This paper constitutes the Case Study Annex to the already published OECD policy report, “Innovation Ecosystems in the Bioeconomy” https://doi.org/10.1787/e2e3d8a1-en.

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Preface

1. This compilation of country case studies in the bioeconomy represents an annex to an OECD Policy Paper: “Innovation ecosystems in the bioeconomy”, OECD Science, Technology and Industry Policy Papers, No. 76, OECD Publishing, Paris, https://doi.org/10.1787/e2e3d8a1-en. This policy paper examined the policy aspects of building the industrial and innovation ecosystems and value chains needed to make a bioeconomy viable as a sustainable means of production. Building on qualitative case studies and face-to-face interviews in ten participating countries, the study reveals the diverse ways countries are seeking to achieve the goals set by national strategies and policies. Lessons drawn from this report include the need for systems-based approaches, attention to policy alignment, more focus on demand-side instruments, diversification of products, enabling medium-sized companies and harnessing converging technologies.


3. The decision to create this annex was taken because the length of the country cases did not allow for publication within the format of an OECD Policy Paper. Nevertheless, because these cases constitute an extremely rich resource for policy makers, practitioners, and researchers alike, it was important to make the full case studies available.

4. Due credit must be given to the ten countries who provided case studies of such quality: Belgium (Flanders), Canada, People’s Republic of China, Finland, France, Italy, Japan, Norway, Sweden, United States.

1. Belgium (Flanders)

1.1. Country position and policies for bio- and circular economies

5. In 2006 Flanders opted to develop a sustainable bioeconomy as a transition strategy to respond to the threat presented by the exhaustion and use of fossil raw materials. In addition, Flanders wants to be ready to cope with major societal challenges such as population growth, climate change, the increasing scarcity of other raw materials, pressure on ecosystems and economic development. A sustainable Flemish bioeconomy provides opportunities for green growth and job creation, the further development of a circular economy, cross-border clustering, strengthening of competitiveness and the potential for research and innovation in Flanders. In 2013, the Government of Flanders published its strategy for a sustainable and competitive bioeconomy in 2030. The vision for the bioeconomy in Flanders in 2030 can be described in three ambitions:

1. By 2030 Flanders will be one of the most competitive bioeconomy regions in Europe:
   • By developing a coherent and integrated policy for the bioeconomy, with a constructive collaboration between a policy for research and innovation, economy, agriculture, environment, materials, raw materials, energy, education and taxation,
and a policy aligned as much as possible with European regulations and developments

- In which the bioeconomy sector makes an important contribution to employment and economic growth in Flanders
- In which all partners from the various related value chains enjoy sufficient benefits and added value
- In which the strong industrial sectors that are the drivers of the bioeconomy have based major research and production centres in Flanders
- With several new companies emerging from their own research.

2. In 2030, Flanders will be one of the top regions in Europe for innovation and research relating to the bioeconomy:

- With maximum cooperation between governments, civil society, the academic world, research institutions, industry, logistics and primary production
- With cooperation between and within the various sectors
- With structured strategic basic research
- With research projects and networks that involve the entire value chain with accessible upscaling, infrastructure and financing for development and demonstration projects
- With numerous new spin-off companies that convert innovation and research into economic activity
- With a Flemish bioeconomy cluster that has set up collaborations on innovation and research with key bioeconomy regions in Europe and the world.

3. By 2030, Flanders will have created one of the most sustainable bioeconomies in Europe:

- In which Flanders is recognised as a forerunner in the efficient and flexible use of biomass
- In which all the biomass used is produced sustainably and deployed along the entire value chain and at least takes account of generally accepted sustainability criteria at European level
- In which the bioeconomy guarantees sustainable employment based on a strengthened activation and skills policy
- In which, as a general principle, biomass is firstly converted into food and high-quality bio-based products, prior to energy recovery at the end of the life cycle
- With material- and energy-efficient, environmentally friendly and ‘zero waste’ production processes
- In which the government stimulates the market for sustainable bio-based products with adequate policy-related and stimulating measures
- In which the products placed on the market are of a high-quality value and reliability that convince consumers (citizens, businesses, governments)
- In which Flanders is a recognised partner in EU and international cooperation on knowledge sharing, harmonisation of regulations and generally accepted sustainability criteria
- In which there is broad support for a bioeconomy among the key stakeholders in society.

6. An interdepartmental working group (IWG) was created to oversee the actions and progress towards this vision. This IWG provides the initial impetus for the development of an integrated, cross-policy approach to a sustainable and competitive Flemish bioeconomy. The working group ensures complementarity between the actions of the Administration’s Departments of Economy, Science and Innovation (EWI), Agriculture and Fisheries (LV), Environment, Nature and Energy (LNE), Work and Social Economy (WSE) and Education and Training (OV), together with the executive agencies VITO (Flemish Institute for Technological Research), ILVO (Institute for Agricultural and Fisheries Research), OVAM (Public Waste Agency of Flanders), VEA (Flemish Energy Agency), ANB (Agency for Nature and Forests in Flanders), VMM (Flemish Environment Agency), VLM (Flemish Land Agency), VDAB (Flemish Employment and Vocational Training Service), IWT (Agency for Innovation by Science and Technology) and Enterprise Flanders.

7. The IWG strategy is divided in five broad clusters. Each cluster combines a set of actions that are annually reported to the Flemish Government. These clusters reflect the lines set out in the roadmap and are summarised under the headings:

1. The development of a coherent Flemish policy that supports and facilitates a sustainable bioeconomy
2. To put Flanders at the top for education, training, research and innovation in future-oriented bioeconomy clusters
3. Biomass is optimally and sustainably produced and used across the entire value chain.
4. Strengthening of markets and competitiveness of bioeconomic sectors in Flanders
5. Flanders is a key partner within European and international joint ventures.

8. The turnover of the bio-based economy grew from 1.51% in 2008 to 1.74% in 2014 of the entire Flemish economy. This represents growth as a share of industrial turnover from 7.4% in 2008 to 9.59% in 2014. The bio-based economy was estimated to employ 8,650 FTE in 2014.

9. The case study is part of a general revision and adaptation of policies for the bioeconomy within the IWG for the Bioeconomy. The state of the bioeconomy in Flanders shows that the first steps in the transition are taking place, and that new alliances are being formed for short-circuit revalorisation of bio-based resources. The current challenge is to assist innovative and more complex value chains and to integrate these within the current economic structure in Flanders.

10. The case study describes the current state of the bioeconomy in Flanders, and links this to policy challenges and adaptation options.
1.2. Current state of the bioeconomy in Flanders

1.2.1. Technological trends and developments

11. The policy review process started by analysing the prevalent technological trends and their potential for further development in the near future. The current situation in the development of the bioeconomy in Flanders can be characterised by four main technological pathways.

Transformation of organic waste matter to bio-based chemical products and primary sources for industrial production

12. This value chain is estimated by the stakeholders to provide the largest potentials in the short run. Especially the valorisation of organic waste streams has become a major focus during the last years. The market expectations are that organic waste will continue to be produced, and higher valorisation options are the best way to deal with these waste streams. This development is ongoing and has brought forward the following focus:

- It is not always necessary to include chemical transformation. Production of bio-based material without conversion to chemical components can be a preliminary step. This material revalorisation can provide, for instance, fibres for building materials and feed or alternative fillers for plastic or composite materials. By dissociating organic waste streams into components, multiple waste streams are created that can be targeted to different revalorisation processes.
- Local and decentralised units for waste collections and transformation may provide larger local benefits.

Production of specialty chemicals from sugars and starch and other renewable sources

13. There is a lot of interest in this technology pathway both from companies and research institutes. This is reflected also by the fact that it is one of the principal research topics of the chemical research cluster Catalisti, and by the construction of a new large-scale factory in the Antwerp harbour that was announced as a collaboration between Avantium and BASF.

14. The production of specialty chemicals is a trend that is expected to continue to grow at a level with the growth of industrial interest. At the same time the sugar supply is expected to grow, because the European production quota have been recently abolished (2017), and sugar content in foods is declining. Moreover, the Belgian agricultural sector has a large experience and tradition in sugar production.

Production and use of second generation sugars as a base for industrial biotechnology and green chemistry

15. This pathway focuses on the reconversion of cellulose in waste streams. By transforming cellulose from waste streams from agriculture or manufacturing, the ecological impact of the bioeconomy can be further reduced.

16. During the last five years, important technological breakthroughs have been achieved in chemo-catalytic transformations to produce valuable materials and chemicals from cellulose, such as biosurfactants, emulsifiers, pigments, lubricants, specialty materials.
polymers, additives. Industrial and agricultural waste streams exist in Flanders with high cellulose content, providing the basis for successful business cases in the long term.

Conversion of waste gases to chemicals

17. This last trend is a very recent and quickly growing development. The high industrialisation of Flanders provides numerous sources of waste gases that can be transformed by bio-based processes. Very recently the Arcelor Mittal steel factory has started a pioneering transformation plant to produce ethanol based on waste gases by bacterial transformation. Similar processes and set-ups are under investigation by companies and research institutes.

1.2.2. Actors and projects

18. A large diversity of actors is involved in these projects, ranging from large companies, innovative SMEs, research organisations and public authorities. There are a few crucial actors that structure the landscape.

Spearhead clusters

19. Starting from 2016, the Flemish authorities implemented a policy of spearhead clusters and innovative business networks. Spearhead clusters are private organisations formed by a federation of companies gathered around one theme of industrial innovation. These spearhead clusters can benefit from structural support and earmarked R&D budgets for industrial development and collaboration projects. As cluster organisations, they typically foster networking between its members (companies, government, knowledge and research institutes) and follow up and communicate on strategic sectorial trends and business intelligence. The spearhead clusters involved in the bioeconomy are:

Catalisti

20. This is the spearhead cluster of the chemical sector. Around 100 companies and all Flemish universities are partnering with Catalisti together with Essenscia Vlaanderen (sector federation for the chemical industry), VITO (Flemish Institute for Technology Research), Centexbel (research centre for the textile industry) and the Bio Base Europe Pilot Plant (an independent pilot facility for the bio-based industry)

21. The innovation agenda of Catalisti is centred around four main innovation programmes: “Renewable Chemicals”, “Sidestream Valorisation”, “Process Intensification and Optimisation” and “Advanced Sustainable Products”. Within these innovation programmes, the cluster is working on the elaboration of the following strategic themes: Carbon Capture and Utilisation (CCU), Bio-aromatics, Sugar as feedstock, Plastics conversion, Industry 4.0 and Circular economy.

Flanders’ Food

22. This is the spearhead cluster of the Flemish government for the agro-food business. Flanders’ Food has two knowledge-driven strategic objectives (lead in knowledge and lead to knowledge) and two business-driven strategic objectives (accelerate efficient and effective innovation and cross/create value chains). The knowledge-driven strategic goals will focus on three programme lines: (1) World class food production, (2) Resilient and sustainable agrifood systems and (3) Personalised food products and healthy diets.
23. A number of activities contribute to the realisation of the strategic goals, such as: development of dedicated roadmaps; creation of a (virtual) inspiration centre; education of the target group; distribution of information beyond the target group; establishment of a scientific and technological advisory network, enabling access to pilot infrastructure; support in workplace innovation; support in research implementation, and; guidance towards co-creation and co-development.

BioBase Europe Pilot Plant

24. This is an independent and combined pilot annex training facility that supports the development of sustainable, bio-based products such as biochemicals, bioplastics, biomaterials, biodetergents and bioenergy from renewable biomass resources. Its mission is to stimulate sustainable development and economic growth by facilitating R&D and training for bio-based process development. It consists of a pilot plant for the bio-based economy located in the port of Gent (Belgium), and a training centre for the bio-based economy in Terneuzen (Netherlands). Both facilities are located in the cross-border Gent-Terneuzen harbour area.

25. The pilot plant offers unique and independent piloting facilities able to close the gap between scientific feasibility and industrial application. The processes done in the pilot plant can be roughly divided into the following categories:
   4. Biorefining - biomass fractionation and pre-treatment
   5. Industrial biotechnology
   6. Green chemistry
   7. Downstream processing.

Universities, research organisations and Strategic Research Centres (SOC)

26. Flanders has a long experience in fundamental and applied research in biotechnology, bio-based processes and agriculture. The Flemish universities (KU Leuven, Gent University, University of Antwerp, Hasselt University, Free University of Brussels) are successful in attracting national and European competitive funding for bio-based innovation. To enable the transfer of research results to industry, the universities have built a strong technology transfer policy. Other notable research organisation that are actively contributing to the development of the bio-based economy in Flanders are the following.

ILVO (Institute for Agriculture and Fisheries Research)

27. This is a multidisciplinary, independent research and specialised service provider in all fields related to agriculture, fisheries and food in Flanders. ILVO is an internationally recognised scientific institute and a part of the Government of Flanders. As such, ILVO provides independent research (laboratory analyses) and advisory and consulting services towards industry and government. It also delivers reference working, inspection and certification work or ad hoc research projects.

VITO (Vlaamse Instelling voor Technologisch Onderzoek)

28. VITO is a strategic research centre that builds connections between knowledge, policy and business to realise high-impact change in the fields of energy, chemistry, materials, health care and land use. VITO was founded in 1991, and currently its headquarters are located in Mol with premises in Berchem, Genk and Oostende.
29. VITO mainly focuses its research and development activities on sustainable development and clean technology. Companies can turn to VITO for expertise, test facilities, joint ventures, joint project proposals, and more. For example, VITO offers new and sustainable technologies that can be demonstrated in living labs or through external set-ups by clients. VITO also provides specific services/projects for the Flemish Government, as well as policy-related tasks for other public bodies in Belgium and abroad. Lastly, VITO has a close collaboration with Flemish universities and other research institutes, and supervises and finances PhD and post-doctoral fellows in collaboration with the universities.

1.2.3. Examples of international collaborations

30. Industrial clusters in Flanders, the southern part of the Netherlands and North Rhine Westphalia have formed the BIG-C smart specialisation initiative. BIG-C (Bioinnovation Growth mega-Cluster) aims at transforming the mega cluster in these three regions into the global region of bio-based innovation growth. BIG-C focuses on new value chains for bio-based aromatics, chemicals from CO and CO₂, and aviation fuels from various feedstocks.

31. Biorizon was initiated by major Dutch and Flemish independent research organisations with expertise in clean technology and sustainable development (TNO, VITO), energy innovation (ECN Energy Research Centre of the Netherlands), an open innovation chemical incubator and accelerator park (Green Chemistry Campus) and a platform organisation for businesses, authorities and knowledge institutes in the South West Netherlands (Bio-based Delta). At the core of Biorizon stands technology development for the production of bio-based bulk aromatics and functionalised bio-based aromatics for performance materials, chemicals and coatings.

32. The EU Smart Specialisation Vanguard initiative includes the bioeconomy pilot with two ‘cases’ that are the heart of this TSSP project: bio-based aromatics and waste gas conversion. Participating regions active in the former are Emilia Romagna, Flanders, Lower Austria, Navarra, NRW and South Netherlands (in this TSSP project represented by Noord-Brabant). In the latter: Emilia Romagna, Flanders, Navarra, NRW, South Netherlands and Wallonia.

33. Biobase Europe started in 2008 as a cross-border Flemish-Dutch initiative and has since then always kept a strong international focus. At present companies from all over the EU and from elsewhere in the world come to Gent to scale-up and pilot their own research and/or products. Biobase Europe itself is also strongly engaged in EU-wide and international cooperation with other world class piloting facilities and has collected several EU awards and citations.

1.3. Policy challenges and adaptation options

34. The Bioeconomy policies in Flanders are currently being evaluated. This evaluation draws from the official policy document and stakeholder participation. In a first stage, an extensive survey was addressed to a wide range of private bioeconomy actors. Based on the survey results, priority themes were identified for the organisation of workshops. In these workshops, policy challenges were identified, discussed in detail, and potential options for solutions were proposed. This section includes a structured and shortened overview of the policy challenges, and provides a list of potential adaptation options.
1.3.1. Bioeconomy challenges

In logistics and value chain construction

35. The extension of the value chain towards the inclusion of primary producers remains problematic. Farmers and professional field labourers need to ensure constant biomass streams to be able to provide sufficient critical mass for industrial applications. Cooperatives may be a solution. The agricultural sector has a large experience in this type of set-up. However, the creation of cooperatives is a time-consuming and complex process.

36. Providers of industrial bio-based waste streams are often companies that are not interested in new bio-based industrial development. For instance, breweries can provide large quantities of spent grains for innovative chemical transformation, but their interest is not in creating new value chains for spent grains. Additional effort may motivate providers of bio-based waste streams to engage themselves in new value chains that surpass their own professional sector.

37. The most valuable bio-based waste streams are unmixed streams that can be easily transported and stored. This brings generic challenges for the recuperation of the available organic waste streams. At the moment, Flanders excels in the separate collection of waste streams, and the focus on separate collection of waste streams has to continue. Additionally, pre-treatment methods can increase the value and applicability of waste streams. Drying, separating or compacting waste may provide bio-based sources that have new applications or that are easier to store and transport. Shared and mobile facilities for these pre-treatments are important to reduce transport and capital costs, but these are currently not available, and this hampers the creation of new value chains.

38. Several technological projects are working on innovative value chains with gaseous intermediary or final products (e.g. CO, H₂, CH₄) The density of the chemical industry in Flanders is high, and as a consequence, the pipeline network for these gases is well developed. However, access to these private networks is very limited, and this also reduces the number of options for innovative business models making use of this infrastructure.

In technological development and innovation

39. The bioeconomy created a very diverse group of actors spanning several sectors (e.g. agriculture, food and nutrition, pharma, chemistry, manufacturing). The current spearhead cluster policy, however, is too sector-centred and provides no visibility to the bioeconomy network. There is no central network or bioeconomy representation at the moment. Therefore, cross-sectoral R&D projects cannot benefit from the spearhead cluster budgets and have to fall back to the generic and highly competitive R&D budgets.

40. The administrative procedures to create new pilot plants or business ventures remain too complex. The use of bio-based materials provides an additional layer of complexity. The policy principle in Flanders is to focus on the cascading use of biomass. New bioeconomy ventures are expected to provide the highest added value for the biomass stream. This steers away from direct combustion or gasification for energy purposes, and ensures a more sustainable use of biomass.

41. In itself this principle is accepted and understood by private partners. However, for more complex value chains, it is not possible to set up all necessary steps in the biorefinery process at once. There is an evolutionary process necessary to start from simple transformation steps and to gradually increase the complexity of the value chain structure and technologies. These first steps do not always adhere to the optimal cascading rule, and
higher valorisation is only achieved in successive steps. The investments for the first steps often get no support or approval, because the projects are evaluated in isolation and not within a larger timeframe. The more complex the value chain, the more necessary it is to look at the cascading use of biomass in a longer timeframe.

42. International projects become increasingly important to bring new knowledge and initiatives. Although Flanders is relatively limited in size and capacities, the high level of specialisation of Flemish actors demonstrated a solid international position, which should be maintained and reinforced.

*For financing and business plan creation*

43. There is no level playing field between applications of biomass for energy and for materials. Energy applications are less sustainable, provide lower added-value, but can achieve higher profitability as regional, national and European legislations and support instruments are not fully coherent for both applications. As a result, valuable waste streams of organic materials (e.g. municipal organic waste, black liquor from paper production) are used in direct combustion and the involved actors are not inclined to provide the basis for more innovative value chains.

*1.3.2. Bioeconomy policy adaptation options*

44. Several options have been proposed to improve the policy framework for the developing bio-based economy in Flanders.

*Bioeconomy network organisation*

45. Currently there is no representation of the diverse group of actors involved in the bioeconomy. A designated network representative could increase the visibility for policy makers and society. Additionally, the representative should also organise targeted networking activities. Very targeted meetings should be organised, each time around one detailed technology or local value chain.

46. Finally, the research and development activities are numerous but dispersed. More coherence and synergy can be achieved by increasing the knowledge on these initiatives amongst stakeholders. Moreover, a central R&D knowledge centre should also support further internationalisation of the projects.

*Flanders Bioeconomy advisory council*

47. The current policy revision has highlighted the latest trends and challenges in the policies for the new bio-based economy. It would be beneficial both for policy makers and private stakeholders to maintain a closer relation to the field activities in the future. It was proposed to establish a Flanders Bioeconomy advisory council of private actors to work in parallel with the IWG for the bioeconomy at the policy level. This council should provide a bridge to channel feedback for policy discussions and information on new developments and initiatives to policy makers.

*Permitting procedures*

48. It can be investigated if the new Flemish legislation for temporary “regulatory poor areas” can be applied for bio-based initiatives. These areas are designed to allow experimental developments with temporary regulatory alleviation. The approach is powerful in enabling complex initiatives that span multiple societal areas and include
several stakeholders. For innovative complex bio-based initiatives, these areas may be able to provide impetus.

Regulatory adaptation

49. Legislative frameworks cannot follow the pace of the newest technological advancements. Markets for new bio-based products can be supported by adapting regulations, both within the regional authorities and by collaborating with the federal authorities on, as examples:

- Food regulations, to include opportunities for bio-based ingredients made from organic waste streams
- Municipal solid waste treatment, to incentivise new technologies that derive higher value from MSW compared to the standard solution of composting
- Regulations for organic waste combination and usage, to improve the market primary resources made from waste for high value applications. At the moment, circular solutions that derive high value components from waste streams cannot be used in food or feed products as they remain defined as waste.

Financing initiatives

50. It remains difficult to find finance for new initiatives corresponding to different phases of development, in particular for pilot infrastructure and industrial development. Public venture capital is available in Flanders, but these institutions are not attuned to the specific working conditions of bioeconomic ventures. The additional risks involved in the creation of downstream value chains, the large number of partnerships, or the environmental restrictions, mean that new projects are valued less than other industrial ventures.

1.4. Overall Conclusions

51. The bioeconomy in Flanders is an active community of industrial actors, start-ups, research groups and knowledge centres. Based on the historical economic activity in wood-based products and agro-food, new initiatives have sprung up and the initial formative years of the bioeconomy seem to have given way to a new phase where more complex technologies and value chains will be created.

52. The policy framework should also adapt to this new phase of development. The main conclusion is that generic policy instruments are not applicable any more as the diversity of solutions and technologies increases sharply. More targeted instruments and actions are necessary, requiring a more flexible policy framework. At the same time, closer interaction between policy makers and local stakeholders has to be created. This interaction should enable all stakeholders to identify the emerging niches in the sector, and to design targeted actions to enable their development.

53. The sector should also investigate options to structure itself more coherently. A better network can provide visibility, increased synergies and faster development. Also international partners may be better guided by a central structure in order to speed up international collaboration and project proposals.
2. Canada

2.1. Country position and policies for bio- and circular economies

2.1.1. Definitions of bio- and circular economies

54. In a working definition used by the federal bioeconomy policy community, “bioeconomy” is described as economic activity generated from the production of innovative non-conventional products, including bioenergy, from biomass using novel processes (e.g., industrial biotechnology, synthetic biology). “Bioeconomy” is also referred to as “advanced bioeconomy” to distinguish it from “traditional bioeconomy”, i.e., all economic activity generated from the production of food, energy, products and services from biomass. The “traditional bioeconomy” definition includes agriculture, forestry and marine products but excludes those products and services that fall within the “advanced bioeconomy”.

55. The concept of the “circular economy” is beginning to be adopted in Canada, particularly in the province of Ontario with its recent Strategy for a Waste-Free Ontario: Building the Circular Economy. The Waste-Free Ontario Act, enacted by the Government of Ontario in 2016, provides the following definition: “circular economy” means an economy in which participants strive, (a) to minimise the use of raw materials, (b) to maximise the useful life of materials and other resources through resource recovery, and (c) to minimise waste generated at the end of life of products and packaging. “Resource recovery” is further defined as the extraction of useful materials or other resources from things that might otherwise be waste, including through reuse, recycling, reintegration, regeneration or other activities.

56. Interestingly, mirroring recent discussions in other countries, the federal bioeconomy policy community and the Canadian bioeconomy community at large are also beginning to explore the concept of a “circular bioeconomy”, recognising that the bioeconomy and circular economy can in fact be complementary to one another.

2.1.2. Main priorities and drivers for transition to bio- and circular economy

57. Mitigating climate change, and growing an innovative and clean economy are among the key priorities for the Government of Canada that are creating opportunities to grow Canada’s bio- and circular economy. At an international level, Canada has demonstrated its commitment to these priorities by, for example, signing on to the Paris Agreement on Climate Change, and participating in Mission Innovation. At a national level, Canada has been acting on its commitments through several measures that collectively could be summarised as “Canada’s clean technology plan, investments and innovations for a clean growth future”. The “Innovation and Skills Plan”, announced in 2017, is also focused on making Canada a global centre for innovation and creating a world-leading clean economy. Recent measures that are helping drive the transition to a bio-circular economy include the following.

Investments in clean technology R&D and innovation, commercialisation, and deployment/adoptions

58. Since Budget 2016, the Canadian government has been making strategic and significant investments focused on supporting clean technology, and growing an innovative and clean economy. For example, Budget 2017 announced more than CAD 2.3 billion to
support clean technology in Canada and the growth of Canadian firms and exports. Particular initiatives being supported by these investments include: clean technology research, development and demonstration and the adoption of clean technology, including in Canada’s natural resources sectors; green infrastructure (e.g., alternative fuelling networks); development of a clean technology data strategy to inform decision-making, improve knowledge and foster innovation; and creation of a Clean Growth Hub to streamline client services, improve federal programme coordination, enable tracking and reporting on clean technology results across government, and connect stakeholders to international markets.

Pan-Canadian Framework on Clean Growth and Climate Change

59. This was developed in collaboration by the federal Prime Minister, provincial and territorial premiers, and the Indigenous Peoples, and was adopted in 2016. The framework outlines Canada’s plan to meet its 2030 greenhouse gas (GHG) emissions reduction target, grow the economy, and build resilience to a changing climate. The four main pillars of the framework are: pricing carbon pollution; complementary measures to further reduce emissions across the economy; measures to adapt to the impacts of climate change and build resilience; and actions to accelerate innovation, support clean technology, and create jobs. One of the actions is specifically to identify opportunities to produce bioenergy, renewable fuels and bioproducts.

Clean Fuel Standard (CFS)

60. In 2016, the Canadian government announced that it would consult with provinces and territories, Indigenous Peoples, industries, and non-governmental organisations to develop a CFS to reduce Canada’s GHG emissions—30 million metric tons of annual reductions by 2030—through the increased use of lower carbon fuels, energy sources and technologies. The CFS is intended to be a performance-based approach that would incentivise the use of a broad range of low-carbon fuels, energy sources and technologies, and will apply to all fuels (liquid, gaseous and solid) used in transportation, industry and buildings. The regulatory framework for the CFS was released in 2017, and further regulatory design and development of the CFS are ongoing.

61. It should be noted that the provinces and territories have also been taking actions to support clean technology and clean growth, and that federal investments are intended to supplement and accelerate their investments. Taking into account their particular priorities, circumstances and strengths, the provincial and territorial governments have identified multiple areas for potential partnerships with the federal government, and as set out in the Pan-Canadian Framework on Clean Growth and Climate Change, the governments are committed to continue working together closely.

2.1.3. Existence and main content of relevant strategies/visions/roadmaps

62. Although Canada currently does not have a comprehensive national bioeconomy strategy1, the federal government does have a history of supporting the development of Canada’s emerging bioeconomy through policies and programmes that have largely been coordinated within departments. With Agriculture and Agri-Food Canada (AAFC) and Natural Resources Canada (NRCan) being among the leading federal players in the bioeconomy, support for the bioeconomy has tended to focus on specific sectors (e.g.,

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1 Since the time of writing of the case study, Canada has released its national bioeconomy strategy.
agriculture and forestry). More recently, however, given the current government-wide priorities and commitments to clean technology and a clean growth economy, AAFC, NRCan, and other federal departments/agencies, together with stakeholders in the Canadian bioeconomy community, have begun collaborating on national initiatives that could help develop and grow the Canadian bioeconomy.

**A Forest Bioeconomy Framework for Canada**

63. Developed by the Canadian Council of Forest Ministers (CCFM) in consultation with a wide range of stakeholders, the framework was unanimously endorsed by the CCFM in 2017. Given that it also aims to help meet other priorities (including the objectives of the Pan-Canadian Framework on Clean Growth and Climate Change, clean technology innovation, green infrastructure, and green job creation), the framework has been well-received not only by forestry sector stakeholders, but by the Canadian bioeconomy community as a whole. The framework outlines a comprehensive approach to stimulating new economic activity by converting sustainably managed renewable forest-based resources into value-added products and services using novel and repurposed processes. The vision behind the framework – “Canada will be a global leader in the use of forest biomass for advanced bioproducts and innovative solutions” – rests on four pillars: Communities and relationships; Supply of forest resources and advanced bioproducts; Demand for advanced forest bioproducts and services; and Support for innovation.

64. The Canadian bioeconomy community is now looking to leverage this framework, together with previous and ongoing work with the agricultural sector, to develop a national and cross-sectoral bioeconomy strategy. The BioDesign Consortium, a cohort of industry, research and association stakeholders focused on accelerating Canada’s bioeconomy (and whose leadership includes Bioindustrial Innovation Canada, the feature organisation in this case study), has just launched consultations to develop such a strategy.

**Clean Technology Data Strategy²**

65. In 2017, as part of its commitment to the Pan-Canadian Framework on Clean Growth and Climate Change, the Canadian government announced the establishment of a Clean Technology Data Strategy to foster innovation, improve knowledge in the private sector and stakeholder communities, and help inform future government decision-making. The strategy aims to provide enhanced clean technology data comprising aggregate survey and macroeconomic data produced by Statistics Canada, supplemented by industry-level data (company-level characteristics) that can provide further information about the clean technology economy. The strategy also aims to develop standards and guidelines in an effort to move toward aligning various data sources with Statistics Canada data and with each other.

**Roadmap for the Development of a Biojet Fuel Industry in Canada**

66. Given recent analyses of trends in the biojet fuel world, federal departments with interests in biojet fuel recognised that there was a clear need to develop a more integrative approach to support the development and future growth of a biojet fuel industry in Canada.

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In 2017, NRCan initiated and took the lead on this project by commissioning an internal report on a biojet fuel roadmap. The report includes recommendations on how Canada can better coordinate its activities to support the development of a domestic biojet fuel industry, as well as short, medium and long-term (2030-2050) strategies to develop a biojet fuel roadmap for Canada. NRCan in collaboration with other federal departments are now evaluating the different options and consulting stakeholders on the future of biojet fuel. The roadmap and the supporting strategies can also be leveraged by the Canadian government to support bioeconomy strategies more broadly and the transition to a low-carbon economy.

Innovation Business Development Strategy for Clean Technology

67. Launched in 2018, this strategy was designed to encourage and support Canadian firms in their efforts to capitalise on growing opportunities in the global market for clean technology. The strategy will be delivered through Canada’s Trade Commissioner Service and will position 15 new trade commissioners in key global hubs. Activities that the strategy will deliver include: establishing a new Climate Finance Business Development team comprising climate finance trade commissioners; participating in Canada’s Clean Growth Hub to offer improved and streamlined services to clean technology firms; and launching Cleantech Global, a domestic outreach campaign to increase clean technology firms’ understanding of and access to, a growing number of Government of Canada programmes and services that are available to support their international business development needs.

68. With regard to a circular economy strategy, Canada does not yet have an integrated, comprehensive circular economy strategy, but as mentioned earlier, the province of Ontario is leading the way: in 2017, the Government of Ontario announced its Strategy for a Waste-Free Ontario: Building the Circular Economy. The reasons for Ontario’s push towards a circular economy include: to protect the environment; to help Ontario businesses stay competitive; and to drive innovation and accelerate collaboration globally and across sectors. The strategy lays out Ontario’s vision for a circular economy (“waste is seen as a resource that can be recovered, reused and reintegrated to achieve a circular economy”), and the goals (“to achieve a zero-waste Ontario and zero greenhouse gas emissions from the waste sector”), as well as the actions to achieve the vision and goals. The strategy also sets out three interim goals for waste diversion: 30% diversion rate by 2020, 50% by 2030, and 80% by 2050. It is interesting to note that, although energy from waste and alternative fuels are permitted as waste management options, these methods will not count towards diversion in Ontario. The recovery of nutrients, such as digestate from anaerobic digestion, is considered diversion.

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4 E.g., AAFC; Transport Canada; Department of National Defence; National Research Council; Innovation, Science and Economic Development Canada; etc.


2.2. Description of case study value chain

2.2.1. Name and key features of focus organisation

69. The Sarnia-Lambton Hybrid Chemistry Cluster began as an evolution of the traditional petrochemical industry. Knowing that diversification of the area was necessary so that growth would continue, Bioindustrial Innovation Canada (BIC) was formed to facilitate this change. As a government funded non-profit organisation, BIC is well-positioned to provide critical investment, advice and services to early-stage companies with clean, green and sustainable technologies. This case study will focus on the role that BIC and other partners played in growing the Sarnia-Lambton Hybrid Chemistry Cluster.

2.2.2. Type of biomass being refined, main biomass suppliers, refining techniques

70. The economy in Sarnia-Lambton has traditionally been agriculture and petrochemical based. These assets have been pivotal in growing a bioeconomy from these industries. The major biomass opportunity in Sarnia-Lambton is agricultural residue from the cash-crop industry present in Lambton county. These agricultural residues include corn stover, the field residue left after corn harvest, and wheat straw, a similar residue to stover from the wheat harvest. These biomass products are supplied entirely by the farmers who grow them. However, creating the supply chain was an effort involving many organisations which resulted in the formation of biomass supply cooperatives.

71. Woody biomass is also available in lesser quantities. It is primarily supplied by from construction and demolition wood and other recycled sources. The members of these cooperatives commit a minimum amount of acreage and biomass. The cooperative then provides the agricultural residue to the off-takers, in these cases a member of the Sarnia-Lambton Hybrid Chemistry Cluster. Refining is done by these off-takers who have many different conversion technologies. Hydrolysis, gasification, pyrolysis, enzymatic processing, and catalytic reforming are examples of the technologies used in the Sarnia-Lambton Hybrid Chemistry Cluster to convert biomass to higher value-added products.

2.2.3. Types of products/processes/services being developed

72. The products and processes vary widely in the developing cluster. A key focus is the biofuel industry, a clear pivot from the petrochemical industry that was the basis for the regions initial growth. Ethanol, cellulosic ethanol, biodiesel, biocrude, and renewable natural gas are seen as valuable products that can be produced in the region. The food ingredient and food packaging industries are also being targeted by developments in the Sarnia-Lambton bioeconomy. Transformation of cellulosic biomass to dextrose for fermentation to biochemicals and the conversion of biomass to intermediate biochemicals for the production of bio-based polyethylene terephthalate (PET) bottles are good examples.

2.2.4. Main ecosystem companies, type of companies and relationship with these

73. Sarnia-Lambton provides a number of important benefits for the development of the Hybrid Chemistry Cluster. Petrochemical companies in the region have a long history of collaboration as they partner with colleges and universities around Sarnia-Lambton for access to more highly qualified personnel. Industrial partners in the area contribute skilled labour, industry experience, and ongoing education and training. The Industrial Education
Cooperative offers training for a variety of skills that are well respected by the industry that includes confined space, forklift operation, safety training, WHMIS, respirator fit, and site-specific training for the companies in Sarnia-Lambton. The Sarnia-Lambton Environmental Association is a cooperative agreement between 20 companies in the Sarnia area to monitor and control the environmental conditions. The implementation of this cooperative in 1952 has led to more careful and cautious monitoring of the Sarnia-Lambton environment and has improved the quality of the region’s air and water over the years in all measured pollutants. The Community Awareness and Emergency Response (CAER) organisation has developed an alert system to ensure the safety of the community is always a focus for the industry. Citizens and workers will be alerted by CAER if there are dangers or risks to the public. These associations advocate for the advancement of Sarnia-Lambton and are important elements of the industrial ecosystem.

74. There are many other factors drawing companies to the Sarnia area, including: the existing infrastructure at TransAlta, Arlanxeo, and other sites; the highly qualified personnel and training potentials; and the network of contractors, consulting agencies, and logistics coordinators.

75. The first company to start the shift from petrochemicals to bio-based products was Suncor with the construction of their 400 million litre/year first generation ethanol plant in Sarnia-Lambton. Constructed in 2006, Suncor Ethanol uses 20% of the Ontario corn crop to produce ethanol for gasoline blending. It is one of the largest biofuel plants by volume in Canada and was the start of the shift from a petrochemical industrial valley to a Hybrid Chemistry Cluster in Sarnia-Lambton.

76. In 2015, BioAmber selected Sarnia-Lambton for the location of their first commercial production facility. These assets were an initial draw for BioAmber, a company that developed a fermentation process to produce the world’s first biosuccinic acid from glucose. Using a proprietary yeast for the process, it was determined that BioAmber could produce a bio-based product that could compete in the market with oil-based succinic acid.

77. Supply of glucose to BioAmber was identified as a gap in the supply chain and a business case study was developed to build a supply system. The use of cornstalks and other crop residues from the Sarnia-Lambton area as the feedstock for the bioindustrial production of cellulosic sugar was examined as well as the impact and viability of the collection of crop residue from the farm. A sustainable method of removal was needed so that sufficient nutrients remained in the fields and that providing the feedstock was economically viable for the farmers. The case study determined that:

- There is a suitable amount of crop residue for supply in the 4-county area around Sarnia-Lambton
- There are benefits to the farmers for joining the Cooperative, including earlier planting, extra revenues, and diversification
- The cellulosic sugar producer and off-takers would have a much lower greenhouse gas intensity rating than traditional sugar production.

78. Knowing that a farmers’ cooperative was viable, the Cellulosic Sugar Producers Cooperative (CSPC) was formed and the selection process for a technology provider was started. Nineteen potential technologies were identified, and careful examination and study of each company was performed. Comet Biorefining was selected as the preferred partner by the CSPC based on recommendation from BIC. Comet is currently set to become the third bioindustrial process constructed in Sarnia-Lambton. The Comet process uses
enzymatic hydrolysis to convert corn stover provided by the CSPC to glucose, hemicellulose, and lignin products. Glucose is the primary focus of Comet, being the highest value product and most versatile. They are developing applications for lignin as well.

79. Glucose is used as both a finished product and a feedstock for additional products. Members of the Sarnia-Lambton Hybrid Chemistry Cluster use glucose in fermentation reactors, such as BioAmber, Suncor Ethanol, Greenfield Ethanol, and IGPC Ethanol. The utility of glucose supply for biochemical fermentation, in BioAmber’s case, or biofuel fermentation, as with Suncor, Greenfield and IGPC, strategically positions Sarnia-Lambton for the growing world bioeconomy.

80. More supply chains have also started emerging in the Sarnia-Lambton Hybrid Chemistry Cluster since the announcement of Comet and the CSPC. Origin Materials is also using cellulosic biomass as a feedstock and could work with the CSPC as another off-taker of farm residue. Their technology also has the flexibility to use wood products and so can be fed from multiple markets. Origin will also be the first company in the Sarnia cluster to produce advanced biochemical intermediates that can be used to produce PET. This is the most used plastic in the world and the bio-based form of the plastic has received interest from Nestle, Danone, and Pepsico to create the NaturAll Alliance for production of a 100% bio-based water bottle.

81. Further farm-based sugar supply is being investigated by the Ontario Innovative Sugarbeet Processers Cooperative (OISPC). The proposed cooperative would grow 30 000 acres of sugar beet crops, build a processing facility for sugar conversion, and sell the sugars directly to chemical conversion processes. Sugar beet processing is a well-known industry, with many farmers in the cluster area currently supplying sugar beets to the Michigan Sugar Company, another cooperative. With this knowledge already in the area, expanding to a Canadian-based cooperative would be supported, as the demand for finished sugars increases for the chemical and biochemical industry. These sugars could be sold in the same way that Comet products are, directly to manufacturers without further refinement, adding more raw material assets to the Sarnia-Lambton Hybrid Chemistry Cluster value chain.

2.3. Ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

2.3.1. Potentials for utilising biomass across a broader range of industries/sectors/higher value-added sectors, drivers to achieve these potentials

82. In Sarnia-Lambton, a market has been established for agricultural residues. It has been determined that approximately 1 million combined tonnes of corn stover and wheat straw could be sustainably harvested from the four counties closest to the Sarnia-Lambton Hybrid Chemistry Cluster. This is shown in Figure 1 below, excerpted from the 2013 report “Development of a Business Case for a Cornstalks to Bioprocessing Venture”.

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7 Development of a Business Case for a Cornstalks to Bioprocessing Venture, 2013. Duffy, R. Marchand, L.
Comet Biorefining plans to take advantage of this plentiful biomass for conversion to cellulosic sugars. The CSPC has been growing steadily and will soon begin harvesting biomass for use within the Sarnia-Lambton Hybrid Chemistry Cluster. Origin Materials’ technology can also be fed with agricultural residues to produce biomaterials. Currently, Origin has set construction and demolition wood waste as the initial feedstock for their first plant. This plant will be flexible and feedstock-agnostic, able to use any cellulosic material.

Ontario also has large supplies of a variety of biomass that could be used in value-added processes. Eastern and Northern Ontario are rich in wood sources, currently used in the construction, paper, and other industries. There is potential and traction in these areas to begin using biomass for higher value production of industrial chemicals and materials. An example of this is Woodland Biofuels. This company has a demonstration facility operating at the Western Sarnia-Lambton Research Park, and it uses wood from the construction and demolition industry as a feedstock to produce cellulosic ethanol. With their proprietary methods, Woodland claims to be producing the lowest cost fuel in the world, verified by AMEC Foster Wheeler. This is a potential high-value market shift for Eastern and Northern Ontario, with the possibility to develop a cluster around an anchor company using wood biomass similarly to Woodland Biofuels. Creating value for potential feedstocks is critical to development and innovation in clusters. Wood can also be utilised in the project plans of Comet Biorefining as an alternate feedstock and Origin Materials as the current primary feedstock.

Examples of ongoing biomass refining/utilisation experiments/ventures and related new cross-industrial collaborations to diversify to new business areas, foreseen economic or other impacts of these

The diversification of Sarnia-Lambton began with the shift from an entirely petrochemical based industry sector to a hybrid model which included bio-based products.
Biomass-fed and bio-based chemical production facilities have begun shifting the focus of the Sarnia-Lambton region.

86. The established bio-based companies in the Sarnia-Lambton Hybrid Chemistry Cluster have secondary markets they are interested in developing. Comet Biorefining, whose focus is producing high dextrose syrup, also makes co-products that can serve other markets. The hemicellulose syrup that is created through the cellulosic sugar process is made up mostly of C5 sugar and is very energy-dense. It can be used as part of an animal nutrition plan to maintain animal health.

87. Origin Materials is focused on creating chloromethylfurfural (CMF), which can be a building block for PET plastic. However, the coproduct, hydrothermal carbon (HTC) is produced and can be used as a replacement for carbon black in plastic applications and composites for applications in industries such as automotive and aerospace. This is expected to encourage progress in the advanced material sector and further advance the supply of materials coming from Sarnia-Lambton.

88. Collaboration in-between the new industries in Sarnia-Lambton and the existing infrastructure have been important to forming the cluster in the area. With access to land, utilities, personnel, and expertise, many concerns that would come with quick growth have been avoided. Transalta, who own and operate a 500 MW steam turbine power station, and Arlanxeo, a producer of butyl rubber, have been vital to expansion, offering start-up companies land and facilities for construction of first-of-kind production facilities. Having this infrastructure available removes barriers for these companies and repurposes land and resources that were under-utilised. Construction on brownfield land can reduce mobilisation and capital costs for start-ups, and access to behind-the-fence utility costs lower operating costs.

2.3.3. Examples of need for/already tested/new business models to facilitate extension/collaboration/diversification

89. For successful cluster development, cooperation and collaboration along the supply and value chains are essential. Two examples within the Sarnia-Lambton Hybrid Chemistry Cluster are the agricultural cooperative structures of the CSPC and the OISPC. These cooperatives enable the producers of feedstock to become direct participants in the ownership of projects along the supply chain. Collaborating along the supply chain reduces risk, guarantees supply, and improves returns for the cooperative members and their industry partners. An anchor company, with a partner cooperative supplying feedstock, will find it easier to gain financing and accelerate their progress towards successful commercialisation. Business accelerators and funding agencies support this process, by encouraging collaboration and potentially providing funds to de-risk commercialisation.

2.3.4. Relevance of circular economy solutions and viewpoints for extending value chains and diversifying to new business areas

90. Circular economy solutions are emerging in Sarnia-Lambton. As part of the first wave of growth of the Canadian bioeconomy, it is important that the local cluster shows that it is committed to sustainable growth and resource replenishment. For example, the CSPC is harvesting biomass from farmer fields that has historically not been removed. This biomass is being used by Comet Biorefining to produce cellulosic sugars. As part of the Comet process, the wastewater produced is rich in organics and cannot be processed in standard wastewater treatment without incurring excessive costs. Comet requires anaerobic digestion to treat the wastewater, which can be a circular solution to the area. Anaerobic
digestion of the wastewater will eliminate the high organic loading, as well as generate a stream of renewable natural gas and an organic fertilizer. The renewable natural gas can be used to offset higher carbon intensity natural gas usage in the pipeline, and the fertilizer can be used by the CSPC to return organic matter and nutrients back to their fields after harvest.

91. With Origin Materials positioned to produce bio-based PET for plastic bottles and packaging applications, expanding recycling centres in the Sarnia area would create a circular economy setting for plastics. This could improve market traction and adoption for the bio-based plastic as the renewability of plastics becomes a larger focus for society.

2.3.5. Examples of how policies, agencies and their specific instruments have facilitated extension/ collaboration/ diversification

92. BIC has spent nine years building the Sarnia-Lambton Hybrid Chemistry Cluster and assisting other companies across Southern Ontario. This initial work was supported through CAD 15 million of funding from the Federal government’s Natural Science and Engineering Research Council (NSERC) and its Centres of Excellence for Commercialization and Research (CECR) Programme. BIC’s track record of job creation and investments in Ontario has been significant with over 3,600 jobs created. To date, CAD 11 million has been invested in 20 early stage companies through the Sustainable Chemistry Alliance (SCA) Investment Fund. These investments have leveraged CAD 215 million of non-governmental investment funds and more than CAD 500 million of follow-on investment.

93. In 2016 through CAD 12 million in support from the Federal Government’s Investing in Regional Diversification Program and CAD 3 million from the Province of Ontario’s Ministry of Economic Development, Job Creation and Trade, BIC expanded its business support model and accelerator capability with the launch of the CAD 27 million Centre for Commercialisation of Sustainable Chemistry Innovation (COMM SCI). COMM SCI is a hub for the commercialisation of bio-based and sustainable chemistry-based innovation, providing business and technical support to participating SMEs. COMM SCI services provide participating companies expert training, mentorship, and access to risk capital for technology demonstration and scale-up.

94. Beginning in 2019, the Ontario Bioindustrial Innovation Network (OBIN) will be an evolution of the successful COMM SCI programme. This plan has 3 key focus areas.

1. Support the development of two additional clusters in southern Ontario. BIC will use its funding and provide its advice, services, knowledge and experience and apply it regionally to develop high performing clusters that generate jobs, create economic value and build low-carbon clean technology companies with reduced environmental impact. This will include utilising COMM SCI projects and investments as tools for growth.

8. Build stronger hybrid chemistry value chains in southern Ontario by identifying and addressing value chain gaps. BIC will accelerate low-carbon clean economic growth and support competitive technology companies to grow to global scale in southern Ontario by building robust raw material supply chains, by leveraging regional and global partners along the value chain to strengthen market pull and by removing barriers to commercialisation through COMM SCI projects.
9. Invest in emerging low-carbon companies to commercialise and assist businesses to increase scale and become world-class players through the Sustainable Chemistry Alliance (SCA) Investment Fund through COMM SCI investments.

95. The focus for industry growth will shift towards market pull with continued supply push. Building connections with existing companies or finding novel companies to fill gaps will become necessary to make new and existing clusters sustainable. This becomes increasingly important with the addition of new value chains.

96. OBIN will enable BIC to continue to support economic development across Southern Ontario and is projected to create significant outcomes over the next five years of activity in rural communities (project timeline: April 2019 – March 2024). Jobs will be created with early stage companies commercialising clean, green and sustainable technologies and are expected to be stable, long-term and highly skilled. Based on BIC’s track record of job creation and investments in Ontario, OBIN expects to create 600 direct jobs and retain an additional 100 direct jobs over the five years. While direct jobs are important, indirect and construction jobs provide significant benefits. Indirect jobs will be created in engineering, logistics, R&D, sales and service, supply chains and downstream value chains. It is projected that 3,000 indirect jobs and 1,800 FTEs of construction work will be created through implementation of successful commercialisation projects over the five years.

97. Working alongside partner organisations, BIC is exploring opportunities in growing additional clusters in Ontario. BIC has begun the process in Leeds-Grenville and intends to establish an eastern office for BIC communication and coordination. Interacting directly with local industry partners, BIC will extend the model that has been successful in Sarnia-Lambton and apply it to the specific needs of Leeds-Grenville. A report was composed with BIC’s support that laid out a blueprint for successful cluster development. This report, “Key Aspects of Developing a Cluster, a case study of Sarnia-Lambton’s Hybrid Chemistry Cluster and Saskatoon’s Agriculture Biotechnology Cluster”, gives a basis for the efforts planned to develop new clusters. OBIN will assess the opportunities within Ontario to determine which cluster locations have the best opportunity for success. Strengths of these locations will become the basis to build successful clusters. Weaknesses will be identified, and strategies will be developed to address these weaknesses. There may be opportunities in these clusters to work with rural, remote and Aboriginal communities. The strategies to leverage the strengths identified and to address the weakness will become the implementation blueprint for each cluster location.

98. A critical component of building successful clusters is training and maintaining highly qualified personnel and the advancement of science and technology. Colleges & Universities (C&U) are the cornerstone for innovation and must be engaged to effectively build long-term sustainable technology clusters. For example, Western University was an integral partner to enable the creation and successful implementation of the BIC Centre of Excellence for Commercialization and Research (CECR). Since then, Lambton College has partnered effectively with BIC in the Sarnia-Lambton Hybrid Chemistry Cluster to provide valuable applied research and development capability through its five research “Centres of Excellence” that cluster companies leverage to reduce barriers to commercialisation (e.g., optimise process technologies, obtain skilled human resources, improve competitiveness). Creating partnerships between C&U and cluster companies is critical to reduce the barriers to commercialisation.

99. BIC has developed a number of strong international collaborations since its inception (e.g. Biobased Delta (BBD) in the Netherlands, Bio-based Pilot Plant Europe in
Belgium, CLIB2021 in Germany, VITO in Belgium, Michigan Biotechnology Institute (MBI) at Michigan State University and Queensland University of Technology (QUT) in Australia). BIC will work with Canadian C&U to establish international collaborations. Through these collaborations, C&U will have access to global technologies and knowledge to strengthen their research capabilities which will enable accelerated commercialisation of technologies in Canada. In addition, there will be experiential learning opportunities for youth to develop highly qualified persons through student exchanges and collaborative international research activities.

100. The Federal Government also supports internal research agencies such as the AAFC Research Stations, the National Research Council (NRC) and FPInnovations. BIC and the Network partners will continue to strengthen relationships with these groups and leverage the capabilities of these organisations to accelerate commercialisation of emerging technology companies.

2.3.6. Challenges related to extension/collaboration/diversification in general, specifically related to the regulatory/institutional regime

101. Building and strengthening value chains within Canada has been a focus of BIC since its inception in 2008. BIC has been facilitating these activities and building collaborations between industry, academia, and government. These collaborations have allowed companies to find synergies within the cluster which have helped establish supply chains, reduce costs and strengthen market links. Although this was not enabled by direct regulation from the three levels of government (municipal, provincial, federal), the various governmental funding sources for BIC was critical for removing these barriers to commercialisation. This funding remains an integral part of ongoing developments to extend and further strengthen value chains.

102. Recognising that an efficient and predictable regulatory system can not only protect health, safety, security and the environment, but also help promote innovation and economic growth, the federal government has recently launched consultations to review and modernise Canada’s regulatory system\(^8\). The goal is to make the Canadian regulatory system more agile, transparent and responsive, so that businesses can explore and act on new opportunities. Targeted regulatory reviews are exploring ways to reduce barriers to innovation, economic development, and investment in the Canadian economy, and help ensure that the Canadian regulatory system can accommodate emerging technologies and businesses. To begin, the targeted reviews will examine regulatory requirements and practices in three key sectors: agri-food and aquaculture, health/bio-sciences, and transportation and infrastructure.

103. The targeted reviews will focus on identifying and addressing regulatory irritants and bottlenecks to innovation, competitiveness, and economic growth. The Canadian government also proposes to streamline legislation to reduce the regulatory burden faced by businesses. Given the lens of economic growth and competitiveness on this review, the consultations give an opportunity to provide tangible examples of existing regulatory requirements or practices that impede economic growth, competitiveness, or the adoption of existing and emerging technologies.

2.4. Overall synthesis of findings

2.4.1. Main highlights, policy issues and findings from the case study

104. The bioeconomy in Canada is centred around the innovative use of biomass for production of non-conventional products. Also referred to as the “advanced bioeconomy” to distinguish from traditional bioeconomy practices such as agriculture, forestry, and marine products. Canada, and the provinces, are beginning to focus on creating a circular economy to move towards waste-free societies. Ontario, for example, has enacted the Waste Free Ontario Act to begin this transition where resource recovery, minimisation of raw material use, and minimisation of end-of-life waste are the key elements of the circular economy.

105. Creating a bio-based and circular economy in Canada is driven by the goals to meet climate change limits and develop new and innovative economies in the country. Demonstrated by the signing of the Paris Agreement and through national level action plans, Canada is setting an example of changing the systems currently used in the country.

106. Part of Canada’s ongoing work is creating a national comprehensive bioeconomy strategy. National initiatives have been developed by governmental organisations and are supported by federal players. It is expected that work on these will transition to a national strategy and be examples of how to create the national framework. Ontario’s efforts in waste-free development are also being used as examples of how to set goals and maintain economic advantages.

107. The Sarnia-Lambton Hybrid Chemistry Cluster is a story of diversification and collaboration. Beginning with Suncor developing a corn ethanol facility, the cluster has since expanded. With two constructed commercial plants, three planned commercial plants, and many interested parties at a variety of stages ranging from concept to pilot, Sarnia-Lambton has become a centre for collaboration and innovation of industrial products. The key pieces leading to this are the availability of feedstock, either biological or chemical, industry collaboration, and existing infrastructure.

108. Feedstock availability in the region is split between agricultural residue from farmland, construction and demolition material used in the area and traditional petrochemical feedstock and associated chemicals. The new companies choosing to locate to Sarnia-Lambton are focusing on renewable materials more than petrochemicals, showing the shift towards a bioeconomy. BioAmber entered the cluster to create a bio-based alternative to the traditionally petrochemical based succinic acid by fermenting sugar with a proprietary yeast. BioAmber entering the cluster began the formation of other cluster members, such as the CSPC and Comet Biorefining. The cluster has since found success attracting further bio-based and sustainable companies, such as Origin Materials, Benefuel, and Woodland Biofuels.

109. Bioindustrial Innovation Canada was formed to facilitate industrial collaboration and help remove barriers to commercialisation for early stage companies. Industry collaboration was seen as an important step in creating a viable ecosystem for new companies to grow and for the existing companies to diversify their business interests. With the world slowly shifting away from fossil fuel resources, many existing companies are looking at being a part of sustainable business ventures. BIC is assisting with this shift, helping to bridge communication in the cluster, facilitate improvements and diversification.

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9 Now published.
and provide funds to early stage companies. Industrial support of this type is critical to the success of the cluster.

110. Sarnia-Lambton has all the infrastructure required to help new companies streamline their start-up process. With brownfield land available that has close connection to water, power, natural gas, steam and water treatment, it is much easier to establish a plant compared to greenfield construction. Industry partners in Sarnia-Lambton, namely Transalta and Arlanxeo, have been key in coordinating the use of this land and assisting early-stage companies in becoming established.

111. The above, along with other factors, have positioned Sarnia-Lambton as a high-growth location for the bioeconomy. Clusters in the style of the Sarnia-Lambton Hybrid Chemistry Cluster would likely find success, and it is the goal of BIC to establish two more clusters under the OBIN program, expected to begin in 2019.
3. The People’s Republic of China (hereafter “China”)

3.1. Country position and policies for bio- and circular economies

3.1.1. Definitions of bio- and circular economies

112. Although the concept of the bioeconomy has not been officially defined by Chinese governments, the contents of bioeconomy have been mentioned a lot in Chinese strategy documents such as 13th Five-Year Plan (FYP) (2016-20) on Bioindustry Development. In the Chinese context, bioindustry particularly covers the health sector (including biopharma and biomedicine), agriculture, manufacturing and bioenergy.

113. Circular economy, as defined in the Circular Economy Promotion Law of the People's Republic of China, “is a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption.” The term “reducing” refers to reducing the consumption of resources and the production of wastes in the process of production, circulation and consumption. The term “reusing” refers to using wastes as products directly, using wastes after repair, renewal or reproduction or using part or all wastes as components of other products. The term “recycling” refers to using wastes as raw materials directly or after regeneration.

3.1.2. Main priorities and drivers for transition to bio- and circular economy

114. In the 13th FYP on bioindustry development issued by the National Development and Reform Commission (NDRC) in 2017, it is clearly stated that by 2020, the scale of the bioindustry will reach CNY 8 to 10 trillion, and the added value of the bioindustry will account for more than 4% of GDP. It is anticipated to become the leading industry of the national economy. Innovation in agriculture and food production remains a key priority. In the area of bioenergy, the focus is on promoting non-food biomass for electricity, biofuels and heating. The strategy plans further emphasise the promotion of environmental and recycling technologies to improve water and soil quality, foster circular production, reduce carbon emissions and protect biodiversity.

115. In the first 20 years of this century, China will be in the stage of accelerating industrialisation and urbanisation, and the resource and environmental situation is very serious. In order to seize the important strategic opportunity period and realise the strategic goal of building an affluent society in an all-round way, it is necessary to develop a circular economy and adopt various effective measures in accordance with the principle of “reduce, reuse, and recycle” to minimise consumption of resources. With the lowest environmental cost, the largest economic output and the least waste discharge, China has to take effective measures to achieve the integration of economic, environmental and social benefits, and the construction of a resource-saving and environment-friendly society.

3.1.3. Existence and main content of relevant strategies/visions/roadmaps

116. Since the 1980s, China has successively issued a series of laws and regulations, comprehensive policies, industrial policies, economic policies, and related environmental policies on circular economy. Laws and regulations are legal protection and play supporting role in the development of circular economy. These include the Cleaner Production Promotion Law, the Energy Conservation Law, the Circular Economy Promotion Law. Many of them include, or are related to, the bioeconomy, especially in the area of agriculture waste utilisation. Table 1 shows the major relevant bio- and circular strategies in China.
117. The National Development and Reform Commission with thirteen other governmental departments have jointly launched the Circular Development Leading Action in 2017, the goals of which are to promote: (1) the green recycling low carbon industry system; (2) the urban recycling development system; (3) a new resource strategy guarantee system as well as; (4) the green lifestyle. By 2020, the main resource output rate will increase by 15% compared with 2015, and the main waste recycling rate will reach 54.6%. The general utilisation rate of industrial solid waste reached 73%, the comprehensive utilisation rate of crop straw reached 85%, and the industrial output value of resource recycling industry reached CNY 3 trillion. 75% of national-level parks and 50% of provincial-level parks are undergoing circular transformation.

Table 1. Strategies related to bio- and circular economy in China.

<table>
<thead>
<tr>
<th>Regulation/Department/Year</th>
<th>Target</th>
<th>Current Situation and Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular Economy Promotion Law of the People's Republic of China Issued by Standing Committee of the National People's Congress in 2008</td>
<td>The purpose is to facilitate circular economy, raising resources utilisation rate, protecting and improving environment and realising sustainable development. The state encourages agricultural producers and the relevant enterprises to take advantage of advanced or applicable technologies to make comprehensive utilisation of crop straw, livestock and poultry excrements, byproducts of the agro-product processing industry and waste agricultural films, and develop and use biogas and other biomass energies.</td>
<td>The circular economy is developing quickly in China. In terms of comprehensive utilisation of agricultural and forestry waste in 2015, the annual utilisation of crop straw is about 900 million tons, the installed capacity of biomass power generation is 10.3 million kilowatts, and the annual power generation reached 52 billion kilowatt hours.</td>
</tr>
<tr>
<td>Circular Economy Development Strategy and Immediate Action Plan Issued by State Council of the People's Republic of China in 2013</td>
<td>To accelerate the promotion of resource utilisation, cleaner production, industrial chain recycling, waste treatment and resource recycling in the agricultural sector, and form a circular agricultural production mode. By 2015, the comprehensive utilisation rate of straw will increase to 80%.</td>
<td>In 2015, the comprehensive utilisation rate of straw was 80.1%.</td>
</tr>
<tr>
<td>13th Five-Year Plan on Biomass Energy Issued by National Energy Administration in 2016</td>
<td>By 2020, the annual biomass utilisation is about 58 million tons of standard coal. The total installed capacity of biomass power generation reaches 15 million kilowatts, the annual power generation capacity is 90 billion kilowatt hours; the annual utilisation of biological natural gas is 8 billion cubic metres; the annual</td>
<td>Until 2015, the annual biomass utilisation was about 35 million tons of standard coal. The total installed capacity of biomass power generation reaches 10.3 million kilowatts, the annual power generation capacity is 52 billion kilowatt hours; the annual utilisation of biological natural gas was 5 billion cubic metres; the</td>
</tr>
</tbody>
</table>
utilisation of biological liquid fuel is 6 million tons; and the annual utilisation of biomass forming fuel is 30 million tons.

annual production of fuel ethanol was about 2.1 million tons, and the annual output of biodiesel was about 0.8 million tons. In 2017, the total installed capacity of biomass power generation reached 14.88 million kilowatts, the annual power generation capacity was 79.4 billion kilowatt hours.

It is pointed out that by 2020, the comprehensive utilisation rate of crop straw has to reach 85%, and the industrial output value of resource recycling utilisation has to reach CNY 3 trillion. Until 2017, the comprehensive utilisation rate of crop straw reached 82%. Currently, the industrial output value of resource recycling utilisation is about 2 trillion CNY.

3.2. Description of case study value chain

3.2.1. Background

118. China is a traditional agricultural producer that generates huge quantities of crop straw. According to the data published by the National Bureau of Statistics of China, crop straw in China is mainly corn stalk, rice straw and wheat straw. At present, crop straw is mainly utilised in five ways, which are collectively called “five transformations”, namely transforming crop straw into raw material, substrate, fertilizer, energy and feed. Statistics show that, among China's collectable crop straw in 2015, those utilised through the “five transformations” accounted for 2.70%, 4.0%, 43.20%, 11.40% and 18.80% respectively, while the discarding or burning of the remaining accounted for 19.90% (151 million tons) resulting in severe air pollution, potential safety hazards, and a waste of biomass. It is imperative to figure out ways of utilising of straw as a resource.

119. As more effort is devoted to the development and utilisation of new energy, the technologies for energy production from straw have drawn increasingly wider attention. The technology for the production of methane and bio-natural gas (BNG) from straw with anaerobic fermentation as the core is an effective approach for processing straw and generating bioenergy.

120. In China, anaerobic fermentation technology has its origin in agriculture and rural areas. It is designed to address environmental pollution caused by agricultural waste and provide rural dwellers with clean energy. Between 2003 and 2015, the central government invested a total of CNY 38.4 billion in building household methane facilities for 41 933 000 households and 110 975 various large-scale methane projects, which produced 15.8 billion cubic metres of methane annually. Among them, 458 large methane projects used straw as the main raw material, which marked the start of the production of methane with anaerobic fermentation of straw in China. However, in the wake of accelerated new urbanisation, and change in agricultural mode of production and energy consumption by rural dwellers, the central government adjusted investment direction in 2015, which was mainly diverted to large-scale methane projects and BNG projects. Hence, China’s
development of methane in rural areas entered the new stage of “transformation and upgrade”.

121. In 2015, 2016 and 2017, the central government invested a total of about CNY 2.7 billion to support the construction of 25, 22 and 18 large BNG projects respectively. Most of these BNG projects used straw as the main raw material. The methane produced by the projects was purified and then sent into the natural gas pipe network, or used as vehicle fuel, or gas for businesses or residential use; fermented BNG residue and BNG slurry were used to produce organic fertilizer, which was applied in farmland for production of crops. In this way, these three functions, namely control of environmental pollution by straw, production of renewable clean energy and organic fertilizer were fulfilled in one process. This production system involves biological fermentation, bioenergy and biofertilizer and is a representative of the “biological circular economy”.

122. The straw to BNG industry has become an important part of China’s initiative for promoting the development of the circular economy, environmental protection and new energy development. In 2008, the State Council issued the Opinions of the General Office of the State Council on Accelerating the Promotion of the Comprehensive Utilization of Crop Straw, which states the general guiding opinions on the comprehensive utilisation of straw in China. In 2016, the National Energy Administration issued the 13th FYP on Bioenergy, which states, “to develop and utilize bioenergy is an important task for improving environment and developing circular economy”. The 13th FYP on the Development of Methane in China’s Rural Areas issued by the Ministry of Agriculture states that, by 2020, central government funds will be allocated to build 197 BNG projects. In addition, local governments have enacted supporting policies. The support from central and local governments facilitates the development of the BNG industry.

3.2.2. Name and key features of focus organisation

123. Chifeng in Inner Mongolia is an important corn-producing region. To cope with stalk processing and utilisation, Chifeng Yuanyi Biogas Technology Co., Ltd invested and developed a large-scale project (Ar Banner Project) for the ecological recycling and utilisation of BNG and organic fertilizer from straw. The project is one of the 65 BNG demonstration projects supported by the central government and a major demonstration project of the local government of Inner Mongolia Autonomous Region.

124. Founded in 2012, Chifeng Yuanyi Biogas Technology Co., Ltd is an enterprise specialising in the production and trading of bioenergy and organic fertilizer. Based on the comprehensive utilisation of agricultural organic waste, the company promotes large-scale, commercial, standardised and modular integration according to the “three-in-one” technology roadmap of “agricultural waste, clean energy and organic fertilizer”, and provides urban and rural bioenergy systematic solutions. The company has 160 employees, including 10 senior engineers and 27 engineers.

125. The total investment in the Ar Banner Project amounts to CNY 150 million, among which CNY 50 million are from the funds for national BNG demonstration projects. The project covers an area of 200,000 m², which comprises 12 fermentation tanks with unit fermentation volume of 5,000 m³; the total effective fermentation volume is 60,000 m³. Every year, it absorbs 48,000 tons of crop straw, produces 21,900,000 cubic metres of methane and 10,950,000 cubic metres of pure BNG, which are supplied to urban and rural dwellers, industrial enterprises and vehicles. It also produces over 50,000 tons of organic fertilizer for neighbouring farmer households.
3.2.3. Type of biomass being refined, main biomass suppliers, refining techniques

126. The project comprises four parts, namely a raw material collection, storage and transport system, the BNG transformation and purification system, a biogas residue and slurry fertilizer transformation system, and the system of rural distributed energy station and fuel gas transmission and distribution pipe network. This thereby forms a complete system of biological transformation and production from waste, and a value chain for the ecological recycling of crop straw (Figure 2).

Figure 2. System for the ecological recycling and production from straw.

Raw material collection, storage and transport system

127. Chifeng, located in the east of Inner Mongolia, is mainly planted with corn; in theory, the 5 560 km² of corn can produce about 4 610 000 tons of corn straw a year. Except for those that have been utilised and those that cannot be gathered, the straw available for utilisation is about 2 213 800 tons. To ensure sufficient straw for the project, a raw material guarantee system including a professional collection and transport company, the “Farm Nurse”, and the mode of product replacement, is established to ensure the supply and reasonable prices of raw materials; 60 000 tons of straw can be collected a year with the price kept at CNY 200-220 per ton.

BNG transformation and purification system

128. The system, the core of the whole project, is comprised of three parts - raw material pre-treatment, high solid anaerobic fermentation, washing and purification of methane for BNG. The raw material pre-treatment adopts enhanced hydrolysis and acidification of back-flow of biogas slurry to improve straw biodegradability and subsequent transformation efficiency significantly. The anaerobic fermentation adopts a two-stage fermentation process, and the reactor uses a complete-mix anaerobic digestion reactor. Methane is purified by washing; in the product gas, CH₄ is above 98%, CO₂ is less than 1% and H₂S is less than 10 ppm, which meet the national standard on natural gas for vehicles. The biogas residue and slurry from anaerobic fermentation first go through separation
between solids and liquids; the separated biogas slurry is used for biological pre-treatment of straw and adjustment of water content in the straw feedstock; the biogas residue is processed into organic fertilizer and complex fertilizer.

**System of rural distributed energy station and fuel gas transmission and distribution pipe network**

129. The system in this project produces about 30,000 cubic metres of BNG daily. The produced BNG is transmitted and distributed through a pipe network to supply residents, businesses, taxis and buses in Tianshan Town. The biogas is also supplied to neighbouring villages and towns through a rural distributed energy station, thereby forming a new value chain for the supply of clean energy to both urban and rural areas.

**3.2.4. Types of products/processes/services being developed**

130. The products of the Ar Banner Project are BNG and organic fertilizer. At present, there is one primary BNG station, one secondary BNG station and about 8 kilometres of fuel gas transmission and distribution pipe network established in Tianshan Town, which can supply gas for 80,000 residents, hotels, restaurants and schools, and for production of five industrial enterprises in Tianshan Town. A natural gas filling station is established, and can offer up to 10,000 cubic metres of gas and refuel 300 taxis and 20 buses; there are 3 rural distributed energy stations established in Shuangsheng Town, which can supply gas for residential use for 3 villages and about 1,000 residents. There is a fertilizer-processing workshop that can produce organic fertilizer and complex fertilizer with fermentation residue. The annual production is about 50,000 tons of fertilizer for neighbouring farmer households for agricultural production.

**3.2.5. Main ecosystem companies, type of companies and relationship with these**

131. For constructing and popularising a complete ecological cycle value chain system, multiple organisations need to cooperate closely including those engaged in technological research and development, investment and construction, and departments of central or local governments. The main stakeholders involved in China are listed in Table 2.

**Table 2. Stakeholders involved in the ecological cycle value chain system.**

<table>
<thead>
<tr>
<th>Category</th>
<th>Nature</th>
<th>Examples of Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology research and development organisations</td>
<td>Colleges and universities</td>
<td>Tsinghua University, Tongji University, Zhejiang University, Harbin Institute of Technology, Beijing University of Chemical Technology, University of Science and Technology Beijing, Huazhong University of Science and Technology, and Chongqing University, etc.</td>
</tr>
<tr>
<td>Research institutes</td>
<td></td>
<td>Institute of Process Engineering (Chinese Academy of Sciences), Guangzhou Institute of Energy Conservation (Chinese Academy of Sciences), Qingdao Institute of Bioenergy and Bioprocess Technology (Chinese Academy of Sciences), Tianjin Institute of Industrial Biotechnology (Chinese Academy of Sciences), Chinese Research Academy of Environmental Sciences, related provincial research institutes, etc.</td>
</tr>
<tr>
<td>Enterprise research &amp; development</td>
<td></td>
<td>China Huadian Corporation, China Investment Corporation, China Resources Group, and COFCO, etc.</td>
</tr>
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</tr>
<tr>
<td>Local government departments</td>
<td>Governments at provincial level, their development and reform commissions, energy bureaus, departments of finance, departments of agriculture, and departments of ecology and environment.</td>
<td></td>
</tr>
<tr>
<td>Enterprises (state-owned, private)</td>
<td>North China (Hebei and Inner Mongolia, etc.): Hebei Gucheng Fulong Breeding Co., Ltd, CGN Anping Bioenergy Co., Ltd, Inner Mongolia Chifeng Yuanji Biogas Technology Co., Ltd, etc;</td>
<td></td>
</tr>
<tr>
<td>Investment, engineering construction and operation</td>
<td>Northeast China (Liaoning, Jilin, Heilongjiang): Liaoning Haosheng Methane Power Generation Co., Ltd, Jilin Tianyan Bioenergy Co., Ltd, Heilongjiang Kedong Yongjin Bioenergy Investment Co., Ltd, etc;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>East China (Jiangsu, Zhejiang, Anhui, Jiangxi and Shandong, etc.): Jiangsu Shanghai-Electric Qingneng Bioenergy Co., Ltd, Anhui Maanshan Borui New Energy Technology Co., Ltd, Shandong Leling Shengli New Energy Co., Ltd, etc;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Central China (Henan, Hubei and Hunan): Henan Tianguan Group, Hubei Modern Farming Co., Ltd, Hubei Zhongkai New Energy Co., Ltd, Hunan Yueyang Fengshuwan Livestock Co., Ltd, etc;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>South China, Southwest China (Guangxi, Sichuan, etc.): Guangxi Wuming Anning Starch Co., Ltd, Hainan Chengmai Shenzhou Vehicle Biogas Co., Ltd, Sichuan Zigong Jiahe New Energy Technology Co., Ltd, Guizhou China Energy Conservation Green Carbon (Zunyi) Environmental Protection Co., Ltd, Yunnan Shunfeng Puerhai Environmental Protection Technology Co., Ltd, etc;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Northwest China (Shaanxi, Gansu and Xinjiang, etc.): Shaanxi Shangluo Youyuan Ecological Farming Technology Co., Ltd, Gansu Gaotai Fangzheng Energy Conservation Technology Service Co., Ltd, Xinjiang CGN Hutubi Bioenergy Co., Ltd, etc.</td>
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</tr>
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</table>

### 3.3. Ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

#### 3.3.1. Potentials for utilising biomass across a broader range of industries/sectors/higher value-added sectors, drivers to achieve these potentials

132. The ecological recycling value chain of straw, which meets inner demand, facilitates not only an ecological cycle and high value utilisation, but also cross-sectoral extension. Three main factors – increasingly severe environmental pollution, rapidly growing demand for clean energy and need of ecological agriculture development – have resulted in the need of the chain.
133. With the rapid social and economic development, and rising living standard in China, there is an increasing number of wastes. At present, China generates 1.04 billion tons of crop straw, 2.05 billion tons of animal manure, 260 million tons of fruit and vegetable waste, 210 million tons of waste from processing industry for agricultural products, about 80 million tons of rural organic rubbish and 164 million tons of urban organic household rubbish every year, which totals 3.804 billion tons. Among them, 1.404 billion tons are not processed which causes increasingly severe environmental pollution and health hazards. Thus, effective treatment and utilisation, and improvement in urban and rural ecological environment are urgently needed.

134. With rich coal resources, insufficient oil and gas, China has great demands and broad market for BNG. According to the China Statistic Yearbook 2017, the total energy consumption in China in 2016 was 4.36 billion tons of standard coal; the consumption of coal, oil and natural gas respectively accounted for 62%, 18.3% and a mere 6.4%. Over 30% of natural gas was imported. China’s energy production and consumption will be based on diversified domestic supply to ensure energy security, and an energy supply system driven by multiple resources including coal, oil, gas and renewable energy will be established. At the G20 summit and the Paris Climate Summit, China promised to improve non-fossil fuel use to around 20% of total energy consumption by 2030. Utilising waste and developing BNG is one important way to improve China’s energy mix, ensure energy security and keep promises to the international community. Estimation according to the 13th FYP on the Development of Methane in China’s Rural Areas indicates that the waste from crop planting, the breeding industry, relevant processing industry and rural waste, which can be used to produce BNG, totals about 1.404 billion tons, and can produce 73.6 billion cubic metres and replace about 87 600 000 tons of standard coal.

135. Fertilizer in China is essential for supporting agricultural production. With a fast-acting feature, rich nutrients and excellent performance for increasing production, chemical fertilizers are widely applied in production. At present, China ranks first in the production and use of chemical fertilizer in the world. According to the data published by the Ministry of Agriculture, China uses 21.9 kilogrammes of chemical fertilizer per 666 square metres of crops, which is much higher than the average world level (8 kilogrammes per 666 square metres), 2.6 times that of the United States and 2.7 times that of the European Union. Excessive or blind use of chemical fertilizer brings a number of problems, such as increase in cost, environmental pollution and degeneration of soil, which severely restrict the sustainable development of agriculture, and the high and stable yield of crops in China. Therefore, the Ministry of Agriculture targets zero growth in the use of chemical fertilizer by 2020 and plans to reduce the use of chemical fertilizer gradually after 2020. To ensure long-term stable high yield of crops, development of organic fertilizer is a matter of great urgency. After anaerobic fermentation, straw, excreta and other waste are biologically matured and become excellent raw materials for the production of organic fertilizer, and can be further processed into organic fertilizer or complex fertilizer for agricultural production.

136. The cross-industry extension of this value chain satisfies the urgent need of China’s society and economy for sustainable development. Furthermore, the value chain has a broad market and large space for development. With this value chain, about 50% of waste can be converted. That is to say, waste emission can be cut by about 50%, thereby significantly alleviating the environmental pollution problems imposed by waste in China; 73.6 billion cubic metres of BNG can be produced, which amounts to 31% of natural gas consumption, 49.5% of natural gas production and 80% of natural gas imports in China in 2017. This is of great importance for satisfying the need for clean energy and ensuring national energy
security; in addition, about 290 million tons of raw materials for the production of organic fertilizer can be provided which is significant in ensuring food safety and the development of ecological agriculture. From the perspective of environmental protection, promotion of ecological civilisation, clean energy production and development of ecological agriculture, this value chain has much potential for development and enormous market potential.

3.3.2. Examples of ongoing biomass refining/utilisation experiments/ventures and related new cross-industrial collaborations to diversify to new business areas, foreseen economic or other impacts of these

137. Compared with the methane projects vigorously promoted in China in the past, BNG projects have formed a new entire industrial chain production system, which is longer and at higher level, and a new commercial market is gradually created. Many domestic enterprises are beginning to enter the field of BNG (see Table 2) for investment and project development. These enterprises consist of state-owned enterprises and private enterprises. The state-owned enterprises include China Energy Conservation and Environmental Protection Group, China Huadian Corporation, and China General Nuclear Power Corporation. The private enterprises include Chifeng Yuanyi Biogas Technology, and Hubei Zhongkai New Energy Co., Ltd.

138. Compared with China’s mainstream technology for the production of methane with animal manure, the new value chain of waste disposal and ecological circular cycle derives greater economic, social and environmental benefits, and has broader market and stronger sustainability. This is manifested in the following aspects: it better facilitates environmental protection as waste from many industries can be processed; it has longer industrial and value chains, and more significant benefits in many aspects; its products range from low-grade methane to high-grade BNG; it has higher value, and thus there is a greater market demand.

3.3.3. Examples of need for/already tested/new business models to facilitate extension/collaboration/diversification

139. The BNG industry is still in its initial stage, and the following problems should be addressed to facilitate cross-sectoral extension and create a new commercial market.

Production cost control

140. The production cost of BNG is influenced by many factors, in which the cost for the collection and transport of raw materials has the greatest impact. Small farmers, who normally cultivate a small land area, account for a major part in China’s agriculture. Straw has to be collected from many scattered settlements, which leads to difficult large-scale collection. In addition, China has a vast territory, with varied geographical features and planting mixes. Mechanised collection is barely possible in many places, which result in excessively high cost. Currently, the cost of straw collection in most regions is CNY 250-350 per ton, and peaks at CNY 700 per ton. As a result, the BNG production cost is very high, thus significantly reducing the profitability of BNG production. Therefore, establishment of a collection and transport mode for straw and other raw materials suitable to local conditions is a crucial issue.
Innovation in technology and equipment

141. With a long history in developing small methane projects, China has accumulated mature technology and extensive experience in small projects; however, industrialised large-scale BNG projects are newly established, and China is short of core technology and key equipment. Moreover, a BNG project is a complex production system and single technology cannot be a solution for all project problems. “Systematic” research is required for establishing a complete “technology system” and a complete “equipment system” that suit the conditions of China. At present, China is in urgent need of research, development and improvement of the following technologies: stalk modification and upgrade technology, high-solid and high-efficiency anaerobic fermentation technology, high-efficiency and low-consumption purification technology and associated equipment.

Building a standardised system

142. A BNG project is a complex production system involving technology, equipment, engineering design, operation monitoring and natural gas products. As it is still in its initial stage, industrial development and expansion are severely restricted due to a lack of standards. Relevant standard systems will be established promptly. Industrial standards will be adopted to regulate and promote the development of the BNG industry and the expansion of a new commercial market.

Establishment of diversified investment and financing mechanisms

143. Industrialised BNG projects demand more investment and substantial funds. However, the low profitability of the BNG industry cannot stimulate investment in the whole market. Therefore, a multi-channel investment and financing system under the guidance of government funds is to be established. A “diversified” investment and financing mechanism with input and guidance by government finance, input from social capital, market operation by enterprises and active participation by farmer households, is to be established to attract state-owned enterprises, private capitals and overseas capitals to the field of BNG. A variety of equity funds and industrial funds are to be attracted, a special BNG project development fund is to be established, and a scientific and reasonable investment compensation mechanism is to be set up based on project proceeds.

3.3.4. Relevance of circular economy solutions and viewpoints for extending value chains and diversifying to new business areas

144. The core of circular economy is the recycling of resources. As a major waste from planting, straw not only acts as a pollutant to the environment but also can be used as helpful renewable resource. Anaerobes can convert straw into high-grade BNG and organic fertilizer for the full ecological recycling of crop straw. This is a typical model of circular economy. Straw is transformed into BNG, while organic fertilizer is applied in farmland for production of crops, generating straw that will be used as raw materials for the next cycle. With such a cycle, straw is fully processed and recycled and a complete high value-added industrial chain is formed.

145. Besides straw, this circular model can be applied in the treatment and utilisation of other industrial waste. Urban household rubbish, kitchen rubbish and human excreta, residuals from light industries as food fermentation, may be transformed into clean energy or organic fertilizer with the same technology, methods and models for recycling and high
value-added utilisation. In this way, the transformation technology with anaerobes can be further expanded for industry and the commercial market.

3.3.5. Examples of how policies, agencies and their specific instruments have facilitated extension/collaboration/diversification

146. China’s BNG industry, which is at its initial stage, faces many challenges in raw material collection, production technology and product utilisation. Considering the development and operation of the 65 large BNG projects supported by the national government, they bring great environmental and social benefit, but deliver poor economic benefit for sustainable development. The main problems include: owing to high cost in production, BNG cannot compete with cheap fossil natural gas in the near future, thus an industrial chain can hardly be established and BNG can hardly give full play to its functions in waste treatment and environmental protection. Therefore, policy support appears essential in the near future.

147. At present, the support to BNG projects in China is mainly from the central and local governments; several departments of the central government are providing their support (Table 3). Besides, local governments at all levels also give support through local finance, among which Jiangsu, Anhui, Jilin and Shanxi province offer relatively strong support. The support is provided in many forms, such as subsidy for engineering construction, subsidy for collection and transport of raw materials, subsidy for organic fertilizer, subsidy for methane power generation and tax reduction or exemption.

Table 3. Supportive policies by the departments of the central government

<table>
<thead>
<tr>
<th>Year</th>
<th>Department</th>
<th>Policy / programme</th>
<th>Form of support</th>
<th>Financial support</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>MoA, MoF</td>
<td>Notice on Carrying out Pilot Projects for the Comprehensive Utilization of Straw to Promote the Improvement in Arable Land Quality</td>
<td>Reward as subsidy</td>
<td>Supporting 10 provinces, with CNY 100 million per province on average and a total of CNY 1 billion</td>
</tr>
<tr>
<td>2015-2017</td>
<td>NDRC, MoA</td>
<td>Budgetary Investment Plan for Rural Methane Projects</td>
<td>Subsidy for construction</td>
<td>Supporting 65 projects, with CNY 30 to 50 million per project and a total of CNY 2.7 billion in 3 years</td>
</tr>
<tr>
<td>2015</td>
<td>NEA</td>
<td>Programme of Central Government's Budgetary Investment in Strategic Emerging Industries (Energy) in 2015</td>
<td>Subsidy for construction</td>
<td>10% of total investment</td>
</tr>
<tr>
<td>2014</td>
<td>MoA, MoF</td>
<td>Guiding Opinion for Implementing the Pilot Programme for the Comprehensive Utilization of Agricultural and Rural Waste Such as livestock and poultry in 2014</td>
<td>Subsidy for construction</td>
<td>Supporting 10 projects with CNY 20 million per project</td>
</tr>
<tr>
<td>Year</td>
<td>Ministry</td>
<td>Notice</td>
<td>Interim Measures for the</td>
<td>Subsidy for</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>2010</td>
<td>NDRC</td>
<td>Notice on Improving the Policies on Pricing of Forestry and Rural Biomass Power Generation</td>
<td>Product subsidy</td>
<td>CNY 0.75 per degree</td>
</tr>
<tr>
<td>2008</td>
<td>MoF</td>
<td>Interim Measures for the Administration of the Subsidy Funds for the Utilization of Straw as Energy</td>
<td>Subsidy for treatment expense</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>MoF, SAT</td>
<td>Catalogue of Income Tax Preference for Enterprises Engaged in Comprehensive Utilization of Resources</td>
<td>Reduction and exemption of tax</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>MoF</td>
<td>Interim Measures for the Administration of the Special Funds for the Development of Renewable Energy</td>
<td>Free aid or preferential loan</td>
<td>Interest discount for 1 to 3 years, with annual discount no higher than 3%.</td>
</tr>
</tbody>
</table>

Note: Ministry of Agriculture (MoA), Ministry of Finance (MoF), National Development and Reform Commission (NDRC), National Energy Administration (NEA), State Administration of Taxation (SAT).

3.3.6. Challenges related to extension/collaboration/diversification in general, specifically related to the regulatory/institutional regime

The knowledge of circular economy is inadequate

148. Although the Circular Economy Promotion Law of the People’s Republic of China has been put into practice in China since 2009, there is not enough understanding of scientific knowledge of circular economy. Some people still do not thoroughly understand the circular economy’s connotations. What the entire society pursues is developing rapidly at the expense of consuming large amounts of resources and severely polluting the environment. The awareness of sustainable development has yet to be raised in the entire society on resources saving and environment protection. Since extension of value chain across industries and creating new business modes cannot be made without the public, enterprises, and other social entities, it is crucial to spread the knowledge and concept of circular economy and transform people’s development concept.

149. **BNG faces barriers in entering the existing natural gas pipeline network**

150. To achieve a large scale of application, BNG must access the existing natural gas pipeline network. However, because of China’s special situation that the existing fossil gas transmission and distribution network are monopolised by Sinopec, CNPC and other large state-owned enterprises which are strong competitors for BNG manufacturers. It is mainly caused by difficult access to the existing natural gas pipeline network and the cheap price after the access. These lead to low sales volume of BNG products and inefficiency, which seriously restrict the large-scale application of BNG industry.

The way that governments subsidise the BNG industry is irrational

151. At present, the responsibility of BNG construction in China just falls on the agricultural departments that have subsidised 65 national BNG demonstration projects for 3 consecutive years from 2015 to 2017. But these subsidies from the agricultural infrastructure funds come to the “front end”, termed construction subsidy. In doing so, the main problem lies in the fact that even though the enterprise obtains the support funds, it
may not be able to manage a project smoothly and steadily. If so, the project does not play its expected role. On the contrary, the developed countries like Germany normally adopt “back-end” subsidy or product subsidy. If the government subsidises the back-end based on BNG production, manufacturers will be motivated to create and run a better project. This measure is good for attracting social capitals to fuel the development of the BNG industry.

3.4. Overall synthesis of findings

3.4.1. BNG industry is an effective way to efficiently recycle crop straw

152. As a leading producer of agriculture, China annually produces 1.04 billion tons of crop straw, among which 180 million tons have not been effectively used and a large number have been disposed by open burning, resulting in serious air pollution, fire accidents and traffic accidents. By means of anaerobic biological fermentation and separation and purification, crop straw can be transformed into high-grade renewable clean energy – BNG - and organic fertilizer. This corn straw recycle chain based on the concept of circular economy is an effective way to recycle crop straw. This value chain is long and highly value-added, and can achieve a high recycling rate.

3.4.2. The corn straw recycling value chain is applicable in different industries and form new business fields

153. Apart from corn straw, this value chain can treat and transform organic waste of animals, urban and rural residential waste, and light industry including food. In this way, it will play a more important role in environmental governance. In addition, it produces organic fertilizers for developing eco-agriculture and BNG on a large scale, thus filling the clean energy gap in China. As China’s energy consumption structure is characterised by “rich in coal, short in oil, and rare in gas”, the demand for natural gas is very strong. China's agriculture is dependent on chemical fertilizers. Nevertheless, there is an inevitable trend to reduce applying chemical fertilizers, providing good opportunities and potential for organic fertilizer to develop. Widely applicable, technically feasible and highly value-added, this long waste recycle chain is in strong demand in the market and has a development potential to generate new business opportunities and modes.

3.4.3. Promoting the recycling value chain in high-valued cross-sector still faces challenges and problems

154. Challenges facing the cross-industry promotion of recycle value chain mainly include:

- The overall profit of the BNG industry is so low that it cannot compete with conventional natural gas
- As China’s natural gas pipeline network and petrol stations are under franchise rights and are mainly controlled by giant state-owned enterprises. Access for BNG is difficult and the entry rate is low, resulting in severe restriction on BNG sales and market expansion and BNG wider application
- Preferential policies that central and local governments have introduced are inadequate and unreasonable
China's BNG industry is still in its infancy, lacking systematic core technologies and key equipment that are unable to satisfy industrial production.

Standards are absent in BNG industry. It is urgent to establish standards based on China's conditions.

The solutions include: more preferential policies, diversified financing channels, different supporting methods, technological innovation, equipment upgrade, and industrial standards.

3.4.4. Supporting policies are key to promoting recycling value chain and establishing new business modes

Now China urgently needs clean energy and ecological agriculture for sustainable growth. Recycling waste and developing the BNG industry are not only the important ways for China to develop the circular economy, but this is an important measure for national ecological progress and energy security. The State Council, the National Energy Administration and the Ministry of Agriculture, and other central government departments have been actively promoting such development. However, as China’s BNG industry is in its initial stage, it is immature and is still faced with challenges. As to the development and operation of the 65 large BNG projects supported by the central government, they have brought great benefits to the environment and society, but produced poor economic benefit for sustainable development. Therefore, it is crucial for the central and local governments to provide policy support to promote recycling value chains and generate new business fields. Although the central and local governments at all levels have issued a number of policies supporting BNG industry, the results have not met expectations. Therefore, the following two aspects need adjustment.

1. First, front-end subsidies should be replaced by more back-end subsidies. Some issues have been detected for subsidies at the front end as engineering construction and operation management are difficult and not organised. If the government provides back-end subsidy based on the BNG production, enterprises are more likely to build and run projects smoothly. In addition, it is convenient for enterprises to apply Internet, Big Data and other technologies for supervision and management. Besides, the back-end subsidy standards should be set after accurately calculating the actual operation of existing projects. Subsidies should be enough to support investors' long-term and stable economic benefits, thus attracting more social capitals to form and develop the BNG industry.

2. Second, BNG should have preferential access to the franchised gas pipeline network. BNG and fossil gas should use the quota system. The franchised operation system is implemented in gas pipelines in China. So far, the gas pipeline network franchised rights in most cities have been granted, making it difficult for BNG to enter the existing gas pipeline network. Even if BNG gets access, the network owners deliberately lower the prices, causing BNG manufacturers to barely make profit, not to mention sustainable development. As a result, it is recommended that the Chinese government demand franchised companies to give priority to purchasing BNG, with reference to policies for solar power generation, wind power generation and biomass power generation. At the same time, a quota system should be in place indicating the proportion of BNG in fossil natural gas consumption for ensuring the back-end market for BNG. The quota should be reviewed annually according to the production of BNG manufacturers and the sales volume of suppliers.
4. Finland

4.1. Country position and policies for bio- and circular economies

4.1.1. Definitions of bio- and circular economies

157. According to the Finnish Bioeconomy Strategy, bioeconomy refers to an economy that “relies on renewable natural resources to produce food, energy, products and services. The bioeconomy will reduce our dependence on fossil natural resources, prevent biodiversity loss and create new economic growth and jobs in line with the principles of sustainable development.”

158. Circular economy, as defined by the Finnish Innovation Fund Sitra, “strives to maximise the circulation of products, components and materials and the value bound to them as much as possible in the economy. In a circular economy, production and consumption create the smallest possible amount of loss and waste.”

4.1.2. Main priorities and drivers for transition to bio- and circular economy

159. According to a report published by the Finnish Ministry of Economic Affairs and Employment, population growth and the increasing standard of living are the two key megatrends that drive the increasing demand for natural resources, which is the key growth driver for bioeconomy. Additionally, consumer preferences can promote more sustainable solutions, especially when sustainability can be communicated clearly and reliably. These can include e.g. bio-based plastics that can replace alternatives produced from fossil raw materials. The scarcity of natural resources drives towards resource efficiency and circular economy which subsequently can be used as competitive factors by manufacturers.

160. The drivers for circular economy are two-fold: the Finnish road map to a circular economy 2016–2025 lists both environmental and economic reasons that drive the systemic change towards circular economy. From the economic point of view, circular economy is estimated to create 75 000 jobs and provide Finland’s national economy with EUR 2 to 3 billion in added-value potential by 2030. Moreover, a road map to circular economy is seen to improve Finland’s ecological sustainability.

4.1.3. Existence and main content of relevant strategies/visions/road maps

161. There are several relevant national strategies in place regarding the development of forest-based bioeconomy in Finland. The Ministry of Economic Affairs and Employment has launched the Finnish Bioeconomy Strategy in 2014, the goals of which are to promote:

1. A competitive operating environment for the bioeconomy
2. New business from the bioeconomy
10. A strong bioeconomy competence base

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12 Sitra – Leading the cycle – Finnish road map to a circular economy 2016-2025
13 Ministry of Economic Affairs and Employment (2017) - Growth and employment from sustainable solutions – A study into the dynamics of growth and employment in the bioeconomy, cleantech and circular economy.
11. Accessibility and sustainability of biomass.

162. For the circular economy, The Finnish Innovation Fund Sitra has published a road map for the years 2016-2025. The goals set out for 2025 in the strategy are that circular economy will be a new cornerstone for the Finnish economy, that Finland is a model country for the challenge of scarcity, and that as a society Finland will be a pioneer rather than an adapter.

163. Prime Minister Juha Sipilä’s government is working towards its five strategic priorities by implementing 26 key projects. One of the key priorities is ‘Bioeconomy and clean solutions’, under which one of the key projects is labelled ‘Wood on the move and new products from forests’, and another ‘Breakthrough to a circular economy and adoption of clean solutions’.

164. Wood on the move and new products from forests aims to increase, diversify, and grow the value of the wood used in Finland. Its goal is to create competitive and sustainable bioeconomy solutions in Finland as well as to create new business, employment and exports.

165. Breakthrough to a circular economy and adoption of clean solutions aims to leverage the growing opportunities enabled by circular economy and clean solutions. It promotes experiments, R&D and demonstration projects to increase the reuse of materials and related ‘clean tech’ business\(^\text{14}\).

166. The Academy of Finland, the governmental funding body for scientific research in Finland, has published its own strategy for scientific research concerning bioeconomy. The strategy lists 21 research priorities, including e.g. increasing the value of bioeconomy with multidisciplinary cooperation, biorefineries, technically and economically sound bio-based raw materials, tailored biomass, bio-based compounds and substances, systemic changes in the bioeconomy/reforming value networks, dynamic bioeconomy, values and value networks (including the creation and adoption of innovations)\(^\text{15}\).

167. Another relevant strategy is the Forestry Research Strategy published by the Finnish Forest Association. It lists three strategic goals:

1. Finland as a competitive operating environment for forest-based business
2. The forest industry and its structures are renewed and diversified
3. Forests are in active, economically, ecologically and socially sustainable and diverse usage\(^\text{16}\).

\(^{14}\) http://valtioneuvosto.fi/hallitusohjelman-toteutus/biotalous


\(^{16}\) Metsäalan tutkimusstrategia 2025 – Kohti parempaa yhteistyötä ja kokeilukulttuuria - available at: http://nmm.fi/documents/1410837/1504826/Mets%C3%A4alan+tutkimusstrategia/07e7935d-b27e-4736-910c-76c724a6f29b
4.2. Description of case study value chain

4.2.1. Name and key features of focus organisation

168. Bioeconomy in Finland is based mainly on the structures that rely on the forest sector value chains. Due to development of new technologies and requirements of sustainable development, forest-based biomass is finding new higher value added applications when compared to applications that it has traditionally been used for, such as pulp and paper.

169. The aim of this study is to give understanding of innovation development pathways of two important new application areas in Finland that use forest-based biomass:

1. Cellulose-based textiles
2. Bioproducts and biocomposites replacing plastics.

170. Special emphasis in the study is given to the renewal of existing companies and the formation of new companies enabled by these development pathways and innovations. Thus, interviews were conducted with big multinational companies, start-ups and research organisations, the latter especially from the point of view of commercialisation, as well as for policy perspective also with a public private partnership and a funding organisation. Altogether 20 organisations were interviewed for this study, shown in Table 4 below.

Table 4. Interviewed organisations with selected application pathways

<table>
<thead>
<tr>
<th>Organization</th>
<th>Most relevant development pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aalto University</td>
<td>cellulose based textiles</td>
</tr>
<tr>
<td>Business Finland</td>
<td>both pathways</td>
</tr>
<tr>
<td>CLIC Innovation</td>
<td>both pathways</td>
</tr>
<tr>
<td>Elastopoli</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Infinitied Fiber Company /VTT</td>
<td>cellulose based textiles</td>
</tr>
<tr>
<td>Kotkamills</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Marimekko</td>
<td>cellulose based textiles</td>
</tr>
<tr>
<td>Metsä Fibre</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Neste</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Paptic</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Spinnova</td>
<td>cellulose based textiles</td>
</tr>
<tr>
<td>Stora Enso Biomaterials</td>
<td>cellulose based textiles</td>
</tr>
<tr>
<td>Sulapac</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>University of Borås/Tampere University of Technology</td>
<td>both pathways</td>
</tr>
<tr>
<td>UPM</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Welmu International</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Valio</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>VTT</td>
<td>both pathways</td>
</tr>
<tr>
<td>Åbo Akademi Process Chemistry Center</td>
<td>bioproducts and biocomposites</td>
</tr>
<tr>
<td>Woodio</td>
<td>bioproducts and biocomposites</td>
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</tbody>
</table>

4.2.2. Type of biomass being refined, main biomass suppliers, refining techniques

171. In the context of this study, softwood and/or hardwood are the primary biomass sources processed further. Wood is refined by mechanical, chemical and/or thermal
processing techniques to cellulose fibres, lignin and hemicelluloses that are used as raw materials for new bio-based applications.

172. For cellulose-based textiles, dissolving pulp is the main raw material used. Dissolving pulp is bleached wood pulp with high cellulose content dissolved in a solvent or homogenous solution. Dissolving pulp can also be mixed with other raw materials, such as cotton fibres. As special requirements, dissolving pulp needs to be extremely pure with low hemicellulose content. The Kraft pulping process, predominant in Finland, has limited potential, according to some interviews, for biorefinery purposes. There is not, however, enough relevant funding for the development of alternative fractionation methods.

173. Specific refining technologies have been developed and defined by new applications such as the biomass-based composite production. Also, when combining the cellulose fibres with polymers, compatibilisation techniques are needed for the biomass, which is hydrophilic, to be combined with the normally hydrophobic polymers. Commonly, the specific refining technologies are trade secrets. Some companies utilise injection moulding to produce bioproducts and biocomposites. Also, new techniques to process biomass are under research and at laboratory/pilot state, such as technologies based on foam forming. Scaling up the production would require investments to demonstrator-scale facilities and to supply higher volumes of raw material than are presently available.

174. In Finland, forest ownership is fragmented and two-thirds of the forest is privately owned by a large number of single owners of small forests. Private forest owners supply the wood biomass for sawmills as well as for the pulp and paper companies such as UPM, Stora Enso and Metsä, who also own forests. Most of the Finnish start-ups purchase wood from Finnish companies, but some use also global suppliers for wood chips. Many of the start-ups did not want to disclose their suppliers.

175. Some research organisations and small companies reported that there is a lack of supply for more specialised raw materials from current forest industry companies and suggested it to be due to a lack of interest to develop their product portfolio to be more diversified than it is currently. For example, there is plenty of bulk cellulose on the market; however, it can be difficult to obtain certain side streams such as hemicellulose and lignin as their fractionation requires variations to the bulk process. Thus, instead of developing and selling smaller amounts of high-value products, a high volume of bulk products are being produced to few customers. Innovations related to raw materials are usually spun off from start-ups.

176. The new technology developers reported that the demand of recycled biomass (both paper/carton as well as textiles) greatly exceeds its supply. Thus, even though their technology could process these recycled materials and thus they could be used as raw material, the material is not available.

177. For the end product manufacturers in the cellulose-based textile pathway, the limited amount of fabric available for prototyping poses a considerable barrier for further development. The fabric is currently procurable at laboratory-scale amounts or from small pilots, whereas the required amounts would be at demonstrator scale.

4.2.3. Type of products/processes/services being developed

178. In the textile value chain, all types of new wood-based fabric products are being developed: fabrics for clothes and furniture, technical and professional textiles, as well as hygienic textiles and medical textiles such as bandages. In general, cellulose fibres can be
utilised in all textiles that can replace cotton and viscose. Viscose is also based on cellulose but its production process has sustainability issues and thus alternatives are looked for.

179. In the bio-based plastics and composites value chain, virtually everything that is currently being produced from fossil-based plastics can be replaced with bio-based ones. Examples include consumer packages (e.g. food and drink, jewellery, cosmetics), hygiene products, toys, consumer electronics (e.g. cell phone covers, loudspeaker frames) as well as air and water filtration solutions. Bio-based composites can also be used as reinforcement material in the automotive and home electronic industries, the construction industry as well as e.g. in interior design. Light and durable structures can be made from nanocellulose fibres. In the automotive industry, for example, lighter bio-based composite structures that replace glass fibre-enhanced synthetic plastics can have a substantial impact on mileage and fuel economy.

180. In addition to cellulose, developments are ongoing to use pulp production side streams in very high value-added products, such as pharmaceuticals and other fine chemicals. Examples include barriers for food packaging developed from black liquor, as well as wood glue processed from lignin.

4.2.4. Main ecosystem companies, type of companies and relationship with these

181. Traditional forest companies are looking for partners with insight from a broader range of sectors than what their companies are traditionally representing. These new partner ecosystems with research institutes, start-ups and established companies from other sectors, are driving innovation in a way that corresponds to consumer needs. The Finnish bioeconomy ecosystem for cellulose-based products consists of the traditional forest industry giants such as UPM, Stora Enso and Metsä Group and a number of innovative start-ups developing new bioproducts and biocomposites like Paptic, Elastopoli, Woodio, Sulapac and Welmu International, and for cellulose-based textiles like Spinnova, INFIBER Company, with very few mid-sized companies in between. Universities and research institutes have an important role in the commercial ecosystem, as many of them are focused not only on basic research but also applied research and commercialisation. In the development of cellulose-based textiles, Marimekko as the brand owner has been actively participating already in the development phase. However, overall, the group that is missing from the established innovation ecosystem are the clients.

182. Typical criteria for selecting new partners for industrial ecosystem include market knowledge from the business field or market area or substance knowledge about technologies or materials. For some companies, key value for partner selection is to enable quick market entry. Criteria might also be sustainability commitments or strategies and quality standards. Others target big volumes: global brand owners with big sales potential and then on the other hand producers with big production capacities to meet the demand.

4.3. Ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

4.3.1. Potentials for utilising biomass across a broader range of industries/sectors/higher value-added sectors, drivers to achieve these potentials

183. There is great potential for new and more sustainable bio-based materials. The demand for both plastics and textiles is expected to increase greatly, and existing raw material sources – fossil-based oil for plastics and water-intensive cotton for textiles – are
depleting or their usage is unsustainable. Forest-based biomass can be utilised in a variety of consumer product sectors where their value-added is considerably higher than in the traditional products, such as pulp, paper and bioenergy. By 2020, the non-woven fibre market is estimated to be EUR 47.7 billion and the bioplastic market (especially drop-in-biopolymers) is estimated to be EUR 3.4 billion. The Finnish government strategy aims to nearly double the current bioeconomy turnover from EUR 60 billion to EUR 100 billion before 2025.

184. For the bio-based plastics and composites, the biggest potential volume is in food and drink packaging. Other packaging, such as hygienic products, toys and consumer electronics also show potential. Additional industries include the construction industry, where biocomposites can be used in insulation as well as material for interior surfaces.

185. For bio-based fibres, micro- and nano-fibrillated cellulose have been developed into biomedical solutions, such as wound treatment products and cell cultivation equipment, used in medical and pharmaceutical research and development. Moreover, bio-based fibres can be combined with bio-based composites to develop technical fibres that have even higher functionality and added value.

186. It has to be taken into consideration, however, that the product features of bio-based materials need to be equal or better than the existing solution, e.g. the biocomposite materials need to be long-lasting and should not break or compost during the use phase.

4.3.2. Examples of ongoing biomass refining/utilisation experiments/ventures and related new cross-industrial collaborations to diversify to new business areas, foreseen economic or other impacts of these

187. There are a few open-access pilot facilities in Finland for the forest-based bio- and circular economy. Pilot facilities focused on biofuels and thermochemical conversions are located in Technical Research Centre of Finland (VTT Ltd), University of Eastern Finland (UEF), and Kouvolan Region Vocational College. Biomass processing and pulp production pilot facilities are located at KCL in Espoo, Mikkeli University of Applied Sciences (MAMK), VTT as well as Åbo Academy. Chemical process technology and industrial biotechnology pilot facilities are located only in VTT premises. Bio-based material pilot facilities are located at KCL, VTT, Tampere University of Technology (TUT) as well as Lappeenranta University of Technology (LUT).

188. Examples of new ventures include e.g. the Ioncell-F technology for producing man-made cellulosic textile fibres, developed at Aalto University in collaboration with the University of Helsinki. A cross-industrial collaboration combining technical knowledge from the pulp and paper industry with the fabric industry, it provides an alternative to cotton. Another similar innovation is the method developed by Spinnova, whose patented spinning technology produces textile fibre from pulp without harmful chemicals. Moreover, Infinited Fiber Company has developed a technology for turning cotton rich textile waste into new fibres for the textile industry in pulp and dissolving plants. In the biocomposite value chain, examples of new ventures include Aqvacomp, a new type of biocomposite that utilises pulp fibre from the forest to reinforce plastic materials.

189. Relevant research programmes include e.g. ACEL (Advanced Cellulose to Novel Products) which brings together universities, pulp and paper companies, as well as companies from the chemical and textile industries. The programme ran up until the end of 2017, promoting wood cellulose fibre-based material opportunities in textile fibres, thermoformable composites and cationic chemicals. Another relevant research programme
under CLIC Innovation Ltd is the New Fibre Products, which aims to increase renewable materials usage by focusing: on new cellulose modification methods (new enzymes and high consistency processes); on enabling foam technologies as well as; on new product solutions in the area of antimicrobial products.

190. CH-Bioforce, founded in 2016, is delivering a new biomass fractionation technology to offer a new feedstock source for the chemical industry providing high-end value products. The technology can fractionate biomass into its three main constituents: cellulose, sulphur-free lignin, and hemicellulose.

4.3.3. Examples of need for/already tested/new business models to facilitate extension/collaboration/diversification

191. The value creation logic is changing in the industry. From the forest industry point of view, the business logic of selling large volumes of bulk to few clients differs from the new model of selling small batches to many clients. Networking becomes crucial and subcontracting increases. New collaboration models are needed because the market (industry and clients) are new to the traditional players (forest industry). The new solutions are closer to the end-users so product development requires knowledge about end-user needs.

192. One of the key challenges in utilising the biomass in new business areas is to understand the various value chains. It is important to define the right contact point to deliver the message at the end of the value chain (OEM, brand owner) and then get them to convince their own suppliers. There are lots of educational points that need to be completed before introducing new material. For example, one must be familiar with polymer technology and processing opportunities in order to understand the end use opportunities well enough. Raw material must be processed in a way that is applicable to end use. For example, coffee cups and animal food packaging have different kind of quality criteria for raw material.

193. The common business model among start-up companies is to license their production technology – a relatively novel business model in the forest-based biomass industry. They sell their concept straight to the brand owners in contrast to current industry players who sell their products only to the next value chain level. Also, the production is often licensed to the existing vertical value chain companies (forest companies). Normally the challenge of material start-ups is that the required initial investment is considerable. This challenge can be tackled through licensing the production. Start-ups may also cooperate with the raw material suppliers and seek international impact through collaboration.

4.3.4. Relevance of circular economy solutions and viewpoints for extending value chains and diversifying to new business areas

194. Circular economy can be seen as inherent to the forest based industries, which are a core base for selected value chains and raw materials. The term circular economy has not been used by the industry, however, but rather strongly overlapping theme of ‘cascading use’. The cascading use of biomass is part of circular economy, where the target is to increase resource efficiency and decrease the use of primary raw materials. Selected bioeconomy value chains contribute to circular economy by utilising side streams and waste fractions from forestry, cascading use of bio-based products, composites and cellulose based textiles as well as returning biodegradable products to organic and nutrient cycles. The relevance of circular economy in the selected innovation pathways is keeping it as one aspect of product design.
4.3.5. Examples of how policies, agencies and their specific instruments have facilitated extension/collaboration/diversification

195. Developing new technologies to enable the extension of value chains is costly, which entails high risks for the R&D investments. Consequently, public funding is required to alleviate the risk that private companies have to face.

196. Finland’s Bioeconomy Strategy, Sitra’s Finnish road map to a circular economy 2016-2025 as well as Prime Minister Juha Sipilä’s government’s key projects have given the forest-based industry a high profile in the Finnish society. Design Driven Value Chains in the World of Cellulose (DWoC) was a multidisciplinary research collaboration project funded by Tekes (the former Finnish Funding Agency for Innovation) focused on finding new and innovative applications for cellulosic materials, thus promoting e.g. the development of biocomposites.

197. **Tekes (Business Finland from 1/1/2018)** has enabled technology development for start-ups and large companies alike. It has had several bioeconomy related programmes, such as:

- EUR 81 million Green Growth programme from 2011 to 2015
- EUR 128 million Biorefine programme in 2007-2012
- EUR 33 million SymBio programme in 2006-2011

198. The Smart & Green Growth programme has focused on activating bioeconomy through projects such as BioNets, CleanWeb, Clean Soil as well as a number of pilot and demonstration projects. Additionally, bioeconomy projects are included in the following programmes: Functional materials (2007-2013), FinNano (2005-2010), Water programme (2008-212) and Sapuska (2009-2012).

199. Tekes also contributed to the operations of Strategic Centres for Science, Technology and Innovation (known in Finnish under the acronym SHOK) in cooperation with the Academy of Finland by combining the funding of leading-edge research with development between 2008 and 2015. The SHOKs led to a number of ideas that are currently being commercialised. The most relevant bioeconomy SHOKs were FIBIC and CLEEN, which have been merged as CLIC Innovation thereafter. The value for these programmes was EUR 100 million in total including both Tekes support as well investments by the participating companies.

200. The Academy of Finland has more recently focused funding to the bioeconomy sector through its programmes and other applied research instruments. In particular, as one of its two first flagship programs, CERES – the Competence Centre for the Materials Bioeconomy: A Flagship for our Sustainable Future, was selected for funding in April 2018.

201. At the EU level, the EU’s plastic strategy has created interest in bio-based materials. In addition, energy efficiency requirements in the automotive industry create demand for lighter materials, e.g. biocomposites. Many Finnish companies, have been active participants in the Bio-based Industries Joint Undertaking (BBI JU), a public-private partnership that operates under EU framework programme Horizon2020.
4.3.6. Challenges related to extension/collaboration/diversification in general, specifically related to the regulatory/institutional regime

202. The key challenges are related to sharing costs and risks, as well as variable standards. There is a need for public support to share the risks entailed by high pre-production development costs, to support ecosystem development and company demonstrations, to educate consumers about the benefits of bio-based materials, as well as to unify and clarify the variable regulations, rules and standards.

203. Relating to cost, one of the key challenges is production costs. Especially when replacing plastics in packages, the new material needs to be competitive. Currently, the higher production prices are hindering the market demand and willingness to invest in large scale production. The question is how much the end user is willing to pay for the added value. The opinions on the price competitiveness of the new bio-based solutions varies between SMEs/start-ups and forest industry companies/brand owners. SMEs need competitive prices and larger companies can allow more expensive production costs.

204. The attributes of the products have to correspond to those of the existing materials. In composites, there are very strict end-user specifications, which are difficult to fulfil. Some demanding application areas cannot bear risk in the durability, such as in heavy vehicles, trains, planes, sports equipment and building materials. Thus, one should focus on the markets where biocomposites fill the requirements, and where there is a possibility to gain competitive edge for the bio-based material.

205. Commercialisation is an issue especially for the research organisations. The entire innovation process might take 10 years or more and it is difficult to identify which organisation should take responsibility for the commercialisation. Commonly cooperation is done with big companies but there is a risk that all innovations are not interesting to them. After engaging with the big companies, a step back is needed to establish a spin-off.

206. There is also a need for new players and cross-industry collaboration. New industries do not evolve because big companies buy innovative SMEs when they succeed. Medium-sized companies are missing, and the Finnish market consists of existing big companies and micro companies. Moreover, consortia covering the entire value chain are missing and more cross-disciplinary discussions are needed. Discussion platforms (such as Biobased Industries Consortium BIC), where different industries could meet each other and clients, would be useful. Business Finland’s financing instruments are much needed; however, the fact that they are inclusive for only Finnish companies leads to a situation where cross-disciplinary development is not achieved. For example, parts of the value chain in the textile industry cannot be found in Finland and these parts are missing from the innovation ecosystem. This, however, is normal practice when using public national money and thus it is important to find such collaboration mechanisms that would allow to overcome this situation.

207. Standards are built for current materials, which might cause difficulties for producers of new materials who need to follow standards that do not fit in with their new material. The rules and regulations, as well as industry standards, are also considered too complicated, not only by smaller companies, but also larger ones. The competition of PEFC and FSC certificates poses also some challenges, which could be mitigated on a governmental level. Recycling rules and regulations vary even between EU countries, which is an issue when developing and commercialising new materials.
208. Certifications (forest land use) are needed in order to ensure sustainability of the new bio-based materials. Also, certifications for recycled materials are needed. In general, increasing public awareness about what is sustainable, should be done.

4.4. Overall synthesis of findings

209. The analysis framework adapted from the Hekkert et al.\textsuperscript{17} is used to synthesise the main findings of this case study. The analysis is based on two parts. The first part, structure of the innovation system, consists of actors and rules that make up the system. The second part, how the system is functioning, is validated through seven system functions. These system functions are:

1. Entrepreneurial activities
2. Knowledge development
3. Knowledge exchange
4. Guidance of the search
5. Formation of markets
6. Mobilisation of resources
7. Counteracting resistance to change.

210. The importance of the different system functions varies according to the different phases of the development. The functions can be used to identify any system problems that might act as barriers to the effective functioning of the innovation system. These barriers are a manifestation of problems in the structure. Subsequently this analysis framework can be used to determine what kind of new policies are needed to overcome these barriers.

211. For the entrepreneurial activities, one of main findings is that the traditional business models do not match with the new needs: selling large volumes of bulk to few clients \textit{versus} developing higher value products to a more fragmented market. The key players in this function are in particular start-ups and research organisations that commercialise their research results. Also, the traditional forest industry companies, food and textile brand owners as well as other relevant big companies are acting to some extent on the entrepreneurial field. The traditional forest industry companies control the beginning of the value chain. However, they concentrate mainly on bulk production and selling these large volumes to few clients rather than developing value-added products to a more fragmented market. The pulp being sold as raw material to the new application areas presents only a tiny fraction of their total production volume. Many times, the large companies are reluctant to produce raw materials from the side streams since it might require adjustment or even special production lines additional to their normal processes.

212. Other findings for the entrepreneurial activities are that research organisations are still closely involved in the ecosystem. The new applications may not be on the priority list of traditional companies and thus innovations are mostly commercialised through start-ups directly from the research organisations even if big companies have participated in the preceding research phase. This creates also intellectual property rights (IPR) problems and,

\textsuperscript{17} Marko Hekkert, Simona Negro, Gaston Heimeriks, Robert Harmsen: Technological Innovation System Analysis, A manual for analysts, Utrecht University Faculty of Gelsciences, November 2011
together with the lacking production capacities of the start-ups, this slows down the innovation process.

213. Also, a finding for the entrepreneurial activities is that many start-ups have a business model based on licensing: new concepts are sold straight to the brand owners. Medium-sized companies are missing and there is a lack of investment decisions on industrial demonstration scale factories which is slowing down the commercialisation process. As their business model, at least some of the start-ups have outsourced almost everything other than portfolio management and marketing. Their strategy is many times to utilise the existing linear value chain to develop and produce new applications which would allow prompt large scale production of innovations.

214. However, few start-ups are yet at this stage of the scaling process. At the same time, big companies buy innovative SMEs when they succeed and this inhibits the evolution of new industries and results in the market consisting mainly of large and micro-companies with the missing sector of mid-sized companies. Also financing for R&D is overall not sufficient for implementing mid-sized production facilities (between EUR 1-100 million). Subsequently investment decisions for demonstration infrastructure are crucially needed and it should be located nearby the companies.

215. In terms of knowledge development, networking is crucial to increase knowledge about new business areas and customer need: cooperation throughout the value chain is important in order to ensure meeting the client needs. The main knowledge gaps are related to the end of the value chain: lack of market knowledge of the new industry. Thus, networking within the extended value chain is critical and cooperation with the brand owners is needed. The market knowledge can be increased if target market players are included as participants and partners already at the product development phase.

216. For the guidance of search, new standards and EU regulations are needed to fit the new materials and products: industry standards should be renewed to be based on functionality and not on materials used, recycling issues versus materials used in processes should be cleared, and also more uniformity is needed. For example, the new EU biocomposite definition and what is says about the materials recycling possibilities can drastically change the business potentials for an industry.

217. A finding for the market formation function is that product development focus is on the consumer segment and the importance of industrial solutions is overlooked. The consumer market is many times more familiar to the investors and other funders than the industrial solutions market. Even if the latter has a huge potential that might be accessed easier than the consumer market, this is an important factor.

218. As overall synthesis of these findings, when considering the phase of development on a scale of Pre-development – Development – Take-off – Acceleration – Stabilisation, from main functions present, a conclusion can be made that the phase of development in Finland for the cellulose-based textiles and bioproducts and biocomposites replacing plastics is at the end of the Development phase and at the beginning of the Take-off phase.

219. When considering policy implications and needed instruments, the following recommendations are suggested:

- Foster the growth of mid-sized companies
- Promote funding for demonstrator-scale activities
- Encourage and build capacities to renew current business models
- Enhance networks and capacities to understand the entire value chain and the client needs
- Pave the way to widen market view from consumer products to possibilities in the industry sector
- Promote at national and international level uptake of standards and regulations accustomed to the specific needs of the sector.

220. The first two recommendations call for especially public funding instruments as well as policies that promote supportive private investments that would take into consideration the particular challenges that the start-ups face in the bioeconomy sector, which is very different than for example when fostering start-ups in the ICT sector.

221. The third and fourth recommendations call particularly for programme actions in such a manner to motivate the established industry in the field to extend its will and capabilities to make business with different means than has been and is still very much the state-of-the-art. Such programme actions might also be the best means to enhance networks and support measures that would help build capabilities to understanding the value chain and the client needs.

222. The fifth recommendation calls for similar network enhancement and capacity building actions as for the fourth recommendation. Widening of market view might also be achieved by such policy actions that would promote and enhance the consciousness of sustainability improvements in various industry sectors and the capabilities of these industries to use these improvements as their competitive advantage in the market.

223. The best way to approach the sixth recommendation might be to take the development of needed standards and regulations as a strategic goal in national as well as international policy work and subsequently ensure that there are means for appropriate actions by the right organisations.

224. Overall there has been many effective practices and policies in use in Finland over the years that have effectively moved forward the development of the bioeconomy in general and the two development lines discussed in this report in particular. Finland has invested in research activities for a long time and promoted collaboration between research organisations and companies. The start-up funding has allowed creation of spin-offs. In general, a lot of actions are promoted in the commercialisation space. All these have given a good ground to grow new business of the developments in the bioeconomy. What is needed now are the activities according to recommendations above. Also, orchestration of the ecosystems will need specific effort, something that particular should be paid attention to.

5. France

5.1. The biomass-utilising value chain

5.1.1. What types of biomass are envisaged as the priority feedstocks, and is this unusual relative to other enterprises in your country?

225. The feedstocks are sugar beet (approximately 2.5 million metric tons per annum), wheat (approximately 1 million metric tons), wheat straw, wood pellets and others. These
feedstocks are usual for France. In addition, others found in France include rapeseed, hemp, wood (e.g. poplar).

5.1.2. In your sphere of operations, who are the main suppliers of biomass, and what are the challenges in supply?

226. The main suppliers are farmers from the neighbourhood, within 50 km maximum from the site, and farmers’ cooperatives specifically for wheat.

5.1.3. Which type of refining technique(s) are to be used or are being used?

Sugar beet

227. Sugar beet: A sucrose extraction liquid-solid process, two further processing routes for liquid fraction:

1. Purification, concentration, end product being Thick Juice, liquor at 70% Total Solid and 94% of sucrose on dry substance
2. Fermentation, distillation, purification for alcohol 96 production, or drying for 99% ethanol production.

228. Thick juice: three routes:

1. Crystallisation to produce refined sugar
2. Fermentation, distillation, purification for alcohol 96% production, or drying for 99% ethanol production
3. Other fermentation processes outside of the biorefinery (to produce e.g. amino acids, chemicals).

229. Solid fraction (beet pulps): Drying and formulation to produce cattle feed.

230. Water: water in excess is reused for washing, or as dilution media in another process of the biorefinery.

Wheat

- Dry milling, to separate flour and bran
- Flour with two routes:
  a. Wet process, to separate protein (gluten) and starch
  b. Drying of gluten.
- Hydrolysis of starch and purification to produce a range of glucose syrups from 38% dextrose equivalent (DE) to 96% DE
- Fermentation of glucose, extraction and purification of metabolite or microorganisms to produce food and cosmetic ingredients, fine chemicals and chemical intermediates at laboratory, demonstration and industrial scale
- Non-glucose fraction of the glucose purification is used as complimentary feed for alcohol and ethanol production
- Flour dilution and direct hydrolysis without gluten extraction, distillation and purification to produce ethanol 96, or drying to produce ethanol 99
• Bran with two routes:
  a. Used as such as cattle feed
  b. Formulated with vinasses from distillation to produce cattle feed.

5.1.4. In your region, is it easy or difficult to find employees with suitable qualifications and experience for these operations?

231. The biorefinery is located in a rural area close to Reims, therefore, it is easy to find graduates, and workers who come from surrounding villages (5 to 20 km from the site). The positive image of bioeconomy makes the site attractive. However the plants are running round the clock, seven days a week, on a 5-shift basis, and recruitment for these types of jobs is difficult.

5.1.5. What types of products/processes/services are being developed?

232. The biorefinery hosts an open innovation cluster, including:

• CEBB (European Centre for Biorefinery and Biotechnology) an academic research centre within the frame of a partnership between “Region Grand Est, Departement de la Marne and Grand Reims” Public financing party and research chair are from “Ecole Centrale Supelec, Agro Paristech (two high level engineering school in France), Neoma Business School, and URCA (University of Reims Champagne Ardenne)

• A research Company (ARD), established in late 80s by local farmers cooperatives, to develop new products and processes to better valorise agricultural products and co-products produced in the Region, (typically, wheat, sugar beet, alfalfa), in the field of food ingredients, energy, specialty chemicals, cosmetic ingredients, this company offers nowadays process definition and scaling up from laboratory size to industrial demonstration for white biotechnology and green chemistry

• A pilot plant for the scaling up of a lignocellulosic ethanol process (Futurol Project) developed by Procethol 2G, a company established for this purpose and partly financed by BPI. The project being under the commercial phase, the pilot plant has been taken over by ARD to provide new services in the frame of lignocellulosic fermentation media for production of intermediate chemicals, food, feed and cosmetic ingredients

• This innovation cluster offers development services for the bioeconomy, and will shortly offer a risk sharing opportunity with SMEs or start-ups for covering the cost of technical feasibility of new projects including process scaling up, and cost price for the products. This will be made through Alfa Project which will be a public-private partnership between Region Grand Est, BPI, Venture Capital (SE Mia, DEMETER, ARD and CEBB with a coordination by IAR French Competitiveness Cluster for Bioeconomy.

233. The main products from the industry are: sucrose, glucose, ethanol; proteins; bran and DDG’s, dehydrated or concentrated beet pulps; cosmetic active ingredients (hyaluronic acid, dihydroxyacetone); methane; surfactants. At demonstration scale there are specialty food ingredients and chemical intermediates. Under construction is a black pellet fuel production plant from wood.
5.1.6. Can you give examples of end-user industries for these products/processes/services?

234. The biorefinery serves several market segments:

- Business to Customer (B2C) for refined sugar in various shapes and packaging
- Business to Business (B2B) such as food industries for sucrose, glucose, starch, ethanol, gluten, and specialty ingredients, feed industries for beet pulps, bran, DDG’s, cosmetic industries with actives ingredients, surfactants and ethanol, detergent industry with surfactants, ethanol, plant protection industry with surfactants and premix, energy with fuel ethanol, methane, and industrial black pellets.

5.1.7. What are the greatest challenges related to operating the current biomass utilising value chain?

235. The profitability of the biorefinery is for its food, feed, and energy linked to the world market price of the raw biomass, and oil, as raw material, and to the world market price of first transformation products such as sucrose, ethanol, gluten, methane and coal. The usage value of the other products being higher, they are less affected by economic variations.

5.1.8. What are the greatest opportunities related to operating the current biomass utilising value chain?

236. The opportunities are linked to a product diversification to serve “niche” markets that do not require large volume of biomass, but a strong market, scientific and technology knowledge to be a differentiation strength. It is the case with Bazancourt Pomacle, with specialty chemicals like surfactants, cosmetic active ingredients and food ingredients. A second opportunity is in the diversification of the type of biomass, to produce bulk products, such as fuel ethanol and black pellets.

5.2. Extension of value chain towards cross-industrial networks/industrial ecosystems

5.2.1. Is there potential for utilising biomass across a broader set of end-user industries?

237. One of the more promising industries which may be interested to have a biomass sourcing is the chemical industry for intermediates such as adipic, acrylic acids, bioplastics or new type of products bringing additional properties to existing ones such as polyethylene furanoate as a substitute to polyethylene terephthalate.

238. These kind of products would require some plants with unit capacity of 20 to 100 000 metric tons, thus consuming between 20 and 200 000 metric tons of sucrose or glucose, these numbers are achievable in biorefineries like the one of Bazancourt-Pomacle.

5.2.2. What kinds of knowledge and knowledge networks will be necessary to extend the value chain?

239. Outside of conventional process and products knowledge, the following has to be developed:
- Business: understanding the usage value of the existing product for its various applications, and potential volume growth according to price and performance
- Understanding the cost of existing products to be substituted, and the flexibility towards oil or gas price variation, and compare with those anticipated when using biomass
- Process: Identifying the potential difficulties for product acceptance by the users, i.e. good knowledge of the users’ processes and constraints.

5.2.3. Do you have examples of ongoing biomass refining/utilisation experiments, ventures, demonstrations for new products/processes/services?

240. There are several examples:
- Joint venture (JV) between Dupont Tate and Lyle for the production of 1,3-propanediol in the United States,
- JV between Corbion and Total in Thailand to produce poly-lactic acid (PLA) based on lactic acid produced at Corbion’s plant on-site
- JV between BASF and Avantium for the production of PEF (polyethylene furanoate) at demonstration and industrial scales
- JV between Global Bioenergies and Cristal Union for elaboration of a business plan and process optimisation stage prior to the construction of an isobutene production plant.
6. Italy

6.1. Country position and policies for bio- and circular economies

6.1.1. Definitions of bio- and circular economies

241. The Italian Bioeconomy Strategy defines bioeconomy according to the Europe’s Bioeconomy Strategy definition: “The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy.” Thus, it includes primary production - such as agriculture, forestry, fisheries and aquaculture, and industrial sectors using and/or processing biological resources, such as the food and pulp and paper industries and parts of the chemical, biotechnological and energy industries.

242. Circular economy, as defined by the Italian Ministry of the Environment, Land and Sea, is an economy “in which today’s products are the resources of tomorrow, where the value of products is preserved or recovered for as long as possible and in which there is a minimisation of waste and impacts on the environment”

6.1.2. Main priorities and drivers for transition to bio- and circular economy

243. As reported in the Italian Bioeconomy Strategy: “The global population increase, the adverse impacts of climate change and a reduction in ecosystem resilience all call for an improved use of renewable biological resources, i.e. for more sustainable primary production and more efficient processing systems able to produce food, fibres and other bio-based products with fewer inputs, less waste and greenhouse gas emissions and with greater benefits for human health and the environment (…) These elements are at the heart of a sustainable development that delivers strong communities by creating a flourishing economy that respects the environment. This is done by reducing dependence on fossil fuels and finite materials without overexploiting renewable resources, preventing biodiversity loss and land use change, regenerating the environment and creating new economic growth and jobs and leveraging on local diversities and traditions - in particular in the rural, coastal and industrial areas (including those that have been abandoned) - in line with the principles contained in the Juncker’s Agenda for Jobs, Growth, Fairness and Democratic Change”.

244. According to a report published by the Italian Ministry for Economic Development together with the Ministry of the Environment, Land and Sea in 2017, the demand for natural resources, especially raw materials, is expected to grow exponentially in the coming decades, due to an increase in the world population (more than 9 billion people expected for 2050) and the rapid economic growth of the developing countries. This trend, without the implementation of specific policies and measures for a more efficient use of resources, will also determine an increase in environmental and climate impacts. In this context, the diffusion of a new “circular” model of production and consumption is an element of strategic importance to achieve global sustainability goals, and it represents at the same time a key factor to relaunch the competitiveness of the country.

6.1.3. Existence and main content of relevant strategies/visions/road maps

245. The Italian Bioeconomy Strategy (2017) aims to achieve a 20% increase of bioeconomy-related economic activities and job positions in Italy through improvements in sustainability production and quality of products in each sector and through the creation of new investments. To achieve the first goal, many perspectives have to be considered:
exploitation of all the interconnections between primary production and transformation sectors; valorisation of marine and terrestrial biodiversity, circularity and ecosystem services; creation of new value chains, longer and routed, allowing the restoration of abandoned areas/plants and marginal lands. In order to facilitate the creation of new business, the main issues considered are: increase in investments in R&D, spin-off, start-up, communication, education and training; improvements in the coordination between stakeholders and policies on a European, national and regional level; promotion of specific actions for the development of a bioeconomy market, such as green public procurement. The strategy aims to produce new knowledge, technologies, services, but also to develop regulatory capacity, and public awareness. The strategy also includes action aimed at the promotion of bioeconomy in the Mediterranean area, through a more effective participation to the BLUEMED and PRIMA initiatives,

246. The National Energy Strategy and the National Plan for Climate and Energy have been developed in order to meet the requirements on GHG emissions reduction and renewable energy share.

247. Moreover, in 2010 Italy adopted the National Marine Strategy and the National Biodiversity Strategy: the former deals with the requirements necessary to achieve the Good Environmental Status for marine waters, the latter is focused on conservation targets and sustainable use of natural resources in sectoral policies.

248. The National Smart Specialization Strategy (2016) is designed to identify investment priorities in R&D and innovation, in order to complement the resources and productive capacity of territories, creating comparative advantage and sustainable growth. Two strategic plans have been specifically defined in order to support the Bioeconomy: the agro-food and bio-based economy, originated from an interactive process of cooperation between the public and the private sectors. Italian regions see great potential for development in the field of bio-based industry: an analysis of the regional Research and Innovation Strategies for Smart Specialization (RIS3), provided by the Italian Conference of Regions and Autonomous Provinces, shows how in the strategic assessment bio-based industry is second only to the agro-food sector. The potentials are related in large part both to the valorisation of wastes coming from food supply chains, with the aim of reducing environmental impacts, and to the development of dedicated crops in marginal agricultural areas, not in competition with food production.

249. The National Strategy for Sustainable Development has been approved in 2017. It integrates the SDG objectives and it is aimed to be the main tool for the creation of a new economic circular model, with low CO₂ emissions, resilient to climate change and other global changes. In order to orient the efforts of this economic and environmental transition in the right direction, the strategy defines 5 areas of intervention – people, planet, prosperity, peace, partnership – each of which is made up of a system of strategic policies translated into national objectives.

6.2. Description of case study value chain

6.2.1. Name and key features of focus organisation

250. Bioeconomy is the crucial innovation for realising the transition from an industrial production based on fossil resources to one that is based on the use of renewables. As reported in the Italian Strategy, “the bio-based industry is the segment of the bioeconomy that uses renewable biological resources in innovative industrial processes for manufacturing biomass-derived goods/products and services”. This sector supplies inputs
and knowledge for crucial sustainability-oriented technologies such as biofuels, bioplastics, biogas, biocosmetics, biolubricants, bioherbicides.

251. Italy is playing a role in the bio-based industry, thanks to the high level of innovation achieved through the development of several proprietary technologies in the field of green chemistry and industrial biotechnology sectors, the investments made and the availability of several value chains. As reported in the Italian bioeconomy strategy “Bio-based chemistry is one of the few sectors where our country is a leading player in a high-tech environment, with large private investments, and important projects underway for the reconversion of industrial sites affected by the crisis into biorefineries for the production of bio-products and bio-chemicals from renewable sources. Over a billion euros has already been invested in the re-industrialisation of decommissioned or non-competitive sites of national importance and for the construction and launch of four flagship plants - the first of their kind in the world”.

252. This report will focus on a specific Italian bioeconomy virtuous sector, that is, the bioplastics and biochemicals supply chain. Chemistry from renewable raw materials in Italy can count on thirty years of research and innovation and on a pioneering activity in the bioplastics and biochemicals sector, which has generated successful case studies, and a series of virtuous partnerships with the agricultural and business world, based on shared projects. The chain born and raised around this sector is inspired by a bioeconomy model conceived in a circular perspective as a tool for territorial regeneration, converting renewable biomass in high quality products within innovative biorefineries integrated into the territory. The model aims to create products from renewable origins designed to safeguard and protect water and soil from specific problems related to the accidental release of the corresponding fossil products, generating environmental, economic and social advantages.

6.2.2. Type of biomass being refined, main biomass suppliers, refining techniques

253. The Italian bioplastics and biochemicals supply chain is based on a green chemistry model promoting the use of low input vegetable raw materials, which can be exploited in all their components and can be cultivated on marginal lands. This renewable biomass is then transformed into high quality products within innovative biorefineries integrated into the territory. According to this approach, the construction of integrated agro-industrial value-chains based on the sustainable use of biomass is a decisive element in ensuring that the model for bioplastics and biochemical production is successful and sustainable from all perspectives.

254. As a matter of fact, renewable raw materials do not represent the solution to all the problems of pollution and to declining oil supply: agricultural crops are not all alike and even the same crops can have a completely different impact depending on the geographic area in which they are grown. It is therefore important to promote regional biodiversity, multiplying the opportunities coming from the study of different plant raw materials and local waste products, minimising transportation and maximising the creation of knowledge circuits and multidisciplinary projects with the various local stakeholders (universities, research institutes, high schools, voluntary associations, the agricultural sector, institutions and small and medium-sized companies). To achieve these goals, for many years the main industries of the bioplastics and biochemical chain collaborated with the academic world and with leading Italian and international research institutes to identify and study
oleaginous dryland crops with potential industrial applications, which can be grown on marginal lands unsuitable for traditional crops.

255. A key element affecting the crops selection is that they need to require a lower supply of inputs, especially in terms of water, a valuable and precious resource, particularly in Italy and the Mediterranean area. These marginal lands are not suitable for food crops, because of economic profitability, physical properties and geographical position. For this reason, if properly designed, bioplastics and biochemical crops cultivation is not in competition with food by nature. Targeted value chain projects can create additional production and income opportunities.

256. Another key aspect related to the choice of biomass is the use of renewable resources that are grown using sustainable techniques in lands which are not characterised by high biodiversity and without exploiting virgin or deforested land. Regarding the geographical origin of raw materials, as a general approach, the industries of the bioplastics and biochemical supply chain prioritises raw materials coming from European producers, within the logic of both creating positive impacts along the European value chain and reducing transport emissions and externalities.

257. These renewable raw materials can be converted into high value products through physical, chemical and biological processes based on pioneering proprietary technologies, resulting from huge investments in research and development. These technologies are implemented in biorefineries originated from the reconversion of abandoned industrial sites, helping in the renovation of abandoned environments and reducing land consumption.

6.2.3. Type of products/processes/services being developed

258. Biodegradable and compostable bioplastics are born with the objective to be a solution for specific environmental problems associated with the end-of-life of a number of traditional plastics applications. In fact this material helps to eliminate organic waste from landfill, especially when the packaging is prone to be mixed with organic contents during or after use, so that, if the packaging is compostable, it can be recycled together in organic recycling streams. After being processed in composting plants, these bioplastics, together with the organic content, are converted into high quality compost, a valuable soil improver, an important tool against desertification. In this way bioplastics return to agricultural land from which they are generated, closing the link of this circular approach. Some market applications that are produced with compostable bioplastics are carrier bags for supermarkets, organic waste bags, food service and packaging used in closed-loop, specific packaging items designed to be mixed with organic matter (teabags, coffee capsules, etc.). Another bioplastic application, different form packaging, is mulching film for agricultural use, which can be directly left on its natural environment since it naturally biodegrades in soil.

259. Biolubricants are the optimal solution for all machinery operating in ecologically sensitive areas such as agricultural, forest, marine or urban areas. In the event of accidental dispersion in the environment, biolubricants biodegrade in a few days without leaving any trace, while in case of normal use they guarantee the functionality and the integrity of all equipment. Another interesting advantage in term of safety is that the flash and fire point of natural and synthetic esters, such as biodegradable dielectric fluids, is higher with respect to the mineral oil values, meaning that using biodegradable vegetable oils reduces fire risk.

260. Biodegradable products for organic weed control, such as pelargonic-based herbicides, could represent a sustainable solution, in line with the principle of circular
economy and resource efficiency. Pelargonic acid is a product of natural origin based on vegetable oil that can be industrially produced in the biorefinery through a low-impact process. The results of pelargonic acid applications are visible after a few hours from the treatment, since it produces a rapid effect by contact. At the same time it allows the protection of soil microorganisms and it is totally degraded in the soil within a short period, without leaving any residues in plants and water and posing no risk to wildlife.

261. Another important field of application of the bioeconomy for the resolution of environmental problems is that of biocosmetics, i.e. cosmetics made with biodegradable ingredients, which avoid the contamination of sewage sludge and the dispersion of microplastics in the sea, since they are designed to directly biodegrade. These biodegradable ingredients from renewable origins can be used in both “leave on” and “rinse off” cosmetics products, such as exfoliating creams, toothpastes, make-up, moisturising creams.

6.2.4. Main ecosystem companies, type of companies and relationship with these

262. As reported in the Italian Bioeconomy Strategy, “the Italian bio-based industrial sector is characterised by a network of large, medium and small-sized companies which work together, leveraging on the sustainable production and efficient use of biomass, following a cascading approach to increase the added value of agricultural production with complete respect for the biodiversity of local areas, in collaboration with the agricultural world and creating partnerships with local actors”. The leading supply chain companies are active and participate in research, development and innovation projects, in collaboration with Italian and international subjects, in the field of bio-based economy, with the aim of creating strategic partnerships and connections between the world of research, industry, agriculture and institutions.

263. More specifically the main Italian player in this field is Novamont, global leader in the production of bioplastics and biochemicals (three different production facilities, plus the headquarters). The supply chain created by Novamont involves the production of building blocks for the industry, the research and development facilities and the production plants, creating a total employment of around 1 000 jobs, 60% of which are direct jobs and 40% are derived from indirect employment.

264. FaterSMART the business unit of Fater, in a joint venture between P&G and Angelini Group, are leading a 13-partner strong consortium (EMBRACED) from 7 different EU member states, which is demonstrating in a relevant industrial environment a replicable, circular, economically viable and environmentally sustainable model of integrated biorefinery based on the valorisation of the cellulosic fraction of post-consumer absorbent hygiene products (e.g. nappies) waste towards the production of bio-based building blocks, polymers, and fertilizers.

265. Caviro, located in the heart of Romagna region, is one of the most significant examples of integrated agri-food industry, with 30 wineries in 7 regions, 12 500 Italian winegrowers producing 10% of national grape production in over 35 000 hectares of vineyards. Thanks to its corporate know-how and equipment Caviro not only produces wine, but also gives value to by-products of grape processing, which become real “secondary raw materials” for the extraction of active ingredients such as oenocinque (E163), tartaric acid and polyphenols (OPC). Further waste products become in their turn raw materials for the production of energy and compost. Caviro will continue to search for
the enhancement of its products and the development of new ones, such as new active ingredients, bioplastics from waste and new fertilizers.

266. As reported in the Italian Bioeconomy strategy, an important factor that contributes to Italy’s success in bio-based chemistry is the existence of the Cluster of “Green Chemistry” SPRING, as “it represents a proven, effective collaboration between public and private stakeholders, and research bodies with strong competences on the main value chains of the bio-based industry; and a network of large, medium and small-sized companies which work together”. The SPRING Cluster is a national platform which brings together over 100 of the main stakeholders of the value chain, from farmers to entrepreneurial associations and it is aimed at encouraging the development of bio-based industries in Italy, through a holistic approach to innovation, aimed at relaunching the Italian chemical industry, focusing on environmental, social and economic sustainability. More specifically, SPRING has the objective of facilitating the transition from a product oriented economy to a system oriented economy, starting from territorial valorisation and from the collaboration between different public and private stakeholders. The goal is to maximise the impact of research and innovation, giving answer to the challenges of our planet, applying a concerted approach and diverting resources towards common goals.
7. Japan

7.1. Country position and policies for bio- and circular economies

7.1.1. Definitions of bio- and circular economies

267. Bioeconomy is considered, within the discussion group of biotechnology and bioindustry, to utilise renewable natural resources, i.e., biomass and biotechnology in the field of food, energy and manufacturing goods, although there is no official definition of bioeconomy in Japan. It will also cover the aspects of human health and environmental protection. The Japanese government is working on a formulation of a new bio-strategy.

268. Regarding circular economy, its similar concept of “Sound Material-Cycle Society” is defined in the Basic Act on Establishing a Sound Material-Cycle Society. The Act prioritised the utilisation of wastes to reduce, reuse, recycle, recover as heat, and to adequately dispose of wastes to minimise natural resources consumption and environmental burdens. Also, the Waste Management and Public Cleansing Act intends to ensure appropriate and recycle-based use of waste and the Act on Promotion of Recycling and Related Activities for Treatment of Cyclical Food Resources encourages the minimisation of food waste and to recycle the waste as feed or fertilizer.

269. Biomass is considered the resource of organic matter of plants or animals excluding fossil resources. It is characterised as the sustainable and renewable source of energy and raw material resources that can be utilised in several ways. In actual practice, biomasses are unused wood, wastes such as animal manures and microbes and algae. Unused and waste-derived biomass usually has no value or even requires disposal costs. Converting this biomass into energy or valuable goods could benefit local communities, where biomass is stored, for new business opportunities.

7.1.2. Main priorities and drivers for transition to bio- and circular economy

270. Possible priorities for the shift to a bioeconomy can be:

- Contribution to a stable global food supply through the development of ground-breaking agriculture, forestry and fisheries by biotechnology application
- Diversification of energy sources and enhancement of disaster resilience through expanding or renewable energy introduction including those from biomass
- Decrease of greenhouse gas emissions through the substitution effect for fossil fuels
- Revitalisation of rural areas by utilising biomass as regional resources
- Further promotion of cyclical use of resources.

271. Reflecting the adoption of 2030 Agenda for Sustainable Development at the United Nations in September 2015, the Japanese government set the guiding principle for realisation of Sustainable Development Goals (SDGs) such as “Zero hunger”, “Affordable and clean energy”, “Responsible consumption and production”, ”Climate action”, “Life below water” or “Life on land” in 2016, and various policy measures have been underway.

272. Also, adoption of Paris Agreement at COP 21 of the United Nations Framework Convention on Climate Change in 2015 led the government to the elaboration of the Global Warming Countermeasure Plan in 2016, aiming to reduce greenhouse gas emissions by 26% in 2030 and 80% in 2050 (compared to emission level in 2013). In this plan, responsibilities of central and prefectural governments, municipalities, businesses and citizens are stated respectively.
273. Furthermore, taking advantage of holding the Tokyo Olympic-Paralympic Games in 2020, the Japanese government is going to accelerate the establishment of a Sound Material-Cycle society as well as a low-carbon economy.

7.1.3. Existence and main content of relevant strategies/visions/roadmaps

274. Among the above measures, priorities related to biomass are specified in the Basic Plan for the Promotion of Biomass Utilization that sets directions of policy measures and relevant national goals. This plan was decided in December 2010 but the following Great East Japan Earthquake in March 2011 (the Fukushima Daiichi Nuclear Power Station was destroyed) led to a surge in demand for renewable energy introduction. Then the feed-in tariff system for renewable energy was enacted in July 2012. It encourages the production of biomass-derived renewable energy. Reflecting such changes in situations, the new Basic Plan for the Promotion of Biomass Utilization was decided in September 2016. Under the new plan, concrete national goals include: an increase of biomass utilisation from 24 million tons (CO₂ equivalent) in 2015 to 26 million tons in 2025, and; an expansion of new biomass industry from JPY 350 billion in 2015 to JPY 500 billion in 2025. The plan requires the government to take comprehensive and systematic measures to achieve these goals.

275. Specifically under the plan, the government promotes:
   1. Advanced use of biomass to create more economic value
   2. Multiple-stage application of biomass for thorough use of limited resources
   8. Biomass utilisation for heat that is energy-efficient in general.

276. Regarding advanced use of biomass, a clear-cut case is the transition of animal manure utilisation, from using it directly as fertilizer to conversion to methane gas that generates power while co-produced residual heat is used for heating facilities; CO₂ for feeding to greenhouse farming, and; the digested liquid to be delivered to fields as fertilizer. This example simply indicates the advanced use of biomass results in more diverse and high value-adding activities.

277. In the case of multiple-stage application of biomass, one example is that listings derived from sawmills are chipped to produce paper, feed or fertilizer and the remaining sawdust and smaller residues can be pelletised to generate electricity and heat.

278. In agricultural production sites, approximately 80% of energy is used as heat but biomass-derived heat is rarely used although direct use of heat is more efficient than applying electricity in these sites. This aspect is one of the reasons why the plan promotes using biomass as heat.

279. It is expected that when the efforts of advanced and multi-stage use of biomass and its utilisation as heat are made continuously, this will leads to revitalisation of local communities (especially in rural areas) and the further promotion of sustainable society with less environmental burdens.

280. In the case of biotechnology promotion, the Biotechnology Strategy in 2002 was followed by Dream Japan Biotechnology in 2008. Now the creation of a new strategy with a bioeconomy concept is underway. In this strategy, there will be a fusion of information technology and conventional biotechnology to enable energy generation, improve manufacturing and promotion of longevity and health, and restructuring the health care system.
281. Municipalities, which have jurisdiction for the management of wastes and are appropriate for harmonising views among local stakeholders, are primarily responsible for making plans of regionally stored biomass utilisation in an effective and efficient manner. From 2005 to 2011, towns and villages, with the encouragement of central government, made Biomass Town Plans. A total of 318 municipalities made a Biomass Town Plan. However, due to the nature of biomass existing widely and thinly, a certain number of plans did not meet with continued commercial success of biomass utilisation. Based on the policy evaluation of those results, the Biomass Commercialization Strategy was formulated by seven ministries in 2012 and the Biomass Industrial City/Region Scheme, which concentrates on economic sustainability, started in 2013. Awarding of Biomass Industrial City/Town involves evaluation by technological experts as well as financial experts. So far, 79 municipalities are recognised as Biomass Industrial Cities/Regions.

7.2. Description of case study value chain

7.2.1. Name and key features of focus organisation

282. Based on the Fundamental Law of Promoting Biomass Utilization, seven ministries are collaboratively in charge of promoting measures contributing to biomass utilisation in Japan. These are:

- Ministry of Agriculture, Forestry and Fisheries (revitalising rural areas and increasing farmers’ income by utilising locally existing biomass)
- Cabinet Office (basic national plans including the Cross-Ministerial Strategic Innovation Promotion Program that includes the verification research for enabling material utilisation of certain biomass)
- Ministry of Internal Affairs and Communications (ensuring municipal fiscal resources including through short-term funding for strengthening fiscal self-sustainability)
- Ministry of Education, Culture, Sports, Science and Technology (promoting research and development including low-carbon technologies)
- Ministry of Economy, Trade and Industry (ensuring stable energy supply including through promotion of renewable energy)
- Ministry of Land, Infrastructure, Transport and Tourism (streamlining sewage lines including utilisation of sewage-derived biomass)
- Ministry of the Environment (management of wastes, tackling global warming).

283. Moreover, several national R&D institutions/organisations conduct a number of biomass utilisation technology developments from the standpoint of each organisation’s objectives. Representative organisations are as follows.

284. In the agricultural sector, the National Agriculture and Food Research Organization (NARO) is engaged in the development of thermal energy conversion and utilisation technology of unutilised biomass as well as breeding new varieties of resource crops (such as Erianthus).

285. The Forest Research and Management Organization is engaged in research on development of technologies related to efficiently collecting and transporting wood biomass as well as material utilisation of cellulose nanofibres and modified lignin, both of which are assumed to have high potential. The organisation has also developed the business profitability evaluation tool related to wood biomass power generation and distributed it to people/enterprises involved as needed.
286. The Japan International Research Center for Agricultural Sciences (JIRCAS) promotes the development of an efficient and cost-effective saccharification technology for tropical crop residues in Southeast Asia, e.g., oil palm trunk (OPT), cassava pulp, sugarcane bagasse, as well as the practical use of biomaterial production technologies. In particular, technologies for bioethanol, biogas, and pellet fuel production from OPT and cassava pulp have already reached the practical level.

287. The New Energy and Industrial Technology Development Organization (NEDO) promotes applied research and development for social implementation of renewable energy. As Japan’s largest public research and development management (funding) institution, it conducts research as a part of economic and industrial administration and is engaged in two large missions: “Solving energy and global environmental issues” and “Strengthening industrial technology capabilities”.

288. The National Institute of Advanced Industrial Science and Technology (AIST) focuses on the creation and practical application of technologies useful for industries and society in Japan and the bridging function for connecting innovative technical initiatives to commercialisation. The organisation conducts studies for: the realisation of a sustainable society; the realisation of enriched and environmentally friendly society through green technology; the realisation of healthy, safe and secure living through life technology, and; the realisation of “super smart society” through information technology.

289. In the basic research field, the Japan Science and Technology Agency (JST) plays a core role in promoting the national science and technology basic plan, making strategic planning, promoting research and development, and promoting science and technology innovation. It develops a wide range of projects related to promotion of science and technology and contributes to advancing research and development to promote the SDGs and to the realisation of a low-carbon society.

290. In addition, the Japan Organic Resources Association (JORA), an incorporated association, has several member companies that are biogas plant manufacturers and biomass-related organisations. They conduct business feasibility studies on biomass power generation and heat utilisation equipment. They conduct information gathering and on-site surveying related to Biomass Industrial City/Region and publicly announces results obtained.

7.2.2. Type of biomass being refined, main biomass suppliers, refining techniques

291. Major biomass utilised in Japan is broadly classified as woody biomass, livestock manure, food wastes and sewage sludge. Regarding woody biomass, forest management bodies (or foresters) mainly supply unused timber from forest thinning and forest residues, and wood processing companies supply listings wasted from sawn timber. Animal husbandry farmers supply livestock manure, and food businesses (manufacturers, distributors and retailers) as well as households supply food wastes. Municipalities are major suppliers of sewage sludge.

292. Among refining techniques, in terms of biomass utilisation for energy, methane fermentation for gas power generation has been established. Especially methane fermentation efforts using livestock manure as a raw material has spread to some extent in a certain areas of Japan. In addition, there are also some cases of conducting methane fermentation by using food waste, sewage sludge, or the mixture of these raw materials. The digested liquid which is produced in large quantities in association with methane
fermentation is used as liquid fertilizer in fields and other farmlands, whereas in urban and inter-mountainous areas there is usually little or no place to use it as liquid fertilizer; thus in many cases it is treated in sewage systems after separation from solid matter. This process of treatment may cost tens of millions of yen per year. For this reason, the possibility of using liquid fertilizer of digested liquid largely affects whether the methane fermentation business is economically feasible.

7.2.3. Types of products/processes/services being developed

293. Some examples for products, processes and services at the demonstration stage are: the diversification of raw material biomass used as chips and pellets (e.g. Erianthus, oil palm trunk, bamboo, willow); production of light hydrocarbons through hydrogenated catalytic degradation of animal and vegetable oil; cellulose nanofibre combined with enzymatic and physical treatments without using chemicals.

294. Other examples at the research stages being conducted are:
- Production of liquid fuels by rapid thermal decomposition from woody biomass
- Production of modified lignin from Japanese cedar (a unique species in Japan) using polyethylene glycol
- Development of electronic materials from modified lignin
- Methane fermentation of woody biomass by wet milling treatment
- Manufacturing of jet fuel by mass-cultured algae with high oil productivity.

7.2.4. Main ecosystem companies, type of companies and relationship with these

295. Companies related to the use of biomass mentioned by JORA on Biomass Town or Biomass Industrial City/Area are multiple engineering companies, construction companies and shipbuilding companies involved in biomass utilisation, and within numerous biomass towns and biomass industrial cities, each company tries to elucidate respective features. Some of the examples of the companies are as below.

296. Kajima Corporation has technology related to biogas and contributes to a wide range of biomass business such as garbage, food residue, sewage sludge and soil. Recently, the company has put into practical use a project to greatly reduce sewage sludge by lowering molecular weight by hydrothermal treatment of sewage sludge. The company also manufactures and uses biodiesel.

297. Maezawa Industry Co., Ltd. specialises in the purification business for improvement of water supply for sewage and agriculture, biogas production from livestock manure and food waste using wet mesophilic fermenting bacteria, as well as biomass boilers using wood chips, refuse-derived fuel (RDF), waste paper, plastic fuel and so on.

298. Tsukishima Machinery Co., Ltd. is involved in carbonising sewage sludge to make fuel to substitute coal and thereby generate electricity. It is also characterised by the recovery of phosphorus resources.

299. Sanki Industry Co., Ltd. conducts biomass power generation using sewage sludge and woody biomass using a turbocharged fluidised-bed furnace. In addition, they are also working on effective utilisation of methane gas at sludge recycling facilities and thermal storage and transportation systems.
300. Ohara Iron Works Co., Ltd., which used to be an equipment parts manufacturer for oil extraction, sells small and low-cost biogas power generators. It also sells grinding machines, sorting machines, mixing processors with biogas, and responds to various needs.

301. Mitsui Engineering and Shipbuilding Co. Ltd. is involved in the biogas business as well as making feed and fertilizer using distillation residues of spirit and food waste.

302. Sato Industry has long produced fertilizer from livestock waste but in addition to that, they have constructed and delivered a high-speed fermentation treatment system targeting food residues and food sludge.

303. Hitachi Zosen is actively engaged in the utilisation of biomass and conducts phosphorus recovery, methane fermentation, woody biomass power generation, energy conversion of biofuels, etc. by using sewage, human waste and livestock manure. It has several options for methane fermentation depending on the raw material properties and mixes.

304. Dainippon Consultant Co. Ltd. is a general consultancy that conducts verification of commercialisation of digested gas power generation at sewage treatment plants, composting projects at parks, or verification of business performance of biomass boilers at tourist hotels.

7.3. Ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

7.3.1. Potentials for utilising biomass across a broader range of industries/sectors/higher value-added sectors, drivers to achieve these potentials

305. As for the potential of biomass utilisation, the amount of biomass in Japan is estimated to be approximately 34 million tons (2015) in total (mass of carbon), of which about 24 million tons (about 70%) is being used. In the medium to long term, it is thought that the stock of biomass will decrease due to efforts to control the generation of waste biomass. However, in order to promote the advanced use that creates more economic value, the target amount of use for each type of biomass as well as the national goal of biomass utilisation (approximately 26 million tons in total) are set in the plan of the government.

306. The market size of the biomass industry was about JPY 120 billion as of 2010. Then it expanded, mainly because of power generation efforts taking advantage of the feed-in tariff (FIT) system for renewable energy that came into force in 2012. The market value has thus increased to about JPY 350 billion as of 2015. The government’s Basic Plan aims to form a biomass industry market of JPY 500 billion in 2025, while promoting expansion of the market size beyond power generation.

307. In order to expand the use of biomass and its market size, the government promotes the construction, by each municipality’s effort, of the Biomass Industrial City/Region. It is an economically efficient system centring on the biomass industry that makes use of characteristics of the area, and aiming for environmentally friendly, disaster-resistant communities. In total 79 municipalities have been selected as Biomass Industrial Cities/Regions through the evaluation of financial and technical experts. In 27 of these municipalities, 45 facilities have newly started to operate since their selection as Biomass Industrial Cities, as of 2016. To further boost projects of the Biomass Industrial City/Region, the government offers support such as: related governmental budget project introduction and matching; introduction of best practices; technical direction towards the
realisation of the project of Biomass Industrial City, and; matching with plant/equipment manufacturers, consultans or financial institutions.

308. Shikaoi-cho in Hokkaido, one of the Biomass Industrial City/Regions, has large-scale dairy farmland, and odour from domestic animal manure and environmental loads on groundwater and rivers are target problems to be solved. Therefore, biogas plants and composting facilities have been envisaged. Electricity generated by biogas power generation is used in the facility and surplus electricity is sold to the electric power company by the FIT system to ensure economic efficiency. The digested liquid is released to agricultural land as liquid fertilizer and surplus heat is supplied to agricultural greenhouses and an aquaculture facility prepared at the adjacent site of biogas plant. As such, Shikaoi-cho works on various economic activities while utilising energy efficiently. Furthermore, in anticipation of the future hydrogen society, under the budgetary assistance of the government, a demonstration project to manufacture hydrogen from methane gas produced at the biogas plant and use it as automobile fuel is also underway.

7.3.2. Examples of ongoing biomass refining/utilisation experiments/ventures and related new cross-industrial collaborations to diversify to new business areas, foreseen economic or other impacts of these

309. Several companies in bioplastics have developed 100% bio-based plastics from biomass and are leading to industrialisation. Mitsubishi Chemical's DURABIO® is a bioengineering plastic made from the renewable plant-derived raw material isosorbide, which is superior to traditional fossil-based engineering plastics in terms of impact resistance, heat resistance or weather resistance. With good dying properties, it is possible to express smooth and deep colouring like a mirror surface that exceeds that of the equivalent painted item simply by incorporating pigment. In addition, because the surface is hard and scratch-resistant, painting is unnecessary, and volatile organic compounds (VOCs) can be reduced in the manufacturing process. Utilising this characteristic, in addition to various interior decorative design parts, it can be used on exterior parts such as pillars. Use by Renault, Mazda and other automobile companies is expanding.

310. Kaneka Corporation has been granted the certification of "OK Biodegradable MARINE" for biodegradable plastic (brand name: KANEKA Biodegradable Polymer™). This certification is based on VINÇOTTE of Europe, which proactively adopts bioplastics. KANEKA Biodegradable Polymer™ is 100% derived from plant or renewable resources and displays excellent biodegradability in both industrial and home composting systems, as well as in marine conditions. KANEKA is currently developing markets mainly for plastic bag applications in Europe. By regulating the manufacturing process of the polymer, flexible or rigid polymers can be produced for many applications such as plastic bags, composting bags, injection moulding applications, cutlery, paper coating or fibres.

311. Sekisui Chemical Co., Ltd. developed a technology to convert all household waste containing biomass and non-biomass as a whole into gas, then convert it to ethanol using microorganisms. Testing on a 1:1 000 scale pilot plant for three years, demonstrated the successful production of 20 000 litres of bioethanol per year. The plan is to manufacture a full-scale plant in the future and to produce tens of millions of litres of bioethanol. Also, by breeding/modifying microorganisms, it is possible to produce other chemical raw materials. This microorganism is provided from LanzaTech of the United States.

312. With regard to microalgae, universities and companies continued to make their own efforts, but in 2009 the “Cooperative Research Group on Agriculture, Forestry and Fishery and Industry” was formed, and the Industrial Competitiveness Committee COCN was
created in fiscal year 2011. The “Development of fuel utilising microalgae” was established, and in the same year The Japan Association for Microalgae Fuels (JMAF) was established. Until now, algae evaluation criteria have been investigated, along with as fundamental business tasks, such as cost calculation methods, low cost pond design, relaxation of requirements and overseas trends. In the future the plan is to produce the roadmap for practical use of fuel and cooperate in making rules for open field use.

7.3.3. Examples of need for/already tested/new business models to facilitate extension/collaboration/diversification

313. For the bioethanol mentioned above, Nissan Motors is developing a vehicle equipped with a system using a solid oxide fuel cell (SOFC) as a power generator. This is the world’s first to install SOFC as a power source of a car in a vehicle. The prototype vehicle was equipped with Nissan’s new fuel cell vehicle system “e-Bio Fuel-Cell” for the multi-purpose commercial electric van Nissan e-NV 200. Using 100% ethanol as a fuel, electricity generated by the SOFC is stored in a 24 kWh (kilowatt-hour) battery. Thirty litres of ethanol is said to achieve a range of over 600 km.

7.3.4. Relevance of circular economy solutions and viewpoints for extending value chains and diversifying to new business areas

314. Regarding the circular economy, with respect to food recycling for feed or fertilizer, the recycling rate for large-scale food manufacturing industries, with homogeneous properties and small amount of contaminants, is already over 95%. On the other hand, in food manufacturing on the smaller scale (food wholesale businesses, food retailing businesses, and the food service industry), recycling is not progressing much because of relative heterogeneity and relatively high sorting costs required for feed conversion and fertilisation. For this reason, by incorporating industrial ecology principles by these businesses (e.g. discharges from one business as a raw material for another), there can be room for expansion of the value chain through efficient resource utilisation and diversification to new energy production business. An example is performing methane fermentation for gas power generation (and heating). In this sense, it is of critical importance for the economy to have the viewpoint of the circular economy.

315. As an example, Bright Pig Co., Ltd, Chiba, utilises food residues discharged from major distribution chains (such as convenience stores and agricultural products such as feed rice and sweet potato produced in the area), and produces liquid feed for pig farms. The produced pork is sold through the same major distribution chains that are discharging food residues and a “food recycling loop” is thus being constructed. Also, the company composts pig manure, provides it to farmers and contributes to a ‘circulating’ agriculture.

7.3.5. Examples of how policies, agencies and their specific instruments have facilitated extension/collaboration/diversification

316. Regarding the use of biomass, energy utilisation through selling electricity has been greatly expanded by the FIT system of renewable energy that came into effect in July 2012. The scheme is a system whereby electric power companies purchase electricity from a renewable energy power generation company at a fixed price for a certain period of time (20 years), using the levies paid by the electricity consumers according to the usage amount. In particular, the procurement price of woody biomass derived from timber from forest thinning is JPY 40 per kWh or JPY 32 per kWh according to the output of the power plant. These procurement prices are higher than those derived from general timber, which
is JPY 24 per kWh or JPY 21 per kWh according to the output of the plant. The difference in procurement price between the two types of woody biomass is policy-driven so as to expand the use of timber from forest thinning. As a result, the capacity of power plants certified in the FIT system that uses thinned timber has increased sharply by about 24-fold compared to the capacity before introduction of the FIT. The procurement price of methane fermentation gas is set, under the FIT system, at JPY 39 per kWh, and the capacity after the FIT introduction has increased about four times compared to the capacity before introduction of the FIT.

317. The progress of energy utilisation of biomass as above can be seen to be brought primarily through policy guidance by the FIT system. At the same time, however, it is also largely due to the effects of policy measures for streamlining agriculture and forestry sectors which are responsible for the supply of raw materials. For example, it is pointed out that the improvement of forest roads and networks, which is the foundation of forest management, led to reducing the collection and transportation cost of biomass derived from thinning timber, resulting in expansion of its utilisation for electricity generation. In addition, technical and operational advances are also behind the expansion of energy use of biomass. For example, the number of methane fermentation gas power generation facilities using livestock manure as a raw material became 159 as of 2016, which is more than three times higher than in 2010. As a result, the accumulation of know-how related to the operation of a series of facilities such as the methane fermentation tank, gas holder, generator as well as the knowledge concerning the use of digested liquid as fertilizer have enabled the operation of plants in a stable and low cost manner, a major factor in the increase in new facilities.

318. The government expects biomass energy generation to reach 3.7 to 4.6% of the total power supply configuration by 2030. Currently about half of this is realised. From the viewpoint of achieving priorities it is important to accelerate efforts of biomass utilisation through further policy guidance.

7.3.6. Challenges related to extension/collaboration/diversification in general, specifically related to the regulatory/institutional regime

319. Approximately half of the energy demand in Japan is for heating, and heat accounts for most of the energy consumption in agricultural production sites in particular. In the Basic Plan of the government, greater promotion of biomass utilisation for heating is mentioned. However, for utilisation as heat, it is necessary to consider the matching of supply and demand and within broad areas. In particular, since Japan has not been developing effective heat supply infrastructure compared to European countries, in many cases it is necessary to introduce a thermal conduit from scratch in order to carry out district heating by biomass. Introduction of such infrastructure is not easy and requires large investments.

320. In addition, although the crude oil price has recently been in an upward trend, it has been kept relatively low during the medium term. That has also been a factor in reducing the incentive for consumers to switch from fossil fuels to biomass raw materials such as wood chips and pellets for heating. Although such issues cannot be resolved in the short term, it is at least necessary to optimise demand and supply and to lower the running cost of biomass heat utilisation while using the schemes of the aforementioned Biomass Industrial Cities/Regions, for example. It is expected that such economically efficient cases of district heating will increase, even considering initial investment costs for infrastructure.
321. Moreover, in the biomass power generation business, which has been rapidly expanded by utilising the FIT system, an insufficiency of transmission network capacity in many electric power companies has emerged, which is a major challenge for operators who intend to newly develop biomass power generation. In other words, even if a company has a plan to construct a new biomass power plant with the FIT system in mind, it is sometimes difficult for the company to start the business because the electric power supplier asks for the self-payment of new power transmission equipment in place of the existing transmission networks. Unable to bear the burden of such costs leads to abandoning of commercialisation. In response to this situation, the government is examining a mechanism (the Japanese Connect and Manage system) to ease or eliminate the constraints of networks.

322. Regarding power generation and heat utilisation by woody biomass, there may be a risk of uncertainty in the stable supply of raw materials over the medium to long term due to the decline in forestry workers and the aging of the rural society. On the other hand, however, trees were planted right after World War II in large numbers and full-scale logging has been achieved. The ratio of domestically grown timber related to total domestic wood use in FY 2016 was 34.8%, about twice that of 15 years ago. With this increase in timber production, there could be a substantial potential for increasing in use of woody biomass.

323. In general, a large amount of initial investment is required to develop a biomass utilisation facility, and in many cases, business companies face a challenge of initial fund procurement. In response to the adoption of the Paris Agreement, investors in each country have expanded so-called green investments, and there are cases where companies procure funds by issuing green bonds. Under such condition, considering the carbon neutral characteristics of biomass, projects that newly develop and operate biogas plants and district heating facilities can be considered promising as green investment targets. It can also be seen as an effective solution for the challenge of initial cost procurement.

7.4. Overall synthesis of findings

7.4.1. Main highlights, policy issues and findings from the case study

324. As has been investigated above, utilisation of biomass has been gradually expanding in Japan, taking advantage of the government’s Basic Plan for the Promotion of Biomass Utilisation, the Biomass Industrial City/Region scheme and other policy initiatives.

325. Firstly, in major cases, particularly in the utilisation of unused biomass such as such as forest residues and waste-derived biomass such as livestock manures, it can be seen that local stakeholders (including forest owners, forestry associations, farmers, regional agricultural cooperatives, plant manufacturers and operating companies) have been working collaboratively. In activities like burning biomass for electricity or heat generation and treating wastes for methane fermentation, it is essential to understand local residents. It is thus important to form consensus carefully by conducting briefing sessions at a local level. It is one of the major premises for project implementation.

326. For this reason, in promoting the utilisation of regional biomass, holding briefing sessions for residents together with companies to improve their understanding will greatly influence success or failure. Therefore, in the Biomass Industrial City/Region scheme, municipalities are positioned as the main formulators of the plan. They then coordinate with local farmers, plant manufacturers, local residents and other relevant stakeholders in
the planning process in a voluntary manner. In the case of successful commercialisation, for example in Shikaoi-cho, the person in charge of the town office presented the benefits of commercialisation to local residents in an easily understood manner. It is thought to be a secret of success in multiple town projects.

327. Secondly, most of the efforts to manufacture and use next-generation fuels and new materials (such as bioplastics) using resources such as microalgae and some unutilised biomass could bring about positive economic impact once they are put into practical use, and could lead to strengthening the competitiveness of global enterprises. On the other hand, when full-scale use of cellulose nanofibres is realised, raw material producers such as foresters will earn more profits. (These nanofibres are already commercialised in uses such as deodorant sheet material for paper diapers, or as a ball-point pen ink thickening agent). It is thus expected that not only large companies but also the local economy will benefit by such efforts.

328. Thirdly, efforts by collaboration in breeding new varieties and utilisation of biomass, such as development and cultivation of high-yield *Erianthus* varieties that fit Japan’s climate for use as a biomass fuel, may have a great potential. In Japan, demonstration tests are being conducted to cultivate *Erianthus* in abandoned farmland and to pelletise it for fuel use. If this demonstration test goes well, it will become possible to make economic activities by effectively using larger scale abandoned farmland. At the same time, maintaining agricultural land as farmland makes it possible to plant food crops in case of emergency, which is expected to enable supply and demand adjustment of land use. Such an effective utilisation model of agricultural land is considered to have the potential to contribute to food security in other countries. Furthermore, by applying innovative genome editing technology it is expected that further breed improvement will be carried out for climate change adaptation and raising yields.

329. The constraint of the electric network capacity can be a major challenge that needs to be urgently dealt with at national level in light of expanding further utilisation of biomass. Attention has to be paid to securing economic feasibility after the end of the FIT purchase period (20 years). This must be carefully considered at local business level. Moreover, autonomous and decentralised electricity/heat utilisation outside of the FIT system is very important given the high frequency of natural disasters in Japan. It is strongly desired that local stakeholders move ahead on discussing how to commercialise such schemes based on the future perspective of regional demographics and industrial structure.

**Disclaimer statement:** The opinions stated in this report are attributed to the authors and they do not represent the views of organisations to which authors belong.
8. Norway

8.1. Country position and policies for bio- and circular economies

8.1.1. Definitions of bio- and circular economies

330. The Norwegian national strategy for a circular bioeconomy was launched in November 2016. The following definitions and policy considerations are for the most part taken from this strategy document.

“Renewable biological resources from land and sea include resources from agriculture and forestry, marine resources, as well as other uses of living and dead biological material from microorganisms, plants, fungi and animals.”

331. Bioeconomy as a concept can be understood in many ways. Within the framework of the national strategy, the concept includes sustainable, efficient and profitable production, extraction and use of renewable biological resources for food, feed, ingredients, health products, energy, materials, chemicals, paper, textiles and other products. The use of enabling technologies such as biotechnology, nanotechnology and ICT is, in addition to conventional disciplines such as chemistry, key to the development of a modern bioeconomy.

332. Sustainability as a concept describes a development that meets present needs without compromising the ability of future generations to meet their own needs. This includes environmental, economic and social matters.

333. A modern bioeconomy includes several different sectors and industries, including traditional bio-based industries such as agriculture, forestry, fisheries and aquaculture, but increasingly also applications related to energy, transportation, waste, chemicals, health, climate and the environment. In the bioeconomy, value creation is based on the production and use of renewable biological resources as opposed to non-renewable carbon. New knowledge and technology, including biotechnology and industrial process technology, enable the production and use of renewable biological resources in new ways. They can be produced and used more sustainably and efficiently within and across different value chains and for the manufacture of profitable products with new properties or which replace products based on fossil carbon. Meanwhile, the increased use of space and natural resources can result in significant pressure on the environment and the ecosystems. The ability of ecosystems to continue to provide services important to the economy and public welfare is an essential basic condition for production and consumption.

8.1.2. Main priorities and drivers for transition to bio- and circular economy

Increased value creation and employment

334. The potential for value creation within the bioeconomy depends on the availability of renewable biological resources and our ability to optimise their use and maximise value creation. The bulk of the biomass is used for food, feed, building materials, energy, chemicals and cellulose-based products. With an adequate supply of biomass at competitive prices, the bio-based products can replace fossil-based or energy-intensive products to a greater extent. Further development and use of biotechnology and adjacent technology areas such as nanotechnology and ICT will allow for new applications of renewable biological resources, such as products in health and nutrition.
335. Norway has an abundant supply of renewable biological resources both at sea and on land, and an industrial and knowledge base that is well-suited to exploit them. In the short term, it is likely that an increased focus on the bioeconomy will contribute primarily to sustainable adaptation and increased competitiveness within established bioindustries, while in the longer run, it will also have an economically significant impact on the overall economy. If developments in the bioeconomy are to contribute to significant economic growth in terms of new economic activity and new jobs, this will likely require significant adjustment and renewal in the established structures and patterns of interaction in industry.

**Reduction in climate gas emissions**

336. It is a national goal for Norway to be a low-carbon society by 2050. The UN Intergovernmental Panel on Climate Change’s latest Assessment Report stated that increased use of renewable biomass will play an important role in combating climate change. Norway has some large industrial emissions and substantial biomass resources. The Norwegian Environment Agency has pointed out that from a climate perspective, it is important to use bioresources where we have no other solutions. Transportation and industry are sectors where opportunities to make use of bioresources as a substitute for fossil energy are particularly large. In Norway, the transport sector as a whole accounts for the bulk of emissions, with 31% of emissions in 2014. Use of low- and zero-emission technologies and sustainable biofuels can help reduce these emissions significantly in coming years. The climate gas emissions from industry in 2014 made up 23% of Norway’s total emissions. Use of sustainable bioresources can potentially provide large reductions in emissions from industry and possibly form the basis for new industries. For example, biochar can replace fossil coal in metal production. In addition, bio-based chemicals and materials can replace similar products based on fossil carbon. Increased production and use of renewable biomass for chemicals and materials may therefore contribute significantly to lower emissions in a life-cycle perspective.

337. Activities related to the construction and operation of buildings represent over the life cycle nearly 14% of total CO₂ emissions in Norway. The largest share of emissions come from the industry’s production of building materials. Wood is renewable and has lower production emissions than many other building materials. If wood or other bio-based materials can replace more energy-intensive or fossil-based materials, this will provide climate benefits. In 2014, agricultural climate gas emissions made up approximately 8% of total Norwegian emissions. Climate gas emissions from the agricultural sector can be particularly reduced through changes in consumption and improved production methods with lower emissions per unit produced. In addition, efforts must be undertaken to reduce CO₂ emissions from fossil energy and fuels in machinery and buildings, as well as CO₂ emissions from soil.

**More efficient and sustainable use of resources**

338. There is generally extensive waste of resources in the current economy. It has been estimated that 93% of the resource flow in Western economies is lost along the value chain, while just 7% is left in the products that reach the end-user; 85% of the products (measured in kg) become waste after one or no repeated use. From a sustainability perspective, it is desirable to adjust to a circular economy with more sustainable production, use and exploitation of resources. This implies minimising the amount of waste through reuse, recycling, reducing waste and increasing the use of residual materials from different types of productions. A national commitment to the bioeconomy could contribute to such developments. The objective is to exploit and create value from renewable biological
resources, even after a product is no longer used for its original purpose, as opposed to a more linear “use and throw economy” which assumes that resources are unlimited and easily manageable as waste.

339. Well-functioning ecosystems are a prerequisite for growth and prosperity in all societies. The most efficient utilisation of raw materials and resources will have a direct positive impact on both the climate and safeguarding biodiversity. We must come up with a cycle whereby the resources in waste are optimally used. With the potential for more efficient use of resources, there are also business opportunities. Norwegian industry can benefit from it. A goal of better use and reuse of raw materials can both increase the profitability of existing companies and form the basis for new, profitable and sustainable industrial activities in Norway. Norway has the raw materials, energy, access to water and a good skills base to build on. More profitable value chains and more sustainable development are created when residual materials from one production process are incorporated as a valuable resource in new production. In this context, it is important to have a cyclical approach and lifecycle analysis in order to ensure that new products contribute to a green adaptation in all phases of production, use and recycling.

8.1.3. Existence and main content of relevant strategies/visions/roadmaps

Short summary of the Norwegian Bioeconomy strategy

Overarching objectives

340. A national initiative on the bioeconomy shall contribute to increased value creation and a green shift in the economy by facilitating sustainable, efficient and profitable production, extraction and processing of renewable biological resources. The objective is to promote value creation and employment, reduced climate gas emissions, and more efficient and sustainable use of renewable biological resources.

341. Priority shall be given to measures that are believed to have a national effect on value creation/employment, as well as reduced climate gas emissions and/or more efficient and sustainable use of resources. It is a goal that the bioeconomy should be developed within a sustainable framework with an appropriate consideration for climate, biodiversity and other environmental, economic and social values.

342. Much of the potential for value creation in the bioeconomy lies in exploiting new knowledge and technology for more efficient use of resources and development of profitable products. Similarly, there is an untapped growth potential in exploiting synergies and developing new value chains across established industries, sectors and disciplines. On this basis, the initiative shall in particular advance knowledge and technology platforms capable of using renewable biological resources from several productions and with application in several industries. Such generic knowledge and technology platforms may contribute to increased collaboration across sectors and lay the foundation for new knowledge-intensive and profitable commercial activities.

Focus areas

Collaboration across sectors, industries and disciplinary fields

343. Efficient use of resources, where waste and side streams from one value chain is used as a resource in another, will require new collaboration across established sectors, industries and disciplinary fields. Cross-collaboration is thus a prerequisite for the other
focus areas. It is also important to allow for an effective societal dialogue regarding the desired development in this area. The government will therefore facilitate greater collaboration within and between bio-based value chains, as well as increased inter-disciplinarity and societal dialogue.

Markets for renewable bio-based products

344. An important prerequisite for value creation based on renewable biological resources is domestic/international markets that demand and value renewable bio-based products, for instance as an alternative to products based on fossil carbon. The government will facilitate this through better information on renewable bio-based products and reduced market uncertainty.

Efficient use and profitable processing of renewable biological resources

345. Key to the bioeconomy is more efficient use of renewable biological resources with a transition towards a more circular economy where waste is minimised and residual materials are optimally used. There is simultaneously a need for profitable processing and development of products providing high returns. On this basis, the government will both facilitate increased use and reuse of resources, and increased processing towards products with high returns.

Sustainable production and extraction of renewable biological resources

346. Increased use of renewable biological resources on a worldwide basis, including replacing fossil carbon, will require access to significant amounts of biomass. Norway has the potential for increased production and extraction of renewable biomass. Meanwhile, attention to climate, nature and biodiversity creates restrictions on how the increase can be implemented. The government will therefore facilitate increased profitable and sustainable production and extraction, and an appropriate framework for sustainable production and extraction of the renewable biological resources.

8.2. Description of case study value chain/ ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

347. Two cases have been studied, one related to valorisation of residuals from the marine and aquaculture sectors and another illustrating potential utilisation of carbon flue gases from metallurgical industry (CCU). Both case studies possess high relevance and potential as contributions to industrial ecosystems in a sustainable bioeconomy.

8.2.1. CASE 1: Advanced marine biorefining based on enzymes

Description of current value chain

348. The main driver behind this new value chain is technological innovation, here represented by the Norwegian company Biomega AS. Biomega is a pioneer in enzymatic processing of off-cuts from the salmon industry with a dominant patent position related to continuous “first in, first out” type of reactors.

349. The company was established in 2000 and runs a processing plant at Sotra outside of Bergen with a capacity of 60 000 metric tonnes of raw materials per year. In 2016, the company was acquired by the American private equity fund Amerra and with new ambitious owners, Biomega is currently exploring opportunities within other types of
marine feedstock, e.g. other farmed fish species and wild catch, as well as residuals from agricultural meat production.

350. Up to now, the primary products have been feed ingredients, e.g. pet food, but current R&D activities are aiming to develop ingredients for human consumption, e.g. nutritional drinks, potentially with documented health benefits. Fish odour and taste is a barrier to market entry, but may be significantly reduced using appropriate enzymes and downstream purification of products, for instance by filtration.

351. Biomega’s process is based on partial degradation of the protein fraction, leading to a peptide product with high nutritional value and a higher quality oil. A key factor is the availability of suitable enzymes, which need to be tailored to the feedstock in question and the desired product properties. The need for enzymes approved for use in food production limits the number of available alternatives.

352. A key challenge is access to raw materials, which need to be transported and stored as part of an unbroken cold-chain and processed within 48 hours. Hence, to ensure a steady supply of high quality feedstock, it is a strategic imperative to be co-localised with major fish food manufacturing facilities. For the Norwegian salmon industry, there is an increasing trend to export round fish to processing facilities in countries closer to major consumer markets.

353. Main business partners in the current Biomega value chain include:
   • Salmon slaughter houses and processing facilities within a few hours’ drive from Sotra
   • Developers and manufacturers of food grade industrial enzymes.
   • R&D expertise and a national pilot facility (www.biotep.no) operated by the RTO Nofima in Tromsø
   • Suppliers of hardware, such as equipment for phase separation, ultrafiltration and drying
   • Customers within the international speciality feed and pet food industries.

*Potential additional feedstock utilization*

354. Biomega’s technology platform is in principle applicable to any proteinaceous biomass. Compared to conventional fish meal, there are several advantages, including product quality and process economy.

355. A possible expansion strategy could involve partnership with landing sites and processing facilities for wild catch on a world-wide basis, e.g. pelagic and white fishes. Currently, the main showstopper is market acceptance, hence most R&D activities are concentrated on optimising the enzyme cocktail.

356. In addition, Nortura, the main Norwegian meat cooperative, has licensed the Biomega technology, initially to create chicken co-products, but potentially also for livestock residuals. Potentially, ingredients generated from such feedstocks may penetrate the market more easily, but also in this case the specific enzymatic process needs to be developed.
Potential product diversification and cross-sectorial expansion

357. Product diversification could be based on a more sophisticated fractionation of the raw materials. One possibility is cooperation with a company offering a proprietary technology of isolating the fish skin, i.e. separating the skin from the muscle, bone and viscera fractions. This might lead to a wide range of products based on fish leather or alternatively, processing the skin in a separate enzymatic reaction, generating an almost pure collagen peptide fraction applicable in cosmetics.

358. The primary products of the Biomega core process may also be further refined into end-user products through business partnerships or acquisition of companies with relevant market access. This may include peptides with health claims, further processing and engineering of the lipid fraction to speciality oil products and possibly the extraction of minerals from the bone fraction.

359. A further opportunity is to use the proteinaceous product (peptides) as a nitrogen source in microbial fermentation. This has already been tested in a research collaboration with the main fermentation pilot facility in the UK (https://www.uk-cpi.com) with encouraging results. This links the Biomega value chain to the rapidly expanding field of microbial manufacturing.

Need for development of new business models (stimulating a circular economy)

360. Originally, Biomega’s business model has been to operate their own processing plants based on raw materials bought in the marketplace, preferable on long-term contracts. The partnership with Nortura, however, illustrates dissemination of the technology platform to other areas based on licensing.

361. A further alternative would be development of compact portable processing units, paving the way for partnership with owners of fishing vessels with on-board fillet production. One could also envision dedicated Biomega processing vessels exploiting seasonal fisheries by anchoring at local fish landing sites.

Benefits and implications from public policy measures

362. As the Biomega value chain is based on technological innovation, R&D support was the initial public contribution. National grants have been obtained from The Research Council of Norway, as well as from Innovation Norway, the main government agency for industry development. Initially, Biomega had limited in-house research capabilities, hence most R&D was outsourced, primarily to the two major Norwegian RTOs, Nofima and SINTEF, both with expertise on enzymology and process design. NIFES, another research institute based in Bergen, has been involved in evaluating the nutritional properties of the products. The RTOs do not only contribute expertise, but also sophisticated instrumentation beyond the budget of a typical SME.

363. Following any process development, the business case needs to be verified at scale in order to work out process economy and prepare product batches for evaluation by potential customers. In Norway the Biotep facility in Tromsø offers this type of infrastructure. Biotep has been financed primarily by local authorities and is operated by Nofima as an international open access facility. As mentioned above, the Biomega interaction with the CPI pilot facility in the UK was important for testing their product as a fermentation substrate.
364. Innovation Norway has several programmes to stimulate networking and innovation clusters formation. In the Biomega case, this has provided two main benefits. The collaboration with CPI was a direct consequence of a 5-year term collaboration between Innovation Norway and their sister organisation Innovate UK, jointly financing a research project between Biomega, CPI and a potential end-user from the fermentation industry. Another direct effect of the UK networking has been an enabling collaboration between Biomega and expertise on enzyme development in the UK. In a wider perspective, such international co-operation could trigger innovation and business opportunities for the whole Norwegian biomarine sector.

365. In the process of financing the initial commercial processing plant at Sotra, Innovation Norway provided soft loans with a risk reducing effect for the private banks involved. The Biomega case illustrates the high market risk typical for first-in-kind processes and products, and the importance of support measures during the vulnerable industrialisation phase.

Regulatory obstacles to potential value chain expansion and product diversification

366. For Norway, it would be important to encourage local processing of farmed salmon, thereby providing increased availability of residuals, i.e. feedstock for co-products.

367. In order to stimulate development of on-board biorefining of residuals, the fishing authorities could consider regulations that would prohibit discharging these residuals into the sea.

368. The Biomega platform may provide business opportunities related to new marine species such as zooplankton, krill or mesopelagic fish. In this case, the authorities could consider offering licenses for pilot fishing as well as providing research grants.

8.2.2. CASE 2: Fermentation of CO/CO₂ to feed, fuel and chemicals

Description of the proposed value chain

369. As with the previous case, the new value chains proposed in the following are based on novel technology. Focus organisations are feedstock providers from e.g. metallurgical or petrochemical industries, in combination with providers of advanced fermentation technologies, here represented by the US-based companies Lanzatech (Chicago) and Kiverdi (San Francisco Bay Area).

Feedstock examples

370. Eramet Norway AS is a wholly owned subsidiary of the French company Eramet, the world’s largest producer of manganese. Their plant in Sauda produces more than 500 000 metric tonnes of products mainly from imported ore, using Norwegian hydropower and imported coal in their smelters. The flue gas contains primarily carbon monoxide (CO) and some carbon dioxide (CO₂).

371. The CO is currently being burned for energy, but given the increased focus on climate change and policies discouraging carbon emission, Eramet is considering other alternatives for flue gas utilisation.
372. The Equinor (previously Statoil) plant at Mongstad is Norway’s largest petrochemical site, emitting 1.5 million metric tonnes of carbon-rich flue gases per year, primarily CO₂, directly applicable to the Kiverdi technology platform discussed below.

Technology providers

373. The American company Lanzatech has been a pioneer in microbial utilisation of carbon gases and is a globally leading expert on CO fermentation. Using naturally occurring microbes, they convert the CO into ethanol, which may be used as an additive in gasoline or become upgraded into kerosene (jet fuel). The first commercial production plant based on their technology commenced production in 2018 and several other plants are in pipeline.

374. Kiverdi is a relatively young start-up based on technology initially developed by NASA for the purpose of on-board food production during space missions to Mars. They utilise so-called knallgas bacteria, i.e. a different microorganism compared to Lanzatech. Growing on a substrate mix consisting of CO₂, hydrogen and some oxygen, these bacteria are comprised of up to 80% protein, as well as a range of interesting lipids and micronutrients. This technology is currently in early pilot testing, i.e. has not yet been scaled up and industrialised.

375. At Mongstad there is also a large test site for carbon capture. Technology Centre Mongstad (TCM) is a government financed technological infrastructure, which has been instrumental in the development and demonstration of methods for CO₂ concentration and purification. Companies providing such CO₂ upgrading technologies would be important in this business ecosystem.

376. Converting CO and CO₂ to hydrocarbons and other organic compounds, requires energy-rich hydrogen. This opens for synergy with other value chains and industries producing or utilising hydrogen, e.g. the transportation, chemical and metallurgical sectors.

377. Hydrogen can be conveniently produced by reforming natural gas. Alternatively, it can be produced by electrolysis of water, but this would require large amounts of electrical energy. Norway has a long-standing tradition using hydropower in hydrogen production. There are many companies that could offer equipment for electrolysis or over-the-fence hydrogen supply to these proposed CCU value chains.

Potential additional feedstock utilisation

378. Eramet and Equinor (Statoil), mentioned above, are only two examples of potential suppliers of a carbon gas feedstock. Lanzatech has entered into a strategic partnership with Arcelor Mittal, building a bolt-on CCU facility at the Arcelor Mittal plant in Gent, Belgium. Also in Norway there are several ferrosilicon plants and other metallurgical companies that might offer feedstock for either a Lanzatech or a Kiverdi process.

379. Moreover, Norwegian point sources of CO₂ includes manufacturing sites for cement, incinerators of household waste and several petrochemical refineries in addition to Mongstad. Gasification of waste or other bioresources to produce synthesis gas (i.e. CO + hydrogen) could make gas fermentation a key platform in the circular carbon economy.

Potential product diversification and cross-sectorial expansion

380. For Norway, it is strategically important to ensure a sustainable supply chain for aquaculture feed. Norway has three major fish feed companies, all internationally owned.
Skretting, a wholly owned subsidiary of Dutch Nutreco, is the world’s largest producer of fish feed and is currently exploring ways to reduce their dependency on soy protein. Nutreco has recently entered into a partnership with Kiverdi with the ultimate goal of producing fish feed by CCU. In this case, the societal benefit of reusing flue gas carbon would be a potential global reduction of soy monocultures and the related pressure on rain forest and biodiversity.

381. The Lanzatech case might initially provide fuel products, potentially offsetting consumption of fossil carbon in the transportation sector. However, once this infrastructure has been established, the microbes may be tailored to produce a wide range of other products, including precursors for chemicals and plastics, similarly reducing the chemical industry’s dependency on petroleum. Technically, the fermentation processes leading to these novel products might require hydrogen as an additional substrate, increasing the similarities with the Kiverdi process.

382. Chemical building blocks produced from carbon waste gases and renewable hydrogen could form the basis for sustainable materials. Specific opportunities related to polymer-fibre composite materials might emerge through collaborating with Norwegian expertise on wood fibre (microcellulose) and potential end-users among e.g. the Norwegian furniture and leisure boat industries.

Need for development of new business models (stimulating a circular economy)

383. Neither CO/CO$_2$ nor hydrogen are conveniently transported, hence the gas fermentation sites would need to be co-localised with both the carbon source and a high-capacity grid, offering sufficient power for hydrogen production. Given the high CAPEX involved, all supply agreements would need to be based on long-term contracts.

384. The suppliers of carbon gas feedstock are unlikely to differentiate their business into product markets served by the Lanzatech or the Kiverdi technology platforms. The same would probably apply to providers of flue gas purification technologies or electrolysis equipment companies. The most likely vertical integration is probably illustrated by the Nutreco-Kiverdi partnership, where Nutreco provides a reliable market channel. However, in the Lanzatech case one could also envision that an energy company might invest in CCU-derived fuels.

Benefits and implications from public policy measures

385. As with the Biomega case, public R&D support programmes are important for technology driven value chains. However, in both CCU cases, the enabling technology is obtained through international business partnerships. It is noteworthy that the Lanzatech opportunity was triggered by targeted technology scouting and inward investment activities on the part of Innovation Norway.

386. The Lanzatech technology is already fully demonstrated, but Innovation Norway has co-financed a techno-economic assessment and organised a stakeholder workshop to validate the specific business case around Eramet. In the Kiverdi case, the next development step would be a large pilot/demo facility to provide sufficient test material for Nutreco to carry out fish feeding experiments. The capital needed at this stage (TRL 6-7) is ten times larger than laboratory-scale research.

387. The primary objective for the CCU cases is increased sustainability, hence Innovation Norway considers financing an independent LCA comparison of protein obtained from gas fermentation with either yeast fermentation of cellulosic sugar or
conventional soy concentrate. A positive outcome would obviously strengthen the CCU investment case.

Regulatory obstacles to potential value chain expansion and product diversification

388. The interaction between a biotech company and a metal producer such as Eramet represents an interesting example of how existing practices might change. Provided with a bolt-on Lanzatech plant, Eramet’s CO stream could shift to ethanol production (replacing fossil fuel), and their current burning of CO to dry manganese ore would be replaced by hydropower. Overall, this would presumably have a positive climate effect, although this needs to be verified. If so; the question is whether this scenario would be stimulated by existing emissions policies.

8.3. Overall synthesis of findings

389. In this section the main findings are discussed, first issues specifically related to the two case studies, followed by a summary of issues common to both cases, as well as more general policy measures identified during the interviews.

8.3.1. Findings case 1 - Advanced marine biorefining based on enzymes

390. Today, most of the residual material from the seafood industry is utilised through low-grade applications such as silage or conventional processing to fish meal. Through advanced marine biorefining, however, residual material can be transformed into high-value products, including ingredients for human consumption. This industry case is an example of the development towards total and optimal utilisation of biomass and how innovation can benefit global challenges related to human nutrition and food security.

391. Generally, the opportunities in the advanced bioeconomy seem to be poorly understood among many traditional marine industries, which represents an obstacle to investments. Public measures that can facilitate networking and knowledge dissemination would be important to expand and connect existing industrial ecosystems and research communities.

392. A particularly interesting aspect of case 1 is how technology originally developed for the seafood sector has been transferred to the agriculture and livestock industries, creating a blue-green symbiosis that strengthens both value chains and creates common markets. In addition, this cross-sectorial interplay may lead to new innovation both related to the technology itself and to the derived products.

393. In order to further evolve these value chains, sufficient volumes of fresh residual material are needed. A main finding is that policies and instruments that can stimulate an increased and more even supply of raw material throughout the year would be important. Relevant public measures might include:

- Efforts to create increased awareness about the new opportunities in the seafood industry
- Regulations that would prohibit discharge of residuals into the sea and
- Policies that would discourage export of unprocessed fish, leaving more residuals for local use.
394. Measures related to R&D should also be considered, primarily focused on solving the issues connected to market acceptance for the end products and business opportunities provided by feedstocks currently not exploited. To this end, technological symbiosis with e.g. the enzyme developing sector would be beneficial. Furthermore, R&D related to development of smaller scale (portable) processing units and public support for the scaling up of new processes would be important.

8.3.2. Findings case 2 - Fermentation of CO/CO₂ to feed, fuel and chemicals

395. This case is especially interesting from a circular bioeconomy point of view as it contributes to reducing the environmental impact of two completely different industries, representing either end of a potential new CCU value chain. First, it points to an opportunity for the process industry to reduce their carbon gas emissions by capturing CO/CO₂ waste gases. Second, this value chain may generate products of large societal impact such as fuel, chemicals and feed ingredients, substituting current products detrimental to the climate or to biodiversity.

396. In case 2, public facilitation has already triggered increased awareness by proactively connecting companies within relevant industries, informing about the new opportunities. This practice seems to be appreciated by the industry and should be continued. However, findings show that policies and instruments would be crucial to establish a prosperous industry based on CCU in Norway. Availability and price of the two main feedstocks, carbon waste gases and hydrogen, are significantly influenced by government policies. Hence, predictable long-term framework conditions for the industry are perceived to be essential to reduce investment risk.

397. A major issue is uncertainty related to the future availability, quality and price of the carbon waste gases. The high investments required and the unattractiveness of transporting such gases, underscores the importance of long-term supply agreements and stable framework conditions. Relevant policies would be related to tax regulations, e.g. the fee/penalty regime imposed on industrial carbon emission and what industries would be exempt for taxation.

398. Another major cost driver, is the high cost related to the supply of “green” hydrogen, i.e. hydrogen produced by electrolysis using clean energy. In the proposed case 2 industrial ecosystem, hydrogen is generated using Norwegian hydropower; hence policies supporting the availability of cheap renewable energy would be very important for profitability, a fact that provides Norway with a competitive advantage.

399. Microbial utilisation of waste gases is still a relatively immature technology, hence significant R&D funding would be beneficial. Particularly, stronger financial support for mid-to-high TRL-levels (scale up and demonstration) has been identified as a crucial factor for commercialisation. Within the case 2 industrial ecosystem, research and innovation related to carbon gas purification and concentration and more efficient methods for production of hydrogen, would strengthen the competitiveness of the value chain.

400. Finally, the CCU value chain could potentially generate products with high value for society, i.e. climate friendly substitutes for fossil fuels and chemicals or bioresources negatively influencing biodiversity, such as palm oil or soy protein. This fact may justify policies and regulations stimulating the end user markets.
8.3.3. Discussion and suggestions for policies and measures

401. Government policies, measures and regulations will always generate the basic framework conditions for the development of new industrial ecosystems, but their effect can be supportive as well as detrimental to the development.

402. New products in the advanced bioeconomy are often faced with immature markets and competition from cheaper, but less sustainable alternatives. The most important public incentive for stimulating growth in the bio-based industries is predictable, long-term policies that give the industries predictability for their investments into projects which often have a longer payback time. These policies, as well as the underlying national and societal ambitions, should be communicated clearly to the industry.

403. Public involvement in establishing industrial networks/clusters and other measures to stimulate new interactions between companies, has been identified as another important catalyst for developing the bioeconomy and cross-sectoral cooperation. A typical challenge for emerging value chains in the advanced bioeconomy is the interdependency of the distinct subsections of the value chain, which calls for coordinated stimulation. In a circular bioeconomy this systemic risk is enhanced by the need for concomitant utilisation of the various side-streams (residuals), in order to confer profitability on the value chain as a whole.

404. The last category of common findings is the need for public co-financing of research and innovation throughout the TRL-scale. Both industry cases recommend a particular focus on the mid-to-high TRL-levels, as this phase is essential for significant reduction of technology risk and subsequent commercialisation. One example is public support for multi-user process scale-up and pilot production facilities. Maturing a new technology, process or product concept beyond the demonstration phase (TRL 7-8) is generally considered to be a key factor to attract private investments.

405. While policies and instruments should aspire to be as generic as possible to avoid favouring specific industries or technologies, some major societal challenges or market failures may require tailored measures to be effective towards a desired goal.

406. In summary, the case studies suggest the following general policy instruments would be relevant for stimulating the circular bioeconomy and bio-economical business ecosystems (not in order of priority):

- Long-term public strategies on industry regulations and open communication
- Raising awareness by facilitation of knowledge dissemination and networking
- Public funding for early stage research and competence building
- Policies and incentives for product labelling and consumer information
- Public funding and support targeting mid-to-high TRL-levels (scale-up and demonstration)
- Public incentives for industry collaboration and a holistic approach to new value chains.
9. Sweden

9.1. Sweden’s position and policies on a forest-based bio- and circular economy

407. Sweden has large biomass resources and several well-developed industries that already today contribute significantly to the bio-based and circular economy. About two-thirds of the area in Sweden is covered with forest, out of which 80% is cultivated. Approximately 1% of the cultivated forest is felled annually and over the past 90 years Sweden’s forest resource has doubled. Approximately 80% of the forest products are exported at a total value of approximately EUR 10-15 billion per year and the industry has 70 000 people in direct employment. Residues such as tops, branches and bark have also formed the basis for a rapid expansion of heat and power production, benefitting a wide range of industrial purposes, and continues to be the basis for an expansion of a circular bioeconomy and the development of future biorefineries.

408. Sweden’s current position and policies in the forest-based bio- and circular economy have their origin in the 1970s and 1980s, when Sweden was heavily dependent on fossil resources in key economic sectors. During and in the aftermath of the 1970s oil crises, significant efforts were undertaken to reduce oil dependency, and increasing the use of biomass became one of the key strategies that emerged. With the introduction of a carbon tax in 1991, a significant share of oil and coal in industry, district heating and the heat and power sector started to be phased out. As a result of the tax, in combination with earlier experience, the overall national dependency on fossil resources (oil, coal and natural gas) fell from 70% in 1970 to less than 30% in 2018. In this energy transition, biomass as a resource has played a key role for reducing Sweden’s overall dependency on oil. For example, in industry and district heating biomass accounted for as much as 40% and 60%, respectively, of the energy use in 2018. In 2018, 36% of total energy use and roughly 15% of total electricity production in Sweden came from biomass. In total, Sweden uses approximately the same amount of biomass as petroleum products in its total energy mix.

409. To further stimulate the use of biomass in the transport sector, biomass has been exempted from the CO₂ tax and has benefitted from reduced energy tax. Significant research efforts have also been made for scaling up different types of forest-based biorefinery concepts for increasing the domestic production of biofuels. Since the early 1990s, four main industrial scale demonstration facilities have received substantial government funding for demonstrating new value chains from the forest.
The Värnamo facility was first constructed by the electrical utility firm Sydkraft (later E.ON) in collaboration with the technology supplier Alstom (later Foster Wheeler) for demonstrating electricity production in a large scale integrated gasification combined cycle (IGCC) using solid biomass. After successful demonstration, during the 1990s, plans were developed for converting the plant for demonstrating synthetic fuel production through pressurised oxygen fluidised bed gasification. However, due to organisational and institutional problems the plans were abandoned and the plant was mothballed year 2000-2001.

LTU-Green fuels is an industrial scale demonstration plant in Piteå, constructed in 2004 and operated until 2012 by the company Chemrec. The facility has successfully demonstrated the entire value chain from gasification of black liquor for the production of transportation fuels to its use in vehicles, including associated infrastructure. When Chemrec withdrew from the project, due to financial difficulties in 2012, the facility was taken over by Luleå Technical University (LTU). LTU mothballed the plant in 2018 due to lack of funding.

Gobigas is a project in Göteborg, which included the construction of a 20 MW gasification unit for the production of methane from solid biomass. The plant was successfully taken into operation during 2014 and was operated by local energy utility Göteborg Energy until April 2018. The plant was mothballed in 2018, due to a political decision in the municipality. RISE Biorefinery plant is located in Örnsköldsvik. The plant was constructed in 2004 by the company SEKAB, but its operations were taken over by the research institute RISE and is still used to demonstrate various biorefinery concepts and production of small volumes of specialty chemicals.

These four pilot and demonstration projects have been at the core of developments in new biorefinery concepts and forest-based value chains for the transport sector, receiving direct governmental funding for construction and associated research in the range of EUR 20-100 million each. The projects are similar in that they have:

- Successfully managed to demonstrate technically their respective value chain, with the exception from Värnamo which only demonstrated electricity production.
• Focused on taking forest-based biomass into a ready-made fuel that can be used for the transport sector
• Required significant up-front capital investments (in the range of EUR 200-400 million), for taking the next step in development, by industrial actors that could integrate the technology into their operations
• Not been competitive with regards to their production costs against fossil fuels or 1st generation biofuels under existing policy frameworks
• Been associated with significant political risks, making this type of investment not very attractive to the industry.

414. The exemption from CO₂ tax for biofuels going into the transport sector has been re-evaluated every year or every second year by the European Commission. This has created unstable investment conditions since the industrial actors have not known for how long the tax relief would last. With the absence of other policy initiatives that could off-load the initial financial and market risk for the investors, the above-mentioned technology concepts have not been scaled up. Instead the tax exemption has favoured imports, resulting in a situation where only 15% of the 13 terrawatt hours (TWh) of biofuels in the transport sector in 2015 came from domestically produced fuels and less than 6% from forest-based value chains. Swedish biofuel policy can thus be seen as relatively successful, resulting in the national biofuel targets being met, but also as disappointing since they have not created the conditions necessary for scaling up forest-based value chains and allowing for new investments in Sweden.

415. Since January 01, 2018, a new Swedish climate law and policy framework stipulates that Sweden will not contribute any net GHG emissions by 2045, and thereafter will produce negative emissions. Even though significant inroads have been taken for achieving this target, the GHG emissions from the transport sector are only very slowly decreasing and still accounts for more than 30% of total emissions. A specific target has therefore been formulated for the transport sector, stipulating that the emissions from the transport sector will decrease by 70% by 2030 from 2010 emissions levels.

416. It is unclear which role biomass can or should play in realising this new target in relation to other potential uses, since there is no national strategy on the bioeconomy which integrates industrial development with climate goals. There is, however, a research-specific strategy on the bioeconomy formulated by the research councils Formas, Vinnova and the Swedish Energy Agency in 2012. As a result of this strategy there are significant research activities covering a wide range of bioeconomy activities in multiple sectors, but all national regulations are so far focusing on reducing the emissions from the transport sector. Significant incentives for reaching the transport-related target therefore exist, using biomass as a resource, but very few specific fiscal instruments have been identified which provide incentives to actors beyond the transport sector. No other sector-specific targets have been formulated for achieving the national climate target.

9.2. Description of case study value chain: The development of forest-based biorefinery value chains in Sweden

417. Thus, significant efforts in commercialising forest-based biorefineries have had very limited commercial success and only one of four major demonstration facilities is still operating (Figure 4). None of the existing biorefineries producing biofuels in Sweden are based on the above-mentioned and demonstrated concepts and there are only two refineries
that use the forest as their main resources (see Figure 4). The other two are based on agrarian resources such as rapeseed oil (Perstorp) for biodiesel production and wheat for ethanol production (Lantmännen).

Figure 4. Existing large scale biorefinery plants in Sweden producing transportation fuels as one of their main products.

418. In the two cases of forest-based biorefineries, Domsjöfabriker is a sulphite-based speciality pulp mill that was funded in the early 1900s and has then developed into a biorefinery producing a multitude of different products from forest-based resources. Among their main products is a specialty cellulose for the textile industry as well as lignin, bioethanol, biogas, hartz (resin) and CO$_2$. Due to its unique character and lack of similar sulphite-based mills, their concept is not scalable beyond existing sulphite-based mills. The point of departure for this case study is the collaboration between the oil refinery Preem and Sunpine, a joint venture between Preem, the Swedish forest industry and the small engineering company Kiram.

419. Preem is located on the west coast of Sweden and has two main refinery sites, one in Lysekil and the other in Gothenburg. The company is the largest refiner in Sweden, refining approximately 18 million m$^3$ of crude oil every year, out of which approximately two-thirds is exported to the international market. The company is owned by a private investor and was acquired from OK Petroleum in 1994.

420. In spite of the financial crisis and political uncertainty surrounding the temporary tax exemption, Preem entered a joint venture with the engineering company Kiram and the forest industries Södra and Sveaskog in 2008. The purpose of the joint venture was to build a facility in the north of Sweden, using crude tall oil for producing biodiesel. As Preem joined the project, the concept changed from the production of regular biodiesel from tall oil to a less complex intermediate that could be used in Preem’s hydrotreating plant, making a hydrogenated vegetable oil (HVO) 100% blendable with conventional diesel. The idea of a distributed production, creating an intermediate product at one site, and
transporting that to a different site simplified the production at Sunpine significantly. Moreover, it lowered the overall cost of the project since the existing infrastructure at Preem could be used in combination with the know-how on making fuels which can meet existing standards and blending requirements. The concept of distributed production was also going against the basic idea behind the main investments being undertaken in Sweden for developing forest-based biorefineries at the time, which focused on producing a ready-made fuel at the same site that the biomass was refined.

421. Crude tall oil is a dark brown, viscous and sulphur-containing liquid obtained in the production of pulp through the sulphite process. It contains significant amounts of fatty acids that can be distilled into various products. In the Smurfitkappa laboratories in Piteå, it was shown that crude tall oil could be used for the production of advanced biofuels. In 2007 and 2008, the supply of crude tall oil could be secured from pulp and paper companies in the Piteå area and financing for a commercial scale plant was secured in 2008, in spite of the financial crisis. The first-of-kind plant entered operation in 2010. Most of 2011 was spent solving teething problems associated with starting up the new process. In 2012, the production was stabilised and since 2013 the plant has been operating at higher than design capacity with high reliability.

422. The yield of intermediate biodiesel product at the start of production was about 60%, which may seem low. In order to increase the yield of valuable products from the plants, Sunpine started to develop processes for extraction of rosin chemicals from the crude tall oil in collaboration with a Japanese pine chemicals company, Harima Chemicals, and its daughter company Lawter. Lawter and Sunpine agreed to realise the rosin plant investment project, the plant was built in 2015 and Lawter was included as a new partner in the Sunpine consortium. The effort resulted in an increased yield to over 70% with significant impact on overall economics and profitability. As a next step, Sunpine then also started to extract turpentine from tall oil. Turpentine is used in the manufacture of many different products including paint, lacquers and perfume. The turpentine production at Sunpine is around 3 000 tons per annum compared to 25 000 tons of rosin and over 90 000 tons of tall oil diesel per annum. Profitability of the crude tall oil refinery of Sunpine has increased significantly, going from a rather low yield in the first years of operation, by adding other products and increasing plant availability. These measures have had a strong and positive impact on Sunpine’s financial results. However, the primary investment would not have taken place without being able to prove that the production could reach profitability based on the main product, biodiesel, regardless of the potential profitability of future by-products.

423. Crude tall oil is a very limited commodity raw material compared with fossil oil. It will not be possible to increase the Swedish production much more and on a global basis there may not be much more than 2.5 million tons of tall oil. As a result, stakeholders like Preem, Sveaskog, Södra and Kiram as well as a wide range of other firms have started to look for and develop other but similar resources. Following in the footsteps of Sunpine, the goal of these stakeholders is to scale up the current concept of ‘distributed biorefining’ in which the infrastructure at oil refineries is taken advantage of in combination with local facilities for production of intermediate products (such as lignin, pyrolysis or other oils from hydrothermal liquefaction as well as Fisher-Tropsch waxes). However, before being able to pursue a further commercialisation of the distributed biorefinery concept the main policy barrier, the temporary exemption of CO₂ taxes, had to be overcome.
9.3. Ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

424. Leading up to 2018, the main barrier for scaling up the production was still the temporary exemption from CO\textsubscript{2} taxes that had to be approved by the EU every year or every second year. The tax exemption did not create the necessary incentives to speed up the implementation of forest-based alternatives for transport fuels since investment security was not created for more than two years at a time, while the payback time for the necessary investments most often were in the range of 10-15 years.

425. As a relatively small oil refinery in Northern Europe with no control over crude oil resources and operating on what, from a climate perspective, should become a declining market, Preem identified it as strategically important to develop forest-based biomass resources for staying competitive in the long run. Given that favourable market conditions for biofuels would be created, Preem thought that they could potentially turn a global competitive disadvantage into an advantage, by being relatively small scale and a flexible refinery with good connections to the forest industry and national political decision makers. However, for making the business case, it was considered important that, firstly, the biofuels they would develop were not directly exposed to a fluctuating oil price, secondly, that they would be promoted in relation to their CO\textsubscript{2} reduction potential and, thirdly, that the fuels would be considered legitimate in the eyes of the public.

426. Preem together with other leading industry representatives, the Swedish Biomass Association (SVEBIO) and others initiated intensive work to identify and suggest an alternative to the temporary tax exemption as soon as possible. With slight variations, the industry soon settled for, and started to promote, a so-called ‘reduction quota’ to replace the tax break. In parallel, the Swedish Energy Agency, was assigned by the government in 2016 to investigate and propose an alternative to the existing tax exemption. The investigation also suggested a reduction quota, benefitting the biofuels that can provide the highest reduction of greenhouse gas emissions at the lowest cost. In 2017, the Swedish Government announced that the reduction quota would come into effect by July 01, 2018. Emissions reduction levels have been specified for the years 2018-2020 and an indicative reduction has been set to 40% by 2030.

427. With the new incentive structure in place, Preem has increased their ambitions to produce biofuels from 200 000 m\textsuperscript{3} to 3 million m\textsuperscript{3} by 2030. It has also spurred significant entrepreneurial activities in the field that potentially could deliver towards the new goal of Preem and Sweden’s ambitions to significantly reduce domestic emissions from the transport sector (see Figure 5).
Two of the initiatives focus on various types of techniques for separating out lignin from black liquor and then converting the lignin through enzymatic and/or catalytic treatment to a bio-oil that can be shipped and upgraded at the refinery through hydrogen treatment. The technology start-up Suncarbon was founded in 2014 in collaboration with Hulteberg Chemistry and Engineering and Arkell Innovation. In collaboration with the research institute ETC-RISE and a pulp and paper company in Piteå, they have constructed a small-scale pilot plant in which they demonstrate the concept of continuous slurry hydrocracking for the production of a bio-oil that can be upgraded at an oil refinery site. The plant has been running since early 2017 and the results are promising. However, lignin is a highly contaminated and complicated fuel and it is still too early to take the step to a large-scale plant.

Renfuel, a technology start-up company similar to Suncarbon, develops a similar technology, based on lignin separation and catalytic treatment, for creating a bio-oil that can be blended into the refinery process. With financing from the Swedish Energy Agency, the company has constructed an industrial scale pilot plant at the pulp and paper mill Rottneros in Bäckhammar, Sweden. The pilot plant has been in operation since 2017. In May 2018, Renfuel entered a joint venture with Preem called Lignolproduktion AB with the purpose to build the first commercial scale plant in collaboration with Rottneros to process 25 000-30 000 tons of lignin each year at their facility at Vallvik.

The production of 25-30 kilotons of lignin oil at each refinery site may not sound a lot. However, the technology allows for separating the lignin from the black liquor and thus off-loading the recovery boiler at the mill. This allows for increasing the capacity at the mill without making new and expensive investment in their recovery boiler. Hence, through a smaller investment in lignin separation for creating a lignin oil, they can postpone or
avoid a large investment in a new recovery boiler while at the same time making a profit from the lignin oil. The situation brings multiple benefits at Preem. However, given the amount of black liquor in Swedish mills, implementing the technology at a large scale, off-loading 10-25% of their current capacity would enable the production of possibly 2 million tons of lignin oil in Sweden.

431. SCA is a pulp and paper company, venturing into biorefining that includes biofuel production. This example is slightly different from the rest since they have not decided on a distributed production of biofuels. Instead they are developing a drying technique of biomass called torrefaction in combination with lignin separation from black liquor, going all the way to diesel and gasoline production. A small-scale pilot plant that can operate continuously and process 10 kg black liquor per hour has been built and plans for scaling up the production to 300 000 tons of biofuels per year are being developed, based on two production lines, one where biomass is torrified and upgraded and one using lignin separation. A final investment decision has yet not been taken, but if successfully developed, both the torrefaction and pyrolysis of forest residues opens up a significantly larger resource base than lignin separation.

432. Besides the collaborations mentioned above with the large pulp and paper industries, there are three interesting ventures going in different but complementary directions. The first two are two larger sawmills in Sweden and Norway, that have ventured into the biofuel business, using sawdust as the feedstock for producing biofuels. Setra in Sweden, has entered a technology cooperation with a European technology supplier who has been performing tests with sawdust from Setras sawmill in Gävle with good results. In total 6 tons of bio-oil have been produced based on the sawdust from Setra, and the end product has been evaluated with good results by Preem. In June 2017, Setra was granted approximately EUR 11.5 million, covering 45% of the budgeted investment cost, to construct a commercial scale facility producing approximately 25-30 kilotons of bio-oil at their facility in Gävle. A final decision to actually build the plant has yet not been taken. Also, in this case, the volumes may appear small compared to the national demand for oil. However, given the amount of sawdust available only at the Setra mill, it is calculated that more than 100 000 ton per year can be produced in the longer run if the technology would be implemented at their major facilities.

433. A similar initiative exists in Norway, where the sawmill Bergene Holm has created a new daughter company Biozin AS and entered into a cooperation with Preem with the intention to realise full-scale biofuel production sites in Norway. Sawdust is still the main resource, but the collaboration is licensing technology from the oil company Royal Dutch Shell. The technology being licensed is a hydrogen-based technology, which utilises proprietary catalysts to convert lignocellulosic biomass into an intermediate, which consists of oxygen-free distilled hydrocarbons that can be shipped and upgraded into various types of fuels at the Preem refinery site. The announced plan of Bergene Holm AS is to build a first plant in Åmli, Norway and thereafter another four plants in southern Norway with the potential of supplying approximately 600 000 m³ of Biozin.

434. The final example is the Finnish consortium consisting of the Finnish utility Fortum and technology supplier Valmet that has signed an agreement with Preem to explore the possibility of processing the bio-oil being produced in their commercial scale pyrolysis unit in Joensuu, currently producing approximately 50 kilotons of bio-oil annually. The plant is integrated with a combined heat and power (CHP) unit, producing heat and electricity to the local community.
435. Hence, the prospect of supplying various types of forest-based bio-oils that can be upgraded in a refinery infrastructure is well under way and may pave the way to significantly reduced emissions from the transport sector. However, processing organic bio-oils require that the refinery makes investment in renewable hydrogen production. Such a project is also pursued by Preem, where they are collaborating with the state owned electrical utility Vattenfall in order to produce renewable hydrogen from electricity.

9.4. Overall synthesis of findings

436. The introduction to this case study can be summarised with the simple statement “Sweden is forest”. Already today, Sweden makes use of as much biomass in its overall energy mix as it uses oil, in addition to being the third largest exporter of forest-related products. The extensive forest-related biomass resources have constituted the base for the development of important industries such as pulp and paper and district heating. The existing industries, with access to large flows of biomass, create exceptionally good preconditions for the development of a wide range of biomass-based products that may contribute significantly to a circular economy.

437. The ongoing energy transition in Sweden, in which fossil fuels are replaced, took off in the early 1990s with the introduction of a general CO₂ tax. The tax was increased over time and became an important driver in national climate policy. It spurred the development of alternatives to fossil resources and enabled an almost complete phase out of coal and oil in district heating and electricity production, significantly reducing Sweden’s overall oil dependency. Early on, increasing the use of biomass became a cost-effective option both in industry and district heating.

438. To further stimulate the use of biomass in the transport sector, biofuels were exempted from the CO₂ tax and this proved to be a successful strategy for increasing their use in the transport sector. In addition to the tax exemption, significant investments were made in industrial-scale pilot and demonstration plants with the intentions of commercialising forest-based biorefineries that could supply biofuels and other products to the market. However, the exemption was made on a temporary (1-2) years basis and therefore failed to create the necessary preconditions for scaling up these technology concepts.

439. Based on this case study, it is argued that Swedish policy has so far failed to integrate climate policy with an active industrial policy, by setting goals for the development of the industry and designing policies that can both contribute towards mitigating climate change and at the same time creating the necessary preconditions for the development and diffusion of new biorefinery concepts. The current Swedish strategy for the bioeconomy is essentially a research strategy, even if it underlines the importance of changing consumption patterns and attitudes. Hence, it supports the development of various technologies at a laboratory and pilot scale, but does not fully integrate research and market uptake. Several of the interviews also point to ample research funding, but a lack of deployment policies that can enable the construction of the first commercial scale plants.

440. It is also argued that climate policies targeting the transport sector have dominated. Hence, even if there are research initiatives in other areas, they have had difficulties finding traction since sector-specific goals and main fiscal instruments have focused on the transport sector alone. This has also resulted in an emphasis of industry actors on biofuels over higher value bioproducts. Although emissions from transport account for 35-40% of
Sweden’s domestic CO₂ emissions, an effective climate strategy that integrates research and industry policy would most likely need to include other sectors as well.

441. Events leading up to 2018 have made it possible to change the past temporary tax exemption to a more long-term policy framework called a reduction quota, where the fuel distributors are obliged to reduce the CO₂ emissions of the fuels they supply. Emissions reduction targets have been set for 2019 and 2020, and an indicative target of 40% reduction has been set for the year 2030. This policy is seen as more long-term by the interviewed industry actors.

442. Even before being implemented (July 01, 2018), the reduction quota has incentivised a wide range of economic activities, including the construction of new demonstration and commercial scale facilities for producing an intermediate bio-based product that can be upgraded within the infrastructure of a modern oil refinery that includes hydrogenated treatment of oxygen-rich oils. This has also implied a trend shift, from a focus on integrated facilities at a specific site in which resources are turned into a finished product, to a distributed production where smaller streams of an intermediate bio-oil from the pulp and paper mills, sawmills and district heating are made available and upgraded at a central refinery site. It has also shifted the attention to the development of the oil refinery infrastructure, making it a key resource for accomplishing renewable transportation fuels.

443. Another important lesson that comes from this case study is that even if the biorefinery concept allows for making profit from many different products, the Sunpine case illustrates the importance of being able to show profitability in one product for making the initial investment. Realising one profitable base product from forest-based resources is a major undertaking and requires significant efforts. It is not until profitability and a stable operation has been reached for the main product, in this case biofuels, that the actors have been, and will be able to, experiment and develop additional products. This also illustrates the importance of policy for creating a stable market that enables the production of other bio-based products at a later stage. When the production is up and running it can serve as a platform for further experiments, and a traditional R&D strategy can then play a larger role since there are significant resource streams that can form the basis for experiments and further development.

10. United States

10.1. Country position and policies for bio- and circular economies

10.1.1. Definitions of bio- and circular economies

444. Articulated in 2012, the US bioeconomy is defined as the output of research and innovation in the biological sciences for economic activity and public benefit, and its scope includes an array of industrial sectors that exploit the conversion of biomass as well as those that make use of biotechnology to create economic value. Although the United States considers biotechnology and biomass as critical parts of the bioeconomy, “biotechnology” is not included in the vast majority of the 40+ bioeconomy strategies of countries around the world. Biotechnology has for nearly 50 years been driving innovation in a wide variety of biomedical, agricultural, and industrial sectors, biotechnology is inextricably linked to the US bioeconomy.
10.1.2. Main priorities and drivers for transition to bio- and circular economy

445. New technologies drive the US bioeconomy. Biotechnology was born in the United States in the 1970s with the advent of recombinant DNA technology. Advances in genetic engineering approaches and DNA sequencing technologies over four and a half decades have accelerated innovation in the United States. Concurrently, strides were made in computing and data sciences, and the recent emergence of machine learning and artificial intelligence capabilities have catapulted the potential of engineering biology to new levels. Biological “big data” and algorithms capable of integrating large, heterogeneous datasets have enabled the development of new hypotheses, novel approaches to biological systems design and construction approaches, as well as the creation of predictive metabolic models. Adding to the acceleration in advances in biotechnology are automation and robotic liquid handling technologies that replace human labour and enable high-throughput methodologies at multiple steps in the innovation pipeline.

446. When considered an industry in itself, the economic impact of biotechnology in the United States is considerable if not challenging to measure precisely. Recent estimates suggest that US revenues from products of genetically engineering biological systems and organisms (i.e., biologics, crops and seed, products of industrial biotechnology) were in excess of USD 370 billion in 2016, up from USD 324 billion in 2012 and growing more quickly than the rest of the economy. Rob Carlson reports that industrial biotechnology is the fastest growing sector of the US bioeconomy; US revenues were more than USD 105 billion in 2012 and more than USD 140 billion in 2016 compared to genetically modified (GM) crops revenues at USD 128 billion in 2012 and USD 110 billion in 2016, and biologics revenues at USD 91 billion in 2012 and USD 110 billion in 2016. Advances in biological and computing sciences technologies have contributed in important ways to this growth.

447. Another significant driver of the US bioeconomy is the volume of renewable biomass in the United States. A 2016 report by the US Department of Agriculture (USDA) states that the United States “has the future potential to produce at least one billion dry tons of biomass resources (composed of agricultural, forestry, waste, and algal materials) on an annual basis without adversely affecting the environment.” In a 2015 report to the US Congress, direct sales of bio-based products in 2013 were estimated to be around USD 126 billion, and the bio-based products industry alone was credited with directly employing 1.5 million Americans in 2013 and responsible for a total of four million jobs throughout the economy.

448. The rapid adoption of biofuels from crops, including the conversion of corn to ethanol and soy to biofuels, has demonstrated the need for further research to protect water availability and quality, soil composition and nutrients, and to preserve the capacity to produce crops for food. Advances in the bioeconomy can help reduce forest biomass, which would decrease a forest’s susceptibility to fires; reduce downstream nutrients that result from intensified agricultural production, which would decrease the frequency of anoxic zones and Red Tide events; and would help capture gases produced during fossil fuel combustion. It is important that advances in the bioeconomy are coordinated with agricultural producers to increase the adoption of no-till strategies and cover crops that protect soils to reduce downstream nutrients, which would reduce environmental impacts from intensified farming. Further work is needed to develop systems that can segregate non-food crops that produce industrial chemicals and solvents from those grown for food so that industrial products cannot contaminate the food supply.
449. On the horizon, C1 waste gases such as methane and carbon dioxide are predicted to shape the future US bioeconomy. The US National Academies of Sciences, Engineering, and Medicine (NASEM) recently released a 2018 report Developing a Research Agenda for Utilizing Gaseous Carbon Waste Streams, which recommends a research agenda to address challenges associated with commercialising carbon utilisation technologies that can convert gaseous carbon waste feedstocks into valuable products such as fuels, construction materials, and plastics. The US Department of Energy plans to support fundamental research with strong connections to carbon utilisation.

450. Procurement of bio-based products is an important priority for the US government, and recent trends reflect significant progress in the displacement of petroleum feedstocks. In 2002, the US Farm Bill created the BioPreferred programme to “spur economic development, create new jobs and provide new markets for farm commodities. The increased development, purchase, and use of bio-based products reduces the nation’s reliance on petroleum, increases the use of renewable agricultural resources, and contributes to reducing adverse environmental and health impacts.” The BioPreferred programme has two components: a federal procurement mandate for bio-based products and a certification/voluntary labelling initiative for bio-based products. The mandatory purchasing component requires that federal agencies buy bio-based products from categories identified by USDA with bio-based content minimum levels. These include lubricants, inks, cleaning and construction products, and exclude food, feed and fuel. USDA also offers bio-based product manufacturers a voluntary certification and labelling initiative – third-party testing results quantify the products’ ‘new carbon’ content as derived from plants and other renewable agricultural, marine, and forestry materials. Currently, there are around 15 000 products in 109 BioPreferred-announced categories that qualify for US government procurement. There are around 3 000 ‘USDA Certified Bio-based Products’ labelled and sold in the markets above and to consumers.

10.1.3. Existence and main content of relevant strategies/visions/roadmaps

US Policy

451. Released in 2012, the US National Bioeconomy Blueprint had three purposes: set forth strategic objectives for federal agencies, highlight “bioeconomy progress” already being made by federal agencies; and signal to industry sectors a new and significant commitment to biological research as a future economic driver. The blueprint also outlined 5 objectives:

1. Support R&D investments that will provide the foundation for the future US bioeconomy
2. Facilitate the transition of bio-inventions from research laboratory to market
3. Develop and reform regulations
4. Update training programmes and align academic institution incentives with student training for national workforce needs
5. Identify and support opportunities for the development of public-private partnerships.

452. Over the last two years, many of these research areas have continued to be a US priority. In October 2017, the USDA released an interagency task force report, to respond to President Donald J. Trump’s Executive Order 13790, Promoting Agriculture and Rural
Prosperity in America. The strategy outlined in this report will help increase public acceptance of biotechnology products, modernise and streamline the federal regulatory system for biotechnology products, and expedite commercialisation of biotechnology products, all of which will improve the bioeconomy through biotechnology.

453. The FY 2020 Administration Research and Development Budget Priorities memo highlights the importance of biotechnology and the need to invest in early-stage applied research. The budget priorities memo focuses on needed investment in next-generation energy technologies, and improving crop efficiency, nutrition, resilience, and variety, all of which the bioeconomy supports. Further, the memo highlights the need for prioritised investment in precompetitive research regarding the safety of microorganisms, plants, and animals developed using gene editing, in order to better leverage biotechnology products for agriculture. Educating and training a workforce for the 21st century economy and increasing public-private partnerships is also a major theme of the R&D Priorities memo. Executing these priorities will lead to a more robust bioeconomy in the United States.

454. The President’s Management Agenda, released in 2018, lists improving transfer of federally funded technologies from “Lab-to-Market” as an administration priority. Better collaboration and coordination across federal agencies will help ensure products, including those developed to support the bioeconomy, will be brought to market more quickly.

National Academies of Sciences, Engineering, and Medicine Report: Industrialization of Biology

In 2015, NASEM released a report, The Industrialization of Biology, that described the advent of the use of biology as a viable, innovative, and powerful approach to the manufacture of chemicals traditionally derived from petroleum feedstocks, outlined barriers to the adoption of bioprocessing in the chemical industry, and provided a technical roadmap focused on main categories: feedstocks and pre-processing; fermentation and processing; design toolchain; organism (chassis); organism (pathways); and test and measurement.

455. Because roadmaps are “snapshots” that represent the current state of capabilities and challenges, the NASEM report recommended that the US government establish an ongoing road-mapping mechanism to provide direction to technology development, translation, and commercialisation at scale. Subsequently, some US agencies have invested in a recently established public-private consortium, the Engineering Biological Research Consortium, for this purpose.

Engineering Biology Research Consortium

456. Comprised of more than 60 academic researchers (faculty) and a dozen biotechnology organisations, the Engineering Biology Research Consortium (EBRC) has as a central focus to develop a vision of a future where all sectors are impacted by biotechnology. Specific goals and waypoints will be laid out in a research road-mapping and aimed to overcome identified barriers and maximise realisation of opportunities for engineering biology. Main aims of this programme include assessments of:

- Current state of engineering biology
- Global challenges for which engineering biology might be productively deployed
- Gaps in technology requiring research and development
• Opportunities for near term impact in specific sectors
• Security implications of the development of new biotechnologies
• Gaps in workforce development requiring new or better education and training programmes
• Gaps in policy requiring new or better models.

457. With the ongoing development of technical roadmaps, the EBRC aims to: transform roadmaps into coordinated funded programmes; catalyse research teams to address critical needs; identify and address engineering biology workforce needs; and inculcate the values of leadership, service, and responsibility required for safe and productive use of biotechnology.

10.2. Description of case study value chain

10.2.1. Name and key features of focus organisation

US Agile BioFoundry

458. The US supports a network of 17 Department of Energy-funded National Laboratories with a set of complementary core capabilities to:

• Execute long-term government scientific and technological missions, often with complex security, safety, project management, or other operational challenges
• Develop unique, often multidisciplinary, scientific capabilities beyond the scope of academic and industrial institutions, to benefit the nation’s researchers and national strategic priorities
• Develop and sustain critical scientific and technical capabilities to which the government requires assured access.

459. In 2016, it became clear that core capabilities of the US National Laboratory network could be brought together to address significant challenges preventing the acceleration of the US bioeconomy. As a consequence, the Department of Energy established the Agile BioFoundry to unite the capabilities of eight National Laboratories to integrate sophisticated synthetic biology tools including software for biological design, machine learning, high-throughput analytics, techno-economic and life cycle analyses, and expertise, into a platform for biomunufacturing of microbes for production of bio-based fuels and chemicals. The Agile BioFoundry is aimed to develop biological approaches for production of advanced (non-ethanol) biofuels, renewable chemicals, and materials that represent low GHG alternatives to products currently derived from petroleum. The effort is uniting tools, technologies, software, and instrumentation across the National Laboratory system for facile engineering of biology for production of fuels and chemicals from domestic, renewable biomass.

460. Central to the aims of the Agile BioFoundry is the creation of databases and machine learning methods to enable automated bioprocess design with predictable performance and scaling. The Department of Energy recognised that in addition to the production of advanced biofuels, an additional mission-relevant benefit of the success of the Agile BioFoundry would be decreased energy intensity of manufacturing processes that replace traditional chemical manufacturing of petroleum-based products.
461. The mission and vision of the Agile BioFoundry were developed as a consequence of a series of industry listening sessions, where technical experts from a wide variety of industry sectors were brought together to identify shared precompetitive research challenges that might, if overcome, benefit industry widely in the United States and further drive the US bioeconomy. Given that the main “flywheel” of the engineering biology approach to bioproduct manufacturing is the so-called “Design-Build-Test-Learn” cycle, the main precompetitive challenges identified by industry in 2016 were:

1. Design: Better biological pathways for products

462. To design ideal biological pathways for production of bioproducts, industry representatives requested software tools that could be integrated into workflows. The Agile BioFoundry integrated and now offers a variety of software tools for computer-assisted design of biological pathways to generate multiple combinations of genes and organisms to: (1) identify the best possible performing combinations and (2) provide required amounts and types of data for machine learning approaches to improve future design efforts.

2. Build: Putting better biological pathways into new and established host organisms

463. Industry representatives strongly advocated for flexible new host organism and process platforms that could produce a range of desired products, and indicated that software tools and new laboratory automation technologies for automated construction of the thousands of strains generated by design software are needed. The Agile BioFoundry is integrating software and laboratory automation for construction and generation of thousands of strains to test the designs developed by computer-assisted design software.

3. Test: New and better assays and tools to understand performance of biological pathways in hosts

464. Companies that participated in early discussions ranged from very small start-ups to mid-size and large biotechnology companies, and as a consequence there was a broad range of “Test” needs articulated. However, a universal theme was an emphasis on the value of time and a need to accelerate the analytical aspects of the Design-Build-Test-Learn cycle. Building or extending capabilities in high-throughput tools and rapid analytical techniques was a universal need, so tools and assays to screen large numbers of strains — up to 100,000 strain variants per month— have great value to industry. Accuracy and precision are important when assaying for small percentage increases in titres from an already highly productive system. Also universally shared was a need for a vast range of culturing capabilities spanning seven orders of magnitude in volume (100 l to 1,000 l) to facilitate high-throughput analyses and development of scalable bioprocesses.

4. Learn: Machine learning and statistical methods for improving design, build, test, process integration, and scaling

465. Effective and predictive computational tools to analyse the biological “big data” that flow from automated “Test” analyses are key precompetitive industry needs. Development and employment of complex algorithms, techniques and software packages (e.g. machine learning) to find the important biologically relevant leads and proxies amidst heterogeneous, large, complex datasets have the potential to significantly accelerate discovery and development of biomanufacturing advances. Also desired by companies are new tools to link databases, compatible data formats from different instruments and equipment, and standards for datasets. Such standardised formats could improve the quality of the data that are fed to machine learning and statistical models, enabling faster and better analyses.
5. Host On-boarding: Developing robust engineering processes for industrially-relevant host organisms

To avoid bioreactor cooling costs and/or to minimise processing and capital costs, industry representatives highlighted the need for “on-boarding” new, flexible host organisms that are either thermophilic or, those that can match existing process conditions. Also articulated was a need for novel genetic pathways as well as “intellectual property-free” enzymes to overcome barriers to productive host organism performance. Industry experts argued for new biological platform organisms beyond model organisms, including *Escherichia coli* and *Saccharomyces cerevisiae*, that could demonstrate extended productivity phases and operation at high temperature and at low pH, perform effectively in the absence of sterilisation and on complex feedstocks, and contribute to sustainability benefits over the state of the art. The adoption of new organisms by industry traditionally is hindered by the lack of genetic tools such as transformation protocols, gene deletion systems, well-characterised promoters; lack of fundamental knowledge about poorly characterised organisms (i.e., metabolic pathways, gene regulation); unknown phage resistance/sensitivity; unknown robustness; and unknown tolerance to products and intermediates. If a consortium of National Labs could collaborate to break these barriers, major advances in multiple industry sectors would be enabled. The Agile BioFoundry is now focused on on-boarding a few new hosts each year, selected in consultation with industry representatives.

10.2.2. Type of biomass being refined, main biomass suppliers, refining techniques

The Agile BioFoundry is developing processes that promise to expand the use of a wide variety of biomass inputs for biomanufacturing. While the core research efforts funded by the US Department of Energy are constrained to a specific feedstock type for benchmarking and comparative analysis to existing processes, work with private sector companies spans a variety of feedstocks, including algae, lignocellulosic crops, and single-carbon feedstocks. Variability of feedstocks can significantly impact downstream separations of desired products from production media, leading to high costs. Feedstock variability can also limit the speed and success of scaling the process, and the costs/benefits of mitigating this variability need to be well understood early in the development phase to maximise resultant success. Long-range transportation of non-liquid feedstocks presents an additional challenge to biomanufacturing, and an approach that enables distributed manufacturing near sources of biomass not only will address the increased costs and challenges of long-range transportation of feedstock but also promises to create high-value jobs in more rural areas. Hurdling these shared barriers promises significant benefit to a wide variety of industry players as well as significant public benefit.

10.2.3. Main ecosystem companies, type of companies and relationship with these

A broad range of companies, small and large, private and public, bioproducts-focused and software companies are among the first collaborators of the Agile BioFoundry. They include LanzaTech, Agilent Technologies, Lygos, Visolis, Kiverdi, and Teselagen. Broadly speaking, LanzaTech and Kiverdi have research portfolios that include the use of C1 waste gas feedstocks for the production of valuable products. Agilent Technologies provides scientific instruments and has research foci including chemical analysis, life sciences, and diagnostics. Lygos uses biology and sugar to produce valuable bioproducts.
at low costs. Visolis uses a hybrid biological and chemical processing approach to provide sustainable, carbon negative materials. Teselagen offers an artificial intelligence platform to accelerate the design of high-value chemicals, therapeutics and agricultural products.

Examples of newly funded Agile BioFoundry collaborations

469. Lanzatech: develop machine- and deep learning models to optimise continuous fermentation of industrial and synthetic gas using output from LanzaTech’s third generation genome scale model of the acetogen *Clostridium autoethanogenum*, with -omics, and fermentation data into a data warehouse and use the refactored data for machine learning training purposes. A primary aim is the creation of an in-line artificial intelligence-guided process to monitor and adjust industrial fermentation conditions in real time, optimising the fermentation output.

470. Lygos: develop an improved industrial host, *Pichia kudriavzevii*, an acid-tolerant yeast, to produce organic acids, chemicals that are generally expensive to manufacture petrochemically but that are inexpensive to biomanufacture.

471. Teselagen: enhance tools to facilitate biomanufacturing design such as BOOST (Build-Optimization Software Tool) and BLiSS (Black List Sequence Screening), as well as a tool to enable efficient data collection EDD (Experimental Data Depot) to improve aspects of the Design-Build-Test-Learn biomanufacturing cycle.

472. Visolis: create a new host organism that is acid-tolerant (reducing the need for base for pH balance) and capable of utilising cheap feedstocks, such as waste gas, to produce a hydroxyacid intermediate at demonstration scale that can be subsequently upgraded to various valuable compounds using chemical processes for the polymer and plastics industry.

473. The Department of Energy enabled these collaborations through a mechanism called a “Directed Funding Opportunity” (DFO), where the Department of Energy provided funding for the Agile BioFoundry to be used for an industry competition. Companies proposed a number of possible projects to be executed at the Agile BioFoundry with those government funds. As proof of the promise and value of the Agile BioFoundry, industry proposals totalled over four times the available funding for the first DFO in 2017. Through this public private partnership, it is expected that the Agile BioFoundry will also develop new tools and technologies and expertise to broadly benefit future collaborations.

474. Additional mechanisms for industry collaboration with the Agile BioFoundry are Collaborative Research and Development Agreements (CRADAs) and Strategic Partnership Programs (SPPs). CRADAs often involve larger scope collaborations including integrated process steps across subsets of the eight national laboratories and offer industry partners the opportunity to embed their researchers at the Agile BioFoundry. With a CRADA, intellectual property ownership follows inventorship, with the industrial partner generally having a right of first refusal to an exclusive license to Agile BioFoundry (co-)invented intellectual property in specific field(s) of use. In most cases, industrial partners are expected to pay full-cost recovery for all Agile BioFoundry National Laboratory work performed under the scope of the project’s work.

475. Under SPPs, collaborations tend to be smaller engagements and where the Agile BioFoundry performs a specific task (e.g., targeted proteomics analysis) for the industry partner. SPPs may be very attractive to industry, as the industrial partner retains all intellectual property rights derived from the work performed.
476. Academic collaborations are also ongoing at the Agile BioFoundry, with a main criterion for partnership being project alignment with the mission and vision of the Agile BioFoundry.

10.3. Ongoing developments to extend value chain and diversify to new business areas in higher value-added sectors

10.3.1. Potentials for utilising biomass across a broader range of industries / sectors / higher value-added sectors, drivers to achieve these potentials

477. The US Department of Energy continues to explore creative approaches to industry partnerships to drive the bioeconomy through the Agile BioFoundry. In 2018, the US Department of Energy announced the availability of more funds to address gaps in current research and development, including those that hinder the production of high-value, performance-advantaged bioproducts to allow for more profitable biorefineries. This new Agile BioFoundry Industry Partnership Initiative will allow up to five awards in this topic area, with a range of USD 1 million to USD 2 million per award, over a performance period of up to 36 months. Up to 49% of the proposed work budget can be allocated to the Agile BioFoundry. Intended to reach into a broader range of industry sectors and incentivise industry investment in the collaborations, this new public private partnership requires that the proposer’s cost share must be at least 20%.

478. Also in 2018, the US Department of Energy released a call for its Technology Commercialization Fund, a nearly USD 20 million funding opportunity, to support translation of research from the National Laboratory system to the private sector that maximises the impact of that research, and this year’s call includes a specific opportunity for private sector companies interested in adopting and developing technologies developed at the Agile BioFoundry for further commercial use.

10.3.2. Examples of how policies, agencies and their specific instruments have facilitated extension/collaboration/diversification

479. The USDA Biorefinery Assistance Program was created to provide incentives to eligible entities, including loan guarantees, for the development, construction, and retrofitting of commercial-scale biorefineries for the production of advanced biofuels:

- Biofuel derived from cellulose, hemicellulose, or lignin, or other fuels derived from cellulose
- Biofuel derived from sugar, starch, excluding ethanol derived from corn kernel starch
- Biofuel derived from waste material, including crop residue, vegetative waste material, animal waste, food waste, and yard waste
- Diesel fuel derived from renewable biomass, including vegetable oil and animal fat
- Biogas, including landfill gas and sewage waste treatment gas, produced through the conversion of organic matter from renewable biomass.

480. In 2014 the programme was expanded to include loans guarantees for “renewable chemicals and bio-based products” and the name was changed to the Biorefinery, Renewable Chemical, and Bio-based Product Manufacturing Assistance Program. The
programme remains open on an ongoing basis accepting applications on April 01 and October 01 of each year until appropriations have been expended, rather than announcing an available target amount. A phased process was introduced that lowered entry barriers and allowed a collaborative model with industry pioneers, lenders, and USDA all aiming to get projects up and running. The programme experienced an unprecedented year in 2017 as a consequence of improved programme structure and technology advancements, in combination with state-level programmes such as the California Low Carbon Fuel Standard.

481. Other policy instruments provide certainty to farmers, incentivising them to grow biomass crops. The USDA’s Biomass Crop Assistance Program supports the growth of cellulosic non-food crops. Because some biomass crops take one to five years of lead-time, farmers are reluctant to invest in biomass crops without assurance, and this programme provides an assured market.

482. USDA’s BioPreferred Program is an example of a federal procurement policy for bio-based products that is in place to tip, or capture, part of the billions of dollars of spent annually by the federal government for products and services. BioPreferred’s voluntary labelling and certification of these innovative bio-based products is a tool to facilitate market pull to open markets for the increased identification, purchase and use of bio-based products in the commercial and institutional markets, and for consumers.

483. Other policy instruments, such as production credits and tax incentives, are increasingly important, and they appeal to potential bio-based product company investors.

10.3.3. Challenges related to extension/collaboration/diversification in general, specifically related to the regulatory/institutional regime

484. General challenges facing the existing Agile BioFoundry industry collaborations include lack of standardisation across data platforms to enable efficient sharing of non-confidential data. Some general questions also remain about how to handle and protect business confidential information.

485. A major precompetitive Agile BioFoundry research challenge related to predictive bioreactor performance of organisms across fermentation scales exists, and one can imagine that a dedicated “science of scale” multidisciplinary research effort that brings together biologists, process engineers, and computational modellers with expertise in fluid dynamics to address this challenge could greatly accelerate bioeconomy advancements around the world.

486. For biomanufacturing broadly, feedstock challenges exist. Feedstock variability, complexity and transportation present a range of challenges, as do costs. For example, in the case of “waste” biomass, early stage developers can be mistaken in assuming that waste is free, when the average cost of waste feedstock was USD 80 per metric ton in 2015.

487. Regulatory challenges also remain. The lack of horizon-scanning activities by the US agencies means that regulators have little early-stage information about the types of future products of biotechnology under development by companies and what types of regulatory pathways those products might need. In 2017, the US government updated its 1986 Coordinated Framework for the Regulation of Biotechnology. Under this effort, the US regulatory agencies worked together to modernise the US regulatory system, including commissioning an independent expert advisory committee under NASEM to execute a study and issue a report with relevant recommendations. Among other things, the committee recommended that the US regulatory agencies develop a “single point of entry”
for stakeholders (e.g., companies and members of the public) to engage the three agencies early in the development of future products of biotechnology, and also recommended that the regulatory agencies develop a horizon-scanning process to allow regulators to have an early look at future products as they advance through early concept stages. Part of the horizon-scanning approach now includes the development and release of a public “future products of biotechnology” database, a new resource that, as of November 2018, has been accessed by 15 countries around the world. Given that the three agencies, the US Environmental Protection Agency, the US Food and Drug Administration, and the USDA, have different statutory authorities relating to biotechnology products, a ‘one size fits all’ approach remains challenging to implement, although significant progress continues to be made.

488. Regulatory reform is a priority for President Trump’s Administration, as noted in the Report to the President of the United States from the Task Force on Agriculture and Rural Prosperity. Specifically, this report calls for the development of a streamlined, science-based regulatory policy for biotechnology.

10.4. Overall synthesis of findings

10.4.1. A balance of fundamental and applied research investments by governments is important

489. In the United States as in other countries, the balance of government investments in fundamental, use-inspired, and applied research is not strictly defined and can change over time. A persistent view among some federal appropriators is that the US government should invest only in fundamental research given that it is the purview of industry to invest in applied research. When industry sectors can come together to identify high-risk, capital-intensive fundamental research questions that align with government priorities, high-impact partnerships can result and major barriers preventing bioeconomy advances can be overcome.

10.4.2. Public private partnerships are powerful and can serve a broad range of stakeholders

Investment

490. At many levels – local, regional, federal – government has the power to convene stakeholders to collaborate on and invest in shared priorities to effect great impact. The early existence proof of the Agile BioFoundry shows that a broad range of industry stakeholders can be brought together to identify precompetitive research challenges that, if successfully addressed, can benefit many sectors. The Agile BioFoundry case study also shows that with continued industry interest, mechanisms of government investment can evolve toward those that involve cost sharing among companies, further maximising government returns on investment.

Regulatory engagement

491. Future products of biotechnology span a variety of sectors, from biofuels to renewable chemicals to non-livestock food protein sources to complex microbial assemblages for agricultural, mining, and nutritional purposes, to name a few. Early engagement by regulatory agencies of companies with aspirations of bringing such products to market offer the benefit of not only better preparing regulatory agencies for
products that might require new regulatory pathways, but also by providing developers of such aspirational products with early notions of what regulatory steps might be ahead and what data packages might be required for regulatory review. Engagement that expands beyond regulators and developers and includes non-governmental technical experts and members of the public can strengthen governmental regulatory processes, decrease regulatory delays, and increase transparency and trust.

10.4.3. Multiple investment mechanisms provide flexibility in rapidly changing landscapes and fuel a variety of public private partnerships

492. With the assurance that US companies had shared precompetitive needs and industrial priorities that could be addressed by the core capabilities of the National Labs, the Agile BioFoundry was established in 2016 with a Department of Energy investment in a consortium of US National Laboratories to address the fundamental challenges that inhibit the development and deployment of scientific and technological advances that could transform manufacturing in the United States from largely chemical to biomanufacturing. As industry needs continue to evolve and the value of Agile BioFoundry to industry has clearly emerged, the US Department of Energy is now exercising a number of funding mechanisms to broaden industry participation and incentivise co-investment, including Directed Funding Opportunities, Cooperative Research and Development Agreements, and Strategic Partnership Programs, in addition to cost-sharing requirements for applications for government funding opportunities.

10.4.4. Procurement policies provide certainty and create new markets

493. Government procurement strategies can be important policy tools for driving bioeconomies. For example, in January 2017, the US Office of Federal Procurement Policy (OFPP) reported that significant progress had been made in establishing a framework for the procurement of sustainable products. The January 2017 OFPP report stated that Federal Sustainable Acquisition Purchasing has improved steadily over time, more than doubling in the 2012-2016 timeframe, and that 10 federal agencies lead in procurement contracts with sustainability clauses, with the US Department of Defense, US Army Corps of Engineers, and the US Department of Energy as the top three. In their required Fiscal Year 2016 Strategic Sustainability Performance Plans, 21 federal agencies committed to more than 84,000 sustainability contracts worth more than USD 453 million in bio-based products to be delivered in Fiscal Year 2017.

494. As previously mentioned, the USDA’s report, entitled “An Economic Impact Analysis of the US Bio-based Products Industry Report,” demonstrated how the US bio-based products industry’s growth generated substantial economic activity and American jobs:

- 4.2 million American jobs in 2014
- The bio-based products industry contributed a total of USD 393 billion in value added to the US economy. The industry has generated USD 127 billion in direct value with spill-over totalling USD 266 billion.

495. In summary, strategic research investments, innovative and flexible funding mechanisms, public private partnerships, regulatory clarity, and sustainability/bio-based procurement requirements are important policy approaches that can have significant positive impacts on bioeconomies, as described in this US biotechnology focused bioeconomy case study.