and medium sized enterprises who are helping to create a more circular economy. The Circular Economy Investment Fund is a funding opportunity for businesses and organisations in Scotland working in all business and social economy sectors. ZWS are looking for innovative projects that can deliver carbon savings, leverage investment, and create jobs.

They invite proposals from:
- Small to medium sized enterprises (less than 250 employees/turnover less than €50 million).
- Non-profit organisations (charities and social enterprises).

They are interested in:
- Exploring markets for new circular economy products.
- Development and adoption of innovative business models for new circular economy products and services.
- Development and uptake of innovative technologies, products, and services to support a circular economy.

They are focused on impacts in:
- Built environment
- Food systems
- Bioeconomy
- Energy infrastructure
- Heat and energy
- Waste.