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Strategic Rationale for a Bio-Pilot Plant Hub for New Zealand

Circular Business Solutions

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Executive Summary

This report provides a high-level summary of the role of Bio-Pilot Plant facilities and its potential to impact job growth and regional development. It also outlines broader issues that provide context around the rationale for supporting a Bio-Pilot Plant hub.

Introduction & Background

A Pilot Plant is a pre-commercial production facility that employs technology to produce small/medium level volumes of technology driven products, mainly for the purpose of learning about the new technology or product.

The key value proposition for Bio-Pilot Plant facilities is their **critically important role in de-risking capital for investors**. They typically require significant funding in infrastructure, equipment and highly specialized, multi-disciplinary personnel - a scenario that is unappealing to private investors and enterprises.

The pilot phase in a product development cycle is described as the "*valley of death*" *the innovation phase between laboratory prototyping and successful market introduction that comes with a high technological and financial risk.*[1]

As the fees paid by users rarely cover the large overhead costs, Pilot Plant facilities can become unsustainable if there's not government support to ensure long-term viability. In the EU, these facilities are deemed a public good with positive spill over effects on high value job creation and supporting industry growth, so they tend to have long term supportive funding models from Government.

Cost – $3 million stimulus package

NZ has significant infrastructure gaps in Bio-Pilot Production facilities for non-food grade biomass. Based on current international examples a Bio-Pilot hub is likely to cost approximately $50 million spread over the next ten years.

To gain traction with the industry a Government stimulus package circa $3 million could suffice. However, a full scoping phase is required to define the format, configuration and funding model to define exact figures.

Benefits – Economic & High Value jobs

While Bio-Pilot Plant facilities may have a minor impact on job creation for the facility itself, they are instrumental in opening up potential markets for bio-based feedstocks in emerging industries and this is where the long-term benefits will be realized.

Leveraging a plant hub to increase diversification of the forestry product mix has the potential to:

- Grow thousands of high value jobs with significantly higher multipliers than existing industries
- Drive rural regeneration through reindustrialising the manufacturing sector close to bio-mass feedstocks.
- Increase forestry revenue by diversifying into higher value sectors, e.g. mirroring the European Forest Institute's *1% forest solution initiative* demonstrated a 0.25% share for NZ of the markets below by 2030 would equate to:

[1] *Pilot Production in Key Enabling Technologies*, *Crossing the Valley of death*, EU Commission, (2015)

- Construction Sector - $15 billion NZD
- Plastics Sector - $3 – $7.5 billion NZD
- Textiles Sector - $4 – $25 billion NZD

Challenges

The primary challenges to establishing Bio-Pilot Plant Facilities are:

1. Significant gaps in infrastructure
2. Lack of stability in long-term funding for pilot plant initiatives
3. No Bioeconomy strategy to align policy and investment
4. Significant skill gaps - both technical and business innovation
5. Some parts of the forestry sector are risk averse

Conclusions & Recommendations

There is a compelling case for the strategic rationale to develop a Bio-Pilot Plant hub in NZ. A significant global paradigm shift is underway transitioning from a fossil-fuel based economy to a bio-based one which presents unprecedented opportunities for lateral, just and inclusive growth. Bio-Pilot Plants are an essential tool in any effort to capture some of the growth opportunities presented by this transition and could play a key part in unlocking high value sectors, jobs and economic growth.

Bio-Pilot Plant facilities in the EU, Canada, US and China are benefiting from policy and investment coherence provided by national Bioeconomy Strategies. This provides continuity and stability of long-term investment and operation of Bio-Pilot Plant hubs. Many of these strategies are transitioning to Circular Bioeconomy (CBE) strategies as part of a wider transition to a Circular Economy.

New Zealand does not have a Bioeconomy strategy which has led to shortcomings in investment in pilot facilities and in the innovation ecosystem needed to bring existing bio-products to market. Therefore, we recommend the immediate priorities are:

1. The Government should support the establishment of a Bio-Pilot Plant.
2. A full scoping of a Bio-Pilot hub needs to be undertaken as an urgent priority, as New Zealand is significantly behind its international peers. This should include:
    - Identification of specific equipment gaps and costs
    - Long-term funding strategy (especially in the absence of an existing Bioeconomy Strategy)
    - Governance and Management
    - Identification of optimum location
    - Multi-sector and multi-disciplinary stakeholder engagement
    - Workforce Development Plan
3. NZ would benefit from the development of a Circular Bioeconomy Strategy to ensure it understands and leverages the range of opportunities, policy alignment and market shifts underway in the wider global economy.

Introduction & Background

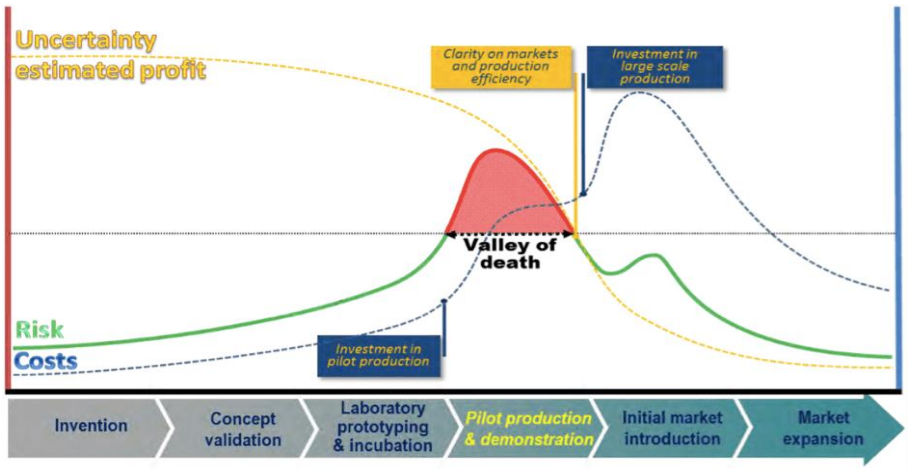
Bio-Pilot Plant Facilities as Economic & Innovation Enablers

A Pilot Plant is a pre-commercial production facility that employs technology to produce small/medium level volumes of technology driven products, mainly for the purpose of learning about the new technology or product. The knowledge obtained is then used to:

- generate realistic data on the performance of prototype products/processes
- enable a better understanding of expected costs & potential profits to support investment decisions.
- Inform design of full-scale production systems
- conduct market validation
- identification of further research objectives

Notwithstanding the description outlined above, the key value proposition for Pilot Plant facilities is their **critically important role in de-risking capital for investors**. Traditionally, pilot production activities require significant funding in infrastructure, equipment and highly specialized, multi-disciplinary personnel. It is **not uncommon for the cost of pilot production to be five times higher than earlier research stages**[2]. Therefore, substantial investments are needed to reduce uncertainties, a scenario that is unappealing to private investors and enterprises, as there are no guarantees that a product/process will be successful. Hence, the pilot phase in a product development cycle is described as the "*valley of death*" *the innovation phase between laboratory prototyping and successful market introduction that comes with a high technological and financial risk.*[3] - see Figure 1 below.

Figure 1. The Valley of Death



Once a process has been demonstrated at pilot scale, the risk decreases, and the potential for valorisation of the technology/product can be better articulated. Pilot production is clearly a vital yet weak link in the successful industrialization and valorisation of new products. This point was raised in 1-on-1 interviews with NZTE, MBIE and former Bioresource Processing Alliance (BPA) staff who are grappling with these issues with current potential investors. Without public support for piloting, it is unlikely that the *valley of death* can be crossed, creating unrealized benefits from public investments into earlier research and development phases.

[2] *Pilot Production in Key Enabling Technologies*, EU Commission, (2015)
[3] ibid

International Perspective

An international analysis of 21 countries showed that all over the world attention is increasingly paid to how governments can support pilot production[4]. Previous pieces of work on the role and value of Bio-Pilot Plant facilities have identified that while infrastructure and equipment are critically important, that successful Bio-Pilot Plants require more than equipment to develop new products. Therefore, significant effort has been put into understanding the critical success factors of Bio-Pilot Plants; a good synopsis is provided by the Bio Base Europe Bio-Pilot Plant[5] project which demonstrated that successful pilot production requires:

- R&D to validate the technology in a laboratory environment and to transfer it to the level of pilot manufacturing
- A pre-commercial pilot manufacturing facility that has open access to a range of external parties for assessing the feasibility and cost efficiency of production processes
- The ability to adjust the product or process design based on pilot production
- Initial production of pre-commercial product batches for testing and validation
- Business development and innovation to attract investors and to create market relationships with customers
- Development of a value chain around the new product to prepare internal and external organizations for full-scale manufacturing

Shared Facilities

The direction of travel for Bio-Pilot Plants in the EU is for facilities that are closer-to-market[6] and that are open to all companies and research institutes. They offer state-of-the-art infrastructure and broad expertise which has enabled SMEs and other innovators to bridge the *valley of death* by reducing the risks and costs associated with pilot production. They leverage their strong central position in the innovation network to create value chains and enable strategic partnerships between academia, industry, public authorities and other cluster organizations.

For SMEs, who typically have limited human and financial capital, shared facilities are often the only way to bring their products to the market as clusters increasingly offer other services. In order to avoid market saturation and duplication of expensive infrastructure, many of these hubs are being connected nationally and across the EU in virtual networks. Because bio-feedstocks are mainly found in rural areas, the EU has additional policy goals that point biotechnology to a distributed, non-economies-of-scale manufacturing model that consistently emphasises rural production and regeneration.[7]

Some EU examples below:

ERIFORE

- Horizon 2020 roadmap project for forest based circular bioeconomy research infrastructure development and collaboration
- Coordinated by VTT

SmartPilots

- Interreg Europe project for bioeconomy pilot cooperation, business models and political influencing

EU-Great

[4] Antikainen, et al. *Renewal of Forest Based manufacturing towards a sustainable Circular Bioeconomy*, (Finnish Environment Institute, 2017).
[5] Ibid 2
[6] Ibid 2
[7] McCallum B, *Summary of OECD Reports on Sustainable Development*, MBIE, 2018

- Exploring best practices and barriers for research infrastructure funding (H2020) Pilots4U

- Combines open access pilots in industrial biotechnology, chemistry and bioenergy.
- Assessing capabilities for industry driven development Projects

Bio Base Europe Bio-Pilot Plant (BBEPP) – Gent, Belgium

As the fees paid by users rarely cover the large overhead costs, Bio-Pilot Plant facilities can become unsustainable if there is not strong government support to ensure their long-term viability. In the EU these facilities are seen as a public good with positive spill-over effects on high value job creation and supporting industry growth, so they tend to have long term supportive funding models to sustain them.

An issue raised in the Coriolis Report[8] relating to the development of the Food Innovation Network was the expectation in NZ that Bio-Pilot Plant facilities pay their way at an early stage and in this regard, "*the requirement that pilot plant significantly funds itself is more aggressive than the policies of the average peer group country*". This stance appears to have had negative impacts on the BPA which has recently lost its funding and an issue currently facing the Food Bowl[9]. As outlined above, this pressure to generate self-sustaining levels of income is not consistent with what is seen internationally. **A lack of long-term funding and succession planning for Pilot Plant hubs was the most pressing concern that came through both from the online survey and the 1-on-1 interviews with stakeholders**.

Bio-Pilot Plants are essential for engaging in higher value sectors

Traditionally forest industries have positioned themselves as raw material suppliers, however many of the emerging business opportunities are likely to require firms to diverge from traditional industry practices and current position in the value chain[10]. An analysis from Sweden of over 110 biorefinery related projects between 2002 to 2015[11] shows that R&D efforts have evolved markedly over the past decade. This analysis indicates that innovation networks are growing and broadening. While forestry industry actors, universities, and fuel/energy companies have up to this point dominated with biofuels as a central theme research institutes involved in materials and chemicals are now taking a larger role, and dominant hubs of activity are forming around chemicals/materials organisations [12]. Figure 2 below from the report provides a new "value pyramid" in a Circular Bioeconomy.[13]

[8] *Review of the International Peers for the NZ Food Innovation Network*, Min of Economic Development, Coriolis, (2009), pg. 14
[9] Personal interviews with BPA and Food Bowl senior leaders, January 2019
[10] Wang, L. *Value chain analysis of bio-coal business in Finland: perspectives from multiple value chain members*. Biomass Bioenergy, 78: (2015), 140–155.
[11] Antikainen, et al. *Renewal of Forest Based manufacturing towards a sustainable Circular Bioeconomy*, (Finnish Environment Institute, 2017).
[12] Novotny, M., Laestadius, S. *Beyond papermaking: technology and market shifts for wood-based biomass industries.* Journal Technology Analysis & Strategic Management 26(8): (2014) 875-891.
[13] Ibid 7.

Figure 2 – Biomass Value Pyramid for a Circular Bioeconomy

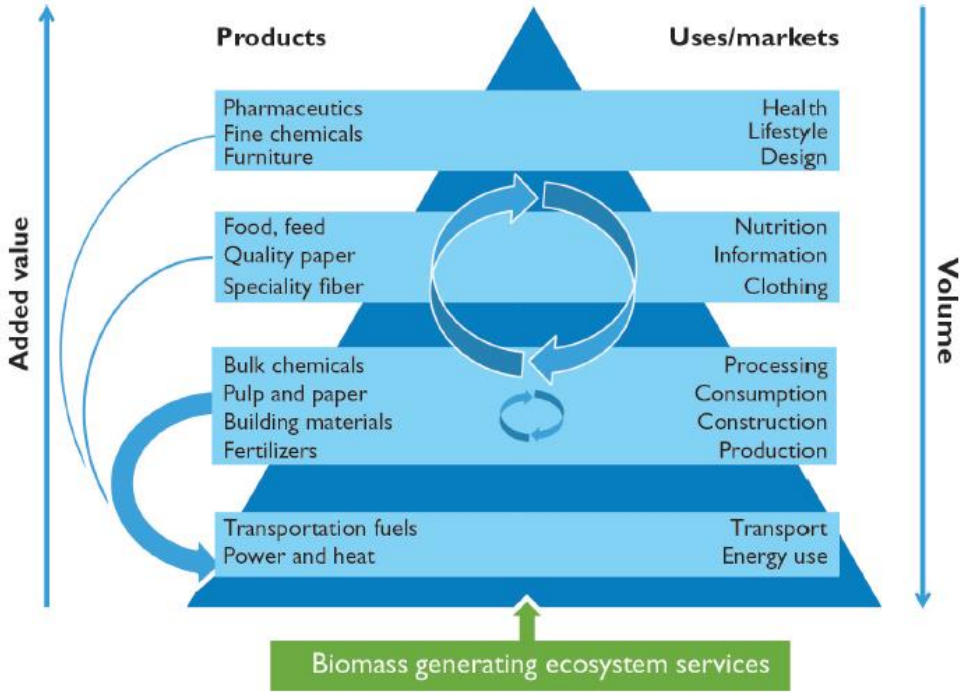


Figure 3. Biomass value pyramid for a circular bioeconomy (modified based on Werkgroep Businessplan Biobased Economy 2011 and Bosman & Rotmans 2014).

Bioeconomy and Circular Bioeconomy Strategies

One of the most important influences on support for Bio Pilot Production are over-arching Bioeconomy Strategies. Bio-Pilot facilities in the EU, China and the US are benefitting from policy and investment coherence driven by national Bioeconomy Strategies, many of which have been in place for over a decade.

These existing bioeconomy strategies have been helpful in demonstrating the need to advance the use of renewable biomass to substitute for fossil-based raw materials and products to create a more sustainable society and engage multiple sectors and services, such as clothing, housing, health, food and transportation. The table below is a sample of some existing global Bioeconomy Strategies.

Figure 3 – Selected Bioeconomy Strategies in Chronological Order[14]

Country	Strategy	Year
OECD-countries	The Bioeconomy to 2030 – Designing a policy agenda	2009
EU	Innovating for Sustainable Growth – A Bioeconomy for Europe	2012
The Netherlands	Framework Memorandum on the Bio-Based Economy	2012
Sweden	Swedish Research and Innovation – Strategy for a Bio-Based Economy	2012
USA	National Bioeconomy Blueprint	2012
Malaysia	Bioeconomy Transformation Program – Enriching the Nation, Securing the Future	2013
South Africa	The Bio-economy Strategy	2013
Germany	National Policy Strategy on Bioeconomy	2014
Finland	Sustainable Growth from Bioeconomy – The Finnish Bioeconomy Strategy	2014
West Nordic countries*	Future Opportunities for Bioeconomy in the West Nordic Countries	2014
France	A Bioeconomy Strategy for France	2016
Italy	BIT – Bioeconomy in Italy	2016
Spain	Spanish Strategy on Bioeconomy Horizon 2030	2016
Norway	Familiar Resources – Undreamt of Possibilities	2016

However, there has been a recent significant shift in thinking and many existing Bioeconomy Strategies are currently under review and are transitioning and/or integrating national Bioeconomy Strategies with Circular Economy strategies in a move towards a Circular Bioeconomy (CBE). Some of them are also integrating the SDGs as part of a CBE framework (see figure 3 below).[15] While other models put human society at the centre, it is generally acknowledged that human society is completely dependent on a functioning biosphere.

Figure 4 – The SDGs and a Circular Bioeconomy

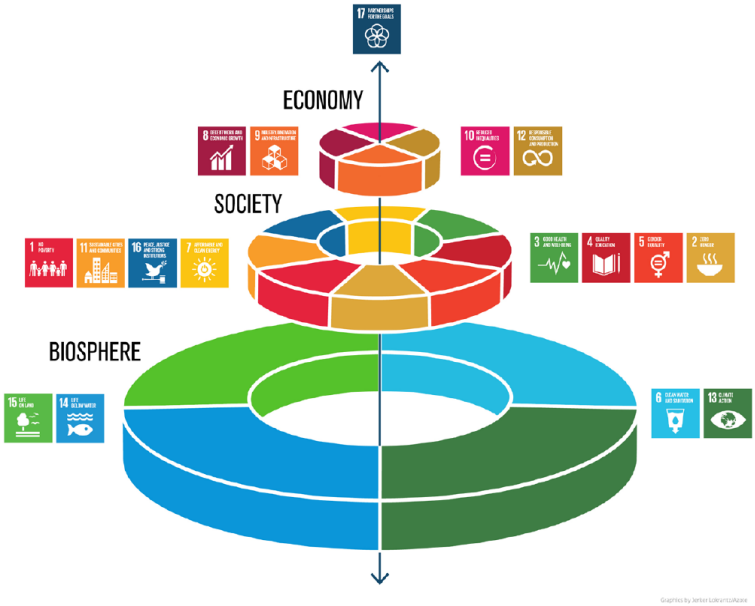


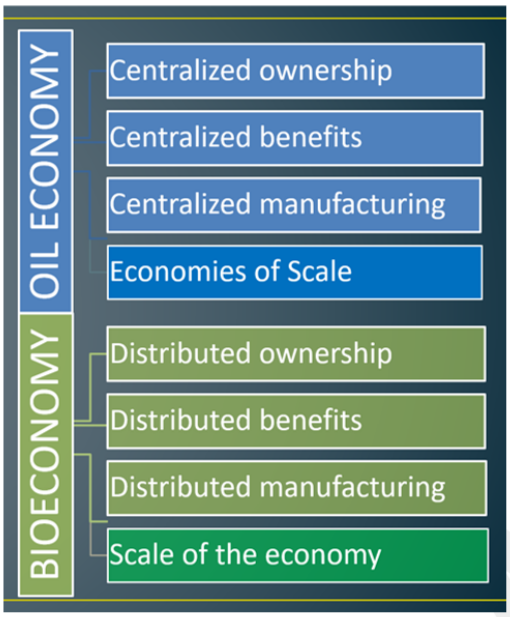
Figure 1. The layers of Sustainable Development Goals that form the basis for a circular bioeconomy strategy.
Source: Azote Images for Stockholm Resilience Centre.

[14] Hutemaki et al, *Leading the way to a European Circular Bioeconomy Strategy: from Science to Policy*, (European Forestry Institute, 2017)
[15] ibid

These strategic documents are moving beyond creating a biological framework for the economy and are aiming to essentially ***biologise the economy itself***: construction-transport-ecotourism-wood construction-bio-based packaging-aviation biofuels are all examples of how forest goods and services can transform major economic sectors[16].

Underlying this paradigm shift to a Circular Bioeconomy is a conversation around fundamental differences in the way a bio-based economy is structured and could function if designed in a new way. There's an acknowledgment that the distributed nature of bio-mass and land ownership throughout the EU (particularly forestry) presents an unprecedented opportunity for more just and inclusive growth in the transition to a low carbon economy.

Figure 5 - A new economic paradigm[17]



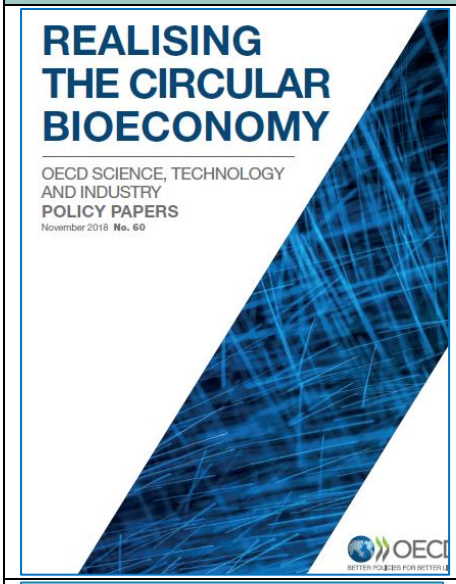
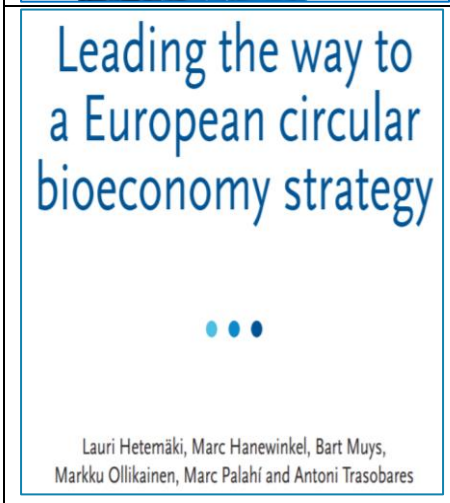
Almost everything about our current linear economic system is fossil fuel based both as an energy source to power manufacturing, to how goods are transported, to the constituents of the products themselves. The limited geographic location and the centralized nature of ownership in the fossil fuel industry has driven the centralized nature of energy, transport and production systems. A bioeconomy that can utilize a range of feedstocks distributed among a much wider range of stakeholders presents an opportunity to completely redesign energy, transport and manufacturing systems as well as thousands of everyday products.

In order to facilitate the transition to higher value-added, more productive activities the following key issues have been identified[18]:

- Innovation capacity is an important element of what has been called bioeconomy readiness.
- existence of bioeconomy strategies
- bioeconomy-related clusters signalling business cooperation

[16] EFI, OECD, Synthesis Report
[17] O'Byrne, D. A new Economic Paradigm, Circular Business Solutions, (2019)
[18] *Forest-based Circular Bioeconomy for Southern Europe*, EFI, (2018)

Outlined below are key issues from 3 of the most relevant documents in the CBE space outlining the structural changes and investment needed in the global shift from oil to biobased economies.

Circular Bioeconomy (CBE) Strategies	
	➢ Supply and value chains, instead of originating at the sources of fossil feedstocks will be local creating jobs much closer to the feedstocks ➢ Creates the need for a new generation of both R&D and production companies *almost entirely missing at present*. ➢ New skills, training and education will be required on a large scale, and the education sectors need to adjust. ➢ Rural job creation and regional development ➢ Relieves pressure on land ➢ GHG emissions savings ➢ Pollution prevention ➢ Waste valorisation ➢ Creation of new circular value chains and innovation ecosystems ➢ Increases the sustainability of primary industry production
	➢ CBE involves development of new processes previously fossil-fuel based ➢ Need to accept and develop comfort level with trial and failure – take a more Venture Capitalist approach ➢ Public sector can de-risk high risk investments ➢ Whole value chains will be disrupted, but also create new industries ➢ Major diversification in the forestry sector opening up a myriad of opportunities for high value products and highly skilled jobs. ➢ Investment needed in R&D for the disruptive innovations this paradigm shift requires ➢ CBE offers Forestry significant opportunities for diversification
	➢ Need for mixed feedstock bio-refineries/plants ➢ closer cooperation between forestry and agriculture ➢ bridging the research innovation divide by supporting Bio-Pilot Plants and upscaling facilities ➢ Secure skilled professionals in the interface of life sciences and forestry with engineering and entrepreneurship, economy and social sciences ➢ Create opportunity for forest owners to participate in downstream value streams ➢ There are skill gaps that need to be closed ➢ Cross-sector clusters will be important to leverage the opportunities a CBE and Bio-Pilot Plants create ➢ Focus on Forestry as a knowledge-intensive portfolio that requires specialized services in design, R&D, consulting, marketing ➢ break down silos to extract values from waste across sectors

Costs & Benefits

Costs - NZ Bio-Pilot Plant Hub requires >$50 million investment

The costs of Bio-Pilot Plants are not insignificant and are driven by the type of feedstocks being processed, how they are configured and the scale of support surrounding them.

Significant investment is needed not just for the infrastructure and operational costs but into the wider ecosystem of support needed to ensure they are successful.

Some examples of the types of government investments and/or partnerships are outlined below.

- Canada, Thunder Bay, – FP Innovations and Resolute Forest Products - $21 million
- Belgium, Flanders' Bio Base Europe Bio-Pilot Plant - $15.6 million
- Ireland
  - -$10 million for the National Bioeconomy Bio-Pilot Plant (excl building costs)
  - $1.7 million for the Digital Innovation Circular Bioeconomy Hub
- Australia - $9 million Mackay Renewable Bio-commodities Bio-Pilot Plant
- Finland - VTT - Estimated total costs by 2019 are $54 Million
  - Thermochemical platform $23 million
  - Biomass Processing platform $13.4 million
  - Green Chemistry platform $16.8 million

New Zealand has good access to Bio-Pilot Plants for food grade feedstocks through the Food Innovation Network, however these cannot be used for non-food grade biomass. Appendix 1 provides a map of existing Pilot Plant infrastructure in NZ and the type of access it facilitates and while no means exhaustive it does give a good overview of the current landscape. However, there are significant gaps in infrastructure for non-food grade biomass particularly fermentation, extrusion and drying facilities[19] and some of the existing infrastructure is extremely old (some of it 100+ years). Many of these facilities are also in the private sector and not open to use by other parties, although academic organizations have secured access on a case by case basis for some projects.

The map also overlays plantation forestry resources which is useful as proximity to bio-mass is an important factor in the locations of Bio-Pilot Plant facilities. In general terms, before any decisions are made regarding the equipment or configuration of a Bio-Pilot Plant hub for NZ, a robust scoping phase would need to be carried out before indicative costs could be factored. However, considering the extensive gaps in NZ Bio-Pilot Plant infrastructure for non-food grade biomass it's reasonable to assume that an investment of at least $50 million (and perhaps substantially more) over a 5-10 year period would be required. An initial $15-20 million stimulus over 4 years would allow essential items to be put in place to encourage and support the forest industry (and other providers of biomass) build a platform to underpin New Zealand's transition to a low emissions bioeconomy. Priorities, based on both industry and researcher feedback to the needs survey, and indicative capital costs are as follows:

- Treatment plant for up to 2.4 m lengths of timber to evaluate preservative options (including alternatives to Copper Chromate Arsenic (CCA)) particularly for an expanding suite of engineered wood product options to support increased use of wood in multi-rise residential buildings and commercial construction (with concurrent carbon storage and offsite prefabrication benefits) - $1,200,000
- Low pressure hydrogenation kit for the development of marine biofuel to reduce in port particulate and sulphur emissions from bio-blended bunker fuel - $1,000,000
- 3 D printing to evaluate additive (and distributed) manufacturing using wood fibre materials - $500,000
- Adaption of extruders (originally designed for fossil oil materials) to make bioplastic products from wood fibre materials - $500,000 per extruder (2-3 required as these are common plant for a range of biomaterial substitutes for fossil oil materials)

[19] Personal interviews, Scion, MBIE, BPA

- Spray drier for tree derived bioproducts - $4,500,000

The investment package should allow for design, Worksafe protocols and certification, appropriate housing; and commissioning of the bio-pilot plant. Of note, is most current equipment for product development (summarised in Appendix I) is at laboratory scale and not well suited to industrial process de-risking or producing sufficient quantities of product for prototype product formulation and test marketing with customers. For some highly specialised and capital-intensive pilot plant it will likely be more cost effective to access these facilities through relationships with offshore partners (e.g. in Japan for nanofibers and some forms of multi-rise building fire testing; or at VITO Belgium for automotive and/or chemical manufacture).

Benefits – Significant Positive Revenue & Job Multiplier Impacts

The benefits of a Bio-Pilot Plant hub to NZ is difficult to quantify in a precise way. While they may have minor direct impacts on jobs numbers and economic growth, they are instrumental in opening up potential markets for bio-based feedstocks in emerging industries and this is where the long-term benefits will be realized. A recent Canadian Report into new wood-based value chains indicates that the most promising markets for emerging wood-based products are textiles and construction, bio-chemicals and biofuels, and packaging and plastics.

Diversification of logs to higher value sectors:

Recent studies in both Canada [20] and the EU [21]have identified that there are significant opportunities for forestry in new wood-based markets that are worthy of consideration in a diversification strategy – construction, textiles, platform chemicals and plastic packaging.

The Canadian report identified that diversifying into these sectors has the potential to increase forestry revenues from €18 – 75 billion ($30 - $125 billion NZD) by 2030. Three graphs from the report shown below demonstrate that diversification:

- delivers high unit values for these products
- increased the need for processing mills to meet the proposed demand, growing higher skilled jobs
- greater opportunities for forestry to capture value from these supply chains than logs.

Figure 6 – Implications on Revenue and Wood Use

	Textiles	Construction	Biofuels	Biochemicals	Plastics and packaging	Total
Production value, billion €	1–6	4–46	4	4	4–15	18–75
Unit values, €·t^{-1}	769–2228	209–2245	815–1250	1000–2725	843–2500	
Sawlog demand, Mm^3		7–117				7–117
Pulpwood demand, Mm^3	7–15				2	8–16
Wood chips and sawdust demand, Mt			27–37	33–45	2	63–85
Lignin demand, Mt		2				2
Tall oil demand, Mt			1			1

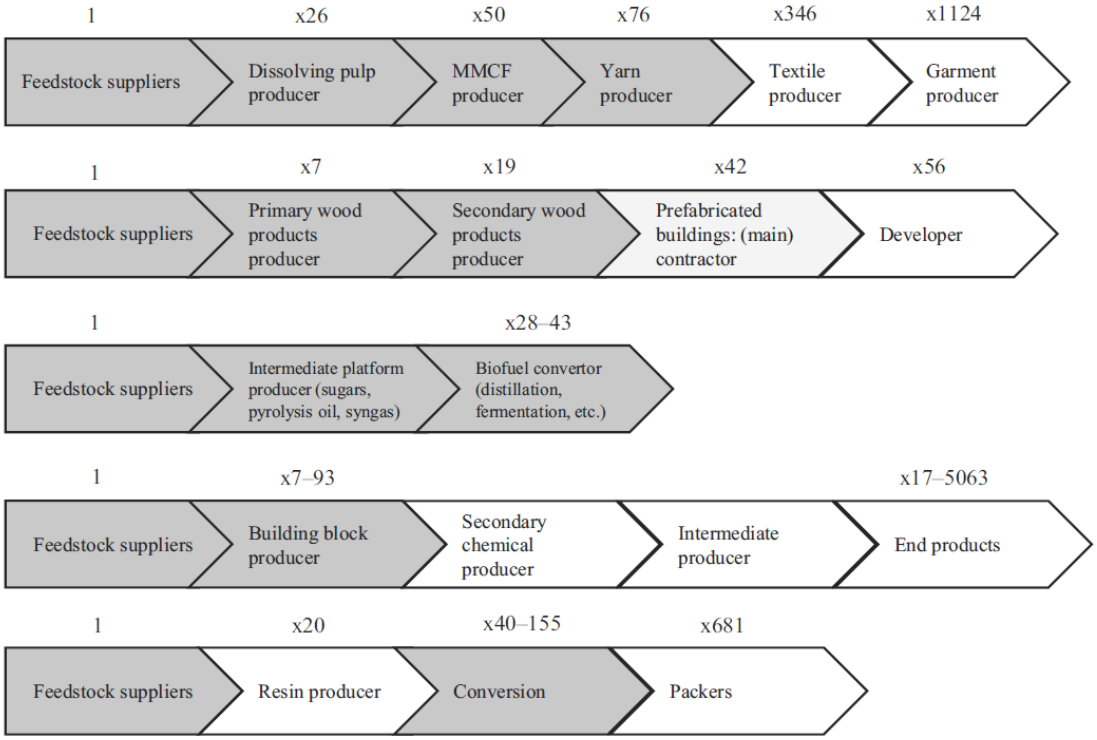
[20] Hurmekoski et al., *Diversification of the forest industries: role of new wood-based Products,* (Canadian Journal Forestry Research 48 (2018): 1417–1432.
and Antikainen, et al. *Renewal of Forest Based manufacturing* (2017).
and Carus, M. et al, *Bio-based drop-in, smart drop-in and dedicated chemicals*. (Nova-Institut GmbH, 2017)
[21] Hutemaki et al, *Leading the way*, (EFI, 2017).

Figure 7 – Approximate number of mills per sector required to meet hypothetical demand

Sector	Assumed mill size	Approximate number of production facilities per country
Textiles	200 000–650 000 t·year^{-1}	1–3
Construction	10 000–450 000 m^3·year^{-1}	2–1000
Biofuels	50 000–500 000 t·year^{-1}	5–50
Chemicals	150 000 t·year^{-1}	5–6
Plastics and packaging	250 000–500 000 t·year^{-1}	1–2
Reduction of graphic paper	500 000 t·year^{-1}	4

Figure 8 – Relative value created in each step of the respective value chains compared with logs (construction) or pulpwood (the rest).

The scores are indicated above the boxes and the assumed position of forest industries is indicated in grey.



Similar opportunities were identified in an analysis carried out by the European Forestry Institute in their *1% Forest-based solution* as outlined in Figure 9 below.

Figure 9 – EFI 1% Forest Solution projections

Hypothetical example:
EU forest-based materials gain 1% share of the global markets in 3 sectors by 2050

Market in 2050	Construction (cement/concrete)	Plastics	Textiles	TOTAL
Production	13.7 Mt**	11.2 Mt	2.5 Mt	**27.4 Mt**
Revenue	~ 1 - 36 billion €	~ 7 - 18 billion €	~ 1.5 - 6 billion €	**~ 10 – 60 bill. €**
Wood use	68 Mm^3	(no primary use – based on side-streams)	15 Mm^3	**> 83 Mm^3**

5% share could even double the current revenue of the EU forest products industry

This analysis calculated revenue forecasts if the EU Forestry sector could gain 1% market share of the following by 2030:

- Construction Sector - up to €36 billion ($60 billion NZD)
- Plastics Sector - €7-18 billion ($12–$30 billion NZD)
- Textiles Sector - €10-60 billion ($17–$100 billion NZD)

If NZ was to capture 0.25% of these markets it would equate to:

- Construction Sector - $15 billion NZD
- Plastics Sector - $3 – $7.5 billion NZD
- Textiles Sector - $4 – 25 billion NZD

Bio-Pilot Plant Hubs facilitate growth and significantly higher job multipliers

While the quantum of direct jobs of a bio-pilot facility are few, they are highly-skilled, highly paid jobs. However, the real value of a Bio-Pilot Plant to New Zealand's is its ability to enable growth of the bioeconomy and open up global markets which a significant impact on jobs in the manufacturing, chemical, textile and wood processing industries.

Reports from the EU[22]: and OECD [23] have demonstrated

- that expanding national bioeconomies have significant positive impacts on Rural Regeneration
- Growing the bioeconomy presents a significant Reindustrialisation opportunity to bring manufacturing jobs back, but in the context of knowledge-driven reindustrialisation
- Bio-production, instead of seeing dependence on natural resource-based industries and manufacturing in rural areas in a negative manner, would leverage this as a strength to build high-technology manufacturing
- manufacturing makes major contributions to overall productivity and to research and innovation, which is four times higher than its input to GDP
- Bio-based production of materials (e.g. chemicals, plastics, textiles) represents far greater economic opportunities (e.g. job creation and value-added) than biofuels and bioenergy, and yet this has been all but been ignored in public policy beyond R&D subsidies

[22] "European Competitiveness Report 2013. *Towards knowledge driven reindustrialisation*", Commission Staff Working Document SWD(2013)347
[23] OECD Working Party on Biotechnology, Nanotechnology and Converging Technologies
Towards Bio-Production of Materials: Replacing the Oil Barrell (2017)

- The distributed manufacturing bio-based model means establishing many interconnected local production plants that are integrated with other nearby industries to ensure residues and wastes are fully utilised at their highest value
- the location of the plants (i.e. distance to the resource) and their access to biomass supply will be crucial to realising the potential of bio-based production
- As well as feedstock production being local, and creating local jobs, the 'industrial ecosystem' created around them indicates many indirect jobs associated with bio refining

Some statistics consistent with these findings from recent reports are

- The Netherlands have identified a need for 10,000 bio-based engineers by 2030 to facilitate the growth targeted in their Bioeconomy Strategy.
- growing bio-based products industry contributes $400 billion and over 4 million highly skilled jobs to the US economy[24]
- ReNEW Circular Economy project has demonstrated that more than 13,000 jobs could be created in Northern Ireland particularly in bio-refining and the bioeconomy" [25]
- Production of sustainable aviation fuels in UK could be worth £265m GVA in 2030, with an additional 4,400 jobs[26]

There are also significantly higher multipliers for jobs in these fields. A 2015 report on the Forest Industry in the USA identified the following multipliers:

Lumber and wood products	- 2.53[27]
Wood Furniture	- 2.05
Pulp and paper	- 4.02

The report did not include other sectors, but other publications have identified even higher positive impacts as per below:

- Chemistry sector – job multipliers of 3.0 (EU), 7.6 (USA) and on average they are highly paid compared to other manufacturing jobs
- Recent OECD reports[28] have identified that compared to jobs in the fossil fuel industry,
  - Biofuel production creates 50-100 times the number of jobs;
  - Electricity from biomass creates 10-20 times the number of jobs;
  - Heat production from biomass creates double the number of jobs
- Modelling in Europe indicates that bio-based chemicals and plastics production can support more jobs per tonne of biomass than biofuels and bioenergy applications
- Materials use for bio-mass can directly support 5-10 times more employment and 4-9 times the value-added compared with energy uses, principally due to longer, more complex supply chains

Bio-Pilot plant hubs are a key enabler in developing the bio-based industries mentioned above. Ireland and the Netherlands are of similar size and have similar strong primary industry sectors as New Zealand so job growth in bio-based industries comparable to their projections would be achievable for New Zealand, i.e. 10 – 13,000 jobs.

Stakeholder Engagement

This comprised 2 parts: An online survey sent out to key stakeholders both internal and external to the Forestry sector and one-on-one interviews with specific stakeholders which enabled a more in-depth view of key issues going forward. Appendix 2 provides a full list of stakeholders engaged either through the online survey or in 1-on-1 interviews. Appendix 3 provides graphs of survey responses.

[24] Info:biopreferred.gov
[25] *The Circular Bioeconomy: OECD Science, Technology & Industry Policy Papers*, 60 (November 2018)
[26] Growing the Bioeconomy: A national bioeconomy Strategy to 2030, HM Government,
[27] *Forest Products Industry Size and Economic Multipliers in the US South* Dahal et al, Forest Products Journal, 2015
[28] OECD: *Replacing the Oil Barrell* (2017), and OECD *Biomass for a Sustainable Bio-economy: Technology and Governance,* (2017)

Summary of online survey:

- 69% indicated that NZ would benefit from a Bio-Pilot Plant Hub
- 73% indicated that a single cluster or a hybrid (lead cluster but connected) is the preferred configuration
- Bio-Products, Bioplastics, Bio-fuels, Wood Modification and new products from waste valorisation where the most commonly listed opportunities created by a Bio-Pilot Plant
- Long term funding, knowledge & expertise, ecosystem of support and government support were listed as the top development needs other than infrastructure
- Affordability, government consistency, co-ordination logistics and protection of IP were listed as the key potential barriers/challenges for a successful Bio-Pilot Plant hub.

Summary of one-on-one interviews

Three themes emerged in the stakeholder interviews:

- Strong appetite for innovation
- Stable funding underpins sustainability
- Core knowledge and expertise gaps are significant challenges

Strong appetite for innovation

There was a range of appetites for innovation captured within the stakeholder group. Some within the forestry sector had an appetite for diversifying into other sectors and could articulate their need for pilot facilities and the equipment gaps this presented. Others were keen to innovate but didn't have a clear knowledge or understanding of the role that Bio-Pilot Plants could play in enabling that – this was particularly the case for Maori landowners who indicated they are keen to gain back ownership of the trees on their land so they could grow higher value businesses and create highly skilled jobs for their communities. Often those outside the forestry sector had a more comprehensive view of the global opportunities in the shift to a bio-based economy and were looking at forestry as one of many potential feedstocks. Those in MBIE and BPA who were familiar with the shift to a Circular Bioeconomy were particularly keen to see any Bio-Pilot Plant facilitate multiple feedstocks.[29] A mixed feedstock plant facility is likely to be more heavily utilized than one that takes only one type while also opening up opportunities to combine wastes from multiple feedstocks in novel ways.

Stable funding underpins sustainability

Concern was raised about the short funding cycles for initiatives like Bio-Pilot Plant facilities. Staff from MBIE, NZTE, BPA, Food Bowl all identified that there is significant pressure for these facilities/initiatives to stand on their own feed quite quickly from a financial point of view. Comments were made that Bio-Pilot Plants can take up to 5 years to be fully operational and another 5 to fully leverage their potential but considering how far behind New Zealand is in this space, a concerted effort would be required to shorten this timeframe. A consistent theme from stakeholders is that NZ must play a long game with these plants and somehow find a way to address the pressure to pay their way at an early stage. However, when looked at in light of the significant global shift to Circular Bioeconomy Strategies and Business Models, questions more critical and urgent to consider are opportunity costs and inability to capture market share by a failure to invest in a critically important infrastructure to enable participation in these markets.

Core knowledge and expertise gaps are significant challenges

While the survey and interviews showed some gaps in knowledge around what Bio-Pilot Plants were and the opportunities they could potentially open, knowledge and expertise gaps were also raised around support needed for the technical use of the plant and the business proficiency in getting products to market. An area of particular importance is stricter regulations around environmental performance, e.g. the EU Product Environmental Footprint (PEF) requirements. This gap in knowledge was even more pronounced in an understanding of the global shift to bio-based and Circular biobased economy. Globally there are over 129 Degree or Vocational training courses in the Circular Economy, none of them in NZ so there are

[29] Personal interview, January 2019.

significant gaps in understanding and expertise. In the EU at least four Master programmes are a direct result from the articulation of a Bioeconomy Strategy:

1. Master's in Management of Bioeconomy Innovation and Governance (University of Edinburgh)
2. Bioeconomy Masters (University Hohenheim)
3. Master of Bioeconomy in Circular Economy (University of Bologna, University of Milano Bicocca, University of Naples Federico II + University of Turin)
4. Master of Science in Bio-economy & Natural Resource Management (University of Eastern Finland)

Almost all documents relating to Bioeconomy and the Circular Bioeconomy Strategies highlight that all countries are facing skills shortages for the challenge ahead. Some of the issues identified are:

- PhDs are trained in a manner mismatched with industry needs
- Universities educate by discipline and lack multi-disciplinary approaches
- Lack of apprenticeships to create a workforce beyond research.
- Significant gaps in the job market: lack of automation engineers and biochemical engineers
- Very few experts who can deal with experimental design when faced with huge amounts of data.

They highlight that what we effectively have is a dislocation between the scientific and engineering methods. For industrial biotechnology to become a force in production, engineering principles such as standardisation, abstraction, separation of design from manufacture will have to be grappled with. They have indicated *"if one phrase were to sum up the situation for the policy maker, it is 'removing the boundary between bioscience and engineering"*[30]

They have also highlighted that the shift away from a fossil fuel-based economy will require not only research to resolve a wide range of technical difficulties this presents and the need for manufacturing system & product redesign but also calls for equally innovative education reform. Scotland has taken a lead with their newly developed Higher National Diploma (HND) which involves study of three crucial disciplines: biology, chemistry and engineering, which is specifically designed to create a corps of technical staff.

New Zealand is very likely to have similar challenges and action will be needed to close gaps in training at vocational, university and professional executive training levels to ensure New Zealand maintains competitiveness with global peers in this space.

[30] OECD Working Party, *: Replacing the Oil Barrel* (2017), pg 10

Conclusions

The role of forests and the forest sector has previously been viewed through a very traditional lens as providers of timber, pulp, paper and some bioenergy. However, the "*biologizing of the economy*" conversations discussed in the CBE strategies outlined previously around new technologies, business models and consumption patterns are creating opportunities that could enable the forest-based sector to make a much greater contribution to sustainable development.

The international forestry sector is already undergoing major structural changes and diversification and producing advanced materials that will enable the transformation of key economic sectors such as energy, construction and manufacturing (e.g. textiles, plastics, chemicals, pharmaceuticals). A knowledge-intensive portfolio of existing and future products will necessitate specialized services (design, R&D, consulting, business model innovation, marketing, sales, etc.) that further multiply its economic impact and its capacity to generate employment.

Going forward, advances in new technologies and distributed manufacturing practices are essential to building and maintaining a competitive and sustainable economy. This is especially true for emerging technologies and products based on bio-based materials and technologies, many of which are nascent and unproven.

In order to advance these potentially game-changing products and processes, significant financial and business resources have been invested in Bio-Pilot Plant facilities globally as they are considered instrumental to the modernization of the industrial base and are seen as crucial to solving complex societal challenges and facilitating the transition to a low-carbon, knowledge-based economy with high-quality jobs[31].

A multitude of bio-based industries (agriculture, food industry, horticulture, paper industry) are looking for new products to replace existing fossil fuel-based ones and also seeking outlets in order to diversify and develop future market position. New Zealand is lagging European countries who have invested significant resource into bio-based innovation and development of bioeconomy strategies. While some of this is related to structural issues around ownership and lack of vertical integration in the forestry sector, the lack of a Bio-Pilot Plant hub is also a significant barrier to diversifying the sector in New Zealand.

A global paradigm shift from oil-based to bio-based products underway presents significant opportunities for countries with strong primary sectors and stable supplies of sustainable biomass. The critical question for the forestry sector has moved past what ***can be*** made of forest biomass, but rather what ***will be*** made, on what scale, where, and driven by what?[32] If New Zealand wants to capture a share of some of these markets, it will need long-term, stable investment into Bio-Pilot Plant facilities.

Recommendations

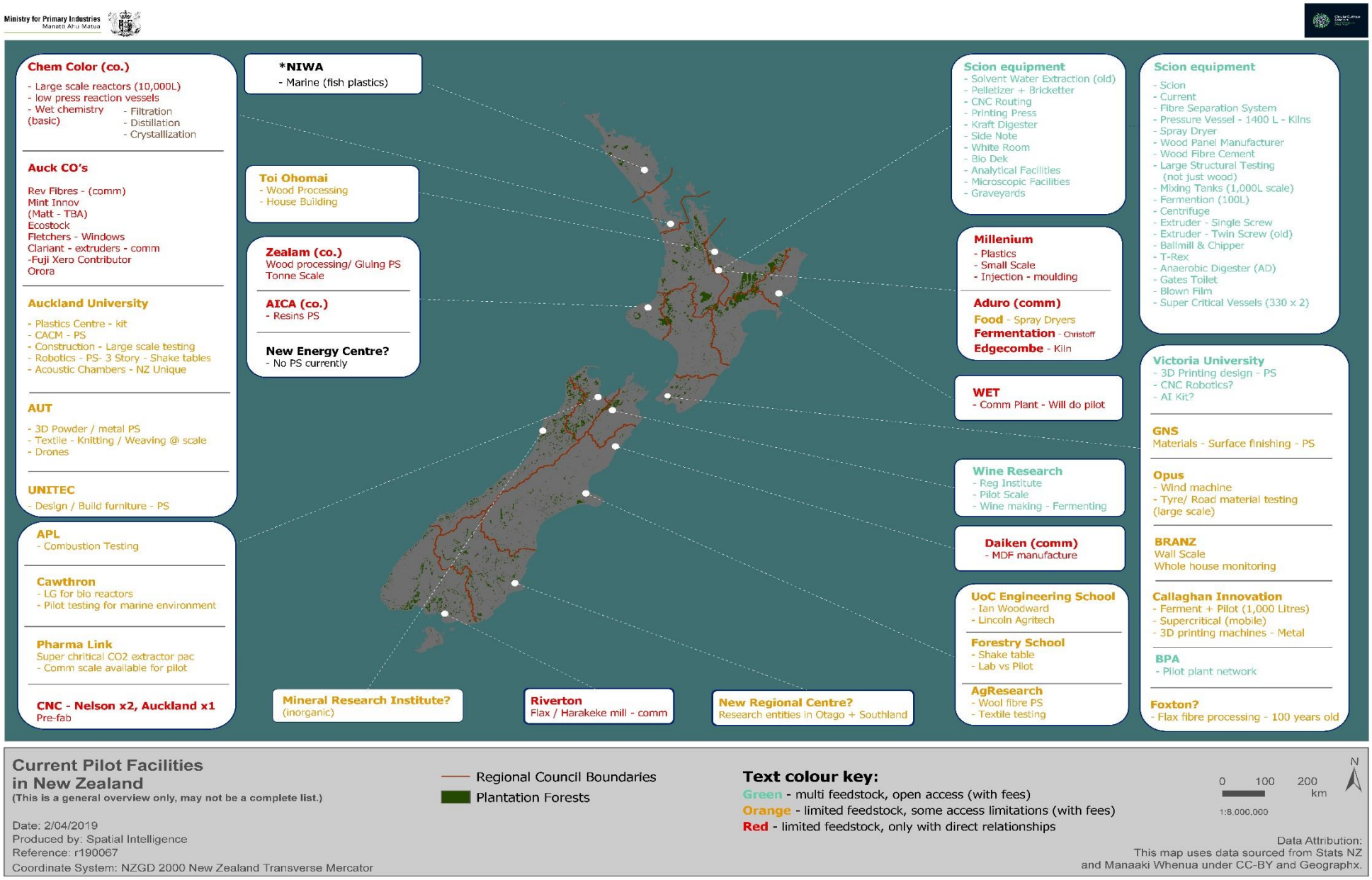
- That the NZ Government supports the establishment of a Bio-Pilot Plant Hub and considers specific funding in the $15-20m range of 4 years to address priorities and key gaps in the current infrastructure.
- Further work is actioned in defining the scope, location and configuration of any proposed Bio Pilot Hub. This should include at a minimum:
  - Identification of specific equipment gaps and costs
  - Long-term funding strategy (especially in the absence of a current Bioeconomy Strategy)
  - Workforce Development Plan
  - Governance and Management
  - Optimum location
  - Stakeholder engagement
- Develop a Circular Bioeconomy (CBE) Strategy

[31] European strategy for Key Enabling Technologies (KETs), European Commission, 2012

[32] Hetemäki, L. & Hurmekoski, E. *Forest products markets under change: review and research implications.* Current Forestry Reports, vol. 2, no. 3(2015); pg.182

Appendices

Appendix 1 – Current Pilot Plant Resources in NZ

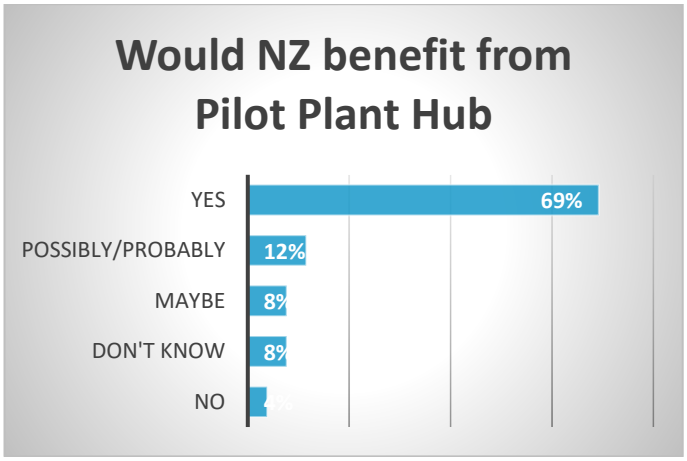


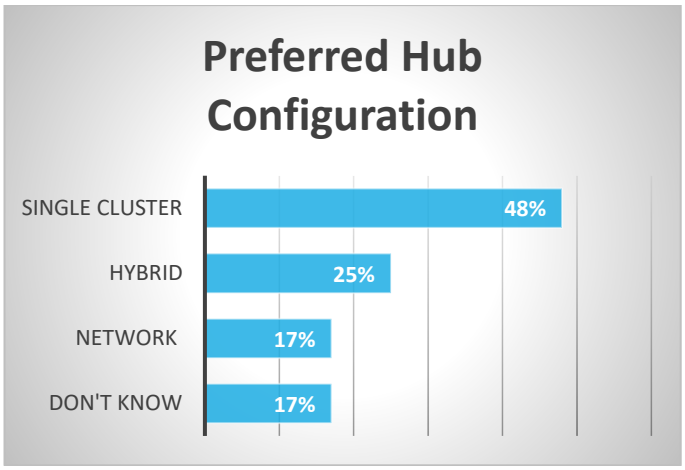
Appendix 2 - List of Stakeholders

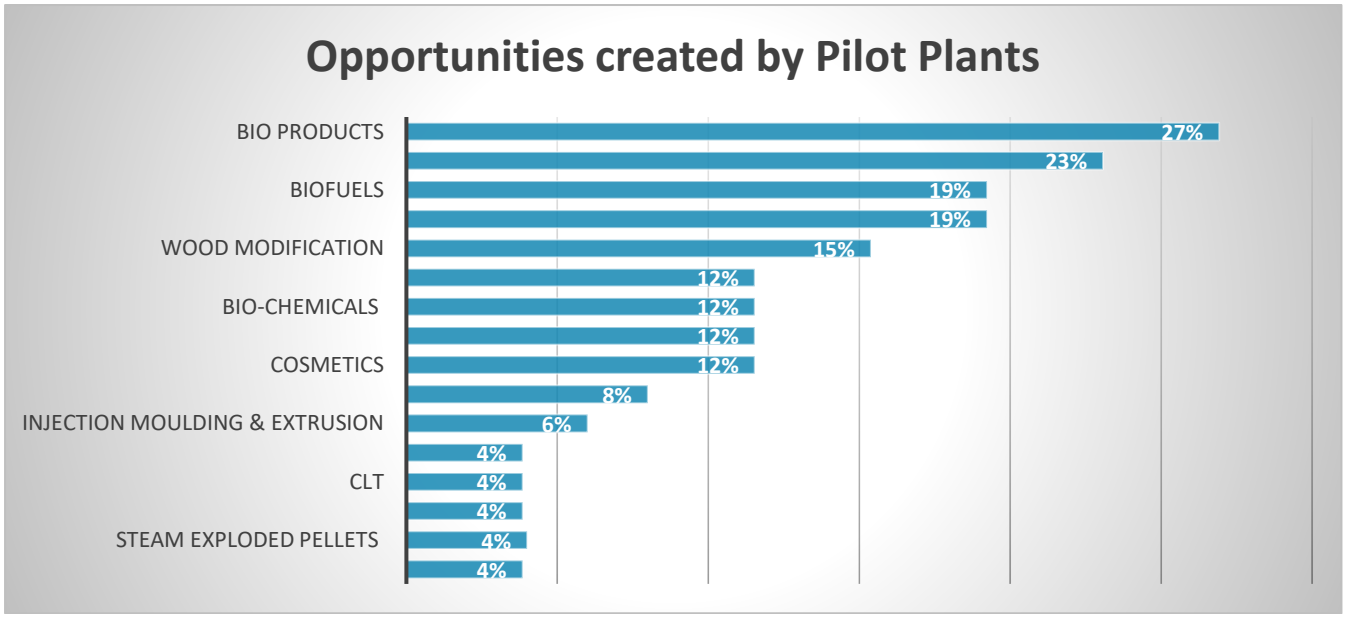
Name	Organization	Interface
John Ryder	Ojis	Survey
Graeme Muller	NZ Tech	Survey
Kim Volanthen	ForestX	Survey
Daniel Gudsell	Abodo	Survey
Iris Kirimaoa	Waipupumahana C	Survey
Warren Parker	Chair, FMAG	Survey
Owen Lloyd	Ngaarikikaiputahi	Survey
Jon Sandbrook	WNT Ventures, Icehouse	Survey
Tom Boon	Taranaki Pine	Survey
Linc Burgess	Talbot Technologies	Survey
David Parle	Windsor Engineering	Survey
Sachin Ekbote	Process Engineer, Beca	Survey
Iain Hosie	Revolutionfibres	Survey
Craig Wilson	Kilwell	Survey
David Binnie	Z Energy	Survey
Anthony Peters	Henkel	Survey
John Brough	Parengarenga Inc	Survey
Will Barker	Mint Innovation	Survey
Paul Lobb	Lonza, Zelam	Survey
Catherine Andrew	Callaghan Innovation	Survey & Interview
Carol Ward	Zespri	Survey
Anna Yallop	Bioresource Processing Alliance (BPA)	Survey & Interview
Brendan Green	Advanced Biotech NZ	Survey
Mike Sang	Ngai Tahu Group Holdings	Survey & Interview
Pita Tipene	Te Tai Tokerau Maori Forestry Collective	Survey & Interview
Seishi Gomibuchi	MBIE	Interview
Max Kennedy	MBIE	Interview
Bruce McCallum	MBIE	Interview
Ron Clink	MBIE	Interview
Finn Speijer	MBIE	Interview
Marianna Tyler	MfE	Interview
Jay Hadfield	MfE	Interview
Eric Swale	NZTE	Interview
Harvey Perkins	Univ of Canterbury	Interview
Peter Pettit	WET Technology	Interview
Tony Johnston	WET Technology	Interview
Ramona Radfield	Maori Advisor, Scion	Interview
Carel Bezuidenhout	Toi Ohomoi	Interview
Victoria Blake	Toi Ohomoi	Interview
Elspeth MacRae	Chief Science & Innovation Officer, Scion	Interview
Alex Allan	Food Bowl	Interview
Catherine Andrews	Callaghan Innovation	Interview
Maui Solomon	Hokotehi Moriori Trust	Interview
Claire Bradley	AgriSea	Interview

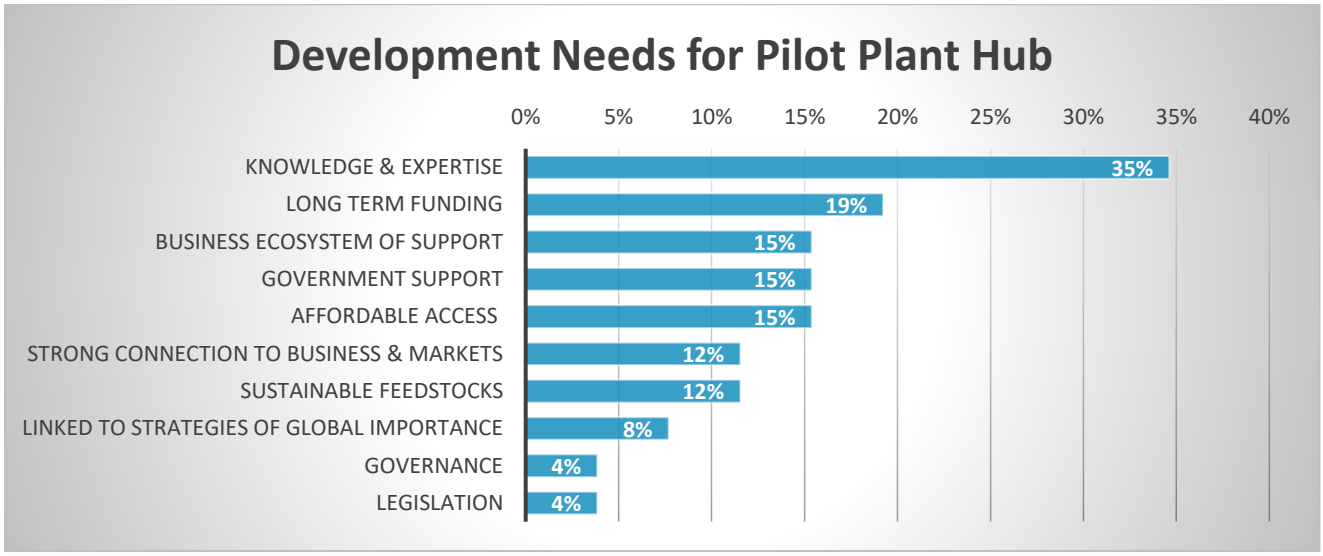
Appendix 3 – Survey Results

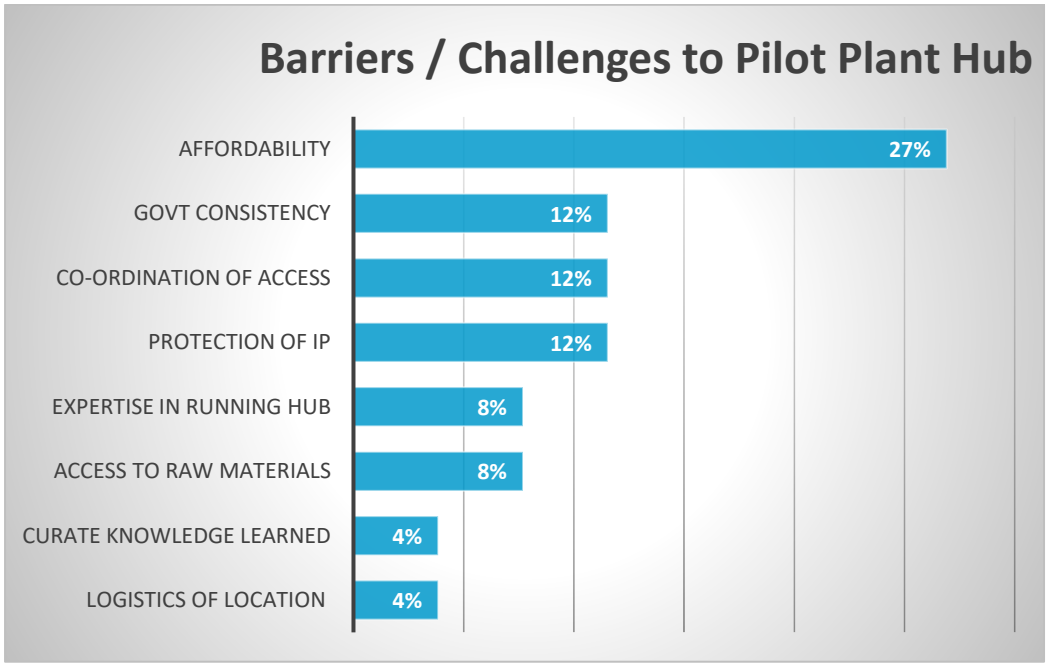
Key findings of the online survey are outlined in the graphs below:

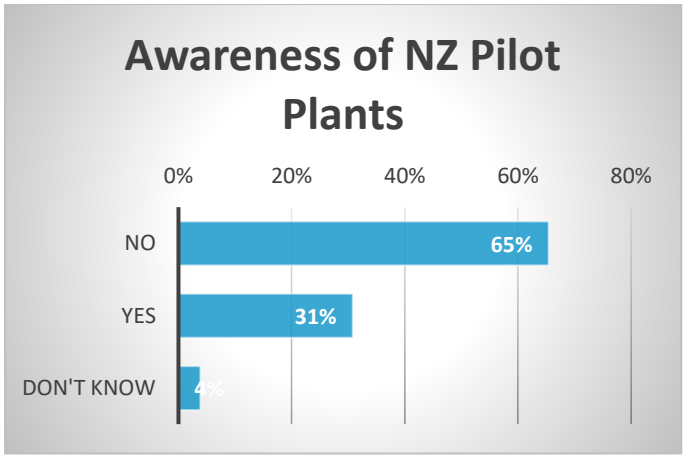







Development Needs for Pilot Plant Hub
0%
5%
10%
15%
20%
25%
30%
35%
40%
KNOWLEDGE & EXPERTISE
35%
LONG TERM FUNDING
19%
BUSINESS ECOSYSTEM OF SUPPORT
15%
GOVERNMENT SUPPORT
15%
AFFORDABLE ACCESS
15%
STRONG CONNECTION TO BUSINESS & MARKETS
12%
SUSTAINABLE FEEDSTOCKS
12%
LINKED TO STRATEGIES OF GLOBAL IMPORTANCE
8%
GOVERNANCE
4%
LEGISLATION
4%


Barriers / Challenges to Pilot Plant Hub
AFFORDABILITY
27%
GOVT CONSISTENCY
12%
CO-ORDINATION OF ACCESS
12%
PROTECTION OF IP
12%
EXPERTISE IN RUNNING HUB
8%
ACCESS TO RAW MATERIALS
8%
CURATE KNOWLEDGE LEARNED
4%
LOGISTICS OF LOCATION
4%


Awareness of NZ Pilot Plants
0%
20%
40%
60%
80%
NO
65%
YES
31%
DON'T KNOW
4%