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Biorefining Clusters Final Report

Report

Scottish Enterprise

August 2018

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Executive Summary

The purpose of this study was to investigate the biorefining ecosystem within three different regions and identify critical success factors in each. The presence and strength of these factors was then assessed for Scotland to determine what may be weak and/or missing.

The approach was to review background material on each region in terms of feedstocks, RTD infrastructure, active companies and strategies/policies for biorefining. This was followed by visits to each of the three regions where stakeholders were interviewed. Although each region has developed differently (and is continuing to do so), a number of critical success factors were identified that underpin biorefining in each region:

- Investment – two of the regions have seen investments of several hundred million pounds equivalent in biorefining infrastructure. The third is projecting similar amounts and has secured some commitment to these.
- Policy support – government on a local, regional and national level are working cooperatively to provide a supportive regulatory and fiscal environment for the biorefinery to succeed.
- Public sector investment – national and regional governments have made significant investments in support infrastructure to encourage cluster development.
- Industrial leadership – while government agency support is important, success of the biorefinery cluster is dictated by the commitment of and work carried out by industrially orientated leaders, either from companies or public sector supported organisations. These individuals connect all the necessary stakeholders and have the vision and skills necessary to make the development a success.
- A strong research environment is necessary to support industrial RTD at all levels from lab through pilot to demo scale, and each region achieves this, albeit in different ways.
- Feedstock availability – a successful biorefinery needs to identify feedstock that will be available in the quantity, quality, price and regular availability that it requires to manufacture product at a profit. In each of the three regions studied this has been achieved using either indigenous feedstock or existing transport infrastructure to access imported feedstock.
- Proximity of supply and value chain players – biorefineries handle large volumes of feedstock, products and waste streams; so co-localisation of companies involved in supply and value chains and/or linkage through pipelines minimises transportation time and costs. In addition, it also stimulates new collaborations and new business opportunities between companies.
- Accessible markets – equally important is that a biorefinery secures commitment from customers to purchase its products at a minimum price and minimum volume over a long-term period (up to 20 years) to be confident of recovering the investment (up to £500M) to build the biorefinery.
- Available serviced brownfield sites – these facilitate company establishment by reducing set-up times and minimising costs.

In comparison to Scotland, two of the regions, Champagne-Ardenne and Sarnia, have invested considerable time and resources (both financial and human) to develop successful biorefinery clusters. There are a number of other aspects that Scotland is relatively weak compared with the other regions and these are summarised in the figure below:

Region	Investment	Policy Support	Industrial Lead	Research Environment	Proximity of Supply & Value Chains	Feedstocks	Products	Brownfield sites
SW Netherlands	++	+++	++	+++	+++	+++	++	+++
Champagne-Ardenne	+++	+++	+++	+++	++	+++	+++	+++
Sarnia	+++	+++	+++	+++	+++	+++	+++	+++
Scotland	+	++	+	+++	+	+	+	++

Attractiveness Ranking

Nevertheless, Scotland has a number of strengths, in particular its RTD capabilities, and opportunities to address weaknesses. The risk is that without significant focus and investment now, opportunity will be lost to other regions, such as Sarnia. As one industry insider reflected: “the question is no longer ‘why Sarnia?’, but ‘why would you go anywhere else?’”

The main conclusions from the study are:

- The time Scotland has been focusing on biorefining is relatively short in comparison to best practice examples elsewhere; so it is reasonable that significant activity has not yet developed
- However, that does not mean that the support system and infrastructure in Scotland are optimised
- Evidence indicates that there has been significantly higher investment in the regions analysed, compared to Scotland
- These regions have all developed clear objectives and strategies, based on local situations, feedstocks and value chains
- This investment has resulted in much better developed support organisations and infrastructures
- The major priority of these best practice examples has been to get the value chains and innovation and industrial ecosystems optimised, rather than investing in specific process equipment

There are two broad options that could be pursued for Scotland to develop its own biorefining cluster:

1. Focus on technology development and validation, exploiting R&D capabilities. This could be extended to niche, small-scale biorefining activities based on specific feedstocks.
2. Pursue large scale biorefining (as with all three regions studied)

It should be noted that if option 1 is pursued and is successful, then option 2 could follow naturally.

The recommendations from this study are:

- Engage with key stakeholders in Scotland to understand and secure commitment to a biorefinery cluster. This includes local government, further and higher education establishments, and industry
- Hold more detailed discussions with key stakeholders in the three regions, to look at ways in which best practices can be translated from their regions to Scotland (perhaps with assistance of their technical people)
- Nurture a dedicated, well supported industrial lead in Scotland. This could be through extending and enhancing IBioIC's remit, but must be delivered by individuals with considerable industry expertise
- Critically assess the potential for different Scottish feedstocks to be used in a biorefinery (quality, quantity, availability and frequency) and focus on developing a strategy for a small number that offer potential

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1 Introduction

The purpose of this study was to investigate how three regions have developed and implemented biorefining, and what useful lessons can be learned from these regions and implemented in Scotland. These regions are Champagne-Ardenne in France, the Port of Rotterdam/South West Netherlands and Sarnia in Canada.

The study specifically aimed to:

1. Benchmark Scotland's attractiveness in biorefining against each of the three regions through an identification and comparison of:
   - Relevant existing and new infrastructure to support the growth of biorefining clusters in these regions
   - Relevant feedstocks within a 50 mile radius of each region
   - Support provided to new biorefining businesses, both domestic and foreign companies
2. Identify activities and policies to develop biorefining within each region that would be relevant to Scotland.
3. Assess the success of the approach in each region and which initiatives in particular have been successful and why.
4. Discuss and assess the applicability of different successful initiatives to Scotland's biorefining sector and identify and scope out the key steps required to implement suitable actions.

For the purpose of this report, biorefining is defined as the conversion of biomass into fuels, chemicals, food, feed and energy (for heat and or power).

Visits to each of the clusters were carried out between June and August 2018.

It is important to note that the clusters investigated in this study, led by Biobased Delta (BBD), European Biorefinery Institute (IEB), and Bioindustrial Innovation Canada (BIC), are actively engaged with other similar clusters. Indeed, they have signed a joint Memorandum of Understanding that focuses on information and student exchange, the joint development of second generation sugars, lignin, and pyrolysis technologies, and business networks.

Further information on meetings and interviews with cluster representatives can be found in Appendix A.

2 Scotland

2.1 Introduction

The National Plan for Industrial Biotechnology is the unifying strategy for developing biorefining in Scotland. It was originally launched in 2013 to 'increase the number of companies using industrial biotechnology processes to 200 by 2025 and overall turnover to £900 million'[1]. Biorefining was identified as key to achieving the objectives of the National Plan and the subsequent Biorefinery Roadmap for Scotland[2] identified the bio-fraction of household, commercial and industrial waste; timber co-products and residues; and macroalgae as the three most attractive feedstocks for development of biorefining in Scotland. A progress report in 2015[3] highlighted some important progress on biorefining but also identified several objectives, covering feedstocks, value chains, markets and R&D support infrastructure that still needed to be achieved.

At around the same time, a value chain and innovation system analysis[4] for a waste based biorefinery identified that most of the key players in the value chain were present in Scotland but that there was no engagement between key players. It further identified that the active players were technology-based SMEs / micro-companies that were focusing on specific technology development and demonstration activities. There were no activities to develop a large scale biorefinery. Value chain gaps, specifically related to biorefining technology, were also identified. More recently[5], available bioresources and the potential for biorefining in Scotland and its role in developing a circular economy were highlighted (as discussed further in Section 2.3).

There have been some important developments in Scotland, with companies such as Celtic Renewables and Cellucomp, achieving significant progress in implementing demonstration plants, as described below. However, much work is required to develop the large scale biorefinery, envisaged in the Roadmap.

1 National Plan for Industrial Biotechnology, Towards a Greener, Cleaner 2025 (Scottish Enterprise, Life Sciences Scotland and Chemical Sciences Scotland, 2013)
2 The Biorefinery Roadmap for Scotland, Chemical Sciences Scotland, January 2015
3 The National Plan for Industrial Biotechnology 2015-2025 – Building on Success, Scottish Enterprise, October 2015
4 Sector Innovation System analysis – Biorefining, An Optimat Study for Scottish Enterprise, March 2016
5 Biorefining Potential for Scotland, Zero Waste Scotland, September 2017

2.2 Leadership

There are a number of organisations that are integral to the realisation of Scotland's Biorefinery Roadmap:

- The Scottish Government
- Economic Development Agencies (Scottish Enterprise (SE), Highlands and Islands Enterprise (HIE), Scottish Development International (SDI) and the new South of Scotland Enterprise)
- Zero Waste Scotland (ZWS)
- Chemical Sciences Scotland (CSS), which is an industry-led body that includes academic and public sector participation, and which is tasked with coordinating activities across Scotland to ensure the sector has the right skills, industrial-academic collaborations, and access to the new innovations to support economic growth.
- A key sub-group within CSS is the SIBDG (Scottish Industrial Biotechnology Development Group) which leads on the National Plan for Industrial Biotechnology, and, as with CSS, is led by industry with academic and public sector participation. SIBDG has a specific Working Group on Biorefining.
- IBioIC (Industrial Biotechnology Innovation Centre), which was established in 2014 as a result of recommendations from CSS. It is mainly funded by the Scottish Funding Council (SFC) with specific financial support through SE and HIE for industry engagement. IBioIC's strategic focus is to:
    - Enhance industry collaboration with Scottish universities, through its member network (>110 members), and themed funding programmes and training programmes at Masters and PhD levels
    - De-risk scale-up of industrial biotechnology processes through access to lab and pilot scale facilities located in partner universities
    - Develop competitive opportunities through networking opportunities around particular themes, its annual conference and missions to other international events
    - Providing a skilled workforce through provision of programmes at further and higher education levels, including industry placements

  IBioIC is now entering Phase II of a ten year plan and is the delivery partner for the National Plan for Industrial Biotechnology.

Scottish Enterprise and IBioIC have taken the lead in activities to date, supported by the SIBDG and CSS more widely.

2.3 Feedstocks

The Zero Waste Scotland study[5] identified 27 million tonnes of potential feedstock for biorefining in Scotland (not including forestry waste or bioresources represented by marine macro algae). This analysis is extremely useful for developing a biorefinery within Scotland as it assesses the amount of biomass available to a potential biorefinery and the commercial viability of using each, based on the:

- percentage of the waste or by-product that is biomass, and what other components might be, thus assessing what pre-processing might be required, level of difficulty in this and costs associated

- current fate of the waste or by-product and whether this has a cost or income associated with it, thus economic viability and likely availability of different material streams
- geographical distribution of the waste or by-product, thus factoring in potential transportation costs
- chemical composition of different bioresources within waste and by-product streams, and thus what process technologies each might be best suited to

Four streams were considered in the study:

- domestic, commercial and industrial waste (paper, cardboard, rubber, wood, mixed household food and garden, animal faeces, urine and manure)
- agricultural wastes (slurries and manure, stalks and trimmings from crops, vegetables and fruits)
- food and drink by products / waste (from e.g. dairies, distilleries, breweries, coffee grounds, fish processing and abattoirs)
- sludges (from waste waters)

Agricultural waste and by-product streams were by far the most abundant at ~16.7 million tonnes. This was followed by domestic, commercial and industrial waste (~5.9 million tonnes), food and drink (~4.2 million tonnes), and sludges (114,725 tonnes). The main issue is that many of the most abundant waste/by-product streams are currently being used in some form or other, or represent dilute and/or mixed quality feedstocks, for example:

- farm slurries/manure ~14.4 million tonnes, all of which is spread onto fields
- straw (various crops) ~1.4 million tonnes used for animal bedding and others, with only ~336,000 tonnes not currently valorised
- Distillers Dark Grains Soluble (254,000 tonnes) and Draff (684,001 tonnes) from the whisky industry, all of which currently goes to cattle feed

Of what is left, pot ale and lees from distilleries represent the most abundant material stream with ~2.4 million tonnes that are not currently valorised. However, existing business strategies from companies such as Celtic Renewables and Horizon Proteins could easily absorb these feedstocks (see below).

This report also identified geographical hotspots for materials streams in Aberdeenshire, Ayrshire and Fife.

2.4 Supply and Value Chains

A number of different feedstocks are being valorised by companies in Scotland including:

Organisation	Activity
Argent Energy	Commercial scale plant in Motherwell that produces 60 million litres of biodiesel p.a. from waste cooking oils and abattoir by-products.
Cellucomp	Developed a process to extract nanoscale cellulose fibres from vegetables (mainly sugar beet) and has established a demonstration scale plant in Fife. The nanocellulose can be used in coatings and composite materials to improve mechanical properties.
Celtic Renewables	Developed a bioprocess using *clostridia* bacteria to convert whisky distillery waste into acetone, butanol and ethanol. The latter two chemicals can be blended with petrol for transportation. The company has just started building a demonstration scale plant at Grangemouth, which it expects to be operational by the end of 2018.
Horizon Proteins	Developed a process to recover protein from pot ale for the purpose of manufacturing fishfeed. It established a pilot plant at Glendullan Distillery in Dufftown in 2015 and has received investment to build a £3.5M facility capable of processing 150,00 tonnes of pot ale p.a..
3F BIO	Uses the by-products of bioethanol refineries to cultivate fungi for the production of mycoprotein for food (as used in Quorn). The company expects to have a pilot plant operational by the end of 2018.
MiAlgae	Start-up which is developing a process to grow microalgae on waste water streams (e.g. from distilleries) for both remediation of these waste streams and production of animal feed.
Marine Biopolymers	Developing chemical process technologies to extract different natural polymers from macro algae (seaweed) for use in food, health and pharma products.

Other organisations are exploring the valorisation of by-products from agrifood sources and developing novel approaches to biorefining including:

- CellsUnited, which is processing by-products from salmon and trout farming to produce high protein drinks for human consumption
- James Hutton Institute, which is investigating the use of fava beans for brewing and distilling (in partnership with Arbikie distillery, and Barney's Beers) and capturing by-products for conversion into animal feed
- Ingenza, which is applying industrial biotechnology and synthetic biology to develop novel bioprocess technologies for the manufacture of chemicals, biologics, drugs and biofuels

2.5 Products

The various commercial and demo/pilot scale plants across Scotland generate a number of products including drop-in fuel substitutes, protein for food and feed, and speciality chemicals, as described above.

2.6 Infrastructure

There are a number of academic facilities in Scotland that are supporting early stage biorefining RTD.

Infrastructure	Facilities and Activities	Ownership and Links
Rapid Bioprocess Prototyping Centre (RBPC)	Supports the development of bioprocess technology from lab to industrially compatible scales (1 to 15l). Its focus is on assessing the potential of new cell lines, bio-products or novel approaches to bioprocessing. Provides additional screening and processing technology.	Based at the University of Strathclyde, IBioIC coordinates access for external users.
Flexible Downstream Bioprocessing Centre (FlexBio)	Flexible bioprocessing plant designed to aid in the rapid translation of bioprocesses from lab to process scale (15 to 100l). Incorporates both upstream and downstream chemical and fermentation process technologies.	Based at Heriot Watt University and funded by the SFC. IBioIC coordinates access for external users.
Scottish Association for Marine Science (SAMS)	Two experimental seaweed farms to identify best species for commercial uses and means to cultivate and harvest them. Analytical labs and small-scale culture of bacteria and microalgae.	Independent not-for profit organisation based outside Oban.

These facilities are supported by other academic research capabilities across Scotland's Higher Education Institutions that seek to understand and manipulate different microbial characteristics for the purpose of improving industrial productivity.

3 South West Netherlands

3.1 Introduction

The Netherlands is one of the richest and most productive farming regions in the world. It also has the largest deep-water seaports in Europe, and extensive waterway, rail and road connections facilitating the import and distribution of a variety of biomass feedstocks.

The region of South West Netherlands includes the provinces of Zuid-Holland, North Brabant and Zeeland. There is no specific biorefinery cluster in the region, but there are a number of individual biorefineries and RTD infrastructures spread across the region. The BioBased Delta (BBD) Foundation aims to stimulate the bioeconomy in the region through linking various stakeholders and promoting the development of infrastructure for the processing and refining of biomass.

The region has a number of additional strengths:

- Part of the largest global chemical cluster (ARRRA – Antwerp, Rotterdam, Rhine, Ruhr Area) – collectively this is ~40% of Europe's chemical industry
- Large-scale petrochemical refining at the Port of Rotterdam
- Presence of a large number of end-users of the chemicals that could be produced through biorefineries
- Imports large volumes of wood pellets and chips via sea ports to fuel power stations
- Extensive process knowledge and capabilities for sugar beet and other biomass
- 'Triple helix' of industry, knowledge institutions and public agencies that are supporting the transition to a bio-based economy

Altogether this means that potential supply and value chains are well-represented within the region.

3.2 Leadership

The BioBased Delta (BBD) Foundation is the key uniting initiative in the region. It was established in 2012 in recognition of the need to address and coordinate developments in the bioeconomy for the benefit of the regions it represents. It is supported by and works with:

- Regional governments from Zuid-Holland, North Brabant, Zeeland, and Flanders.
- Industry such as Cosun, DSM, Cargill, SABIC, Dow, Corbion
- Research institutions such as TNO, University of Wageningen, Centre of Expertise Biobased Economy, TU Delft, VITO
- Others such as the Southern Agriculture and Horticulture Organization (ZLTO)

BBD has nine members of staff plus thirteen supervisory Board Members and a secretary. Most of these individuals work in-kind, only a few are paid, which has been critical to BBD's impact for the budget it commands. Around 80% of BBD's budget comes from the regional governments with the remainder from members' fees and European projects.

It has three large programmes of activities (flagship projects):

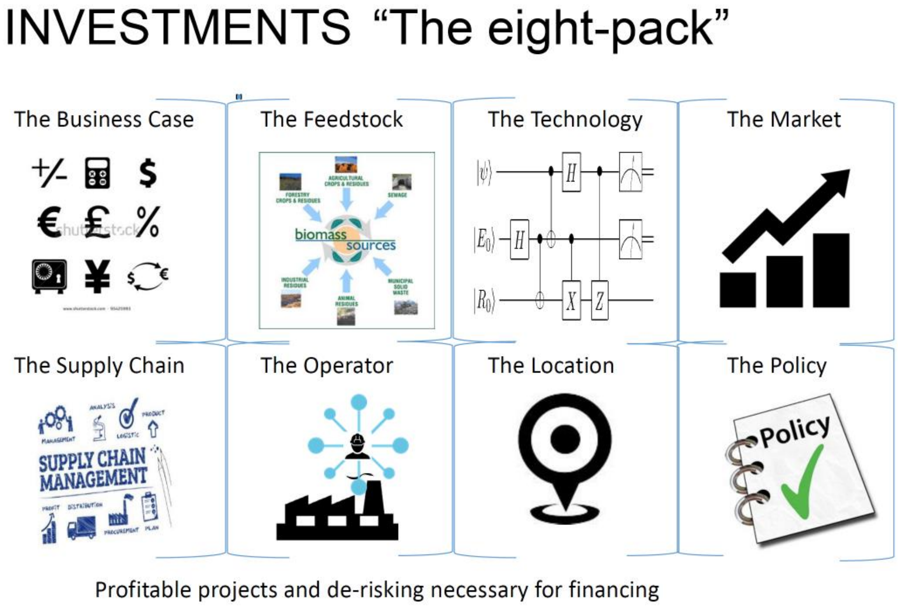
- REDEFINERY – the aim is to develop a large scale complex capable of refining woody biomass (~600Kt p.a.) into lignin, sugars (both C5, e.g. xylose, and C6, e.g. glucose), and energy. The sugars can then be processed by a variety of chemical and biotechnology routes into industrially relevant chemicals and biofuels. At present the lignin can be used to substitute for bitumen in tarmac or as a fuel, but the goal is for further valorisation. The vision for the REDEFINERY is that it will be located at one of the deep-water sea ports (Rotterdam, Antwerp or Zeeland) for the easy supply of woodchips. The sugars and lignin produced would ideally be sold to users co-located at the site as both products will be in aqueous suspension. This helps reduce costs, by avoiding transportation, and maximises economic impact. Companies could be linked by pipework to move feedstock, products and waste around, and share common utilities such as heat, electricity and dealing with waste waters.

- SUGAR DELTA – the aim is to take advantage of the increase in availability of sugars within the EU as a result of the discontinuation of sugar quotas, to convert these sugars into valuable chemicals through bioprocesses. Furthermore, this seeks to attract chemical companies to the region to use sugars refined from sugar beet (or encourage existing companies to look at this opportunity). A commercial scale biorefinery will be built for this.
- BIORIZON – a shared research facility between a number of research and technology organisations (TNO, VITO, and ECN (now part of TNO)) located at the Green Chemistry Campus. The intention is to bring in further expertise from universities within the regions (e.g. Wageningen, Leuven). Its purpose is to develop technologies for the production of functionalised aromatic (ring-structure) chemicals from sugars and lignin derived from agrifood waste and wood. Currently operates on a lab-scale (100s of g) with intention to move to kg/h production. The phase beyond that would be pilot scale at 40t p.a., which will require an investment of ~€15M for one of the processing lines. Demo scale for some of the process technologies is expected by 2020-22, and full-scale commercial operations by 2025.

In addition to these, BBD actively networks businesses, research organisations and government agencies to raise awareness of activities and opportunities across the region, through a variety of events and directly engaging organisations to co-develop a shared vision for the bioeconomy. As part of this it attends international events (such as BIO-World) to promote the BBD regions. Furthermore, it works with all stakeholders to ensure that there is an adequate supply of trained workers coming through the further and higher education systems.

BBD has developed an '8-pack' approach to the realisation of its bioeconomy vision, which has been applied to the development of the REDEFINERY concept:

Figure 1: BBD approach to developing the business case for a biorefinery



BBD first determined the business and economic case for the REDEFINERY concept – who would supply feedstock and who would buy the biorefinery products, what price and what volumes would be required, would buyers commit to purchasing at this price point for 10/20 years and at minimum volumes, and how would these be influenced by market conditions. A technology provider that could deliver then had to be identified, followed by an operator for the biorefinery, a location and suitable regional support. Regional support was difficult as BBD encompasses four regions, which were being asked to support a cluster – not a single company. It has taken two years to get to where they are now, with eight companies involved: Corbion (interested in C6 sugars to produce lactic acid), Alcol (interested in C5 sugars to produce ethanol) and another (interested in lignin as a bitumen substitute) as end-users, a wood pellet provider, UPM (most likely) as the operator, a Swedish technology company (which was identified at last year's BIO-World Congress in Toronto), and two others (including a Port Authority). It seems likely that development, if it goes ahead, will be at the Port of Antwerp, as Flanders has the largest funding on offer. It is likely that the overall cost for the REDEFINERY will be ~€600M. UPM has secured financing for a similar initiative on the Ruhr; so it should be able to do the same for the REDEFINERY project as long as the economics stack up.

In this regard, BBD has applied for funding through the EU LIFE programme to undertake a feasibility study, once the location is chosen.

3.3 Feedstock

The main feedstocks are sugar beet (grown in the region, there are ~9,000 sugar beet farmers across the whole of the Netherlands) and woodchips (imported through the deep-water seaports). There is interest in using seaweed and algae in Zeeland (through the Biobased Economy and Food cluster) and experimental research into the use of other feedstocks, including manure, which is available in large quantities from piggeries.

3.4 Supply and Value Chains

As mentioned above, there are a number of individual players within the region that are active in biorefining, each has its own supply and value chains. Key players are described below.

Organisation	Activity
Port of Rotterdam	Has taken a different stance to petrochemicals since 2016, as a result of various external factors including EU and Dutch climate change policy. The Port Authority is investigating how it can play an active role in the bioeconomy through supporting businesses to transition to sustainable feedstocks and to attract new sustainable technology companies to establish within the Port (e.g. Biobased Port Transition Arena). It has been involved in a number of recent initiatives such as a municipal waste to chemicals refinery that involves Akzo Nobel, Enerkem and Air Liquide (expected to require ~€200M total investment). This will produce up to 220,000 tonnes of methanol from 360,000 tonnes mixed waste.
Corbion	Produce lactic acid through fermentation of sugar (derived from sugar beet in EU, corn in N. America and sugar cane in Brazil and Thailand). Recently established JVs/collaborations to manufacture other chemicals based on Corbion's lactic acid capabilities: • Polylactic acid (including thermostable varieties) with TOTAL (75,000 tonnes p.a. plant under construction in Thailand, feedstock - sugarcane) • 2,5-furandicarboxylic acid (FDCA) to substitute for PTA in the manufacture of polyesters (produces polyethylene furanoate, PEF, for food/drink containers) • Succinic acid with BASF for a variety of purposes, e.g. polyurethanes, pigments and plasticisers. Have a 10Kt p.a. demo plant in Gorinchem (near Rotterdam) that is a re-purposed sugar refinery and is now a feedstock agnostic RTD facility. It can use 2G feedstocks to produce sugars and from these, lactic acid, and other chemicals such as ethanol and butanol.
Neste	Produces 800,000 tonnes of biodiesel (NExBTL) p.a. at a refinery in the Port of Rotterdam that uses vegetable oils and their by-products and waste oils and fats. Took 2 years to build at a cost of ~€670M and opened in 2011.
Uniper	Operates a number of wood-pellet fired power stations (e.g. the Maasvlakte Power Station at the Port of Rotterdam), and has interest in generating higher value from the biomass it uses through co-localising with a biorefinery to provide steam and power to it and other users and to gain lignin from the biorefinery to generate electricity.

3.5 Products

The Netherlands produces significant volumes of sugar, at ~14 tonnes per ha. Cosun operates a number of refineries and can produce more sugar than is required for food. Corbion is major producer of lactic acid (and further derivatives – see above) through the fermentation of sugar. Neste operate a biorefinery at the Port of Rotterdam that produces biodiesel from waste oils and fats.

3.6 Infrastructure

There are a number of research facilities across the region that support bio-based innovations and their commercialisation. Key facilities are described below.

Infrastructure	Facilities and Activities	Ownership and Links
BioTech Campus Delft	Open innovation platform that includes access to TNO, TU Delft and DSM facilities, as well as the Bioprocess Pilot Facility (see below). Offers external users a range of bioprocess technology capabilities at lab to pilot scale, as well as technoeconomic support. Provides incubator space for start-ups as well as access to shared utilities such as waste water treatment, onsite electricity and steam generation.	TNO, TU Delft, DSM
Bioprocess Pilot Facility	Located in Delft, used by a number of companies to develop process technologies: pre-treatment, fermentation, downstream processing and piloting of new bioprocess technologies. Food and non-food applications (such as biochemicals and biofuels). Use steam explosion pre-treatment to liberate cellulose and lignin for further processing.	Funded from public (EU and Dutch national, regional and local authorities) and industry (DSM and Corbion) sources.
Green Chemistry Campus	Business accelerator and open innovation platform that provides office and lab space to bio-based/green chemistry companies, and access to other facilities operated by others in the region. Will open a new demo facility at the end of 2018 for scale-up (unknown scale). Hosts the Biorizon initiative (see above) for development of functionalised aromatics.	Located on the SABIC site in Bergen op Zoom
Plant One Rotterdam	Testing and demonstration of sustainable process technologies at pilot scale. Has an 'umbrella permit' that allows rapid authorisation of new process technologies to be tested.	Independent

Additionally, there are supporting initiatives within the Flanders region of Belgium (part of the BBD initiative) at the Port of Antwerp, VITO and the Bio Base Europe Pilot Plant.

In addition, the deep-water sea ports at Rotterdam, Zeeland, Moerdijk and Antwerp, as well as the business and technology park Nieuw Prinsenland (between Rotterdam and Antwerp), offer substantial space and facilities for companies to establish and grow. Pipelines directly link the chemical clusters at each of the ports.

The industry-academic collaborations are funded through national and EU programmes, which the BBD Foundation facilitates through introduction to the right partners and lobbying national and EU governments for specific biobased RTD calls.

There is likely to be other technologies used by the initiatives taking place within the region, such as pyrolysis and gasification. In this regard, there is interest from BBD in applying Shell's hydrogen supplemented gasification technology to different biomasses, as this leads to higher value residues and removes unwanted chemical elements such as chlorine.

3.7 Supporting Activities and Policies

The development of biorefining in the Netherlands is indirectly supported by the Dutch Government's priority themes for the circular economy:

1. Biomass and food
2. Plastics
3. Manufacturing industry
4. Construction and infrastructure
5. Consumer goods

The first theme correlates well with initiatives of BBD and is manifest in Dutch policies such as the transition from fossil fuel power stations to those powered by biomass, through subsidies to burn wood pellets and chips. This means that infrastructure has developed for the import and use of this biomass as there is insufficient production within the Netherlands itself.

In addition, the Provinces of South Holland, North Brabant and Zeeland are incorporating purchasing of circular and biobased products into their policies, which will help create market demand for the products of biorefineries within the region.

The BBD is actively lobbying other government agencies and large industry to pursue biobased purchasing.

The Process Design Centre (PDC) in Breda have played an important role in BBD's development plans. They have expertise in industrial process design (bio and chemical, also CCSU) and have designed (or helped design) process technologies for a large number of companies (e.g. Avantium). They operate globally, e.g. currently working in Finland to assist the transition of paper mills to chemical manufacture, and have patented 40 bioseparation processes.

3.8 Other Aspects

Not all government policies have been helpful to the development of biorefineries. For example, Corbion was in discussion with Uniper and the Port of Rotterdam a few years ago to build a 2G biorefinery for the production of sugars and from this, lactic acid. This stalled largely because of two reasons:

1. Wood chips are being used to produce energy, and the Dutch government is subsidising this to migrate from coal-based power stations (essentially users are getting feedstock at low or no cost) – this means prices for wood pellets/chips are high and less is available for other uses (e.g. biorefining).
2. Market conditions favour the production of bioethanol over other biochemicals from biomass feedstock. This is due to the price that can be commanded and volumes required for blending bioethanol into petrol (legislative requirement throughout the EU to have at least 5% ethanol in

fuel, and that progressively this should be ethanol derived from non-food sources). There is no such subsidy for other biobased chemicals.

However, the subsidies for burning wood pellets to generate electricity will finish in 2025/26.

In addition, permitting the construction of chemical sites, such as biorefineries, varies significantly between regions and, for example, is easier in Rotterdam than Brabant.

BBD sees its role as transitional, once the initiatives described above are realised it expects to wind down and pass the baton to industry to continue further developments. It is currently reviewing the means by which its work could be continued through public/private financing, and reviews the following KPIs on an annual basis:

	Description of KPIs
1	Number of students following courses in the field of Biobased Economy
2	Number of test facilities
3	Number of application facilities
4	Number of companies cooperating in the value chain (1 or > partner and obtain public funding
5	Number of cluster initiatives initiated
6	Number of initiated and supports business cases
7	Number of companies guided to funding
8	Number of companies guided to funding and 'closing the deal'
9	Number of projects funded aiming at green energy
10	Number of biobased projects funded
11	Number of biobased companies
12	Number of FTE hired by biobased companies
13	Investment volume

Figure 2: BioBased Delta Foundation Key Performance Indicators

3.9 Summary of SW Netherlands' Biorefinery Strengths

The SW Netherlands is developing its biorefining capability. It has:

- Several commercial scale biorefineries
- Available serviced brownfield sites that are well-connected by pipelines, road, rail and waterway transport
- Academic and RTO expertise and equipment, and incubators to support companies to develop biorefining processes at lab and pilot scale
- Feedstock supply is strong, there is both sugar beet grown in the region and an established wood chip importing supply chain
- Well established value chains - ARRRA is the largest chemical cluster in the world
- Industrial leadership driving forward the cluster development (BBD)
- Supportive government at local, regional and national level

4 Champagne-Ardenne

4.1 Introduction

The Champagne-Ardenne region is rich in arable land, producing significant wheat and sugar beet crops, amongst others. The origins of the Bazancourt-Pomacle biorefinery (also known as the European Biorefinery Institute or IEB) lie with two large cooperatives representing the interests of thousands of French farmers: Vivescia and Cristal Union.

A sugar factory was established in 1953 to process sugar beet grown in the region and create greater value for farmers as they produced higher crop yields following the Second World War. This was essentially the seed for further development in the 1990s when the site diversified into R&D activities to generate further added value for crops, partly as a result of changes to the Common Agricultural Policy, which meant that crop prices became more volatile. The first step was the establishment of the Agro-Industry R&D Centre (ARD), which delivers R&D programmes for a number of companies on site, as well as external users, and Chamtor which processes wheat into starch and glucose. This was followed by Cristanol, one of Europe's largest biorefineries, to ferment and distil sugar beet and wheat into bioethanol. In the last ten years these have been further complemented by a demonstration-scale facility (operated by ARD), onsite academic research in the Centre for Biotechnology and the Bioeconomy (CEBB), and a pilot-scale biorefinery for second generation biomass (the FUTUROL project, which is run by Procethol 2G). In addition, there have been further companies that have either spun-out of ARD or been attracted to the site as a result of its RTD capabilities and/or feedstock and other amenities.

The site covers around 160ha, employs >1,200, has an €800M combined annual turnover, and has between €20 and €50M invested on site each year.

4.2 Leadership

This is perhaps where the IEB is weakest. Although there are regular meetings at Board-level between the different companies onsite, there is no single entity that is responsible for overall site integration, cooperation between organisations on site and marketing of the IEB's capabilities, shared resources and opportunities to external clients and potential tenants. Cristal Union and Vivescia are essentially the site owners, and have driven developments to date, through establishing organisations within the site and through leveraging political support at local, regional and national levels. Furthermore, the size of each organisation has allowed access to private finance (for example through the Credit Agricole). Ultimately, however, these two organisations are motivated by the needs of their members, the farmers, who are removed from the wider opportunities that biorefining offers. As such ARD is perhaps the key actor at present as a result of the RTD capabilities it offers to industry. In addition, the Fondation Jacques de Bohan was established in 2013 by Vivescia and Cristal Union to help promote the biorefinery. However, it has limited resources and only one person is directly involved: Jean-Marie Chauvet, who is a project manager at ARD.

There is however an initiative, the Biorefinery Research and Innovation (BRI) open innovation platform, that was established in 2011 and links ARD, CEBB and the BioDemo (demonstration facility – see below), which may evolve to fulfil a leadership role. The plan is to formalise BRI by creating a legal entity that would aim to improve connections within the cluster and to attract external organisations to work with the cluster and/or locate on site.

4.3 Feedstock

The site processes around 3 million tonnes of sugar beet, 1 million tonnes of wheat and 400,000 tonnes of other biomass (such as alfalfa) each year. These are sourced in the region through Vivescia (wheat and alfalfa) and Cristal Union (sugar beet).

In addition, there are RTD activities (at various TRLs) within ARD, CEBB and Procethol 2G, investigating the processing and valorisation of other biomass feedstocks including: wheat (and other crop) stover, soft and hard woods, switchgrass and bamboo.

4.4 Supply and Value Chains

The site is unusual in that the suppliers of biomass, Vivescia and Cristal Union, are also key stakeholders in a number of the companies operating on the site.

The supply and value chains present illustrate the strong interdependence of different companies and supporting organisations and the circular economy nature within the site. The proximity of organisations means that they can share resources such as heat, water, and waste treatment, and can also easily supply materials to each other via pipeline, and where this is not possible, by local transport.

Overall this can be presented in the figure overleaf:

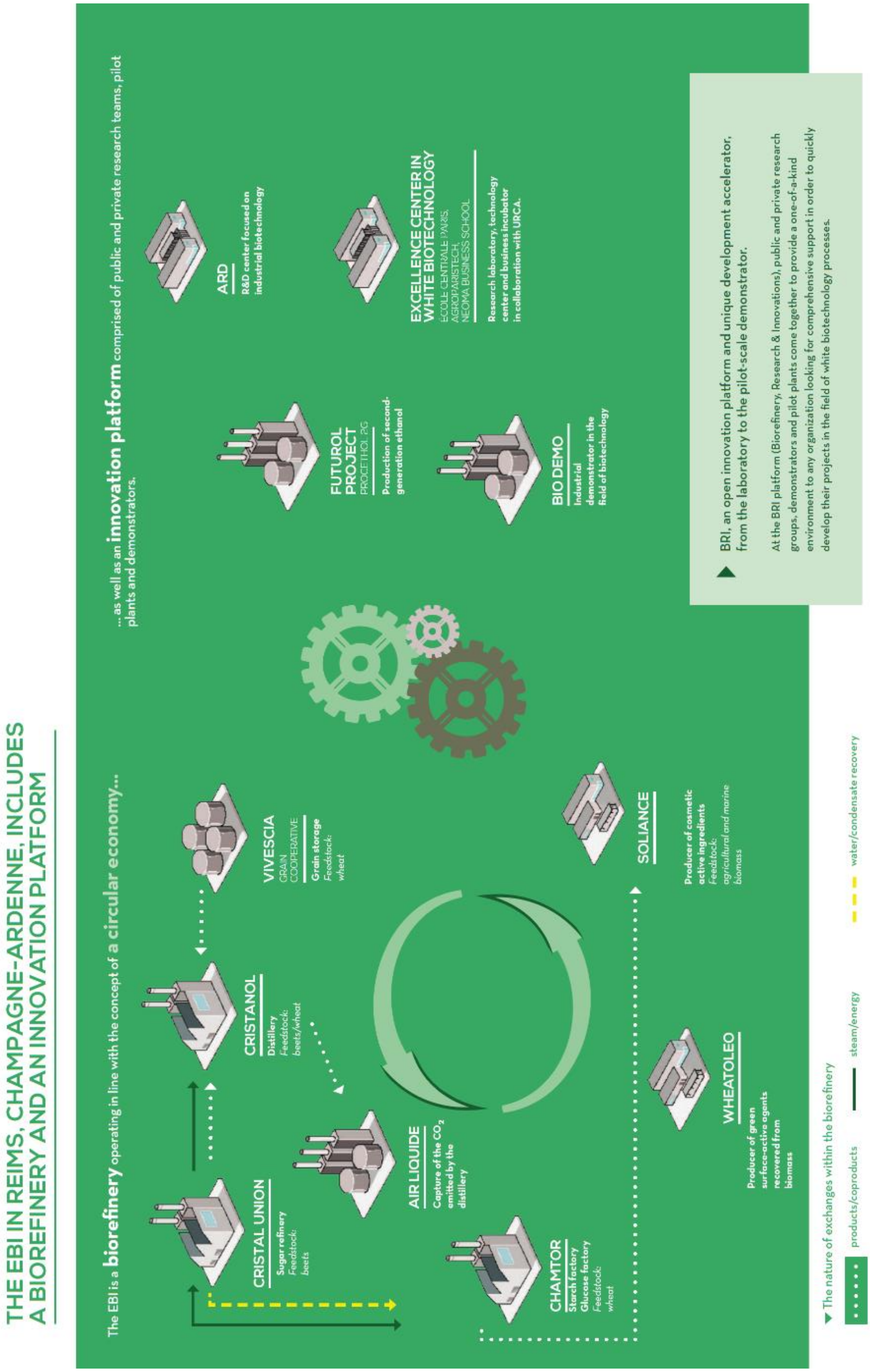


Figure 3: Overview of the IEB

The following table provides further information on the activities of different companies within the site and how they engage with others.

Organisation	Activity
Vivescia	Collects wheat (~1 million tonnes p.a.) and alfalfa from farmers within the cooperative. Supplies wheat to Chamtor and Cristanol.
Cristal Union	Collects sugar beet (~3 million tonnes p.a.) from farmers within the cooperative and processes onsite to sugar, sugar beet pulp and sugar beet syrup (supplied to Cristanol). Operates a dehydration plant for sugar beet and alfalfa.
Chamtor (AMD)	Processes ~450,000 tonnes of wheat p.a. (from Vivescia) to glucose, starches and wheat extract suspension (which it supplies to Cristanol).
Cristanol (Cristal Union and Bletanol)	Largest biorefinery in Europe. Had an initial investment of €272M in 2006 and now produces ~350 million litres of bioethanol p.a. from wheat it mills itself, wheat extract from Chamtor, and sugar beet syrup from Cristal Union. Has two separate, parallel pipelines for the fermentation and distillation of wheat and sugar beet juice. Runs 24/7 with 1 week downtime p.a. for maintenance. Bioethanol is taken by tanker offsite to be used in the production of alcoholic drinks and blending of fuels. Uses several hundred million litres of water p.a.. Operates a waste water treatment plant and re-uses water, pumps it underground to aquifers or sprays it onto the agricultural land. Others onsite can make use of this facility.
Air Liquide	Recovers and purifies ~120,000 tonnes of CO_2 from Cristanol fermentation p.a.. Supplied to other companies on site, and to food and beverage manufacturers.
Soliance (Givaudan) - ARD spinout	Produces cosmetic ingredients (hyaluronic acid and dihydroxyacetone) from the fermentation of glucose (supplied by Chamtor) and ethanol (supplied by Cristanol). These are used within Givaudan's products.
Wheatoléo - ARD spinout	Produces various surfactants from carbohydrates (derived from wheat stover and others) and natural oils. Used within cleaning products.
Procethol 2G (FUTUROL project)	Produces 2nd generation bioethanol and lignin from the processing, fermentation and distillation of wheat stover and other fibrous biomass including other crop stover, soft and hard wood chips, bamboo, switchgrass and miscanthus. Capable of producing ~318 litres of bioethanol from 1 tonne of biomass. Such bioethanol could be used for blending with petrol or for use in pharmaceutical industries, once at full commercial scale. Pilot scale at moment and looking to licence technology.
Global Bioenergies	Produces isobutene, isopropanol, and acetone from the fermentation of glucose (supplied by Chamtor). Using pilot and demo scale facilities at ARD.
Fermentalg	Produces microalgal extracts for food and feed.

4.5 Products

The site produces a number of different products, primarily for food, feed and fuel. These include sugar, wheat, 1st generation bioethanol (for fuel blending and for alcoholic beverages), glucose, and starch. In addition, smaller volumes are produced of speciality chemicals (for cosmetics and consumer goods) and 2nd generation bioethanol.

4.6 Infrastructure

IEB operates a number of RTD facilities which are described in the table below.

Infrastructure	Facilities and Activities	Ownership and Links
ARD (founded 1989)	Develops new process technologies for the valorisation of biomass. Covers all TRLs. Has ability to work with a variety of different microbes under both aerobic and anaerobic conditions. Develops physical and chemical process technologies to complement the fermentation processes. Has lab-scale (1 to 30l) through pilot (150 to 2,000l) to demo-scale (180,000l). The latter is the BioDemo facility, which was established principally to support the commercialisation of BioAmber process technology (see below) and has subsequently been used to demonstrate process technologies that have been developed by others. It had initial core funding of €22M plus additional funding for bespoke kit – much of which was designed in-house. This took ~1 year to plan and build. ARD can run up to 10 projects at lab and pilot scale, and 2-3 projects at demo scale at the same time. It uses a variety of microbes and chemical/physical processes, and delivers contract work for both on- and offsite companies.	ARD is a private company whose majority shareholders are Vivescia, Cristal Union and Credit Agricole. ~30% of its annual budget comes from Vivescia and Cristal Union, the rest comes from contract work.
CEBB (founded 2012, onsite since 2016)	Focus on applied academic research. Have a number of multidisciplinary teams covering bio, chemical and physical process technologies. Work with some organisations across the site (e.g. ARD) and make facilities available to others (as a service or for direct use), but connections not strong. Some work on valorising by-products of biomass fermentation e.g. the lignin suspension from the FUTUROL process, and developing new process technologies for other agricultural by-products (e.g. clippings/trimmings from grapevines).	Initial funding for the establishment of CEBB came from local and regional government. It is a partnership between 4 institutes: Ecole Centrale Paris, AgroParisTech, Neoma Business School and University of Reims Champagne-Ardenne. Most of its funding comes from the national science funding agency (ANR). It has links with various companies on site, most notably ARD.

Procethol 2G (founded 2011)	Pilot scale 2nd generation (2G) bioethanol plant. Process involves physical cleaning and shredding of biomass, resuspension in dilute sulphuric acid, steam explosion via twin screw extruder to produce a slurry of cellulose and lignin, incubation of cellulose with an enzyme cocktail (produced from a fungal culture onsite) to break down the cellulose, yeast fermentation and distillation. Each run takes ~5 days, and can have multiple fermentations at same time. Physical parameters, e.g. temperature, pressure, flow rate of extruder, are easily adjusted for different biomasses. Produce bioethanol at a cost ~€0.60 per litre (1G ethanol is ~€0.50). Lignin is not currently valorised further – produce a cake which can be burned in CHP plants (33% more energy than wood).	Procethol 2G is a private company established to run the FUTUROL project (to produce second generation bioethanol). It has multiple shareholders including ARD and TOTAL. Its primary purpose now is to licence the technology developed. Its facilities could then be re-purposed for other uses.

The co-location of these facilities enables companies on-site, or from elsewhere, to access RTD support at all TRLs. For example, CEBB might be funded by ANR to investigate new means of processing a specific feedstock (low TRL) and support ARD or Procethol 2G to improve an existing process that has already progressed to a higher TRL. ARD makes use of the analytical capabilities present in CEBB to confirm the efficiency of particular processes that it is developing for industrial customers, while companies may use both the capabilities at ARD to develop new processes, and its know-how to assist in the development of new process plants.

In addition to the RTD infrastructure there are a number of other resources that are shared between facilities on site:

- Water and steam are provided to others from the sugar factory and refinery, which also treat waste waters.
- Biomass CHP providing 22MW electricity and steam.
- Network of pipes connect different facilities across the site delivering feedstocks and removing products and wastes.
- There is a rail link for commercial haulage into and out of the facility (at the Air Liquide site).

4.7 Supporting Activities and Policies

The key driver throughout the development of the IEB has been the farmers cooperatives, seeking to gain added value (and therefore security) for their members through the research, development and commercialisation of technologies that valorise the biomass they produce. The key figures in these initiatives have been successful in securing support from local, regional and national government to achieve this. For example, the Champagne-Ardenne Regional Council, Marne Departmental Council and Greater Reims Area provided the initial funding for the CEBB; while the national government recognised the innovation taking place in the region and established an international pole of excellence in industry and agro-resources (IAR) in 2005 which are prestigious initiatives in France aimed at promoting public-private cooperation for industrial innovation.

In the last few years the site has secured permission from the local authorities to develop an experimental farm (located on a 240ha disused military airbase, a few km from IEB) that will investigate improved practices for the cultivation of different crops. Furthermore, there is permission to build a Technology Park on a 147ha plot adjacent to IEB that will house offices, experimental and production facilities. Although for the moment this is just greenfield with some road connections.

Much of the funding to develop the site initially came from within the cooperatives themselves (e.g. farmers forewent income from that year's crop to build the initial sugar refinery), and before the 2008 financial crisis, from banks such as the Credit Agricole. Bank finance has since become more difficult to access and so further developments have been through loans generated within the cooperatives, supplemented by finance from the banks and private investors.

4.8 Other Aspects

ARD has spun-out several companies (either on its own or in partnership with others):

- Soliance: spun-out in 1994, sold to Givaudan
- BioAmber: joint venture with DNP Green Technology spun-out in 2008 and bought over by DNP in 2010. Subsequently re-located to Sarnia, Canada
- Wheatoleo: spun-out in 2010

BioDemo was established in 2011 largely because there was a need to demonstrate BioAmber's process technology to convert glucose (supplied by Chamtor) to succinic acid at scale. It has subsequently been used where appropriate by other companies, including some offsite (such as Amyris) for the demonstration and validation of new process technologies.

IEB has been successful in attracting other companies to the site, namely Global Bioenergies (which is headquartered at Genopole and also makes use of facilities at Delft) and Fermentalg. Both of these companies make use of ARD's facilities, as well as feedstocks and other amenities on site.

4.9 Summary of Champagne-Ardenne's Biorefinery Strengths

The IEB is a mature biorefinery cluster. It has:

- Commercial scale biorefinery capability
- Available serviced brownfield sites for companies to establish office, lab and production facilities, with access to shared utilities
- Academic and RTO expertise and facilities to support biorefining process development at lab, pilot and demo scale. These have been used to develop and demonstrate different process technologies using different feedstocks; so there is a degree of flexibility in RTD support and capability, and this is offered to external users. BioDemo in particular is being used by external companies to demonstrate new process technologies at scale
- Feedstock supply – the farmers cooperatives supply feedstock to the site (wheat, sugar beet and other biomass)
- Well established value chains with companies onsite making use of both feedstock and primary products to manufacture secondary, higher-value products. The new process technologies developed in IEB have been spun-out into a number of companies
- Supportive government at local, regional and national level

5 Sarnia

5.1 Introduction

The Sarnia region is rural, and arguably isolated, with a very stable population - people tend to spend their whole life there. People, stay, work and enjoy leisure in the town. This engenders a commitment to the ongoing sustainability of the town. It's bounded by a border with the USA to the West and Lake Huron to the North so this makes it more isolated than comparable Canadian towns.

The region had the first commercial oil well in North America (in 1858) and throughout most of the 20th century developed considerable expertise in exploiting chemical resources. During the Second World War Sarnia was the key site for the production of synthetic rubber for the Canadian Government. Many multinational petrochemical and chemical companies established facilities including Shell, Sunoco, Bayer, Lanxness, Cabot and Dow. As a result the local economy became very dependent on chemicals and is the leading Canadian chemical cluster. The companies were proactive in their approach and initiated the responsible care initiative in the sector, which has now been adopted globally. However, from the 1980s on, several of these companies scaled down or closed their facilities.

The leaders of the main chemical companies were concerned about the effect that this would have on the local economy and raised the issue with local politicians around the year 2000. Essentially the chemical companies were asserting that the local economy could not continue to depend on the chemical sector as it had for decades and something needed to be done. This resulted in a significant consultation involving industry, unions, local government, local organisations and representatives of the first nation. The outcome of those (lengthy) discussions was to establish initiatives to revitalise the region. Bio-based chemicals were identified as a logical and attractive new opportunity to pursue. In 2003, local economic and government agencies bought the former Dow Chemicals R&D complex in Sarnia and transformed this 300 acre site into the Western Sarnia-Lambton Research Park (WSLRP). Lanxness (now ARLANXEO) opened the Sarnia Bioindustrial Park in 2006/7 and the local chemical sector association was formalised as the Bioindustrial Innovation Centre (BIC) in 2008, an organisation that could be funded to support development of bio-based chemical activity. This organisation was subsequently renamed Bioindustrial Innovation Canada to reflect its role to support biotechnology across the country.

Further, the cluster was named the "***the hybrid chemical cluster***" to highlight its aim to link it with other key regional industries, particularly agriculture. The following industry / value chain diagram[6] is used to show these linkages:

[6] Strategic Plan 2016-2020, Bioindustrial Innovation Canada

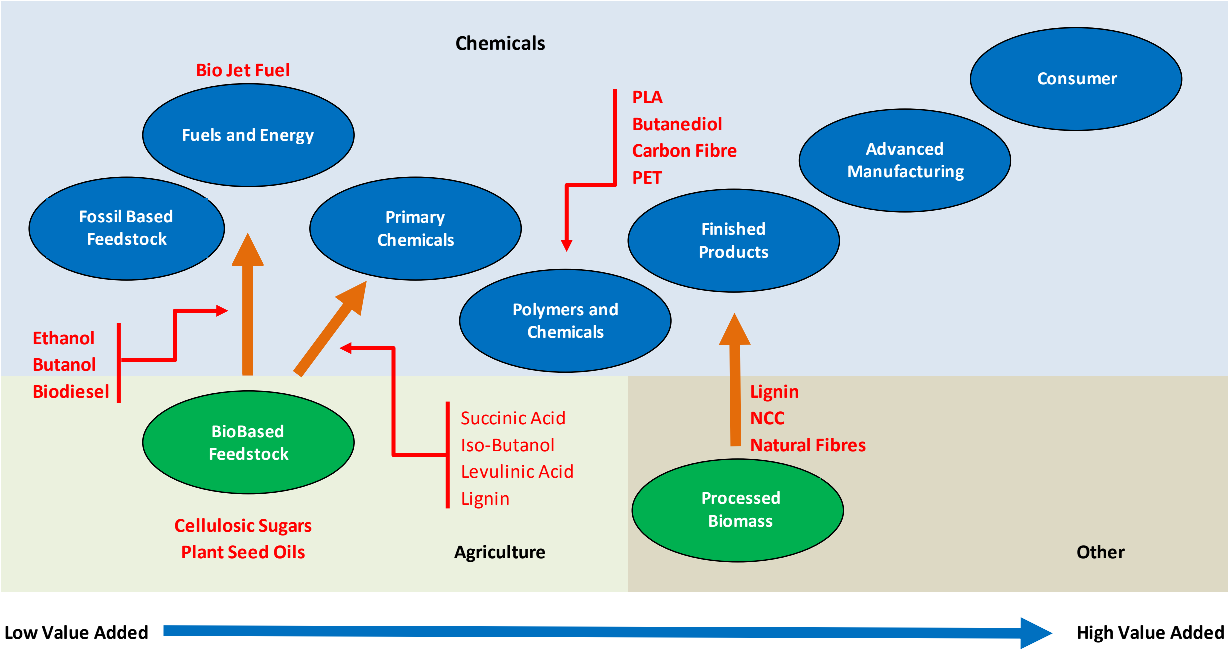


Figure 4: BIC Value Chain Structure

Despite the decline, petrochemical activity in Sarnia remains significant (largely processing oil from Alberta). There are 36 petrochemical and refinery facilities in the region, known as Chemical Valley (just south of the city), employing ~4,500 people. In late 2017 there was an announcement by Nova Chemicals to invest $2 billion Canadian dollars (CAD) in extending its ethylene and polyethylene production.

5.2 Leadership

Leadership has been significantly important to the cluster over the last 18 years with several key leaders playing a role.

Firstly, the senior management of the main chemical companies showed foresight, leadership and a strong commitment to the local economy by raising their concerns about the sustainability of the chemical sector. The local mayor showed leadership in bringing everyone together to build a consensus on the future for the region.

Senior members of the Sarnia Lambton Economic Partnership (SLEP), particularly George Mallay, then drove development of the cluster for over 10 years and more recently Bioindustrial Innovation Canada (BIC), led by Murray McLaughlin and subsequently Sandy Marshall, an individual with over 30 years of experience in the chemical sector in Sarnia has become the key lead / coordinating organisation within Sarnia – BIC is described as the glue that holds the cluster together.

Although BIC's remit is to provide 'critical strategic investment, advice and services to business developers of clean, green and sustainable technologies' across the whole of Canada its focus is clearly Sarnia. It is described as a business accelerator and has helped attract companies, such as BioAmber, to the region. However, its scope is much wider than that. It works closely with all companies interested in locating in Sarnia, offering business development support and mentoring, problem solving and "match-making" with companies of mutual interest.

BIC was established in 2008 with $25 million CAD from national and provincial governments. It subsequently launched a $27 million CAD Centre for Commercialisation of Sustainable Chemistry Innovation in 2013 with $15 million CAD of public sector grants and $12 million CAD from BIC and the private sector. It has 22 companies currently in its portfolio and states that it is has 'created thousands of jobs and leveraged over $150M CAD in investment for its 16 early stage companies'. It has around 10 FTE employees. It is targeting $750,000 CAD per annum core regional government funding in the period to 2020.

This reflects the scale of investment committed to develop the biorefining industry in a small region of Canada (Lambton county has a population of 113,000, with Canada having over 36.25 million inhabitants).

It works closely with other actors in the greater Sarnia region, in particular

- the mayor
- the Sarnia-Lambton Economic Partnership (SLEP), which facilitates companies' access and business activities in the area, as well as industry and the Provincial and National Governments
- Sarnia Lambton Research Park
- Lambton College
- Sarnia BioIndustrial Park (operated by ARLANXEO) and the adjoining Bluewater Energy Park (operated by TransAlta Renewables)

This is one of the key aspects of the region – all these organisations work together in a collaborative way. They have all developed individual strategies that complement others and support the overall goal of a successful regional hybrid chemicals cluster. It is argued that this cohesive and collaborative approach was established by the mayor around the year 2000 when he initiated the consensus approach to identifying future opportunities. This collaboration and cohesion is also supported by

- The rural and isolated characteristic of the region which has led to a strong affinity with Sarnia and a strong commitment to ensure it has a viable future. It has also led to strong personal relationships between leaders of different organisations and a number having board roles in other organisations.
- The long term presence of key leaders – for example, the current mayor has held this role for 30 years, the key player in SLEP was involved for over 30 years and the current BIC CEO has worked in the region for 30 years

In summary, several organisations and leaders are playing key roles in the development of the cluster and, due to the way the support infrastructure has developed this works in a cohesive and constructive manner. A "can-do" culture is very evident, with each organisation striving to support cluster development.

5.3 Feedstock

There have been no feedstock preferences selected. Companies in the Sarnia area are using a variety of locally sourced feedstocks including corn, wheat and agricultural residues from crops; forestry residues; used oils and fats; and waste wood and cardboard.

Companies are encouraged to locate in Sarnia whatever the feedstock they use, but it is recognised that in many cases a large-scale plant is likely to be located elsewhere, due to better access to raw materials.

Sarnia is surrounded by a significant agricultural area with key crops being wheat, corn and soya beans. There has been a significant effort to link agriculture with chemicals and a co-operative has been set-up to gather wheat straw and corn stover from over 100 local farms to supply as a raw material for chemicals manufacture. These are effectively waste for the farmers, which cause problems with soil quality (when they are ploughed into the soil) or costs if disposed of. BIC catalysed this initiative and identified Comet Biorefining (see below) as an ideal customer for the co-operative and successfully encouraged it to locate to the region.

5.4 Supply and Value Chains

There are numerous established and emerging companies in the region. This is based on the availability of:

- Applied R&D capability and facilities at Lambton College
- Space for R&D and pilot plant scale facilities at Sarnia Lambton Research Park
- Small scale serviced industrial facilities at Sarnia Bioindustrial Park
- Larger scale serviced industrial space at Bluewater Energy Park

Those companies that have developed / have been attracted to the area, based on the innovation and industrial ecosystems are:

Organisation	Activity
BioAmber	Biorefinery built in 2015 at cost of $141M CAD. Ferments a variety of C5/C6 sugars (although mainly dextrose from corn) using modified yeast to produce succinic acid (capacity of 30,000t p.a.). Succinic acid can then be converted chemically to 1,4-butanediol (used as a solvent and in the manufacture of several plastics). Moved to Sarnia from IEB in France. The company is currently in financial difficulty as its markets have not developed as expected and, currently, there are efforts ongoing to ensure it survives. It is not clear at this stage if these will be successful.
Comet Biorefining	Building a biorefinery in Sarnia (on the Bluewater Energy Park) that will produce ~27,000t p.a. of dextrose (for use in food), a liquid polysaccharide (hemicellulose extract, for use in animal feed) and lignin (for animal feed, solid fuel and adhesive applications) using locally produced wheat straw and corn stover as raw materials. Demonstrated their technology in Italy on a 10t per day facility. The company has the option to build a second plant of a similar size on an adjacent site.
Benfuel	A renewable energy company that plans to set up a 75 million litre per annum plant on Sarnia BioIndustrial Park (a $73M CAD investment) that produces biodiesel from a variety of food and agricultural waste streams. It is expected to be operational in 2020.
Biox	Biodiesel production facility just outside Sarnia (Sombra) – 50 million litres p.a. production capacity – as well as other facilities in Ontario and Texas. Animal fats, used cooking oils and other vegetal oils are used as feedstock. Also produces glycerine and methyl esters as by-products
Suncor	St Clair Ethanol Plant opened in 2006 and now produces 400 million litres of bioethanol p.a. from ~40 million bushels of corn (~20% of Ontario's annual production, and of a type typically grown for cattle feed) – largest in Canada. Blended into Petro Canada gasoline.

Woodland Biofuels	Demo plant in Sarnia that produces ethanol for blending with petrol from a variety of fibrous feedstock including wood, agricultural and municipal waste.
S2G Biochem	Developed process to produce xylitol and glycols from forestry and agricultural residues. These products can be used in a variety of chemical processes, e.g. as de-icers, detergents and to manufacture polymers. S2G is building a demo plant at the cost of $20M CAD in Sarnia that will produce 2,000t p.a..
Origin Materials	Californian-based company that established a pilot plant ($6M CAD) on Sarnia Lambton Research Park to produce PET precursors from wood and cardboard waste. It now plans to build a demo scale plant at Sarnia BioIndustrial Park at the cost of $32M CAD. The company has significant funding from global players such as Nestle and Danone as it offers the potential of plastic packaging from bio-based raw materials.
CORE Biofuel	Produces 'green gasoline' from waste wood in its facility in Sarnia.
PlantForm Corp.	Biopharmaceuticals
Western Phytoceutica	Manufacture of ginseng-based pharmaceuticals
Forward Water Tech.	Water treatment technology

Several of these companies have identified the following as attractive aspects of the region:

1. Availability of skilled, experienced people – as a result of the strong chemicals sector in the region
2. A high quality supply / service sector – based on its track record of supplying the chemical sector
3. Serviced brownfield sites – companies estimated infrastructure cap-ex costs of $5 million CAD were avoided due to these sites
4. Low cost energy and utilities
5. A supportive ecosystem
6. A supportive innovation support (grant) system
7. A strong emphasis on safety

The first two of these factors were identified as most important by companies as they affect the long-term viability of the company.

These emerging companies complement numerous established chemical companies in the region, including:

Organisation	Activity
ARLANXEO	Synthetic butyl rubber manufacture
Du Pont	Modified polymers
Imperial Oil	Diversified petrochemical plant
Ineos Styrolution	Styrene manufacture
Nova Chemicals	Petrochemical plant – producing basic petrochemicals and polymers
Shell	Petrochemicals plant

5.5 Products

The majority of companies in the area are producing drop-in or substitute petrol and diesel products, although there are notable exceptions, producing versatile products that can be used for a number of chemical processes (e.g. BioAmber, S2G Biochem, and Origin Materials).

5.6 Infrastructure

The major infrastructure in the Sarnia region includes:

Infrastructure	Facilities and Activities	Ownership and Links
Western Sarnia-Lambton Research Park	Established in 2003, this is Canada's largest clean-tech incubator for the commercialisation of large-scale industrial technologies. Provides office, lab and pilot scale space and access to analytical facilities. BIC and the Sarnia-Lambton Economic Partnership are located onsite.	County of Lambton, the City of Sarnia, and Western University
Sarnia Bioindustrial Park	Offers serviced brownfield sites. Provides access to onsite generated electricity and steam. Deepwater dock. Access to waste water treatment and to petrochemical pipelines and industrial gases. Provides support and advice to meet regulatory requirements.	ARLANXEO Canada Inc
Bluewater Energy Park	Offers serviced brownfield sites. Provides access to low cost onsite generated electricity and steam. Deepwater dock. Access to waste water treatment and to petrochemical pipelines and industrial gases. Provides support and advice to meet regulatory requirements.	TransAlta
These two serviced sites are adjacent to each other and all available services from both sites are accessible on either site.		
Lambton College	A college with 3,500 full time and 6,000 part time students in Sarnia, six research centres (energy, bio-Industrial process, water, industrial materials, information technology and technology access) and two research groups (process control and nano-engineered products). Recently made a $14M CAD investment in a new centre of excellence that houses these research Centres. Over $13M CAD of research revenue in 2017-18.	Lambton College

These organisations work together to offer comprehensive support to companies, as follows[7]:

7 Applied Research at Lambton College, personal communication from Medhi Sheikhzadeh, Executive Dean, Applied Research and Innovation

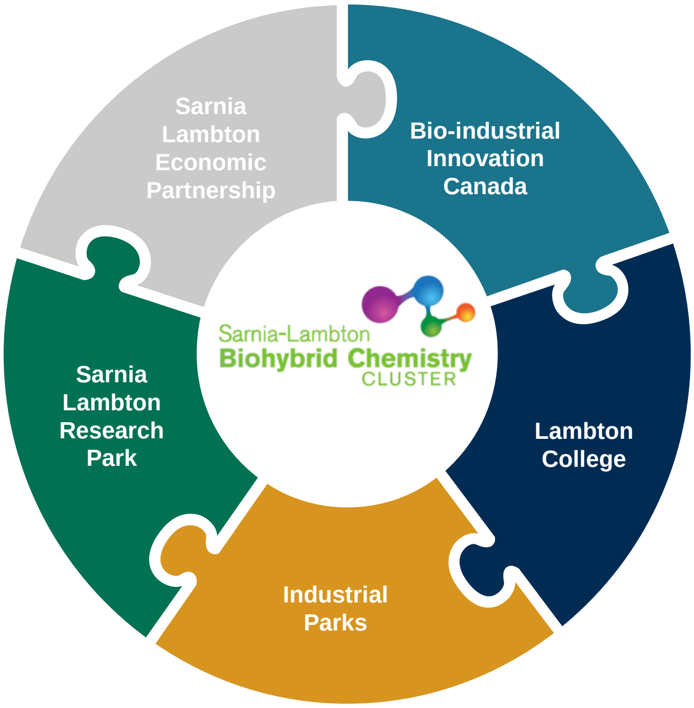


Figure 5: Integrated Cluster Support Infrastructure

5.7 Supporting Activities and Policies

Sarnia's objective is to make it easy for companies to locate and do business there. It does not provide equipment or pilot / demonstration plants for companies. It provides effective and supportive industrial and innovation eco-systems. The key assets that Sarnia can offer are

a. A supportive environment for start-up companies, consisting of R&D space and pilot plant space.

   Companies are not offered equipment. They are offered service space within a supportive environment to build their own pilot plant. The range of types of companies and their activities means that no pilot plant would be relevant to more than one company.

b. An innovation ecosystem – at the research park / with Lambton College

c. Serviced brownfield land – available as a result of the decline in traditional petrochemicals. The owners are strongly committed to developing this land and have each allocated a full-time business development manager to do this.

   This means that companies do not have to commit capex to setting up services / utilities – it is op ex and, as a result, much more manageable.

d. Low cost energy – there is a generation facility on the TransAlta (another ex-Dow) site and people located on this site can access this directly at low cost. They do not have to buy from the grid at grid prices.

e. Skilled workforce – the history and tradition of chemicals in the area means there are lots of skilled people around. Further, the college has a core focus on developing people with the right skills for chemicals / process industries.
f. A high quality support / service sector. New companies can find skilled service companies that can produce what they need, and in a timely manner.
g. A supply chain. The agri community is on board and has developed a co-operative that is committed to supply Comet Biorefining – in fact it has invested significantly in Comet.

   The link to raw materials is considered critical.
h. Supportive individuals who know their way around the systems / local organisations – this means things like permitting are dealt with effectively.

   The perception is that individuals are investing significant personal effort in ensuring that Sarnia develops. It is far more than a 'day job'. The phrase "giving something back" is often used.

   The strong local community and the belonging that most people have is driving this commitment.

5.8 Other Aspects

It has taken fifteen years for Sarnia to be an "overnight success". It has taken time for it to become established, but now mobile organisations pursue Sarnia rather than the other way round. This (recent) transformation is seen as confirmation that Sarnia has got it right.

Arguably, Sarnia has developed a unique ecosystem due to its location and history. There is a strong commitment to ensure the area is successful in the future, a clear plan on how to achieve this and enthusiasm from all key players to work toward this. There is, clearly, joined up thinking and many people are exceeding expectations to support sector development. This will be difficult to replicate elsewhere.

5.9 Summary of Sarnia's Biorefinery Strengths

Sarnia is a mature biorefinery cluster. It has:

- Several commercial scale biorefineries
- Many other companies that have built pilot and demo scale facilities
- Serviced brownfield sites, with shared utilities, that facilitate companies building new production facilities, as well as existing office and lab space for companies to be incubated
- A supportive academic environment providing research services and training to industry
- Feedstock supply – the region has access to a variety of crop and forestry by-products, as well as municipal waste and others
- The region is well-connected to the wider (petro)chemicals industry via a cluster of companies south of the city and extensive pipelines
- Industrial leadership driving forward the cluster development (BIC) and investment available for companies to establish within Sarnia – BIC does not provide access to pilot or demo-scale facilities, but it does offer investment/funding opportunities to build their own
- Supportive government at local, regional and national level

6 Cluster Development Models for the Comparator Regions

In this section we consider how the biorefining clusters have developed in the three regions studied, identify common success factors and lessons learned and consider whether/how these can be applied to the situation in Scotland.

6.1 Critical Success Factors

A review of each of the regions suggests that the following elements as being critical to the success of biorefining cluster:

- Investment – biorefinery infrastructure is expensive, both IEB and Sarnia have received massive investments over a number of years (equivalent of several hundred million GBP). The projected investments for BBD are similar in nature.
- Policy support – government on a local, regional and national level need to work cooperatively to provide a supportive regulatory and fiscal environment for the biorefinery to succeed.
- Public sector investment – national and regional governments have made significant investments in support infrastructure to encourage cluster development.
- Industrial leadership – while government agency support is important, success of the biorefinery is dictated by the commitment of industrially orientated leaders. Developments in Sarnia have been driven by BIC, a well resourced economic agency consisting of ex-industry people who know the region and its industrial make-up, and have worked to attract new companies to the region and build a strong cooperative infrastructure within it. In SW Netherlands, BBD provides a similar role, and although it is at an earlier stage and lacks the economic weight of BIC, it is progressing key developments within the region that will have significant impact. In Champagne-Ardenne, it has been a slower growth, but always led by the farmers cooperatives which have looked at the best means to valorise their members' produce, and established companies to exploit and lead on this. Each cluster has dedicated significant personnel resource to achieving its strategy.
- A strong research environment – all three regions have developed strong connections between the biorefinery and associated companies, and academic/applied research facilities. Co-location has facilitated this collaboration and allowed RTD to be pursued across all TRLs. Flexibility and adaptability are key, however, the approach varies between regions. In Champagne-Ardenne all TRLs are supported from lab-scale (in CEBB and ARD), pilot scale (in ARD and Procethol-2G) and demo-scale (BioDemo in ARD). BioDemo was originally built for BioAmber, but has now been re-purposed and is used for the validation of other companies' process technologies, including those that are not located on site (e.g. Amyris). This means that IEB has the flexibility to work with a number of different process technologies across all TRLs. In Sarnia, pilot and demo scale facilities are not provided, but their construction is facilitated through serviced brownfield sites and funding/investment available through BIC – recognising that the companies coming to Sarnia are using a wide variety of different feedstocks. In SW Netherlands the involvement of RTD clusters at Bergen op Zoom (Green Chemistry Campus) and Delft will support the realisation of the flagship projects promoted by BBD. Both offer lab and pilot scale facilities, as does Corbion's site at Gorinchem.

- Feedstock availability – a successful biorefinery needs to identify feedstock that will be available in the quantity, quality, price and regular availability that it requires to manufacture product at a profit. In each of the three regions studied this has been achieved using either indigenous feedstock or existing transport infrastructure to access imported feedstock.
- Proximity of supply and value chain players – biorefineries handle large volumes of feedstock, products and waste streams; so co-localisation of companies involved in supply and value chains and/or linkage through pipelines minimises transportation time and costs. In addition, it also stimulates new collaborations and new business opportunities between companies.
- Accessible markets – equally important is that the biorefinery secures commitment from customers to purchase its products at a minimum price and minimum volume over a long-term period (up to 20 years) to be confident of recovering the investment (up to £500M) to build the biorefinery.
- Available serviced brownfield sites – these facilitate company establishment by reducing set-up times and minimising costs.

In addition, there is a need to encourage productive dialogue between all stakeholders, ensuring a common vision for the cluster. BIC and BBD have been particularly effective in achieving this, for IEB the BRI is likely to be a better vehicle than ARD or the Jacques de Bohan Foundation to achieve this.

6.2 Power-Influence Maps

The chart below summarises our perspectives of power-influence relationships within each of the three regions, highlighting the important role of different stakeholders in the development of biorefining capabilities. As alluded to above, industry was key, but developments would not have happened without supportive government (at all levels). In addition, each region has needed dedicated human and financial resources to deliver.

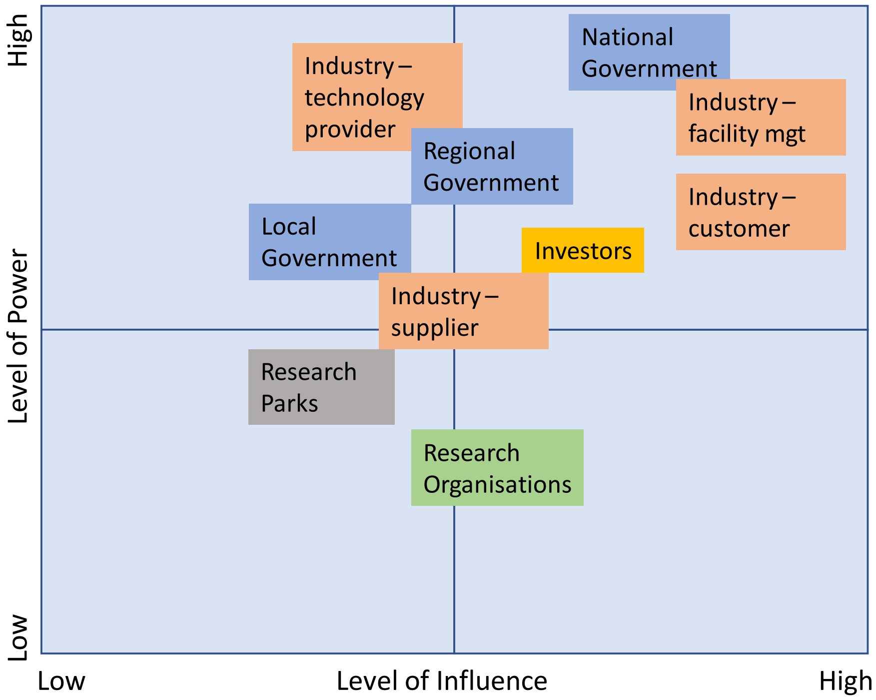


Figure 6: Power-Influence Map

In the figure above, power is the ability for an organisation to do or enable an activity, while influence is the ability to modify the opinions of others and thus outcomes.

It is clear from the analysis that National Government has the greatest power and influence of all policy makers, as it dictates (to a large extent) the fiscal and regulatory environment the biorefinery will operate in. Industry has the greatest influence over how the cluster develops: the facility management is the driver, while the customer is essential to the business model. Investors are also in the upper right quadrant, but as they come into the process later, and are focused on Return on Investment, they arguably have lower power and influence than National Government and industry.

6.3 Time-lines

Above all, time is required to develop a successful biorefining cluster as summarised in the charts below:

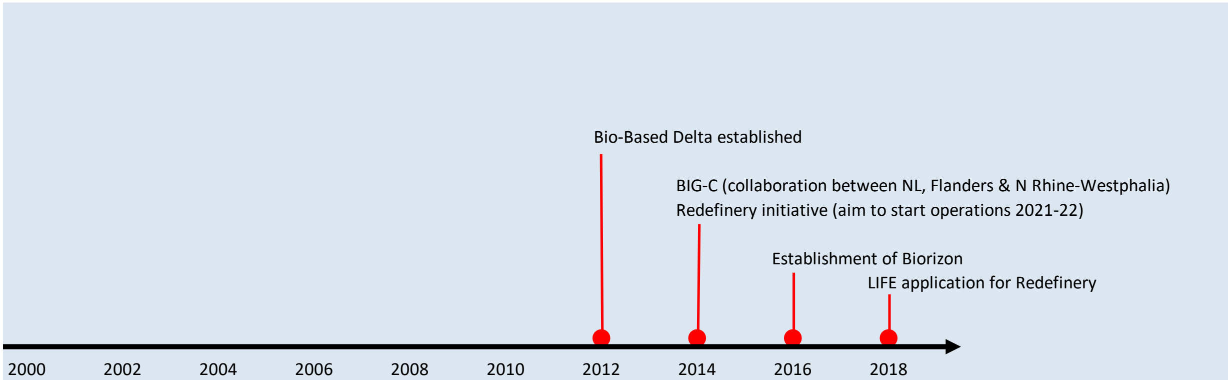


Figure 7: Cluster Development Timeline – SW Netherlands

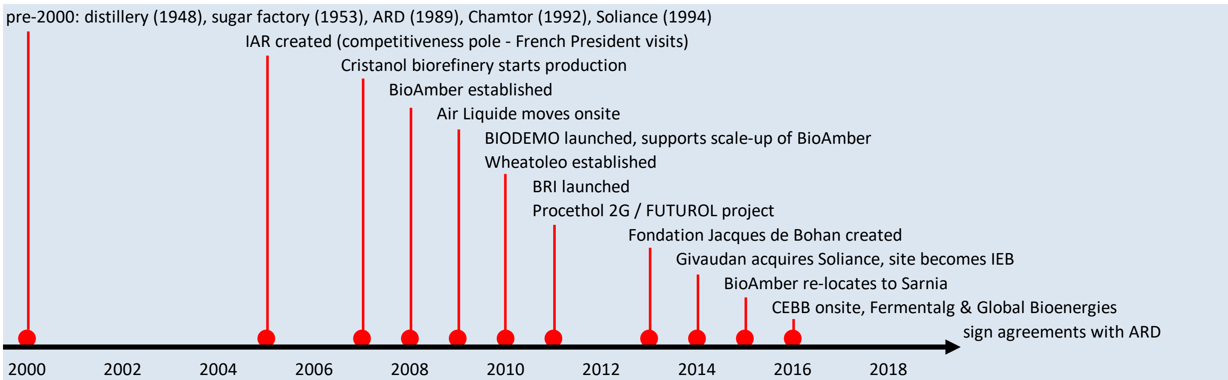


Figure 8: Cluster Development Timeline – Champagne-Ardenne, France

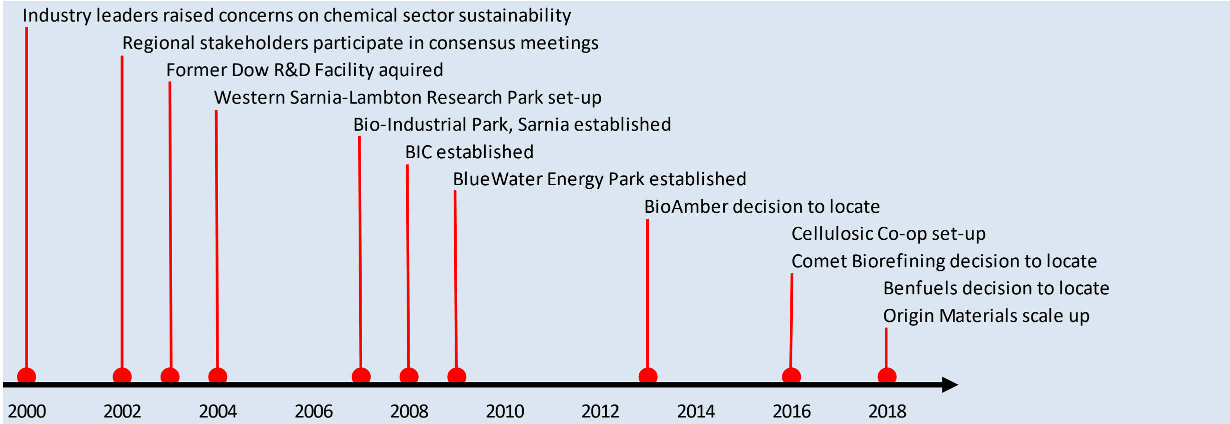


Figure 9: Cluster Development Timeline – Sarnia, Canada

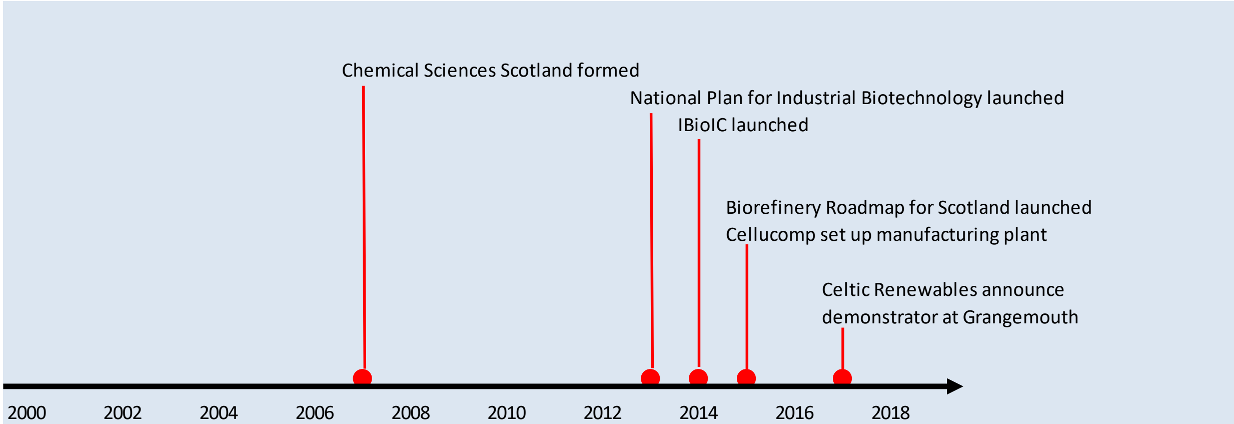


Figure 10: Cluster Development Timeline – Scotland

Note: CSS formation is shown in the Scottish cluster development timeline, but we do not consider that this is the commencement of bio-based cluster development activities. We believe that these started much later.

This clearly shows the time taken to develop industrial activity in Champagne-Ardenne (60+ years with the last 20 or so on bio-based cluster development) and Sarnia (15 years), both with significant financial support, and the comparatively short time that SW Netherlands (6-7 years) and Scotland have been pursuing bio-based cluster development. Even the significant political support in the Netherlands has not been sufficient to catalyse a sector in 6 -7 years.

This would suggest that it is too early to be concerned about progress in Scotland, but we believe that this does not consider the sustainability of the support infrastructure to develop biorefining. As discussed in the following section, we believe that the cluster development strategy in Scotland would benefit from a fundamental review, as the investment and infrastructure are not optimised, thus we consider that it is important to recognise that the Scottish approach needs to be changed.

7 Benchmarking Scotland's Attractiveness Against these Clusters

The following table summarises our analysis of the competitive position of Scotland compared to the three regions investigated in this study, using a number of key characteristics, as presented in the preceding chapters:

Region	Investment	Policy Support	Industrial Lead	Research Environment	Proximity of Supply & Value Chains	Feedstocks	Products	Brownfield sites
SW Netherlands	++	+++	++	+++	+++	+++	++	+++
Champagne-Ardenne	+++	+++	+++	+++	++	+++	+++	+++
Sarnia	+++	+++	+++	+++	+++	+++	+++	+++
Scotland	+	++	+	+++	+	+	+	++

Figure 11: Attractiveness Ranking

The relative maturity of the bio-based cluster development in Scotland, focusing on Grangemouth, can be compared to the situation in other regions by adapting one of the cluster support diagrams from Sarnia (shown in Figure 5) as follows:

Figure 12: Maturity Comparison – three regions vs Grangemouth (Red / Amber / Green)

Key: Green – well developed / Amber – basis for development / Red – infrastructure gaps

This can be further analysed through the following SWOT analysis for Grangemouth, which has used our assessments of the clusters elsewhere to define key cluster development factors.

Strengths

- Skilled people – the (petro)chemical industry has been in place at Grangemouth for almost 100 years, Scotland's further and higher education establishments have a long and successful record of delivery high quality skilled workers.
- Established / skilled supply service sector – as a result of its long history in Scotland, supply chains are well-established to service the chemical industry.
- Available, serviced brownfield sites (although this was not assessed as part of this study) – through INEOS and Calachem.
- Forth Valley College – key provider of skills and training to the chemical and life-sciences sectors and located in Grangemouth.

- University expertise – providing RTD capabilities across chemical engineering and industrial biotechnology, but located at some distance from Grangemouth.
- High level public sector commitment – development of a biorefinery is integral to the National Plan for Industrial Biotechnology to which public sector agencies are committed.
- Wide industry support for industrial biotechnology and biorefining through the leadership of the SIBDG and the Biorefining Working Group.

Weaknesses

- Limited raw materials – while there are a number of potential feedstocks available to a biorefinery, their quality, availability and sustainability need to be fully investigated.
- No dedicated industry orientated and focused resource for developing a biorefinery cluster. While the SIBDG and the Biorefining Working Group are leading the development of a strategy for biorefining in Scotland, this is reliant on the goodwill of individuals within these groups giving up their time to do so. IBioIC in turn may be the delivery partner for the National Plan for Industrial Biotechnology, but the development of a biorefinery is one of its many objectives, and there are limited resources attributed to it. This is in stark contrast to the other regions which have dedicated staff (10-20 FTEs in Sarnia and SW Netherlands) that are focused on developing biorefining clusters.
- While land is being made available for development within Grangemouth sites, the level and nature of local support to companies who would choose to build there is unclear.
- The innovation ecosystem and facilities to support biorefining in Scotland are distributed across a number of sites and organisations. This means the development pathway is fragmented compared to other regions (in particular the IEB), potentially slowing down the pace of innovation.
- Industrial development and innovation support is organised country-wide, whereas the successful regions have had support focused on specific sites and specific activities. The development strategy in Scotland, at present, lacks detail and specific objectives, compared with for example BBD's REDEFINERY. This means efforts are potentially spread across a number of different activities, reducing impact and substantive progress.
- Comparatively low level of cluster development funding – to date Scotland has invested in the order of a few tens of millions of pounds, this is around a tenth of the investment in other regions, particularly Sarnia and IEB.

However, a number of these strengths can be exploited and weaknesses addressed as follows:

Opportunities

- Develop a coherent regional / sectoral plan and infrastructure through consensus.
- Establish a mechanism to improve and promote local brownfield sites (optimised services, dedicated resources to market the space, support interested companies and advice in obtaining regulatory compliance).
- Set-up a dedicated business focused, cluster development organisation for Grangemouth.
- Repurpose an available building as a centre for R&D / pilot facilities.
- Develop an innovation support infrastructure and applied research capability in Grangemouth via
    - IBioIC presence at Grangemouth
    - Extending Forth Valley College's remit
    - Encouraging Scottish academic institutions to actively participate in this innovation and applied research community

  This capability will be able to develop and deliver projects on behalf of local / incoming companies. SMART: Scotland and R&D grants would work as funding mechanisms, as long as the company submits the application and significant subcontracting to local suppliers (as is the case with numerous current applications) is acceptable.

These underline a focus on developing an attractive and supportive innovation, business development and industrial eco-system, rather than large investment in a process plant.

However, we do recognise that there are some aspects of the clusters we have analysed that are not transferable, namely the idiosyncrasies of the different regions.

Threats

- This ‘prize’ is being actively sought elsewhere, and regions such as Sarnia are now actively approached by companies. This gives Sarnia (and others) a first mover advantage.
- Loss of indigenous innovation to other regions if there is not the necessary supportive infrastructure in Scotland.

This analysis clearly focuses on the need for the lead actors in Scotland to collaborate to develop an infrastructure that is attractive to companies and supportive to industrial innovation and development. Therefore we consider that the most value adding next step for developing a biorefinery proposition in Scotland is discussions with key stakeholders to assess what is possible, based on the above analysis, and to gauge their appetite for active involvement. These organisations, and key topics for discussion, would be

- Falkirk Council — What is its willingness to commit resource to the development of a supportive biorefining infrastructure in Grangemouth – or to work with others to obtain funding from a third party?
- IBioIC — What is its commitment to locate some activity in Grangemouth (co-located with Forth Valley College?) and the focus of that activity?
- Universities — Such as Strathclyde and Edinburgh. What is their commitment to participate in an applied R&D Centre in Grangemouth and mechanisms to do this?
- Forth Valley College — What is its commitment to develop activities to support biorefining, scope to extend its remit to applied, market-led research and to accommodate others such as IBioIC and universities in a joint facility?
- INEOS — What is the spare capacity within its infrastructure and its interest in reducing costs by supplying others? What is its willingness to optimise and actively promote and support serviced brownfield sites under its control in Grangemouth and its interest in becoming a customer for products of the biorefinery?
- Calachem — As for INEOS.

It is difficult to recommend the next steps in developing biorefining in Scotland until the interest and commitment of these key stakeholders are clarified.

8 Roadmap for Developing the Scottish Biorefining Cluster

This analysis, based on the three regions assessed, highlights a number of key points and potential actions for development of a biorefining cluster in Scotland / Grangemouth.

The main conclusions from this analysis are:

- The time Scotland has been focusing on biorefining is relatively short in comparison to best practice examples elsewhere; so it is reasonable that significant activity has not yet developed
- However, that does not mean that the support system and infrastructure in Scotland is optimised
- Evidence indicates that there has been significantly higher investment in the regions analysed, compared to Scotland
- These regions have all developed clear objectives and strategies, based on local situations, feedstocks and value chains
- This investment has resulted in much better developed support organisations and infrastructures
- The major priority of these best practice examples has been to get the value chains and innovation and industrial ecosystems optimised, rather than investing in specific process equipment

Our recommendations for the way forward, prior to discussions with key stakeholders, are:

- There is an opportunity now to learn further from others which should be taken.

  Based on the relationships developed during this study and existing links that IBioIC have, key people from the three regions should be invited to Scotland, for IBioIC's conference, to review Scotland's current infrastructure and to discuss best-practices and opportunities for closer collaboration.

- Cluster development activities in Scotland need to be industry-led.

  While the development of a strategy for biorefining in Scotland is being led by industry, there is no dedicated resource to implement the strategy. This needs to be identified and nurtured at the earliest opportunity, whether it is delivered by industry itself or by individuals with in-depth industry experience and credibility.

  IBioIC has an important role to play here (arguably more than SE/HIE) but it will need additional resource as this is not part of its current business plan. However, this will not be successful without a significant level of wider industrial commitment, even if guided by experienced individuals from the industry working in public sector supported organisations.

- Scotland should carry out an updated assessment of the potential for biorefining, based on its key strengths and opportunities, and develop robust, focused objectives and strategy.

  The key question to answer is "what are the best biorefining options for Scotland?" Based on this study we can identify two contrasting scenarios:

  1. Scotland focuses on technology development and validation, exploiting its R&D capabilities. This can be extended to niche, small-scale biorefining activities based on specific feedstocks.

This option would establish Scotland as a technology leader in biorefining. Its innovation eco-system would attract new technology companies to Scotland to embed their RTD centres here. This would, however, not create the number of jobs that a large-scale manufacturing plant would, but it would create significant added value.

It also reflects that the most attractive opportunity for Scotland may be to exploit its technology know-how by targeting niche, small-scale feedstocks. We believe that this should be further investigated. Downscaling as well as upscaling are important biorefining considerations, particularly when feedstocks may be geographically distributed or arising in rural communities (e.g. islands). A focus on technology development and validation using facilities available through e.g. IBioIC and university partners could be leveraged to demonstrate that such technologies can be successfully exploited as modular, lower throughput biorefineries (e.g. a biorefinery processing whisky by-products on Islay).

2. Scotland pursues large scale biorefining (as with all three regions studied)

   To do so, the complete value chain and business proposition needs to be addressed. The BBD 8-pack is an effective example of this. Similar work in Sarnia to develop full value chains offers another reference. This highlights the need to address any opportunity in a holistic way.

   Value chains, and particularly the feedstock in Scotland, need to be identified and developed. The supply of feedstock is critical. What material can be guaranteed at an acceptable quantity, quality, price and frequency? How is this currently used, and will this use be difficult to displace? We believe that companies will not consider a Scottish location until there is confidence in feedstock supply.

   Options should also be examined for the highest valorisation of materials flowing through a biorefinery. This means considering not just primary feedstock and the products that will be derived from this, but the means of using/re-using the by-products and waste products from these processes. This is captured in the circular economy hubs described in the ZWS report on beer, whisky and fish[8], where different enterprises buy and sell different products from each other (whether these are materials or utilities). The key point here is that the maximum/highest value should be achieved within the site as possible, otherwise economic opportunity will be lost elsewhere.

It should be noted that if option 1 is pursued and is successful, then option 2 is more likely to follow naturally.

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8 Sector Study on Beer, Whisky and Fish (ZWS, 2015)

Appendix A: Key Stakeholders

1. SW Netherlands

Individual	Organisation	Interview/Meeting
Marc Lankveld	Corbion	Interview (18.06.18)
Rop Zoetemeyer	BBD	Meeting (25.06.18)
Aldert van der Kooij	BBD	Meeting (25.06.18)
Hans Keuken	PDC	Meeting (25.06.18)
Willem Sederel	BBD	Meeting (26.06.18)

2. Champagne-Ardennes

Individual	Organisation	Interview/Meeting
Jean-Marie Chauvet	ARD	Meeting (13.07.18)
Amandine Flourat	CEBB	Meeting (13.07.18)
Frédéric Martel	Procethol 2G	Meeting (13.07.18)
Michel Mangion	Cristal Union	Meeting (13.07.18)

3. Sarnia

Individual	Organisation	Interview/Meeting
Sandy Marshall	Bioindustrial Innovation Canada	Meeting (31.07.18)
Aung N Oo	Western Sarnia Lambton Research Park	Meeting (31.07.18)
Mehdi Sheikhzadeh	Lambton College	Meeting (31.07.18)
Mike Bradley	Mayor of Sarnia	Meeting (01.08.18)
Tim Knapp	ARLANXEO	Meeting (01.08.18)
Rich Troyer	Comet Biorefining	Meeting (01.08.18)
Matthew Slotwinski	Sarnia-Lambton Economic Partnership	Meeting (01.08.18)
Mike Hartmann	BioAmber	Meeting (02.08.18)
Brian Cofell,	Cellulosic Sugar Producers Co-operative (CSPC)	Meeting (02.08.18)
Dave Park	Parklands Farm and President of CSPC	Meeting (02.08.18)
Rob Tripp	Benfuel	Interview (02.08.18)
Alex Ward	Origin Materials	Meeting (02.08.18)

Appendix B: Discussion Topics

1. Historical aspects
    a. Seed/driver for the cluster
    b. Key individual/organisation leading the cluster development
    c. Policies to support the biorefinery cluster development
    d. Role of local, regional, national government?
    e. Timelines for cluster development and critical events
    f. Nature of technologies necessary for cluster development
    g. Barriers to the cluster development
    h. Lessons learned
2. Cluster dynamics
    a. Whether there is a clear leader or not
    b. Services offered by the cluster
    c. Engagement and collaboration between companies
    d. Impacts on individual companies
    e. Cluster size and growth
    f. Unique qualities and advantages
3. Infrastructure
    a. Capacity and capabilities
    b. Development of infrastructure and operating model
4. Feedstock and supply chains
    a. Nature of feedstock(s), volumes, suppliers and their location
    b. Supply chain dynamics
    c. Alternative uses for feedstocks
    d. Other critical supply aspects
5. Value chains
    a. Nature and development of value chains in the cluster
6. Looking forward
    a. Continued demand and need for the cluster
    b. Best ways in which national, regional and local government can support clusters
    c. Gaps, improvements or future direction for the cluster

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