The Future of Forest-based Bioeconomy Areas

Strategic openings in Uruguay and the World by 2050

Rafael Popper | Nina Rilla | Klaus Niemelä | Juha Oksanen | Matthias Deschryvere | Matti Virkkunen | Torsti Loikkanen

VTT TECHNOLOGY 379

VTT TECHNOLOGY 379

The Future of Forest-based Bioeconomy Areas

Strategic openings in Uruguay and the World by 2050

Rafael Popper, Nina Rilla, Klaus Niemelä, Juha Oksanen, Matthias Deschryvere & Matti Virkkunen

VTT Oy

Torsti Loikkanen

Sapar

ISBN 978-951-38-8739-1 (Soft back ed.)
ISBN 978-951-38-8737-7

VTT Technology 379

ISSN-L 2242-1211
ISSN 2242-1211 (Print)
ISSN 2242-122X (Online)
DOI: 10.32040/2242-122X.2020.T379

JULKAISIJA – PUBLISHER

VTT
PL 1000
02044 VTT
Puh. 020 722 111
https://www.vtt.fi

VTT
P.O. Box 1000
FI-02044 VTT, Finland
Tel. +358 20 722 111
https://www.vttresearch.com

PunaMusta Oy, Helsinki 2020

Preface

The Future of Forest-based Bioeconomy Areas publication is an example of European foresight practice being applied to a Latin American context in a way that local stakeholders feel co-owners and co-producers of project results. Evidence of such are the official 2018 and 2019 bioeconomy reports, pictured below and published by the Office of Planning and Budget of the Presidency of Uruguay (OPP), which include several translations to Spanish of interim and final deliverables.

OPP 2018 Publication
(based on VTT Progress Report)

OPP 2019 Publication
(based on VTT Final Report)

Final results of the project were delivered to OPP in January 2019 with the intention of organising a public event to present a printed version of this report to a large audience with multiple stakeholders. However, due to the 2019 presidential elec-tions and the winds of change in Uruguay's political landscape, the launching of the report was not possible at the time. Now, considering the current Covid-19 environ-ment and the restrictions to business related trips, at VTT we have decided to make this final deliverable available in PDF version. We believe in the importance of the anticipated and recommended visions, opportunities, strategies, policies, regula-tions and action roadmaps for the future of the forest-based bioeconomy areas. Therefore, the VTT team will be ready to support the implementation of the 15 iden-tified action roadmaps, either in Uruguay or anywhere in the world.

Dr. Rafael Popper
Project Leader

Contents

Preface 3

Key Highlights 8

1. Introduction 9

1.1 On the FBA-Uruguay project 9
1.1.1 Project rationales and objectives 9
1.1.2 Project methodology and process 10
1.1.3 Project results and way forward 13
1.2 On forest-based bioeconomy areas (FBA) 15
1.2.1 Concepts and definitions 16
1.2.2 Economic importance 19
1.2.3 Drivers, barriers, opportunities and threats 21

2. Mapping key FBAs in the world 27

2.1 Description of FBAs and experts' appraisal of their potential 28
2.1.1 FBA 1: Forest management 29
2.1.2 FBA 2: Mechanical wood processing 30
2.1.3 FBA 3: Fibre-based biomaterial processing 33
2.1.4 FBA 4: Biorefining 35
2.1.5 FBA 5: Bioenergy 39
2.2 Factiva Global News analysis 41
2.2.1 On the Factiva data 41
2.2.2 On the analysis of key actors 42
2.2.3 Key findings of the Factiva news analysis 45
2.3 Mapping Critical Issues (CI) shaping the future of the FBAs 46
2.3.1 Selecting Critical Issues (CI) 47
2.3.2 Critical Issues Survey in Uruguay and peer countries 50
2.3.3 Assessment of Critical Issues 52

3. Mapping of global value networks 55

3.1 R&D&I in forest-based bioeconomy 55
3.2 Products and value chains in Finnish forest-based bioeconomy 59
3.3 Finnish forest-based bioeconomy innovations and businesses 61
3.4 State-of-the-art of the forest-based bioeconomy 68
3.5 Global Value chains in Forest-based bioeconomy 73
3.5.1 FBA 1: Forest management 74
3.5.2 FBA 2: Mechanical wood processing 81
3.5.3 FBA 3: Pulp-paper / new biomaterial production chain 89
3.5.4 FBA 4: Biorefining for chemicals and energy products 102
3.5.5 FBA 5: Bioenergy 108
3.6 Forest industry in benchmark countries 118
3.6.1 Finland 118

3.6.2 Sweden 121
3.6.3 New Zealand 122
3.6.4 Australia 125
3.6.5 Canada 126
3.6.6 South Africa 128
3.6.7 Brazil 130
3.6.8 Chile 132
3.7 Current FBA value networks in Uruguay 134
3.8 Forest- and wood-based products 140

4. Visions for forest-based bioeconomy areas in Uruguay 144

4.1 Overall vision for the forest-based bioeconomy in Uruguay 144
4.2 Visions by forest-based bioeconomy areas (FBAs) 144

5. Strategies, policies, regulations and action roadmaps for the future 146

5.1 Public policies in transition towards forest-based bioeconomy 146
5.2 MLP framework and public policies for bioeconomy transitions 148
5.3 Common strategies and policies of the forest-based bioeconomy 154
5.3.1 Bioeconomy strategy of the European Union 154
5.3.2 Examples of national bioeconomy strategies and policies 155
5.3.3 Examples of country comparisons in bioeconomy strategies and policies 159
5.4 Forest-based opportunity pathways in Uruguay 163
5.5 Forest-based bioeconomy opportunity pathways of higher focus 165
5.5.1 Fostering EWP and wood-based building (FBA2_OP3) 165
5.5.2 Increasing types of pulp produced (FBA3_OP2) 171
5.5.3 Encouraging networking in the use of forest industry residues and wastes (FBA4_OP2) 178
5.6 Forest-based bioeconomy opportunity pathways of medium focus 182
5.6.1 Maximising the value from existing forest resource base (FBA1_OP2) 182
5.6.2 Using native forests as source of new value added services/products (FBA1_OP1) 185
5.6.3 Creating internationally attractive operational environment for EWP (FBA2_OP1) 188
5.6.4 Supporting domestic actors to develop new products from eucalyptus pulp (FBA3_OP3) 193
5.6.5 Investing in new bioproducts from side streams of pulping (FBA4_OP1) 198
5.6.6 Turning wood-based side-streams into easy-to-storage solid biofuel (FBA5_OP2) 203
5.7 Forest-based bioeconomy opportunity pathways of lower focus 207
5.7.1 Supporting entrepreneurship and competences in forest management (FBA1_OP3) 207

5.7.2 Encouraging investors and firms to get involved in targeted areas (FBA2_OP2) 210
5.7.3 Promoting production of paper and paperboard from local pulp (FBA3_OP1) 213
5.7.4 Developing materials and chemical applications using bark from saw mills (FBA4_OP3) 216
5.7.5 Seizing opportunities for heat & energy production at industry sites (FBA5_OP1) 219
5.7.6 Producing second-generation biomass-based biofuels (FBA5_OP3) 222
5.8 Panoramic and systematic visualisation of FBA action roadmaps 224
5.8.1 Action Roadmap for FBA1 OPs on Forest Management 226
5.8.2 Action Roadmap for FBA2 OPs on Mechanical wood processing 227
5.8.3 Action Roadmap for FBA3 OPs on Fibre-based biomaterial processing 228
5.8.4 Action Roadmap for FBA4 OPs on Biorefining for chemicals and energy products 230
5.8.5 Action Roadmap for FBA5 OPs on Bioenergy 232
Acknowledgements 233
About the authors 235
Recommended Actions for all FBA's Opportunity Pathways (OPs) 239

Abstract

Key Highlights

Forest management highlights • OP1 – The wider use of the native forests for new (non-wood-based) ecosystem services and pharmaceutical and food products will be facilitated. • OP2 – The sustainable use of Uruguayan forest resources will be intensified via optimal uses of overlooked pine wood resources and via improved logistics infrastructure. • OP3 – The skill and competences of key players in the forest management and timber harvesting will be supported and increased by a variety of means. **Mechanical wood processing** highlights • OP1 – Attractive investing conditions will be created for large international companies in different areas of mechanical wood industry, also increasing activities of the local SMEs. • OP2 – The operational conditions for wood-based panel industries and related bioenergy and biorefining areas can be made more attractive for the investors and companies. • OP3 – Engineered wood products from eucalyptus and pine will be found more and more attractive for domestic building and international markets. **Fibre-based biomaterial processing** highlights • OP1 – Increased future manufacture of different paper grades can serve local and regional markets. • OP2 – Investments in the manufacture of different types of pulp from pine and eucalyptus would diversify Uruguay's forest industry products. • OP3 – Cellulosic fibres will provide fascinating raw material for an increasing number of novel and innovative products and applications. **Biorefining** highlights • OP1 – Current and future pulping operations will provide opportunities to recover lignin- and hemicellulose-based by-products, to strengthen local chemical industry. • OP2 – Innovative development of symbiosis products from the wastes and residues of forest industry and other sectors would turn overlooked wastes to useful raw materials. • OP3 – Bark wastes from pine and other woods from saw mills can be turned to wood adhesives and other valuable products. **Bioenergy** highlights • OP1 – Small-to-medium scale combined heat and power plants can find opportunities at mechanical wood processing sites and biorefineries. • OP2 – The use of wood-processing residues for the production of torrefied pellets would bring coal-like material, with good fuel characteristics, to the local and foreign markets. • OP3 – The choice of advanced processes for the potential production of different solid and liquid biofuels will be expanded.	Key highlights 1 shared vision for foresight-based ioeconomy areas (FBA) in Uruguay 5 forest-based bioeconomy areas (FBA) 5 consolidated action roadmaps by FBA 15 opportunity pathways (OP) 15 action roadmaps by OP 511 recommendations

1. Introduction

1.1 On the FBA-Uruguay project

1.1.1 Project rationales and objectives

The **Forest-based Bioeconomy Areas in Uruguay and the World: Strategic openings by 2050** project (FBA-Uruguay) aimed at developing the potential of the forestry resources in Uruguay to diversify into other new and high value products and services, taking into account relevant local issues, and contributing to Uruguay's National Development Strategy by 2050.

The '*National Development Strategy: Uruguay 2050'* is based on sustainability, including environmental, as well as productive, institutional and social-cultural sustainability. To do so, the Uruguayan government created the Planning Direction (PD), in order to highlight the long-term development in the government agenda. The PD is a central government foresight agency designed to reach the professionalization of foresight and its impact on public management and planning. It includes both standardization of foresight methods and better application of foresight to policy problems.

Five intertwined foresight exercises were launched by the PD to create a country vision as an input to the National Development Strategy. These are the following: the ageing of the population and its impact on education, health, social protection and labor market; the transformation of the productive structure; the gender model; the cultural array in terms of values; and the transformation of the territories.

Concerning the one on the transformation of the productive structure, the bioeconomy is a core concept to target its development. The bioeconomy is certainly full of opportunities in a country that, since its foundation, has built its wealth on the basis of natural resources.[1] Particularly, the use of forest biomass to manufacture is becoming an opportunity that matches very well with Uruguay's forest resources, its productive base and its research and technological development.

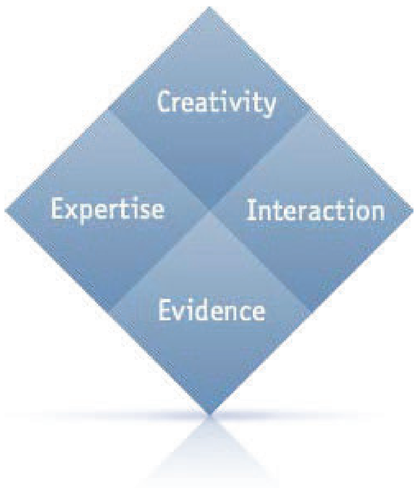
[1] Uruguay is essentially defined as a farming country, with livestock, crops and forestry being the main sources of exports. As to its natural resources, the Uruguayan territory hosts a significant eco-regional and eco-systemic, specific and genetic biodiversity.

The general goal of the FBA-Uruguay project is to develop a Strategic Actions Roadmap (SAR) for key forest-based value chains contributing to Uruguay's National Development Strategy 2050. The ultimate aim is to produce a strategy for Uruguay to transit from a forest-based sector to a forest-based bioeconomy.

- Objective 1: To identify key global forest-based bioeconomy areas by 2050.
- Objective 2: To identify needs and gaps in the prioritised FBA in Uruguay.
- Objective 3: To develop a shared vision for the forest-based bioeconomy in Uruguay by 2050.
- Objective 4: To develop a Strategic Action Roadmap to achieve the shared vision for the forest-based bioeconomy in Uruguay by 2050.

1.1.2 Project methodology and process

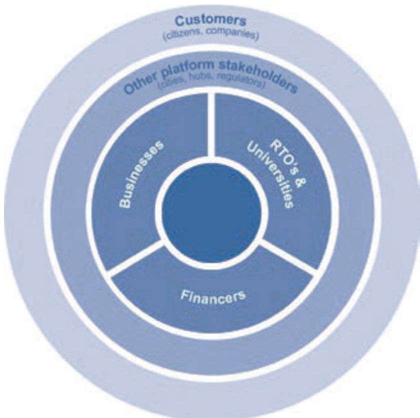
The FBA-Uruguay project methodology blends VTT's *foresight* and *innovation ecosystem* co-creation approaches.



VTT's Foresight approach

Foresight is a systematic, participatory, prospective and policy-oriented process aimed to actively engage key stakeholders into a wide range of activities anticipating, recommending and transforming (ART) technological, economic, environmental, political, social and ethical (TEEPSE) futures.[2]

VTT led foresight projects combine methods that bring expertise, evidence, interaction and creativity to research and innovation processes, thus promoting the co-creation of shared visions and action roadmaps that enable the transition towards sustainable bioeconomy futures.[3]



VTT's Innovation Ecosystem approach

An innovation ecosystem is a partnership of complimentary players who share the same vision and are willing to contribute to joint actions in order to achieve the individual and joint goals.

VTT has a systematic approach to create and develop innovation ecosystems with continuous value add. An innovation ecosystems approach is ever more needed when challenges and solutions are so complex and systemic that no actor has the capacity nor the capability to create successful business applications alone in the needed timeframe.

In order to apply VTT's foresight and innovation ecosystems approaches to the FBA-Uruguay project, a five-step process was co-designed and implemented.

---

2 Popper, R. (2008) Foresight Methodology, in Georghiou, L., Cassingena, J., Keenan, M., Miles, I. and Popper, R. (eds.), The Handbook of Technology Foresight, Edward Elgar, Cheltenham, pp. 44–88.

3 **Popper, R., Popper, M., and Velasco, G. (2020) 'Sustainable Innovation Assessment and Management Framework: Principles, Methodology and Practice' in M**artini, M., Holsgens, R., Popper, R. (2020) (Eds), Governance and Management of Sustainable Innovation: Learning from experience to Shape the Future, Springer.

The **first step** required the organisation of kick-off conference and a multi-stakeholder workshop supporting the *scoping* process and the *mobilisation* of forest-based bioeconomy actors in Uruguay. The main purpose of these events was to co-create a set of forest-based bioeconomy areas (FBA) to become the main research foci of the project. Over 100 representatives from industry, research, university, government, civil society organisations contributed to the various brainstorming sessions, open discussions and focus groups, which ultimately helped to define the five FBA, namely: Forest management (FBA1), Mechanical wood processing (FBA2), Fibre-based biomaterials processing (FBA3), Biorefining (FBA4) and Bioenergy (FBA5).

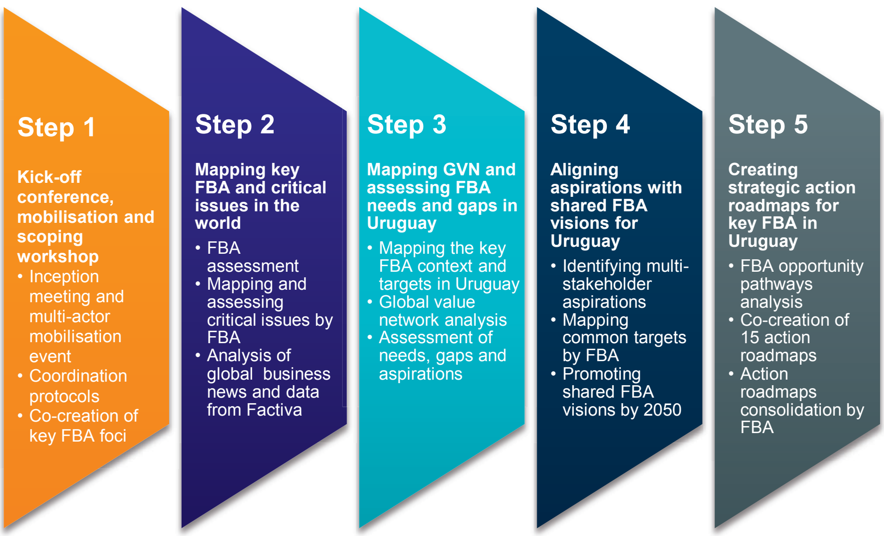
The **second step** was aimed at *mapping key forest-based bioeconomy areas (FBA) in the world*. Several methods and activities supported the global FBA assessment and critical issues analysis undertaken by the project team during the life of the project. This included: a *literature review* of state-of-the-art market, research, foresight and technology reports from around the world followed by targeted *interviews* with selected FBA stakeholders, which helped to map over 300 critical issues (barriers, drivers, opportunities and threats); a Delphi-like *expert survey* on global versus local gap assessment and prioritisation of the most relevant critical issues; *desk research* and analysis of key actors and industries using the Factiva global business news and data; and several meetings and internal workshops with FBA experts from VTT and Luke in Finland.

The **third step** involved several complementary activities aimed at mapping FBA global value networks (GVN) and identifying research, education, innovation and regulation needs, gaps and aspirations (including visions, strategies, objectives, target market goals and products, etc.). A *literature review* was conducted on the state-of-the-art of the global and Finnish forest-based bioeconomy, products, value chains, innovations and businesses. A more detailed qualitative assessment focused on global FBA production and demand in 2030 and 2050. This analysis was used to map key value network actors in each FBA and benchmark the strategic objectives of relevant research, education and innovation/industry actors. A benchmark of the forest industry in selected countries (Finland, Sweden, New Zealand, Australia, Canada, South Africa, Brazil, Chile,) helped to produce a panoramic overview of FBA value networks in Uruguay with a focus on innovation actors, research/university; and institutional actors. The results of the GVN and benchmarking analysis were used gather Finnish and Uruguayan experts' insights on the potential of selected forest- and wood-based products and technologies.

The **fourth step** consisted of aligning multi-stakeholder aspirations with shared FBA visions for Uruguay. The required the organisation of multi-stakeholder workshop in Uruguay in order to gather the hopes and fears of representatives from industry (e.g. large companies and SMEs), government (e.g. ministries, funding agencies, local authorities), civil society organisations (e.g. unions), and research and education (e.g. universities and research institutes). The workshop results were processed and further enriched with experts' insights from Finland. The main purpose of this step was to support the alignment of research, education, innovation and regulation aspirations with shared FBA visions for Uruguay.

The **fifth step** and ultimate goal of the project was the co-creation of strategic action roadmaps for the key FBA in Uruguay. This required a roadmapping workshop in Uruguay and several meetings with VTT and Luke experts. Further analysis and prioritisation of the 15 opportunity pathways helped to validate and improve the typology and timeframe of 511 recommended actions from 15 action roadmaps consolidated by FBA. The final step of the project was supported by big data analysis, market research and insights from Finnish and Uruguayan experts.

The **fifth step** and ultimate goal of the project was the co-creation of strategic action roadmaps for the key FBA in Uruguay. This required a roadmapping workshop in Uruguay and several meetings with VTT and Luke experts. Further analysis and prioritisation of the 15 opportunity pathways helped to validate and improve the typology and timeframe of 511 recommended actions from 15 action roadmaps consolidated by FBA. The final step of the project was supported by big data analysis, market research and insights from Finnish and Uruguayan experts.



1.1.3 Project results and way forward

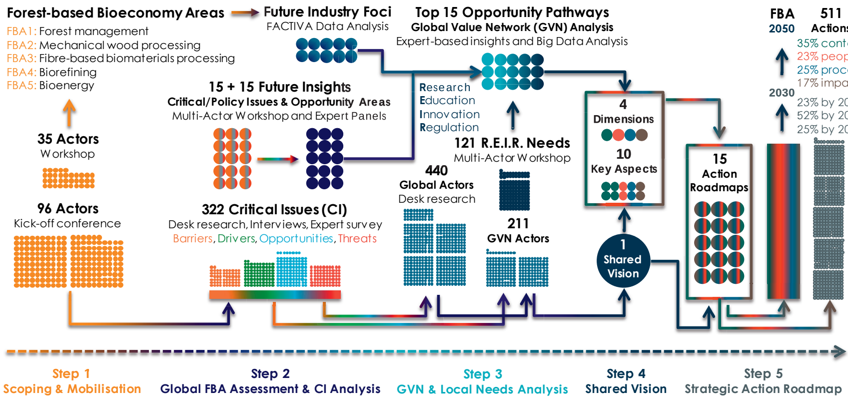
The nature, volume and strategic importance of the **top 10 results** of the FBA-Uruguay project can be better understood when presented and visualised using the five steps of the process.

The **first** result of the project was the co-created list of five key forest-based bioeconomy areas (FBA) for Uruguay. Although the project was focused on FBA from its inception, it was only after the kick-off conference and multi-stakeholder scoping and mobilisation workshop that the following five FBA (see Section 2.1) became widely seen as *key focus areas for Uruguay and the world*: Forest management (FBA1), Mechanical wood processing (FBA2), Fibre-based biomaterials processing

(FBA3), Biorefining (FBA4) and Bioenergy (FBA5). The **second** result is the mapping of key global FBA actors and industries (see Section 2.2). This work was based on the Factiva data analysis and complemented with desk research and expert interviews. In addition to the list of key actors and industries by FBA, an important finding of this work is the identification of ten *future industry foci* for Uruguay (*Agriculture, Cosmetics and toiletries, Electric power generation, Farming, Industrial goods, Packaging, Pharmaceuticals, Residential building construction, Sawmills and wood preservation, and Waste management and recycling services)*, which are highly ranked in the selected eight benchmark countries.

The **third** result is a list of *300+ critical issues (barriers, drivers, opportunities and threats) shaping the future FBA in Uruguay*. The critical issues (CI) were compiled in an internal document and shared with the project team. A more systematic assessment and prioritisation of the CI led to the **fourth** and **fifth** results, namely the identification of *top 15 critical/policy issues* and *top 15 opportunity areas*, respectively (see Section 2.3). The **sixth** set of results include a better understanding of the state-of-the-art of the global and Finnish forest-based bioeconomy as well as the strategic goals of 200+ global value network (GVN) actors. These results supported the organisation of a multi-actor workshop, which led to the identification of 100+ research, education, innovation and regulation needs and aspirations by the key FBA stakeholders in Uruguay (See sections 3.1 to 3.8).

The **seventh** result is the development of a shared understanding of common FBA visions for Uruguay (see Section 4.1 and 4.2), which framed the **eighth** result, which is *one of the two most important results of the project*, consisting of a systematic assessment of the top 15 opportunity pathways (OP) or strategic openings for Uruguay and the World. These findings are preceded by a description of the global and Finnish bioeconomy research and innovation landscape (see Sections 5.1 to 5.7). Finally, the **ninth** and **tenth** results represent the *second most important result of the project*, which include the consolidated *five action roadmaps by FBA* and related *511 recommendations structured around their main implementation dimensions and timeframes*.



1.2 On forest-based bioeconomy areas (FBA)

Driven by the growing awareness of the finite nature of fossil raw materials, population growth and the need for sustainable pathways of production and consumption, the bio-based economy is expected to expand worldwide.[4] The notion of bioeconomy has received an increasing attention since the early 2000s. The bioeconomy is understood to comprise 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. Sustainability in the use of natural resources is the key issue of the current bioeconomy thinking.

The forest-based (or wood-based) bioeconomy is an important sub-sector of the overall bioeconomy. In countries with abundant forest resources the economic magnitude of forests in bioeconomy is high. For example, in Finland it equals roughly to half of total bioeconomy output.[5] The countries with substantial forest resources and related advanced scientific and technological competences have good opportunities to play a role of forerunner in the modern future oriented bioeconomy. There are many convincing concrete examples of new commercialised technologies and products of forest-based bioeconomy businesses, both, in large and small enterprises, and their value chains.

An abundant scientific and policy related literature exists on the transition towards an advanced forest-based bioeconomy. The key elements in the transition are the

4 Cf. Hagemann, N., Gawel, E., Purkus, A., Pannicke, N. and Hauck, J. (2016) Possible Futures towards a Wood-Based Bioeconomy: A Scenario Analysis for Germany. Sustainability 2016, 8, 98.

5 See 'Sustainable growth from bioeconomy - The Finnish Bioeconomy Strategy' in 2014 (Available at http://biotalous.fi/wp-content/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf). Updated figures are published at 'Calculations on the Finnish bioeconomy' website maintained by the Natural Resources Institute of Finland, Luke in collaboration with the Statistics Finland. According to most recent information available, the total output of bioeconomy in Finland in 2016 was estimated to be 64 billion euro in current prices. Share of traditional forest industry alone was 38% (24 billion euro) of the total output. In addition, there are wide range of new wood-based bioproducts, which are in statistics accounted under other sectors.

sustainable use of natural resources, R&D and innovation, and foreseeable environmental and social benefits. Government policies in the form of incentives and regulations are necessary in shaping the transition.

In research, the majority of bioeconomy related studies are carried out within natural sciences and engineering. Moreover the transition from fossil economy towards bioeconomy means a comprehensive systemic change affecting and being affected by economic, industrial and social systems, the deep understanding of which requires interdisciplinary research encompassing economic, social and behavioural studies.

In businesses, forest-based bioeconomy calls for new innovative business models and services. Strategy and policy documents accentuate the importance of democracy, transparency and stakeholder engagement in planning and decision processes towards forest-based bioeconomy. Future oriented exercises are seen necessary in shaping the pathway towards forest-based bioeconomy.

As the first task in FBA-Uruguay 2050 project is to map key forest-based bioeconomy areas in the world and Uruguay, this report offers a general description of selected FBAs, as well as an overview of major global actors and related industries. The report also presents some 30 statements that will be used to further assess the potential impact on wealth creation of a number of forward-looking propositions related to critical issues, technologies and products, and important actions and recommendations potentially shaping the future of the five FBAs.

1.2.1 Concepts and definitions

The term “bioeconomy” was introduced in the early 1970s by Nicholas Georgescu-Roegen in the context of his work on applying the thermodynamic law of entropy to economic processes.[6] The term was based on the insight that the economic process has physical and biological roots and cannot ignore their limitations. According to Meyer[7] the current bioeconomy debates and activities have completely different roots. Starting points are the mergers between international biotech, chemical, pharmaceutical and agribusiness companies, tremendous advances in biological sciences, especially in genetics and molecular technologies, and the increasing biomass demand for non-food applications in energy and chemistry markets.[8] Bioeconomy concept starts from the premises that natural resources are limited and thus

6 Georgescu-Roegen, N. (1971) The Entropy Law and the Economic Process; Harvard University Press: Cambridge, MA, USA, 1971.

7 Meyer, R. (2017) Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates, Sustainability 2017, 9, 1031; doi:10.3390/su9061031.

8 Ibid.

need to be used efficiently.[9] Furthermore, the roots of bioeconomy are in the discourse of ecological modernization, thus economic growth and development can be aligned with environmental protection.[10]

The European Commission defines ”Bioeconomy” as encompassing “the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy.[11] The bioeconomy includes the sectors of agriculture, forestry, fisheries, food, and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. Since the bioeconomy is cross-sectoral in nature and influenced by a wide range of inter-connected global drivers and constraints, understanding and managing the bioeconomy phenomenon requires an integrated multidimensional approach.[12]

The introduction of the term “political bioeconomy” highlights the growing political interest and will towards strengthening bioeconomy.[13] The major aim of political bioeconomy strategies is the call for a shift towards a society relying strongly on renewable biological sources while achieving economic growth. As the EC highlights, knowledge, innovation and sustainable management are identified as core factors contributing to achieve this aim, and forests and the forest sector are expected to provide a significant contribution to bioeconomy.[14]

International Energy Agency (IEA) separates definitions of bioEconomy, biobased economy and biobased industries. BioEconomy (BE) means food and feed industries (agriculture, forestry, horticulture, fisheries and aquaculture, plant and animal breeding, the nutrition and beverage industry) + biobased economy; BioBased

---

9 Kleinschmit, D., Lindstad, B. H., Thorsen, B. J., Toppinen, A., Roos, A., & Baardsen, S. (2014). Shades of green: a social scientific view on bioeconomy in the forest sector. Scandinavian Journal of Forest Research, 29(4), 402–410. Available online: http://macroecointern.dk/pdf-reprints/Kleinschmit_SJFR_2014.pdf.

10 Arts, B., Appelstrand, M, Kleinschmit, D., Pülzl, H., Visseren-Hamakers, I., Eba’a Atyi, R., Enters, T., McGinley, K., Yasmi, Y. (2010) Discourses, actors and instruments in international forest governance. In: Rayner, J., Buck, A., Katila, P. (eds): Embracing complexity: meeting the challenges of international forest governance. IUFRO World Series vol 28. Vienna: 57–73.

11 EC (2012) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Innovating for Sustainable Growth: A Bioeconomy for Europe. {SWD(2012) 11 final}. Available online: http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf.

12 European Commission (2013) Bio-economy and sustainability: a potential contribution to the Bio-economy Observatory. European Commission, Joint Research Centre, Institute for Environment and Sustainability. Available online: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/27454/1/lb-na-25743-en-n.pdf.

13 Kleinschmit, D., Lindstad, B. H., Thorsen, B. J., Toppinen, A., Roos, A., & Baardsen, S. (2014). Shades of green: a social scientific view on bioeconomy in the forest sector. Scandinavian Journal of Forest Research, 29(4), 402–410. Available online: http://macroecointern.dk/pdf-reprints/Kleinschmit_SJFR_2014.pdf.

14 EC (2012) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Innovating for Sustainable Growth: A Bioeconomy for Europe. {SWD(2012) 11 final}. Available online: http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf.

Economy (BBE) refers to non-food industries – chemical, material, medicine, pulp+paper and wood industries + bioenergy (including biorefineries), and BioBased Industries (BBI) to individual sectors of industries – food, biochemical, biomaterial, biomedicine, pulp+paper and wood processing.[15] The terms of "bioeconomy" and "bio-based economy" may differ, when mentioned as a general concept, however the term bioeconomy comprises the term of bio-based economy.[16]

Biorefinery is an often used term in the context of bioeconomy. Biorefinery refers to facilities that convert biomass – biological materials from living or recently living organisms – into fuels, energy, chemicals and materials (and feed).[17] A forest biorefinery refers to a multi-product factory that integrates biomass conversion processes and equipment in order to produce bioenergy (e.g. biodiesel, bio-oil, bioethanol, green electricity, heat and pellets) and bioproducts (e.g. bio-composites, bioplastics) from wood-based biomass.[18]

The wood- or forest-based bioeconomy describes an important sub-sector of the overall bioeconomy. Wood-based bioeconomy can be defined as a bio-based circular economy that uses lignin-containing and, therefore, hard parts of stem, branches and twigs of plants such as trees and scrubs.[19] The biggest part of utilised wood originates from forests such as round timber, pulpwood and forest residues, while smaller parts of utilised wood derive from short rotation coppice and landscape residues. Furthermore, by-products and waste of wood processing and also recycled wood are utilised for material and energetic use. The wood-based bioeconomy has a high relevance for both material and energetic uses because there is no direct competition with food production (ibid.).[20]

In conclusion, the terminology of the bioeconomy, in general, as well as in forest-based bioeconomy is still largely under discussion and the development of consistent concepts and definitions remains a challenge. Establishing a standardized terminology is important in order to be able to synthesize, compare and apply bioeconomy related terms in real managerial situations in businesses or policy-making.

---

15 IEA (2014) BioEconomy Survey 2014 IEA Bioenergy, Task 42 Biorefining. Available online: http://task42.ieabioenergy.com/wp-content/uploads/2017/06/BioEconomy-Survey-IEA-Bioenergy-IA-Countries_website.pdf.

16 Staffas, L., M. Gustavsson and K. McCormick (2013) Strategies and Policies for the Bioeconomy and Bio-Based Economy: An Analysis of Official National Approaches, Sustainability 2013, 5, 2751–2769. Available online: file:///C:/users/torst_000/Downloads/sustainability-05-02751-v3.pdf.

17 WEF (2010) The Future of Industrial Biorefineries, World Economic Forum, Geneve.

18 Näyhä, A., L. Hetemäki and T. Stern (2014) New products outlook, in: Hetemäki, L. (Ed.) (2014) Future of the European Forest-Based Sector: Structural Changes Towards Bioeconomy. European Forest Institute. Available online: http://www.efi.int/files/attachments/publications/efi_wsctu_6_2014.pdf.

19 Hagemann, N. et al. (2016) Possible Futures towards a Wood-Based Bioeconomy: A Scenario Analysis for Germany, Sustainability 2016, 8, 98; doi: 10.3390/su8010098. Available online: www.mdpi.com/journal/sustainability.

20 Ibid.

1.2.2 Economic importance

The opportunities for positive impacts flowing from an advanced bioeconomy appear to be immense. While the technical potential for the bioeconomy seems impressive[21], over 90% of oil-based products could be replaced by bio-based alternatives – the challenge is to increase the scale of activities (e.g. in terms of biomass production) in parallel to meeting key sustainability goals.[22] Concidering that bioeconomy as a concept with a more precise content is in a relatively early stage of development, the estimation of its economic magnitude is for the time being uncertain. Some of the available estimations of the economic importance of the bioeconomy and forest-based bioeconomy are presented below.

Meyer[23] separates two approaches in the strategies of bioeconomy, first defining bioeconomy in a narrower sense and, second, in a broader sense. An understanding of bioeconomy in a narrower sense tends to limit the economic assessment to the biotechnology industry or the emerging bio-based industry, for which economic data is difficult to obtain. It is possible from surveys or company reports mainly.[24] In a broader sense Meyer[25] refers to the definition of bioeconomy in such way that it includes all sectors that produce, process or use biological resources, including traditional bioeconomy sectors such as agriculture and food industry. Statistical data for the primary production of biomass in agriculture, forestry and fishery are well established, but the economic shares of downstream stages in biomass-based value chains are not readily available.

The economic magnitude of bioeconomy is estimated on EU level. EU´s Bioeconomy strategy presents an estimate that EU's bioeconomy sectors are worth € 2 trillion in annual turnover and account for more than 22 million jobs and approximately 9 per cent of the workforce.[26] It is estimated that direct research funding associated to the Bioeconomy Strategy under Horizon 2020 could generate about 130,000 jobs and € 45 billion in value added in bioeconomy sectors by 2025. Estimations exist also of the magnitude of biotechnology, a part of the bioeconomy. In

---

21 Bünger, M. Biofuels: Putting Pressure on Petrol, Renewable Energy World. Available online: http://www.renewableenergyworld.com/rea/news/article/2010/06/biofuels-putting-pressure-on-petrol.

22 McCormick, K. and N. Kautto (2013) The Bioeconomy in Europe: An Overview, Sustainability 2013, 5, 2589–2608. Available online: file:///C:/users/torst_000/Downloads/sustainability-05-02589.pdf

23 Meyer, R. (2017) Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates, Sustainability 2017, 9, 1031; doi:10.3390/su9061031.

24 See for example: Nattrass, L., C. Biggs, A. Bauen, C. Parisi, E. Rodríguez-Cerezo and M. Gómez-Barbero (2016) The EU bio-based Industry: Results from a survey; EUR 27736 EN; doi:10.2791/806858; Publications Office of the European Union: Luxembourg, 2016. Available online: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC100357/jrc100357.pdf.

25 Ibid.

26 EC (2012) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Innovating for Sustainable Growth: A Bioeconomy for Europe. {SWD(2012) 11 final}. Available online: http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf.

the EU industrial biotechnology is assessed to continue to grow due to a relatively supportive regulatory and financial system[27].

Sales of bio-based products in Europe in 2007 amounted to €48 billion, equal to 3.5 per cent of total chemical sales. By 2017, sales are estimated to be €340 billion, totalling 15.4% of all chemical sales. Although Europe is one of the largest economies in the world, most activities aimed at supporting the development of the bioeconomy have, until recently, been conducted at a national level. In the U.S., according to the USDA, revenues in 2010 from genetically modified crops were approximately $76 billion.[28] Beyond agriculture, based on the best available estimate, in 2010 U.S. revenues from industrial biotechnology – fuels, materials, chemicals, and industrial enzymes derived from genetically modified systems – were approximately $100 billion.

The Organization for Economic Cooperation and Development (OECD) suggests that industrial and plant biotechnology will overtake health biotechnology by 2030 and account for 75% of the total gross value added by the biotechnology sector.

In Finland, Statistics Finland has made an estimate based on official statistics of the total annual output, value added, employment and exports of various areas interpreted to belong to the bioeconomy in 2011 (Table 1). In total the output is about 60 billion euro and half of it is forest-based. In Table 1 the figures for construction, chemical industry and nature tourism are estimates of the share of bioeconomy based activities in these sectors.

Table 1. Bioeconomy output, value added, people employed and exports in 2011 (Finnish Bioeconomy strategy (2014). (Source: Statistics Finland 2014)

	Output million EUR	Value added million EUR	Employed	Exports million EUR
Food, total	**16 093**	**4 356**	**128 400**	**515**
Agriculture	4 822	1 658	90 100	0
Food industry	11 271	2 698	38 300	515
Bioeconomy products total	**29 273**	**9 317**	**101 400**	**13 819**
Forestry	4 232	2 898	25 000	68
Wood products industry	6 870	1 542	36 400	2077
Pulp and paper industry	13 653	2 967	23 300	9185
Construction	9 228	3 344	58 120	100
Chemical industry	1 644	434	1 600	1 347
Pharmaceutical industry	1 339	845	4 100	932
Renewable energy	**4 033**	**1 903**	**5 801**	**0**
Water treatment and distribution	**610**	**400**	**2 700**	**0**
Bioeconomy services total	**2 993**	**1 416**	**33 900**	**0**
Nature tourism	2 737	1 226	32 000	0
Hunting	85	79	100	0
Fishing	171	111	1 800	0
Bioeconomy total	**60 685**	**20 104**	**319 321**	**14 248**
National economy total	**375 777**	**163 424**	**2 509 500**	**54 221**
Share of bioeconomy	**16,1 %**	**12,3 %**	**12,7 %**	**26,3 %**

In Germany, the economic sectors related to the bioeconomy were calculated in 2011 to provide around 14 per cent of the country's GDP and 13 per cent of all

[27] Available online: http://www.ey.com/gl/en/industries/life-sciences/biotech-report-2012---bioeconomy-industry-overview.

[28] White House (2012) White House. National Bioeconomy Blueprint; White House: Washington, DC, USA, 2012. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/national_bioeconomy_blueprint_april_2012.pdf.

jobs.[29] The importance of the bioeconomy, within the German economy as a whole, was measured by using the definition of the German Bioeconomy Council according to which the bioeconomy "encompasses all those sectors and their related services which produce, process or use biological resources in whatever form".[30] Various official statistics were exploited for the determination of the different industries and their share of the bioeconomy. The indicators used were employment and gross value added and the analysis covers the developments from the year 2002 to the year 2010. Altogether, about five million employees, representing 10 per cent of all employees and 140 billion Euro, representing 6 per cent of gross national product have been identified as the share of bioeconomy in Germany in the year 2010. The result indicates a strong increase compared to the year 2002.[31]

In conclusion, already several efforts have been made in the economic estimation of the magnitude of bioeconomy, in general, and forest-based bioeconomy, in particular. Still, differing estimations revert to variable terminologies of bioeconomy of these calculations. Challenges that need to be overcome are that neither the available data nor the economic activities themselves can be unambiguously assigned to the bioeconomy or the non-bioeconomy.[32] Meyer[33] adds that varying specifications of system boundaries or bioeconomy definitions lack coherent cross-sectoral reporting systems, unreliability of international trade statistics, insufficient data on the share of bio-based inputs in production processes, and lack of transparency in biomass supply chains. These are the main obstacles for monitoring the economic development of the bioeconomy defined in a broader sense.

1.2.3 Drivers, barriers, opportunities and threats

In order to understand the bioeconomy and its transition to an advanced bio-based economy, it is necessary to examine in more depth the manner in which it is defined and interpreted by different actors, as well as the key factors influencing the development of bioeconomy, including drivers, barriers, opportunities and threats.[34] Growth, declining natural resources, loss of biodiversity and climate change challenge the Mankind to develop a bioeconomy that is based on renewable natural resources. The world is facing many serious challenges of which fast-growing human population, the consequent growing demand for food, energy and water are

---

29 Bio-economy (2011), available at www.bio-economy.net.

30 Efken, J., W. Dirksmeyer, P. Kreins and M. Knecht (2016) Measuring the importance of the bioeconomy in Germany: Concept and illustration, NJAS - Wageningen Journal of Life Sciences, 77 (2016) 9–17. Available online: http://ac.els-cdn.com/S1573521416300082/1-s2.0-S1573521416300082-main.pdf?_tid=02bd0a90-7dbc-11e7-b604-00000aacb35e&acdnat=1502363391_2dd42f04acea03914752b2cf3d61457b.

31 Ibid.

32 Ibid.

33 Meyer, R. (2017) Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates, Sustainability 2017, 9, 1031; doi:10.3390/su9061031.

34 McCormick, K. and N. Kautto (2013) The Bioeconomy in Europe: An Overview, Sustainability 2013, 5, 2589-2608. Available online: file:///C:/users/torst_000/Downloads/sustainability-05-02589.pdf

among the most serious ones. The EC estimates that in 2050 a world population is expected to increase by more than 30 per cent in the next 40 years, from 7 billion in 2012 to more than 9 billion.[35] The growing demand will result in a scarcity of natural resources and push their prices up. Climate change is a severe threat to mankind and requires the reduction of current greenhouse gas (GHG) emissions to avoid detrimental consequences for the globe.[36]

Figure 1 depicts global drivers, barriers, opportunities and threats in the transition towards sustainable forest-based bioeconomy in the TEEPSES (Technological, Economic, Environmental, Political, Societal, Ethical, Spatial) framework.

[35] EC (2012) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Innovating for Sustainable Growth: A Bioeconomy for Europe. {SWD(2012) 11 final}. Available online: http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf.

[36] King, D. (2010) The Future of Industrial Biorefineries, World Economic Forum.

Drivers	T: Increasing research, technology development and innovation efforts in FBA E: Increasing demand and consumption of sustainable commodities and services E: Increasing importance of environmental protection and monitoring activities P: Incentives and initiatives by FBA policies and regulations (e.g. UN SDG) S: Fast-growing human population leading to growing food demand E: Increasingly stringent legislation encourages CSR in FBA S: Proximity to food (export production)
Barriers	T: Prejudices in developing radical R&D and innovations for FBA E: Production and consumption structures lock-in, remaining conservative, using fossil fuels, etc. E: Dissatisfaction in the improvement of the state of the environment as an element of welfare P: System and related policy and governance failures in the development of FBA S: Failures in managing the growing human population, e.g. addressing growing food demand. E: Role of village/local communities in land ownership S: Longer distance to Asian markets
Opportunities	T: Technological forest-based bioeconomy innovations pave the way towards sustainable E: Production, consumption, and market structures favouring sustainable models (CO2 reduction, etc.) E: Importance of clean environment for welfare increases P: Policies manage to change global trend towards sustainable FBA S: Attitudes of citizens and NGOs move towards favouring new consumables based on FBA E: Incentives for industries and consumer to favour forest-based production and consumption S: Optimization of land use
Threats	T: Wild card events leading to degradation and decline of natural resources and loss of biodiversity E: Economic recession/stagnation E: Consequences of climate change – draught, environmental refugees P: Change towards conservative political choices (fossil fuels) S: Political conservatism gets advocacy E: Legislations causing industry frustration and consumers scepticisms on FBA strategies and policies S: Wood allocation and logistics in different processing plants

Figure 1. Drivers, barriers, opportunities and threats in the transition towards sustainable FBA in TEEPSES framework. (Source: The Authors).

The availability of raw materials and the efficiency of their use will become a new competitive advantage. Increasing environmental awareness and more stringent legislation will also be a driver in the manufacture of products with less harmful impact on the environment. Driven by the growing awareness of the finite nature of raw materials and the need for sustainable pathways of industrial production, the bio-based economy is expected to expand worldwide.[37] The United Nations and other international communities, the EU Member States, as well as many individual

[37] Hagemann, N. et al. (2016) Possible Futures towards a Wood-Based Bioeconomy: A Scenario Analysis for Germany, Sustainability 2016, 8, 98; doi: 10.3390/su8010098. Available online: www.mdpi.com/journal/sustainability.

countries have introduced numerous policy initiatives and regulations, which as such are driving the production and consumption structures towards more sustainable direction.

Among the barriers of forest-based bioeconomy areas are conservativeness of industries and consumers, slow change of economic and energy structures, and defence of traditional production and markets. Traditional fossil-based production pathways can still benefit from economies of scale and scope, past learning effects and a co-evolution of technologies and institutions, resulting in a lock-in into fossil fuel-based production structures and demand patterns.[38] For example, on a basis of seven bioeconomy innovation case studies, several obstacles of innovation were identified in Nordic bioeconomy.[39] Lack of capital and funding is a key challenge in the emerging bioeconomy, since the investments have a long life cycle and are capital intensive and at the same time the emerging bioeconomy sector is not familiar to investors or potential customers. Hence, also first industrial scale plants are challenging to establish. In addition, unstable operating environment is largely due to the changing regulation related to some of the biggest drivers of bioeconomy such as carbon prices. The cross-cutting nature of bioeconomy would require, if not a breakdown of traditional sector borders, at least a more active communication and cooperation between the sectors. Market access is crucial, especially in Nordic countries, since the home markets are relatively small, whereas global markets are growing. Lack of actors in ecosystems is also a Nordic challenge; the number of actors and investors is relatively small compared to many other markets such as the USA.[40]

The development of forest-based bioeconomy is not without threats and risks, which seem to be under increasing debate. Among the controversial elements are land uses for forests and agriculture, sufficiency of forests, as well as principles in the management of forest biomass and related issues, also including democracy, participation and decision processes.

The rise of the bioeconomy is usually associated with increased sustainability, however various controversies suggest doubts about this assumed relationship.[41] Results of a systematic review of 87 scientific journal articles show that visions about the relationship between bioeconomy and sustainability differ substantially.[42] Four different visions were identified, including: (1) the assumption that sustainability is an inherent characteristic of the bioeconomy; (2) the expectation of benefits

---

38 Ibid.

39 Rönnlund, I., T. Pursula, M. Bröckl, L. Hakala, P. Luoma, M. Aho, A. Pathan, B. E.Pallesen (2014) Creating value from bioresources, Innovation in Nordic Bioeconomy, Nordic Innovation Publication 2014:01. Available online: http://www.nordicinnovation.org/Global/_Publications/Reports/2014/2014_01%20Innovation%20in%20Nordic%20Bioeconomy_final.pdf.

40 Ibid.

41 Pfau, S.F., J.E. Hagens, B. Dankbaar and A.J.M. Smits Visions of Sustainability in Bioeconomy Research, Sustainability 2014, 6, 1222–1249; doi:10.3390/su6031222. Available online: www.mdpi.com/journal/sustainability.

42 Ibid.

under certain conditions; (3) tentative criticism under consideration of potential pitfalls; and (4) the assumption of a negative impact of the bioeconomy on sustainability. There is a considerable attention for sustainability in the scientific bioeconomy debate, and the results of the review show that bioeconomy cannot be considered as self-evidently sustainable. In further research and policy development, a sufficient consideration should therefore be given to the question of how the bioeconomy could contribute to a more sustainable future.

European Union's Bioeconomy Action Plan (BAP) hardly discusses climate policies and entirely omits the land-use aspects between agriculture and forestry that are important for climate policies.[43] An equally serious shortcoming is that BAP very vaguely recognizes the role and nature of the forest sector as a high-tech biomass utilising sector and omits its current challenge to renew the product matrix from forest biomass as a response to the decreasing demand for paper. [44]

The identification of political and economic trade-offs and conflicting interests of stakeholders in using forests, the assessment of the economic values of forest ecosystem services and biodiversity protection, and the provision of incentives for corporate social responsibility and green consumerism are core challenges in the context of integrated forest management in the bioeconomy.[45]

In Finland, according to the current government's objectives and the climate and energy strategy, the annual felling of domestic timber would increase from about 66 Mm^3 to about 80 Mm^3 (2013–2015) and the use of forest chips from about 8 Mm^3 to 14–18 Mm^3 by 2030. These objectives are too high according to a part of the scientific community. Sixty eight experts from the Finnish academic community express their concern about the climate and biodiversity impacts of Finland's forestry plans. In doing so, increasing logging and wood use will weaken biodiversity and accelerate climate change. Thus, it is becoming increasingly important to apply versatile indicators and tools in the assessment of sustainability impacts of the forest bioeconomy.[46]

Furthermore, the availability of robust data of forest-based bioeconomy areas, products and processes is important for robust action plans and their implementation, both in industries and in policy strategies and policy implementation. Important elements of such data are advanced forest inventory system, life cycle assessment data of forest-based bioeconomy products and processes[47], and several related indicators. One example of forest inventory data is the European Forest Information

---

[43] Ollikainen, M. (2014) Forestry in bioeconomy – smart green growth for the humankind. Scandinavian Journal of Forest Research, Volume 29, 2014 - Issue 4: Biobased Economy.

[44] Ibid.

[45] Kleinschmit, D., Lindstad, B. H., Thorsen, B. J., Toppinen, A., Roos, A., & Baardsen, S. (2014). Shades of green: a social scientific view on bioeconomy in the forest sector. Scandinavian Journal of Forest Research, 29(4), 402–410. Available online: http://macroecointern.dk/pdf-reprints/Kleinschmit_SJFR_2014.pdf.

[46] Karvonen, J., P. Halder, J. Kangas and P. Leskinen (2017) Indicators and tools for assessing sustainability impacts of the forest bioeconomy, Forest Ecosystems (2017) 4:2. Available online: https://forestecosyst.springeropen.com/track/pdf/10.1186/s40663-017-0089-8?site=forestecosyst.springeropen.com.

[47] E.g. German Institute for Standardization. Bio-Based Products—Life Cycle Assessment; German Version EN 16760:2015; Beuth Verlag GmbH: Berlin, Germany, 2015.

Scenario Database (EFISCEN) – a forest inventory database of European countries, based on input from national inventory experts.

In research, the majority of bioeconomy related studies are carried out within natural sciences and engineering. Moreover, the transition from fossil economy towards bioeconomy, and related drivers, barriers, opportunities and threats, means a comprehensive systemic change affecting and being affected by economic, industrial and social systems. The deep understanding of these diverse aspects and policy-making require support from interdisciplinary research, encompassing natural and engineering sciences, as well as economic, social and behavioural sciences. [48]Kleinschmit et al. (2014) present socio-economic theoretical frameworks and research areas relevant for a more holistic understanding of the bioeconomy concept applied to the forest sector, and identified a core set of potential contributions from socio-economic and policy research for enhancing the bioeconomy in the forest sector.

[48] Kleinschmit, D., Lindstad, B. H., Thorsen, B. J., Toppinen, A., Roos, A., & Baardsen, S. (2014). Shades of green: a social scientific view on bioeconomy in the forest sector. Scandinavian Journal of Forest Research, 29(4), 402–410. Available online: http://macroecointern.dk/pdf-reprints/Kleinschmit_SJFR_2014.pdf.

2. Mapping key FBAs in the world

This section focuses on Task 1 which analyses and describes the five Forest-based Bioeconomy Areas (FBAs) jointly defined with local stakeholders in the Uruguay workshop in August 2017. The five areas deemed to have strategic potential are as follows:

- Forest management
- Mechanical wood processing
- Fibre-based biomaterial processing
- Biorefining
- Bioenergy

The general objective of Task 1 (Mapping key FBA in the world) was to assess the global potential (e.g. economic, social, environmental, governance and innovation) of forest-based bioeconomy in the selected FBAs. After a short introduction to key forest-based bioeconomy areas in the world, the report provides a short description of each FBA, followed by selected VTT-Luke experts' appraisal of the global and national potential of FBAs. We then present the results of the Factiva Global News database analysis, which was used to identify global players and key actors in the selected forest-based bioeconomy areas, as well as to recognise the key industries. This is followed by an overview of the findings from the systematic mapping of over 300 critical issues (drivers, barriers, opportunities and threats) shaping all FBAs. Here we also present the 30 statements that were jointly selected between VTT and OPP teams and which will be used in a Delphi-like survey to be implemented in April 2018 as a key element of Task 1.2 Assessing the shapers of FBAs – Global FBA expert survey. Finally, we provide some from the survey and the experts' assessment of critical issues.

Forest-based bioeconomy areas (FBAs) are the cornerstones of forest cluster, which relies on sustainable and resource-efficient use of forest biomass. Five key FBAs include forest management, mechanical wood processing, fibre-based biomaterial processing, biorefining and bioenergy (Figure 2).

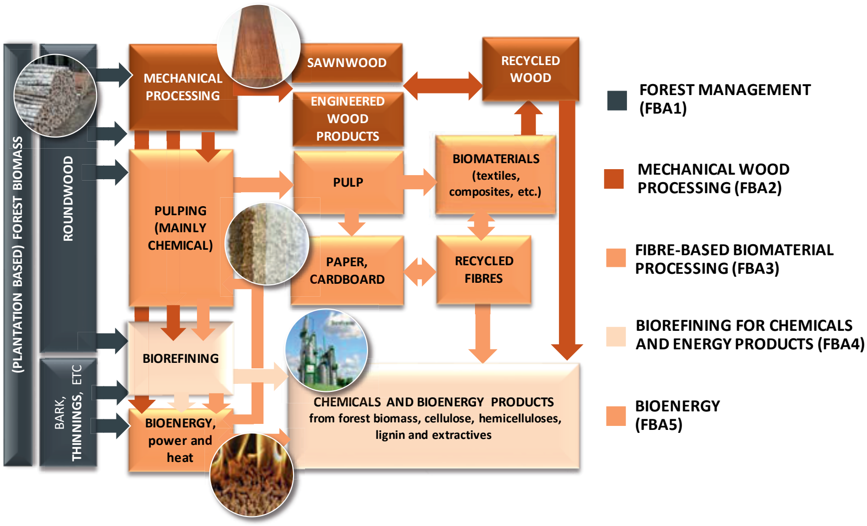


Figure 2. Biomass flows, processes and potential products within Forest-based Bioeconomy Areas.

2.1 Description of FBAs and experts' appraisal of their potential

In this section the main results from the workshops organised with experts of VTT (Technical Research Centre of Finland) and Luke (Natural Resources Institute of Finland) in January 2018 are presented. These workshops, in turn, draw from previous activities that took part in Uruguay in August 2017. In the workshop covering forest management (FBA1) and mechanical wood processing (FBA2) participated the following five experts from Luke: Saija Huuskonen (Senior Scientist), Maarit Kallio (Senior Scientist), Eero Mikkola (Senior Specialist), Raisa Mäkipää (Research Professor), and Erkki Verkasalo (Research Professor). The workshop focusing on fibre-based biomaterial processing (FBA3) and biorefining (FBA4) was organised with four VTT experts in the field: Ali Harlin (Research Professor), Eemeli Hytönen (Technology Manager), Kristiina Kruus (Research Professor), and Klaus Niemelä (Principal Scientist). In the third workshop on bioenergy VTT expertise was represented by the following experts; Eija Alakangas (Principal Scientist), Lauri Kujanpää (Research Scientist), and Matti Virkkunen (Research Scientist).

2.1.1 FBA 1: Forest management

FBA1 Description: *Forest-based biomass is in the centre of all economic activities related to forest-based bioeconomy. Forest management has long-term impacts on future forest biomass, not only the availability and sustainability but also the quality and costs of wood. Ensuring the raw material base for various processes and applications is a key of any future bioeconomy business. Forest management focuses on sustainable forestry activities related to for example silviculture, tree breeding and forest biotechnologies, forest inventory and technologies used in inventories (e.g. techniques utilising satellite data and/or laser scanning), harvesting and transportation of wood-based biomass. Development of intelligent forest machinery as well as digitalisation and use of digital platforms are cross-cutting technologies which are increasingly important in any of the above mentioned areas.*

The experts participating in the workshop were unanimous that future of forest-based bioeconomy in Uruguay cannot rely only on pulp production. Uruguay needs to develop the forest-based business base, and diversify it. The forest-based businesses form a wider integrated network of actors and activities linking together plant and seed production, tree breeding, silviculture, forest management, mechanical wood processing, pulp mills and (bio)energy production. In addition to different uses of roundwood, it is equally important to find uses for side streams and residues generated in different phases of forest operations (small wood, logging residues) and wood processing (by-products of solid wood). In economic terms, forest management and processing of wood for different uses offer room for entrepreneurship, labour demand and rural development and income along the value chain; while entrepreneurial opportunities for companies can be found in operating nurseries, seeding, reforestation, and harvesting as well as in provision of related services (e.g. transportation and forest management).

From the forest management and silviculture perspective sustainable forest management practices and land use are highly important matters to take care of since the land area of forest plantations may further increase by year 2030 in Uruguay. Expansion of plantations is not sure while the current natural forests are partly outside commercial activities. However, if significant investments in pulp, paper and paperboard or saw milling and engineered wood products are aimed, these probably require increasing wood resources through plantations for volume and logistics reasons. Generally speaking, increasing the production, efficiency and value output from the current forest resources should be emphasized in a short and medium term, whereas the plantations would probably be needed in medium and long term.

Sustainable development calls for carbon sink and ecosystem evaluations, assessment of impacts of climate change for water balance, bearing capacity and soil productivity and compaction (e.g. accommodating high-performance forest machinery to the terrestrial conditions), company-level and region-level feasibility studies of business economy, finding opportunities and living needs of rural population and defining requirements for wood species planted, to mention but a few. Other important issues relate to ecological sustainability in plantation forests and the balance in use of land for different purposes, such as forestry, food production and cattle grazing. Water usage of plantation forests is important to consider in a wider context, as there can be potential negative hydrological impacts on environment and society.

As such, increasing total coverage and exploitation of native and plantation forest area in Uruguay was deemed a good direction, provided it is consistently managed. The forests contribute to net balance in greenhouse gas emissions forming a carbon sink, which may open opportunity to sell emission rights to other countries. While plantation area is increased and forest-based activities further developed, there is need to consider variety of planted tree species against future demand. This has to be taken into account in forest management and planning of forest resources to avoid bottlenecks in supply of raw material. In parallel, the supply of different wood assortments should be facilitated (pulpwood, saw and veneer logs, bioenergy). It is vital to understand that commercial benefits from forestry are generated during a much longer term than what is typical for forest industries. However, key prospective products should be a driver for the objectives of commercial forest management as well their market foresights, competitiveness in different market regions and customer segments. In addition to upgraded pulp and paper products, building with wood products from sawn timber and plywood and engineered wood products are expected to provide the core for larger scale industries with both domestic and export demand, whereas furniture, interior and handicraft products, and bioenergy and selected fine chemical products may be based on national and local demand.

Furthermore, from forest management perspective it is relevant to consider alternative uses for forests, particularly native forests but there may be opportunities with plantation forests as well. Nowadays, forest's intangible value for human wellbeing and a source of recreation is increasingly recognized. For example in Finland, nature tourism attracts people not only to protected forests, but also to commercial forests.[49]

2.1.2 FBA 2: Mechanical wood processing

FBA2 Description: *Mechanical wood processing focuses on mechanical transformation of wood to versatile structural and non-structural products, such as sawnwood, veneer, plywood, furniture, construction elements and vehicle industries. Sawmilling is in a focal point of mechanical wood processing value chain along with manufacturing of engineered wood products. Mechanical wood processing is linked with other forest-based bioeconomy areas, as side-streams from mechanical transformation of wood are used in bioenergy production, chemical pulping and biorefining. Sawdust, which is residue of sawmilling, can also be used as an important element in good tree nursery substrate and animal bedding and landscaping material.*

[49] See also Tyrväinen, L., Plieninger, T. and Sanesi, G. (2017) How does the forest-based bioeconomy relate to amenity values? In Winkel, G. (editor) (2017) Towards a sustainable European forest-based bioeconomy – assessment and the way forward. What Science Can Tell Us 8. European Forest Institute (available at https://www.efi.int/sites/default/files/files/publication-bank/2018/efi_wsctu8_2017.pdf)

The experts emphasised the importance to develop pulp industry and mechanical wood processing industries in parallel. Regarding this, Chile was mentioned as an interesting and relevant benchmark country for Uruguay; with a focus on how they have developed forest management and mechanical wood-processing industries alongside of pulp and paper industry. Species grown and used in Chile are either similar or comparable to those growing in native forests or to-be-grown in plantations in Uruguay; their breeding results and experience can be adopted and infrastructure development, industry structure and profiles of wood harvesting and processing companies may be adapted to Uruguay conditions. Other useful benchmarking can be done in selected items of industry development versus Southern Brazil, South Africa, Australia, New Zealand and Southern USA.

Development of mechanical wood processing industry requires that supply of wood matches with demand. It was noted that companies are not investing in sawmills, veneer and plywood mills, and the manufacturing of wood products if there are no relevant raw material available in sufficient volumes, grades and competitive prices (e.g. forest plantations ensuring the wood supply for large scale sawmills). This highlights need to involve all relevant stakeholders of value chains in future oriented activities. In general, ecosystem type of approach is valuable for efficient use of wood-based biomass in the forest-based bioeconomy. Industrial parks can be used as platforms, which enable inclusion of actors not only from forest sector but also from food and chemicals sectors, for example. Mechanical wood processing industries generate large volumes of residues (e.g. sawdust, planer shavings, cutting and peeling waste), which can be utilised in production of engineered wood products and wood-based panels in pulping, bioenergy production to name few of the important application areas. Mechanical wood processing is a mature industry and innovations in the field tend to be incremental, thus highlighting importance of ability to quickly adopt and improve elsewhere-developed solutions for competitiveness.

Strengthening of domestic demand for wood products can induce the mechanical processing industry development in Uruguay. Increasing the use of wood in construction is apparently an opportunity. It would affect positively the demand of sawn wood, plywood and different types of engineered and physically or chemically modified solid wood as well as wood panel products. use of wood as a renewable raw material in construction and production of building materials and furniture would have an additional environmental benefit because of its capacity as carbon storage. However, considering the size of the country, volume of domestic demand alone may not be enough to give a thrust for mechanical processing industry but requires focusing on export markets as well. Large companies as locomotives would be important for development of industry and export. This would prepare ground for small and medium sized companies active in the sector.

Regarding availability of raw material, the experts were in opinion that Uruguay, with the objective to continue increasing forest area in the country, has sufficient basis for developing mechanical wood processing, saw milling and plywood milling sector. Building with wood is currently growing in Europe (esp. Central and Northern

Europe), with the support of both public and industrial stakeholders and (partly) customer demand. Markets of engineered wood products, such as glulam (GL), laminated veneer lumber (LVL) and cross-laminated timber (CLT) are growing and expanding in developed countries, as do also wood-based panels (particle board, fibre board, MDF). Engineered wood products market is projected to grow globally at a compound annual growth rate (CAGR) of 24.8% from 2016 to 2022 and expected to reach over $40 billion by 2022.[50] The global engineering wood market is influenced by the furniture and housing sectors. The market development depends on the type of products such as glulam, laminated veneer lumber (LVL), and oriented strand board (OSB). Despite the downfall in demand for engineered wood products in large-scale remodelling projects and new houses, the volume consumption of engineered wood is expected to increase owing to rise in consumer acceptance. The availability of local produced lumber has significantly increased in the last thirty years in Uruguay due to a governmental policy to promote fast-grown plantations.[51] Given the high volume of timber required for manufacturing, the production of cross-laminated timber (CLT) panels could be an appropriate destiny for the existing surplus of pinewood presently available in Uruguay.[52] Building with wood is based on coniferous species all over the world; hence, current native and suitable exotic pine species should be in the core to develop mechanical wood processing industry. Hardwood species have been and are used in furniture, cabinetry, interior products and utility items as well as in plywood and wood-based panels. Eucalyptus species, the common exotic tree planted in Uruguayan forest plantations, with its suitable dimensions, straight trunk and, for some individual species and hybrids, good technical and mechanical performance is a prospective raw material for mechanical processing toward sawn timber and plywood.

It should be noted that industrial start-ups of mechanical wood processing, particularly large saw mills and plywood mills require detailed analysis of relevant final products, market size and customer segments, opportunities and partnerships in further processing, most feasible technology and cost structure and key players and stakeholders along the value chains and enterprise networks. Needs and benefits of public support to develop infrastructure, proof-of-concepts and actual industrial investments should be investigated case by case. Generally speaking, up-to-date manufacturing technology is available and affordable for sawmills, plywood mills and other woodworking and wood panel industries. According to expert opinions, Uruguay is considered a stable and safe country for industrial investments. This is especially important in order to attract international investors and companies.

50 Engineered Wood Market by Product Type (Plywood, Laminated Veneer Lumber (LVL), Glulam, I-Beams, Oriented Strand Board (OSB), Cross-Laminated Timber (CLT)) and Application Type (Residential Construction and Non-residential Construction) – Global Opportunity Analysis and Industry Forecast, 2014–2022. https://www.alliedmarketresearch.com/engineered-wood-market

51 Moya, L., Cardoso, A., Cagno, M. and O'Neill, H., 2015. Structural characterization of pine lumber from Uruguay. *Maderas: Ciencia y Technologia*, *17*(3), pp. 597–612.

52 Baño, V., Godoy, D. and Vega, A., 2016. Experimental and numerical evaluation of cross-laminated timber (CLT) panels produced with pine timber from thinnings in Uruguay. A conference paper available at ResearchGate.

2.1.3 FBA 3: Fibre-based biomaterial processing

FBA3 Description: *Traditionally the focus in this forest-based bioeconomy area has been in pulp, paper and fibre-based packaging production. Yet, other types of biomaterials have also been produced, such as wood-based textile fibres. Recently, new forms of value-added wood fibre-based biomaterials have being developed. These novel types of biomaterials include foams, new kinds of textile fibres and yarns and (bio)composites. The progress requires not only development of pretreatment and pulping technologies but also advancements in fibre and web technologies and processing of biomaterials – the latter be considered as potential game changers. Technologies applied today in pretreatments, pulping and packaging production are to large extent mature, but with future viability. For example, the current main technology in chemical pulping, kraft process, most probably continues to be dominating technology in coming 15 to 20 years at least.*

In the experts' opinion, integrating the production of different types of papers and paperboard packaging into the existing and possible new pulp mills is an obvious future direction, to be considered as one of the next key steps for Uruguay. This would reduce country´s dependence on imported paper and provide goods for national use and for markets in the same continent, and wider. Sufficient markets are a key prerequisite here and therefore deeper market studies are essential. Naturally, the paper production would also require the availability of water and access to other papermaking materials and process chemicals. In an ideal case, national chemical industry could be harnessed or established for their production. As a whole, this requires a proactive approach as strong dependence on chosen technology characterises pulp production. Critical decisions are done in design phase of a new pulp mill. At later stage, considerable investments are required if any alternations are to be made. Consequently, it is rarely economically feasible to change pulp mill's technology according to alterations in demand. Rather, close down of a plant temporarily or even permanently has been a strategy applied by pulp and paper producers to adapt to fluctuations in demand of market pulp. Detailed market studies are naturally also needed for the selection of the desired paper types; there may also be demand for some specialty papers instead of bulk products.

Technologically, kraft process continues to be dominant technology in chemical pulp manufacture for the coming years and even decades, as no feasible substituting large-scale technology is foreseen in 15–30 year time horizon. There is potential to construct NSSC lines to be integrated into the present kraft pulp mills, for the production of fluting to corrugated board industry (for heavy duty packaging). So far, only some small-scale NSSC pulp production has taken place in Latin America.[53] Due to the small mill sizes, they are not always equipped with the chemical recovery systems and therefore the processes are optimised more for the cooking chemical consumption, instead of product quality. Large NSSC plants integrated to kraft mills

[53] The key examples include Productos Pulpa Moldeada in Argentina and Papeleras Mercedes in Uruguay. The former one produced market pulp, sold at least to Uruguay, Brazil and Turkey.

operate, for example, in Australia, North America, Sweden, Poland and Russia. In Finland, South Africa, and other countries there are also large stand-alone NSSC plants with their own recovery systems. For the NSSC production it is also possible to integrate some by-product separations.

Card and paperboard production was one of the identified opportunities to enhance value added of fibre-based processing in Uruguay. Agriculture sector and food production are important part of Uruguay's economy and is expected to continue growing in the future, thus creating demand for packaging material and packaging solutions. Besides domestic market for cardboard products, there may be demand for folding boxboard and packaging materials in Mercosur area.

One of the recent trends in chemical pulping has been increasing demand for dissolving pulp, especially for textiles but also for other material and chemical uses. To respond to the demand, there have globally been numerous conversions of existing kraft lines to dissolving pulp lines (in North America, Europe and Asia, also one in Brazil). Today, more than 6 million tons of dissolving pulp is produced, of which 7% comes from Latin America (Brazil). Naturally, it would be beneficial if industries for further processing of dissolving pulp to textiles and chemicals (like carboxymethylcellulose and other ethers) could be established close to the pulp production.

Notwithstanding above said, the experts participating in the workshop on fibre-based biomaterial processing noted the importance to ensure diverse wood-based industrial activity in Uruguay – as did the experts participating in the other two workshops. Concentration of forest-based activities on pulp mills only creates a bias in industrial structure and may expose the host country economy to external shocks. To counteract potential risks, it is advisable to develop forest-based production and product portfolio simultaneously in a systemic way.

Regarding pulp production, eucalyptus as a fast growing raw material suitable for plantation environment provides currently a competitive advantage for Uruguay – and other countries with comparable environmental conditions. Current paradigm aims to produce pulp close to the fibre source. Global competition in pulp production is however increasing and market situation requires continuous monitoring. Demand for long (e.g. eucalyptus) and short (e.g. conifers) fibres is a question to take into account as they have different properties. For instance, Brazil is the largest supplier of short fibre bleached pulp of eucalyptus in the world, but has during many years also established plantations producing long fibre wood. Brazil and Chile are already producing pine pulp. Increase of raw material choice by pulping of pine (from plantations) could be considered also in Uruguay. Pine pulping would facilitate for example tall oil and turpentine production – the most recent industrial tall oil distillation plant has been erected in Brazil in 2009.[54]

[54] The Resitec plant in Brazil is the most recent tall oil distillation plant; There may of course have been more recent crude tall oil separation projects (as discussed at http://www.xinhuanet.com/english/2018-04/28/c_137142394.htm). Globally, there are circa 23 tall oil distillation plants in operation, of which only one in South America.

Today, major markets for pulp and pulp-based products locate in the USA, the EU and Asia. Operations in the USA market are however complicated and challenging because of protectionism. In the EU, imported eucalyptus and eucalyptus pulp has become de facto ‘third domestic raw material’ to produce value-added products. Asia and particularly Far East countries continue to be the backbone for growing global demand in basic products produced from wood.

2.1.4 FBA 4: Biorefining

FBA4 Description: *Whereas FBA 3 concentrates on fibre-based biomaterials, the focus in biorefining is in manufacturing value added biochemical and bioenergy products from forest biomass. Circular bioeconomy approach emphasizes the role of industrial symbioses and utilization of industrial by-products and side-streams in biorefineries. The key technology areas related to biorefining include pre-treatments, pulping, conversion, separation and bioprocessing technologies, application of industrial biotechnology and processing technologies for biopolymers.*

Biorefining and development of new bio-products diversifies and increases efficiency of wood use in forest-based industries as a whole, hence contributing to economic sustainability of activities. The aim is to fully utilise renewable wood biomass as a feedstock and to achieve sustainability in manufacturing of selection of products and energy. Biorefining as an FBA relates closely with the other FBAs; use of wood as a raw material ranges from manufacturing of fibres and bio-chemicals to various materials, biofuels and other energy products. The current and foreseen products resulting from biorefining include traditional wood-based products and a number of new products. The latter ones can be substitutes for products previously produced from other resources or may represent new materials or compounds.

Different types of current or emerging wood-based biorefineries can be recognised, based on the production technologies and products. Today, a lot of attention is being paid to the conversion of pulp mills (and other forest industry operations) to more advanced biorefineries or bioproduct mills.[55,56] There is also a lot of R&D&I efforts going on to develop and commercialise different stand-alone processes in the manufacture of biofuels, biochemicals, and various materials (other than pulp and paper) from wood.

According to the general published information, in kraft pulping – the dominating chemical pulping process, the traditional by-products include tall oil (1.5 million tons), turpentine (200,000 tons) and lignin (>100,000 tons). Of them, there is currently more demand than supply for tall oil and turpentine; the demand is also responded by the isolation of increasing amounts of gum rosin and gum turpentine by tapping of conifers. It looks that this type of “biorefining” is increasing in many Latin

55 L.P. Christopher (Ed.), Integrated forest biorefineries. RSC Publishing 2012, 307 p.

56 M.A. Johnson and P.W. Hart, Integrating a biorefinery into an operating kraft mill. BioResources 11 (2016), 10677–10710. The Nordic Wood Biorefinery Conference proceedings provide also abundance on information on ongoing activities. NWBC 2020 - 9th Nordic Wood Biorefinery Conference will take place in March 2020 in Stockholm, Sweden.

American countries, and for example, in Brazil pine plantations have recently been increased for this purpose. The number of tall oil, gum resin and turpentine distilleries in South America is currently very low; apparently further hindering their local value-adding activities. Resitol in Brazil also isolates a valuable fraction, phytosterols, from tall oil pitch. In Finland and Sweden, two companies (UPM and Sunpine) are also producing high-quality biodiesel from tall oil. Current and potentially increased pine wood resources in Uruguay might justify a medium-sized softwood kraft pulp mill, to produce pine chemicals and pine kraft lignin in addition to long fibre pulp for national paper or paperboard production.

Without any doubt, there has been an intensive, global “lignin-interest era” going on for many years now. This is demonstrated by the installation of new kraft lignin recovery capacity in the USA, Canada, Finland and Brazil (and many others are under planning or negotiations between pulp mills and lignin technology suppliers). At the moment, only the Suzano case in Brazil will be offering eucalyptus kraft lignin, the first product of that type after earlier attempts by ENCE to commercialise Eucalin lignin in Spain. In many studies this product turned out to be suitable for example for phenol-formaldehyde resins and polyurethanes.

Currently, kraft lignins from the new installations seem to find the most potential (at least for some time now) application areas from glues and adhesives, especially in wood and plywood adhesives. For example, UPM in Finland has started to use a new lignin based WISA BioBond gluing technology in its own plywood manufacturing. In the new technology 50% of the fossil-based phenol has been replaced by softwood kraft lignin. As a whole, there is wide global interest by many large companies to replace fossil-based resins or their raw materials (e.g. for phenol resins, epoxy resins and polyurethanes) by biobased materials, and from this perspective, the potentially increasing demand for lignin is apparent during the coming years. It may take longer times, however, before more advanced products such as carbon fibres, polymers additives and antioxidants are being manufactures from kraft lignin. Today, there is one company in the us that manufactures kraft lignin based synthetic lignosulphonates (mainly for dispersing applications). It is justified to assume that their demand in the future will increase if traditional lignosulphonate sources continue to disappear (during the past 10 years a large number of sulphite pulp mills providing lignosulphonates have been closed, including the only such mill in Latin America, in Argentina). It is noteworthy that the Venezuelan company Pulpaca has been planning a new kraft pulp mill with lignin recovery; the recovered pine kraft lignin (up to 30,000 tons) should be sulphonated and used mainly for oil industry applications. However, this project seems to be currently on hold.

In addition to the above-mentioned use of lignin in resins, there is currently a strong demand for concrete plasticisers, especially in the regions where strong construction boom is going (China, Near East). For that purpose, an oxidation product (LigniOx) from kraft pulping seems to provide an efficient substitute for commercial lignosulphonates or even synthetic preparations.[57]

[57] See http://www.ligniox.eu

Because eucalyptus pulping does not produce any tall oil or turpentine (or any other similar streams), the recovery of lignin from the pulp mills in Uruguay is clearly worth of careful consideration (both for local uses in wood industry, and for wider markets). From the huge modern mills, substantial amounts of lignin would theoretically be available, although this also requires deep studies on the effects of the recovery processes on the mills´ chemical and energy balances.

Other emerging by-products of current interest from kraft pulping include hemicelluloses (galactoglucomannan from softwood and xylan from hardwood) and rectified methanol from foul condensate stripping. For the hemicelluloses and the corresponding monomeric sugars, several sources or processes can be identified. For example, xylan can be recovered by hot-water extraction of chips before pulping, from early stages of pulping, or by alkaline extraction from bleached pulps (which gives very pure product). The separation of xylan or xylose has just about to start at a couple of Canadian pulp mills and at a Sappi mill in South Africa. In the past, when water prehydrolysis (instead of current steam prehydrolysis) was used in kraft pulping for the manufacture dissolving pulp, varying amounts of xylose and furfural was recovered at several installations.

Metsä Fibre’s new bioproduct mill starting its operation in Autumn 2017 in Central Finland illustrates integration of old and new approaches. Primary products manufactured in the mill do not differ noticeably from any other pulp mill; in addition to pulp, there is produced e.g. tall oil, turpentine, electricity and process steam. The mill was designed, however, from its conception, with the idea to have a potential to contribute in development of high added value bioproducts, such as biocomposites, fertilisers, textile fibres, biofuels, and applications using lignin. New solutions are developed in a network, ecosystem manner in close collaboration among the partners teamed up around the bioproduct mill. There are further softwood pulp or bioproduct mill projects currently going on for example in Finland, Estonia and Russia.

The traditional acidic sulphite pulping, although conducted only at a limited number of pulp mills today, provides a different selection of by-products; the current ones include lignosulphonates, vanillin, xylose and other sugars, ethanol, acetic acid, furfural, yeast and ribonucleic acids. No new such mills have been constructed for 35 years, but strong interest has been shown in Sweden for the potential of “starting again” in that field. Similarly, there is currently more interest being shown for the development of more advanced biorefineries for the semichemical NSSC pulping process, as demonstrated by current R&D activities in Canada, and for example, by recent (2012) start-up of lignosulphonate recovery at a South African Sappi NSSC plant. Another potential by-product from the NSSC mills is acetic acid that has been earlier recovered in Finland and the USA. The integration of the chemical recovery system for the kraft and NSSC mills provides a number of benefits, although large-scale NSSC mills may also have the recovery processes of their own.

Emerging or potential pulping-type fractionation processes include those based on the use of organic solvents (organosolv), ionic liquids and deep eutectic solvents. Of them, only one organosolv process (Organocell) has been applied in full mill scale. Alcell was demonstrated on large demo-scale, and many others demonstrated on different pilot-scale levels. Although their suitability to pulping or pretreatment for various raw materials have frequently been shown, it is too early to predict their roles in any large-scale operations for the years (or even some decades) to come.

The stand-alone wood-based biorefineries, not integrated to pulp and paper production, include different pretreatment-hydrolysis-fermentation systems, direct chemical (degradative) processes, pyrolysis and gasification. In all these areas there have been various pilot-demonstration (or almost mill-scale) activities showing promising potential for further development routes. Examples include the production of ethylene and propylene glycols, where the Finnish company and UPM is considering a mill in Germany, and Fisher-Tropsch processes for biodiesel production (e.g. in Finland). The isolation of chemicals from bio-oil or from charcoal production streams is also attracting some interest. At the moment, some wood vinegar is being sold (especially in Asia) for organic farming, although much more potential could be foreseen here (even to produce crude acetic acid).

Fibre-based composites could be yet another option to value-added products from wood. Fibre-based composites have also linkage to construction sector. However, the first matter to be resolved relates to question about viable component, in addition to wood, that can be used to produce fibre-based composites in Uruguay.

Furthermore, the use of bark may have potential but would benefit from further innovations e.g. in pharmaceuticals. use of bark for chemicals is usually profitable only in large scale, currently typically applied in the recovery of tannins for leather manufacture and other applications. In Chile, for example, pine bark tannins have also been used for the manufacture of adhesives for industrial particleboards. In contrast, eucalyptus leaves and essential oils extracted from them can potentially be much more interesting source than bark for wood-based value-added products. Still, feasibility and demand of essential oils would require closer assessment. Other potential areas of development include sugar platform processes as well as bioproducts and isolation of pharmaceutical and bioactive compounds or their precursors from different parts of trees. Overall, different residues, wastes and tailings of pulping process have potential in production of value-added products and can contribute to the replacement of oil-based materials and chemicals by bio-based ones. Integration of forest industry and other sectors, especially chemical industry, is essential in order to achieve this objective.

2.1.5 FBA 5: Bioenergy

FBA5 Description: *Bioenergy is an integral part of forest-based bioeconomy. Wood-based bioenergy can be produced by using residues from harvesting and mechanical wood processing. It also plays an important part of integrated pulp mills and biorefineries. Thermochemical conversion technologies, like gasification, combustion and co-firing, pyrolysis, gas/liquid fermentation, acid and enzymatic hydrolysis, and metabolic engineering enable production of variety of bioenergy and chemical products from forest biomass. Established, 'safe bet' technologies in bioenergy production include pelletizing and briquetting, gasification, combustion and co-firing and pyrolysis. Emerging technologies relate more to acid and enzymatic hydrolysis and fermentation, metabolic engineering, bio-char production (torrefaction), steam explosion and biodiesel post-processing.*

The use of forest-based biomass has potential in production of electricity, heating and cooling as well as solid and liquid biofuels for domestic use and export. The forest-based biomass considered for energy use should primarily be wood waste, residues and side-streams from the production of higher value products. Many of the technologies used to produce bioenergy from wood feedstock are mature, and can be with minor adaptation used in Uruguay. Examples of less risky, mature technologies include combustion & co-firing, gasification and pyrolysis. The latter thermochemical conversion technologies produce higher value liquid or gaseous intermediate energy products from a variety of raw materials, depending on the downstream processing options. In Finland alone, there are number of sites where these technologies are in use, in the production of energy from wood-based residues and process side-streams. In countries with higher shares of intermittent solar or wind power, bioelectricity plants can contribute to the balancing of the grid, enabling higher share of renewable power in the system.

Drying, grinding and compressing wood biomass into pellets enables both economic transportation of the solid fuel over longer distances compared to wood chips, and co-firing in existing pulverized coal plants with only limited modifications. Pellets are traded globally, the USA being the largest exporter and the European Union consuming 75% of the global production, which was 26 Mt in total in 2015.[58] The main pellet importer in Asia is South Korea. The global pellet markets have been growing during the past decade.

Demand for bioenergy is globally driven by call for use of renewables in energy production and accompanied need to decrease use of fossil fuels. Economic growth and urbanisation in emerging markets (especially in China and Asia) are also increasing demand for alternative energy sources. Biomass, low value waste wood and the by-products of mechanical wood processing and pulp and paper production are already today important sources for renewable energy production in countries with substantial forest resources (e.g. Finland and Sweden).

58 IEA Global wood pellet industry - market and trade study 2016. (http://task40.ieabioenergy.com/wp-content/uploads/2013/09/IEA-Wood-Pellet-Study_final-july-2017.pdf)

In pulp and paper industry, the use of the power produced by the combustion of the side-product black liquor has become a mainstream solution throughout the world. Excess capacity of generated electricity in kraft pulp mills are often fed into external grid. The high demand of pulp-based packaging in the world markets are currently driving up the excess bioelectricity available from the pulp mills. Mechanical wood processing industry has also close linkages with energy production in number of countries; large amounts of wood residues resulting from mechanical processing can be used in energy production.

Wood-based raw material can be converted into energy in combined heat and power production (CHP) with a high overall efficiency. The CHP technology is widely used in Finland and Sweden and some parts of Eastern Europe, linked with major district heating infrastructure. Depending on the plant design, biomass can be co-fired with other fuels or used as the only fuel, in the forms of wood chips or pellets. CHP plants require a market environment with sufficient electricity prices and, naturally, a demand for district or process heat. Heat demand in process industries is usually more stable compared to district heating networks, where seasonal fluctuations can be high. In case of Finland, forest industry has been an additional driver to establish CHP units, which utilise side streams of forestry and low quality wood with no competing uses to produce heat and power required in pulp and paper production as well as providing heat to communities locating in vicinity. Combined with adequate technology, a CHP plant can also be designed to include fast pyrolysis bio-oil production (e.g. Fortum CHP plant in Joensuu, Finland). By applying solar power hydrogen production, biomass gasification and Fischer–Tropsch upstream processes, CHP plants could in the near future evolve into combined heat and fuel (CHF) plants. These technologies would allow the conversion of more biogenic carbon into higher value energy products rather than CO_2, with operational flexibility regarding the production of heat and electricity versus fuels. The operational flexibility becomes more important as solar and wind power availability increases in the grid, such as in the case of Uruguay. A major factor for these future concepts will be the sufficient availability of low cost solar or wind power, in conjunction with absence of cheap fossil alternatives. The latter, the cost of fossil fuel use depending on the energy markets, together with fiscal regulations and possible carbon emission reduction schemes will impact all bio-based energy investments now and in the future even when a good raw material with no competing uses is available. Working towards the climate goal set by the Paris Agreement, a global trend to penalise fossil carbon emissions will need to continue and grow stronger. Therefore, the important future enablers of bioenergy and bio-based fuels for heat, electricity and transportation reside in the availability of sustainable raw materials and industrial processes providing such biomass. Drivers to promote legal frameworks on land use, sustainability and preservation of forest carbon sinks will globally have an effect on bioenergy projects regardless on the policies to cut down fossil carbon emissions.

Renewable synthetic liquid fuel production technologies, such as in the abovementioned concept of CHF production, are one of the potential game changers in bioenergy. Wood-based biofuels can lessen dependence on high value fossil fuels (e.g. gasoline, diesel, jet fuel). Technological knowledge required in development of liquid fuels from wood can be found for example in Finland, Canada and China. For instance, Kaidi Finland, subsidiary of the Chinese Sunshine Kaidi New Energy Group is currently studying prospects to build a globally unique second-generation biorefinery in Northern Finland using energy wood and residues. The project waits for the developments in the EU renewable energy policy, most notably the publication of the new Renewable energy directive that sets, inter alia, new requirements to the allowed raw materials for sustainable biofuels. UPM is among the companies who have researched the use of tall oil for feedstock of bio-based diesel and commercialised their own proprietary biofuel technologies in recent years. UPM biorefinery located next to the UPM Kaukas pulp and paper mill has produced renewable wood-based diesel and naphtha since 2015. There are also prospects to make liquid biofuels (ethanol) from sawdust and/or ligning; for example, Finnish St1 biofuels Oy is currently operating a recently opened plant that produces ethanol from sawdust.

Robust regulatory frameworks are needed to ensure a sustainable production of liquid biofuels and bioenergy. Development and competitiveness of bioenergy solutions are therefore to significant extent influenced by policy decisions and regulation on energy production. Policies applied may create incentives for use of biomass in energy production but can also hinder development and postpone projects. Policies tailored for bioenergy should be technology neutral to avoid negative impacts on energy market.

2.2 Factiva Global News analysis

As part of the qualitative description of the forest-based bioeconomy areas, Factiva Global News database was used as a main source of literature review. The news data was sourced to identify key actors and industries in the FBAs and countries. The analysis was carried out for a five-year period between November 2012 and November 2017. The five-year period helps to smooth fluctuations in the data and increases reliability of the analysis.

Geographically the analysis covered the eight benchmark countries and Uruguay. The news queries for the five forest-based biotechnology areas were made separately for each country. The search terms used in the queries comprise the technologies and products, which were identified to characterise the individual FBAs in the previous phase of the project. The lists of terms used in searches were English by default. In addition, the option in Factiva to query the material in other languages was used as well (national language in case not English).

The original data produced contains in most of the cases a long list of most frequently mentioned actors and industries for each FBA and the country.

2.2.1 On the Factiva data

The Factiva dataset search results include some ’noise’ which is unfortunately a common feature of using database search engines. For example, in case of search terms with multiple meanings in different technology, product or business contexts (such as ‘fibre’), the string of search terms cannot eliminate appearance of irrelevant search results automatically but requires manual assessment afterwards.

There is also some indication about a bias towards large companies and public sector actors in the Factiva Global News database. Consequently, newcomers, start-ups and smaller companies with potentially new and disrupting solutions or offerings are not necessarily covered in the data to the same extent as large businesses.

Despite of the restrictions, closer analysis of the lists of most mentioned actors and industries for the five FBAs do reflect industrial structure of the countries queried.

2.2.2 On the analysis of key actors

The long lists of actors resulting from the Factiva queries were analysed further by identifying the organisations, which appear in most of the FBAs. First, the country lists for each FBA were cleaned by omitting public authorities and organisations not linked to the forest-based area in question. In order to recognise actors who are active in more than one FBA, a further criteria was deployed requiring that to count an actor it has to have presence in 2 FBAs/country minimum. After this step, we were left with a revised list of companies and research organisations having presence in at least two FBAs/country in the Factiva data. In the final phase, the country lists of actors active in more than one FBA were merged for the eight benchmark countries. This step allowed us to identify those actors, which appear the most on global level (global refers here to the eight benchmark countries). The Top-50 actors on global level, identified in at least two FBAs, are presented in Table 2.

Table 2. Top-50 actors on global level.

FBA1	FBA2	FBA3	FBA4	FBA5	Organisation	Appearance	Country
1	2	3	4	5	Stora Enso Oyj	12	FI, SE, BR, CL
1	2	3		5	Metso Corporation	8	FI, SE, BR, CL
1	2	3		5	Metsä Group	8	FI, SE
1	2	3	4	5	UPM-Kymmene Oyj	8	FI, SE
1	2	3		5	Celulosa Arauco y Constitucion SA	7	CL, ZA, BR
1	2	3		5	Empresas CMPC SA	7	CL, BR
1	2	3		5	Fortum Oyj	7	FI, SE
1	2	5			Greenpeace International	7	NZ, FI, SE, CA, BR
				5	Wood Resources International LLC	7	CA, FI, SE, CA, NZ, BR, CL
1	2	3	4	5	Antofagasta PLC	5	CL
1					Eldorado Brasil Celulose S/A	5	BR, CL
1	2	3	4	5	Empresas Copec SA	5	CL
1		3		5	Fibria Celulose S.A.	5	BR, CL
	2			5	Louisiana-Pacific Corporation	5	CA, BR, CL
1	2	3	4	5	Petroleo Brasileiro SA	5	BR
1	2	3		5	Svenska Cellulosa Aktiebolaget	5	SE, AU
1	2	3	4	5	University of Otago	5	NZ
1	2	3	4	5	University of Sao Paulo	5	BR
	2	3		5	Valmet Corporation	5	FI, SE
1	2	3		5	BillerudKorsnäs AB	4	SE
	2	3	4	5	Braskem SA	4	BR
1	2	3		5	Canfor Corp	4	CA
1	2	3		5	Carter Holt Harvey Ltd	4	NZ
	2	3	4	5	Commonwealth Scientific and Industr	4	AU
1	3	4		5	Conselho Nacional de Desenvolvimer	4	BR
1	2	3		5	Eskom Holdings SOC Limited	4	ZA
1	2	4		5	Fonterra Co-operative Group Limited	4	NZ
1				5	Forest Stewardship Council	4	FI, AU, BR
1	2	3		5	Holmen AB	4	SE
				5	John Wood Group PLC	4	CA, AU, ZA, BR
1	2	3		5	Klabin SA	4	BR
	2	3			Metsä Board Corporation	4	FI, SE
1	2	3		5	Mondi PLC	4	ZA
1	2			5	RWE AG	4	FI, SE
1		3	4	5	Sao Paulo State University	4	BR
1	2	3		5	Sappi Ltd	4	ZA
1		3	4	5	Swedish University of Agricultural Sci	4	SE
1		3	4	5	Umeå University	4	SE
1		3	4	5	Universidade Estadual de Campinas	4	BR
1	2		4	5	University of Canterbury	4	NZ
1			4	5	University of Melbourne	4	AU, NZ
1		3	4	5	University of Pretoria	4	ZA
1	2	3		5	West Fraser Timber Co Ltd	4	CA
	2	3	4	5	Ahlstrom Corporation	3	FI
1			4		Alstom S.A.	3	FI, SE, NZ
	2	3			Amcor Ltd	3	AU, NZ
	2	3	4		Atlas Copco AB	3	SE
1			4		Cargotec Oyj	3	FI, SE
1		3		5	Companhia Suzano Papel e Celulose	3	BR
1	2	3			Domtar Corporation	3	CA, BR

Just over half of the listed actors in the Top-50 appear in one country only. This implies that forest-based industries are not necessarily globally as consolidated as some other mature manufacturing industries, such as automotive industry. Geographical clustering among the top 50-actors seems to be apparent. For instance, a number of actors active in Finland are also active in Sweden and vice versa. The same holds true for actors operating in Chile and Brazil. On the other hand, companies are having more activities in several countries and continents, whereas research organisations appear in our data only in domestic context. There are also a few non-profit organisations, which appear in several countries; Greenpeace International and Forest Stewardship Council. About 4/5th of the Top-50 organisations are identified with the more established FBAs 1, 2, 3 and 5, while only 2/5th with the FBA 4 (Biorefining). It is noteworthy that universities are more active in the FBA 4, biorefining, emphasing its status as an emerging area of opportunity with high level of research activity.

The list of industries linked with the five forest-based bioeconomy areas in each analysed country were further explored to identify the most mentioned Top-10 industries emerging from the Factiva news data. As a starting point, we used the industry categorisation of the news by Factiva. The Database uses automatic text analysis, based on which each news has been tagged with an industry category (one or several) following Dow Jones Industry Classification.

To proceed in analysis we followed a stepwise methodology:

1) The original industry lists were cleaned by omitting a number of industry categories not directly linked with forest-based FBAs (banking, car manufacturing, mining & quarrying etc.);
2) A list of most mentioned ('Top-10') industries were produced for each country per FBA and normalised with equal intervals according to appearance of industry classes in the news data;
3) In case of the benchmark countries, the Top-10 industries per FBA were combined into four sub-groups on the basis of countries;
    a. Northern Hemisphere – which covers the Canada, Finland and Sweden (CA, FI, SE)
    b. Australia, New Zealand and South Africa (AU, NZ, ZA)
    c. South American benchmark countries Brazil and Chile (BR, CL)
    d. Uruguay
4) A 'Top-10' industry lists covering all the FBAs was first produced for each of the Benchmark country sub-groups and Uruguay separately, then combined into a table (See Table 3).
5) In the final stage, the lists following the Dow Jones Industry Classification were translated into more commonly used ISIC, Rev.4 (International Standard Industrial Classification of All Economic Activities, Rev.4) to improve comparability of results.

Table 3. Top industries for the benchmark country sub-groups and Uruguay (10 = the most often appearing industry tag in the Factiva search data).

Dow Jones Industry Classification	ISIC, Rev.4	CA_FI_SE	Uruguay	AUS_NZ_ZA	BR_CL
Pulp Mills	17 Manufacture of paper and paper prod	9 (FBA_1,2,3,5)	10 (FBA_1,2,3,5)	9 (FBA_1,3,5)	9 (FBA_1,3,5)
Forestry/Logging	02 Forestry and logging	8 (FBA_1,3,5)	9 (FBA_2,3,5)	6 (FBA_1,5)	7 (FBA_1,3,5)
Paper/Pulp	17 Manufacture of paper and paper prod	0	8 (FBA_1,2,3,5)	0	4 (FBA_3,5)
Converted Paper Products	17 Manufacture of paper and paper prod	3 (FBA_2,3)	7 (FBA_1,2,3)	0	7 (FBA_1,3,5)
Chemicals	20 Manufacture of chemicals and chemi	10 (FBA_1,2,3,4,5)	6 (FBA_2,4,5)	9 (FBA_3,4,5)	10 (FBA_1,2,3,4,5)
Alternative Fuels	20 Manufacture of chemicals and chemi	0	5 (FBA_1,4)	0	0
Biofuels	20 Manufacture of chemicals and chemi	1 (FBA_4,5)	4 (FBA_1,4)	0	3 (FBA_4,5)
Food Products	10 Manufacture of food products	0	3 (FBA_2,4)	0	0
Port/Harbor Operations	52 Warehousing and support activities f	0	3 (FBA_3,5)	0	0
Energy	35 Electricity, gas, steam and air conditi	7 (FBA_1,2,4,5)	1 (FBA_1,2,3)	4 (FBA_2,4,5)	7 (FBA_1,2,3,4,5)
Renewable Energy Facility Construction	35 Electricity, gas, steam and air conditi	0	1 (FBA_1,2)	1 (FBA_2,5)	0
Agriculture	01 Crop and animal production, hunting	0	0	7 (FBA_1,3,5)	0
Farming	01 Crop and animal production, hunting	0	0	5 (FBA_1,3,4)	0
Industrial Goods	28 Manufacture of machinery and equip	6 (FBA_1,2,3)	0	0	0
Packaging	17 Manufacture of paper and paper prod	4 (FBA_2,3)	0	0	8 (FBA_1,2,3,5)
Pharmaceuticals	21 Manufacture of basic pharmaceutical	5 (FBA_2,4)	0	10 (FBA_1,2,3,4)	0
Residential Building Construction	41 Construction of buildings	0	0	4 (FBA_1,3,4)	0
Sawmills/Wood Preservation	16 Manufacture of wood and of products	1 (FBA_1,5)	0	0	0
Waste Management/Recycling Services	38 Waste collection, treatment and disp	2 (FBA_1,5)	0	1 (FBA_2,5)	0
Cosmetics/Toiletries	17 Manufacture of paper and paper prod	0	0	0	3 (FBA_2,5)
Electric Power Generation	35 Electricity, gas, steam and air conditi	0	0	0	3 (FBA_1,2)

2.2.3 Key findings of the Factiva news analysis

Analysis of industry appearance in the Factiva news data shows a strong presence of chemicals across the five forest-based bioeconomy areas (see Table 3). Chemicals are on top of the industry tag appearance lists and linked with all the FBAs in two benchmarking country sub-groups - one of which covers Canada, Finland and Sweden and another Brazil and Chile in Southern America. Further, chemicals are second most often tagged industry in the remaining benchmark sub-group consisting of Australia, New Zealand and South Africa. In addition, chemicals appear in the top industry list of the Factiva news data on Uruguay.

Another common feature in the news data is the visibility of upstream activities (forestry & logging) and production of intermediate products (e.g. pulpmills & pulp) in each geographical location. The news analysis confirm that there is a close linkage between energy production (incl. alternative, renewable fuels) and forest-based bioeconomy. In contrast, mechanical wood processing (sawmills/wood preservation) is remarkably invisible in Factiva news data and appears on the list of most tagged industries only in the northern hemisphere sub-group. In contrast, construction of buildings appears on the list of most mentioned industries only in sub-groups consisting of Australia, New Zealand and South Africa. Low prominence of waste management and recycling is another surprise considering attention given to efficient use of side streams and residues in forest-based production processes – this was underlined for instance in the expert workshops organised with Luke and VTT experts in Finland.

Differences in industry profiles between the benchmark country groups and Uruguay are more discernible in Figure 3, in which the data has been merged into fewer industry classes corresponding to ISIC Rev.4 classification of economic activities. Uruguay's profile resembles closely Brazil-Chile subgroup's outline. The profile of the sub-group consisting of the countries in northern hemisphere is relatively more weighted towards recycling of waste and residues, energy production and machinery.

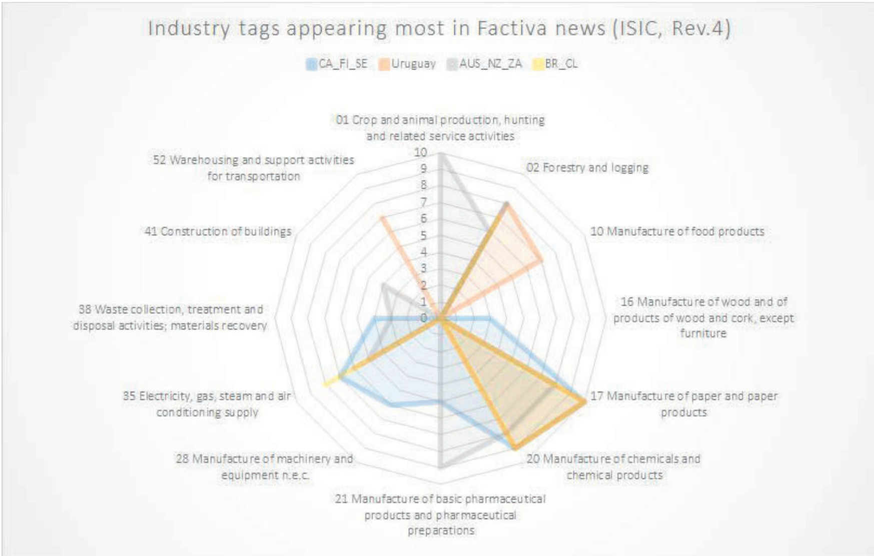


Figure 3. Industry appearance.

2.3 Mapping Critical Issues (CI) shaping the future of the FBAs

In this section main results from the systematic mapping of Critical Issues (CI) shaping the FBAs today (drivers and barriers) and in the future (opportunities and threats) are presented. Several sources of knowledge have been combined to generate a comprehensive dataset of shapers of four types (i.e. barriers, drivers, opportunities and threats) covering the following seven TEEPSES categories (technological, economic, environmental, political, societal, ethical and spatial), see Figure 4.

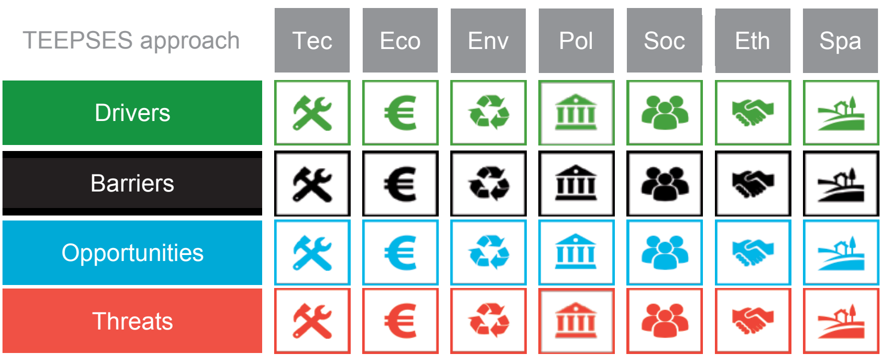
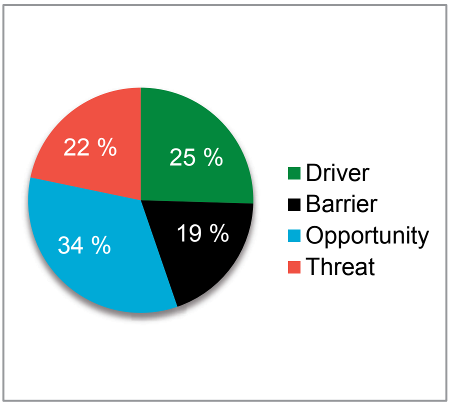


Figure 4. TEEPSES approach to critical issues analysis.



The sources of knowledge for the mapping of shapers draw on Creativity-based methods (such as the brainstorming sessions with VTT and Luke experts), Interaction-based methods (including workshops in Uruguay during and after the kick-off meeting, complemented with the workshops with VTT and Luke experts, Evidence-based methods (combining literature review and trend analysis of the Factiva Global News database and Expertise-based methods (gathering insights from VTT project team members, as well as from the Governance Group and the Uruguayan Technical Experts Group mentioned in the Acknowledgments).

Figure 5. Distribution of 300+ mapped Critical Issues (CI) shaping the future of the FBAs in Uruguay.

Over 300 CI (barriers, drivers, opportunities and threats) were mapped, consisting of some 25% drivers, 19% barriers, 34% opportunities and 22% threats, see Figure 5. The following section presents key highlights from the findings.

2.3.1 Selecting Critical Issues (CI)

The analysis of critical issues (see Figure 6) shows that consulted experts identified significantly more drivers and opportunities shaping the future of FBA3 and FBA4 than other FBAs. Some examples of shared opportunities for FBA3 (Fibre-based biomaterial processing) and FBA4 (Biorefining) include: Energy integration – drying timber, sawn goods; integration into mechanical processing by adhesives and use of chips from mechanical processing or utilisation of side streams and residues. FBA1 (Forest management) and FBA2 (Mechanical wood processing) gathered the highest number of threats. A few of these include the inability to recognise which species are more strategically viable for the industry (e.g. native hardwoods or exotics ones such as eucalyptus, acacia species, pinus taedea, pinus radiate), monoculture in forest cultivation, growing power of a few big corporations, unsustainable land use policies and lack of capacity to provide reliable GHG (greenhouse gas) inventory, which is requirement for CO2 markets. The full list of critical issues gathered under each FBA is provided in a separate Annex.

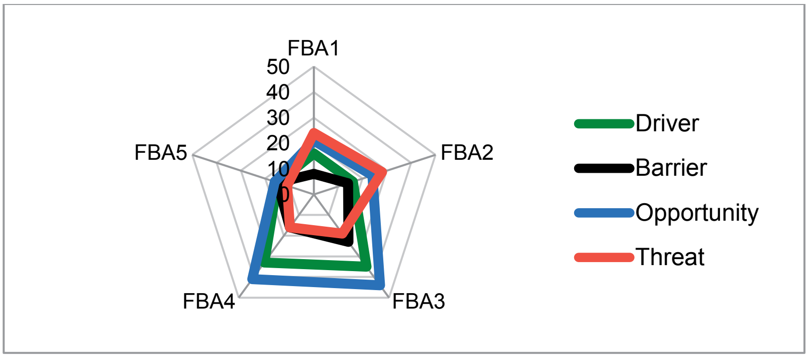


Figure 6. Distribution of identified critical across FBAs.

Following interactive discussions by the project team, 15 statements were prepared to assess the critical issues (4 barriers, 8 opportunities and 3 threats), and another 15 statements to assess 8 technologies and products, as well as 7 actions and recommendations.

Four statements related to key barriers

1) Sufficient research and technology development intensity in eucalyptus and pine genetics for my country's forest-based bioeconomy potential.
2) Developing scalable business from small-scale by-products and side streams of pulp mills is not profitable in my country.
3) For my country the Chinese export markets can not be compensated by more nearby export markets.
4) Clusters and industrial parks (for example around sawmills) are commonly developed in the forest-based value chains in my country.

Eight statements related to opportunities

5) Newcomers in my country's forest-based bioeconomy sector rapidly and efficiently adopt state-of-the-art technologies and practices.
6) Widespread combination of eucalyptus plantations with other sectors' value chains (e.g. food) in my country's forest-based bioeconomy.
7) There is strong development of demand in my country for wood-based construction sector products.
8) In my country wood-based panel/beam manufacturing is prone to be the most profitable export product of the forestry sector.
9) The global demand for card/paperboards in packaging (e.g. recyclable packages in food industry) clearly drives the production of reinforced fibres in my country.
10) Development of integrated mills (for pulp and by-products, for paper & packaging, for kraft and fluting pulp) is becoming standard in my country.

11) In my country wood-based construction is as competitive as traditional construction.
12) In my country the majority of petrochemical based products (such as plastics) will be substituted by bio-based products.

Three statements related to threats

13) Reduced dependency on traditional species (eucalyptus/pine) plantations in my country is reduced thanks to a clear diversification strategy into other species plantations.
14) In my country the use of eucalyptus for engineered products strongly complements its use for pulp and paper production.
15) Maintaining the market position in eucalyptus pulp is impossible for my country due to increased global competition.

Eight statements related to technologies and products

16) In the forest-based bioeconomy softwood products are more important than hardwood products for my country.
17) In developed markets Engineered Wood Products (EWP) are as widely used in the construction sector as traditional materials.
18) Widespread digitalisation reduced the need for paper demand by 50% in my country.
19) Biorefineries are a risky investment for my country because taking advantage of side streams of pulp requires extensive capabilities.
20) In my country lignin has the commercial potential to replace fossils raw materials for instance in production of resins which are applicable as adhesives e.g. in wood-based construction and cement.
21) Small scale wood-based biorefineries are becoming profitable in my country.
22) Aviation biofuels based on wood processing are profitable in my country.
23) X-ray scanning of roundwood is a profitable investment.

Seven statements related to actions and recommendations

24) National environmental policies limit the development of the forest industry in my country.
25) Environmental policies, regulations and customer preferences increased the size of the forest plantations in my country by 25%.
26) The development of an industry policy to support wood-based panel manufacturing and biorefining is a priority for my country.
27) Essential competence development in chemistry and biotechnology are a key priority, to develop wood-based biorefining industry in my country.

28) Global biorefining activities are emerging and my country's economy optimally benefits from this trend by fostering entrepreneurial SME activities in this area.
29) In my country regional demand scale determines the viability of bio energy production.
30) The main objective of my country's energy policy is to increase biomass-based energy production.

2.3.2 Critical Issues Survey in Uruguay and peer countries

This section focuses on a description of the global expert survey results. With global we refer to all key peer countries of Uruguay in terms of the global Bioeconomy. The online survey with three reminders was sent out via the Questback software to 181 experts and produced 45 complete answers, out of which 18 from Uruguay. The experts were selected from related VTT, Luke and Uruguay bioeconomy networks. The aim of the survey was to get an overview on how global experts conceive the critical issues in the industry and which policy actions and recommendations they pay attention to. As the same survey was sent out to Uruguay experts all survey results will be comparing the answers of the global experts with those of the Uruguay experts. All results will be ranked based on the average answers of the global experts. As the experts self-assessed their knowledge in a certain field, only those assessments with intermediate, advanced and expert level were considered valid answers and their non-weighted averages were interpreted as reliable and robust. However, survey answers and their averages are based on a global sample of experts that is not known to be representative of the global population of bioeconomy experts. We believe however the global expert answers offer valuable indications for policy-making. In addition to critical issues, policy actions and recommendations, this section will also discuss a global assessment of technology and products. The survey questions that look into technology and products covered both structured and open questions with the aim of assessing the potential of future markets globally and in relation to Uruguay. Additional survey questions that were sent to Finnish experts from VTT Technical Research Centre of Finland Ltd and Luke National Resources Institute Finland inquired to quantify the expected market potential of a long series of technologies and products. It is noted here that these additional detailed questions were not answered because the experts did not feel they could deliver any sensible estimates better than those available in specialized and expensive market reports.

Background info on respondents

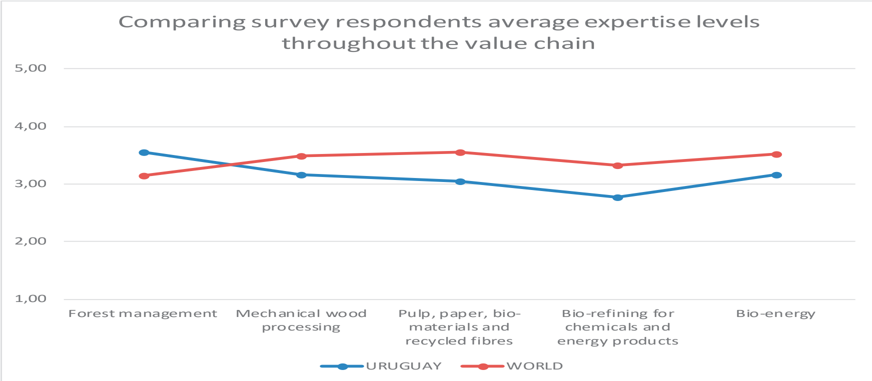


Figure 7. How would you rate your competence level in the five selected fields (FBA's) of the forest-based bioeconomy (From 1 little competence to 5 top competence)?

At first sight, and on average, the profile of the respondents of Uruguay seems to differ from the respondents of other countries, which reflects their technological and sectoral specialization. In essence, the message is that on average Uruguayan experts rate their expertise lower than foreign experts and this gap tends to widen along the value chain. However, Uruguayan experts do perform better on the forest management side. These results tell something about the sample composition of the respondents and do not represent the population of experts. As the survey questions on the specific FBA's have been answered by experts only (scoring their expertise on a specific FBA in the above question from 3 to 5) and we have a total sample of 45 respondents we did not use weights to tabulate the survey results in this report. The peer countries of Uruguay and their representation in the sample of completed questionnaires are tabulated below.

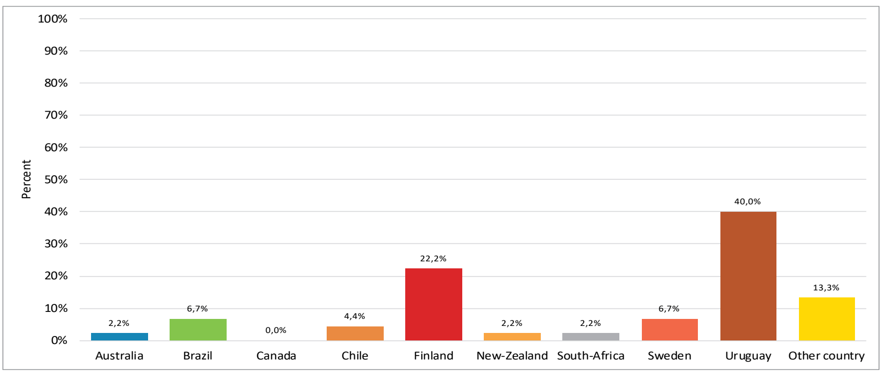


Figure 8. Survey respondents country distribution.

2.3.3 Assessment of Critical Issues

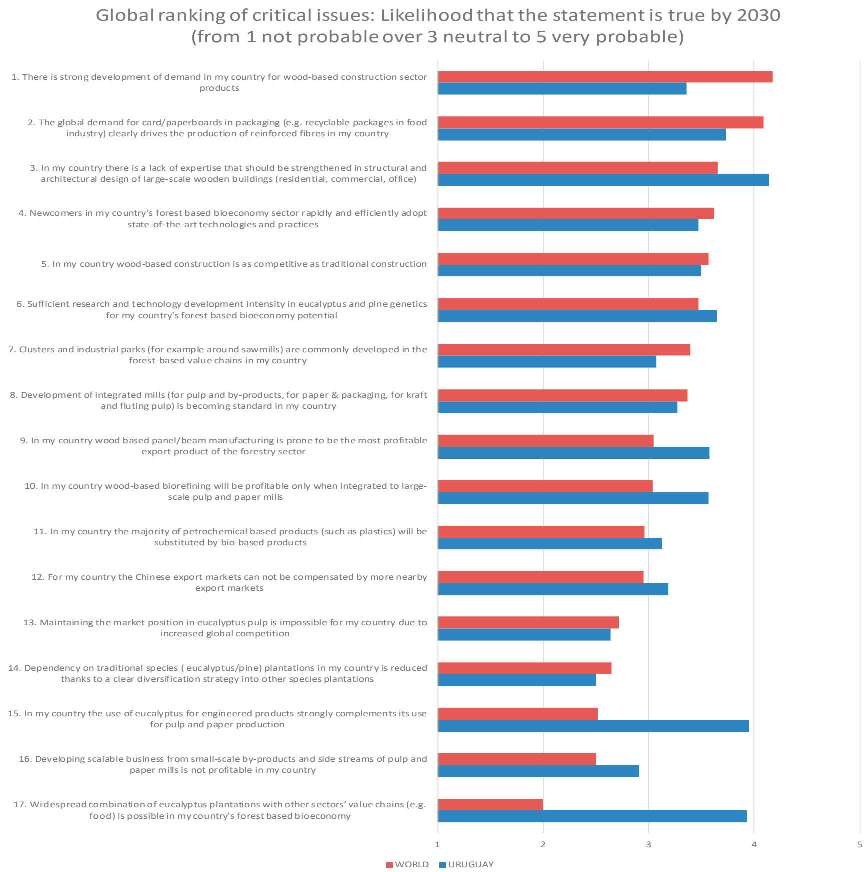
This section covers the critical issues that may apply to the entire forest-based bioeconomy (0) or to a specific FBA (1 to 5). The survey contained a pre-selection of critical issues based on workshops in Uruguay and at VTT and Luke in Finland, as well as consultations with the OPP team (the pre-selected critical issues were presented in Section 2.3.1. The respondents first had to score the likelihood of the critical issue to happen by 2030 (Table 4) and then they had to assess the impact of the critical issue could have on wealth creation by 2030 (Table 5).

When looking at the likelihood survey responses from Uruguay and the rest of the world, some key observations can be made for the following parts of the forest-based bioeconomy value chain:

- The entire forest-based bioeconomy:
  - According to the experts from Uruguay the critical issue 'In my country the use of eucalyptus for engineered products strongly complements its use for pulp and paper production' is more likely to happen by 2030 than according to global experts. As many experts are from countries were eucalyptus is not grown this difference is not surprising. However, the answer also shows the belief that a diversification complementing the pulp production is needed and expected in Uruguay.
  - According to foreign experts the most likely critical issue is that 'Newcomers in my country's forest-based bioeconomy sector rapidly and efficiently adopt state-of-the-art technologies and practices'. Also, the Uruguay experts accredited a high likelihood to this issue. This is not surprising as adoption of existing technology is often the fastest and initially cheapest way to start operations.
- Forest management
  - There is a clear belief that by 2030 'Widespread combination of eucalyptus plantations with other sectors' value chains (e.g. food) is possible in my country's forest-based bioeconomy' will happen in Uruguay. A second signal is that experts believe that diversification will or should take place.
  - According to foreign experts it is most likely that there is 'Sufficient research and technology development intensity in eucalyptus and pine genetics for my country's forest-based bioeconomy potential' by 2030. Also for the experts of Uruguay this critical issue is highly likely.
- Mechanical wood processing:
  - For experts from Uruguay the most important critical issue in the mechanical wood processing industry seems to be the lack of expertise in design of wooden buildings ('In my country there is a lack of expertise that should be strengthened in structural and architectural design of large-scale wooden buildings (residential, commercial, office)') while according to global experts the critical issue is a high demand for wood-based construction ('There is strong development of demand in my country for wood-based construction sector products'). The identified gap

seems to be that the demand for wood building is bigger in other countries than in Uruguay. This may be related to the culture, climate and available wood types. Certainly this is a space Uruguay could enter by focusing on the right wood production relevant to building new value chains around engineered wood products and wood-based construction.

Table 4. Likelihood (averages of Uruguay experts vs. global experts) of critical issues by 2030 ranked according to assessment of global experts.



- Pulp, paper, bio-materials and recycled fibres
  - Both the experts of Uruguay and other countries agreed that the most likely critical issue to materialize by 2030 would be ”The global demand for card/paperboards in packaging (e.g. recyclable packages in food industry) clearly drives the production of reinforced fibres in my country”.

The above picture also appears to evolve from the responses on the impact of the critical issues. One clear additional topic that arose was the greater dependency of Uruguay on the Chinese markets than for other countries represented.

Table 5. Impact on wealth creation (averages of Uruguay experts vs. global experts) of critical issues by 2030 ranked according to assessment of global experts.

3. Mapping of global value networks

Part 2 of this report aims to construct a realistic and valid picture of the current state of global value chains in FBAs, identify critical gaps and future options for the selected FBAs in Uruguay. Section 3.1 gives an introduction to research, development and innovation and to ecosystem and value chain approaches in forest-based bioeconomy, Section 3.2 considers new technologies and products in forest-based bioeconomy. Section 3.3 presents Finnish examples of forest-based bioeconomy innovations and businesses.

3.1 R&D&I in forest-based bioeconomy

Globalization and the dynamics of knowledge and innovation are among key drivers of enterprises and of economies. The success of companies depends on their ability to create higher value than competitors, and value creation depends on their capability to innovate. Research and development (R&D) investments are seen as a necessary (though not sufficient) condition for successful businesses. Along with product, process and service innovations, economic structures will renew by new business concepts.

Since Joseph Schumpeter innovations were believed to lead to the creative destruction of economic structure by destroying low-productivity firms, creating new areas of innovation, and thus boosting productivity across the economy. In the future, such changes will be made possible especially by digitization. In order to understand the structural changes, the dynamics of innovation and their business and economic impacts must be known. Innovations and their background organizations require systematically compiled information and research based on it. For example, at VTT, the SFINNO database of over 5000 innovations developed by Finnish companies and research organizations enables such in-depth research.

In spite of the differences between industries successfully innovative companies have several common factors.[59] They have close links with users of products and services; they are actively anticipating future developments and users' needs. In the fields of pharmaceuticals and other knowledge-intensive sectors where the development cycles of innovations are long, companies invest in long-term research and are in close interaction with research communities. Experiences from business and innovation ecosystems emphasize the importance of open innovation, co-operation and the ability to orchestrate innovation throughout entire value chains.[60],[61] Innovative companies often swim upstream: when the downturn often may lead to cutbacks

59 Freeman, C. and Soete, L. 1999 The Economics of Industrial Innovation, Third Edition, Pinter.

60 Chesbrough, H. (2006) Open Innovation. The new Imperative for Creating and Profiting from Technology, (Harvard Business School Press), 2006.

61 von Hippel, E. (2005) Democratizing Innovation, The MIT Press.

in costs and labour, there are examples of companies that invest in product development and innovation instead of cost cuts.[62],[63]

Business value chains, business and innovation ecosystems and platform economies are common buzzwords in today´s business, innovation and management talks. Value chain may refer to internal value creation process of company from R&D to innovation, commercialisation, and markets, or common value creation process between companies in upstream and downstream in supplier chains. The scope of the currently popular term ecosystem is broader than the scope of value chain. Many organisations in business ecosystems fall outside traditional value chain of suppliers and distributors that directly contribute to the creation and delivery of a product or service.[64] Business ecosystems connect several linear value chains into vibrant and often complex bio-based value networks.

Technological development can be divided into (1) invention, the creation of an idea for potential innovation by R&D activities; (2) innovation, referring to new products or processes with commercial value in markets; (3) diffusion, referring to the spread of innovations throughout industries, economies and societies; and (4) impacts on industrial, ecological and socio-economic development. Figure 9 presents a general logic model of innovation process pathway. The model starts from foresight, roadmaps or other future-oriented exercises, then to R&D inputs via co-creation of innovations and via diffusion of innovations to markets, competitiveness enhancements of companies, and gradually towards final socio-economic and ecological impacts.

---

[62] Loikkanen, T. (2017a) Intelligent machinery for sustainable forestry, in: Lilja, K and K. Loukola-Ruskeeniemi (Eds.) (2017), 52–52. Available online: https://julkaisut.valtioneuvosto.fi/handle/10024/79985.

[63] Loikkanen, T. (2017b) Evolving Engineering Ecosystems – Case Study of Finnish Forest Machine Industry, Research Report, VTT.

[64] Iansiti, M. and R. Levien (2004) The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability. Boston: Harvard Business School Press, 2004.

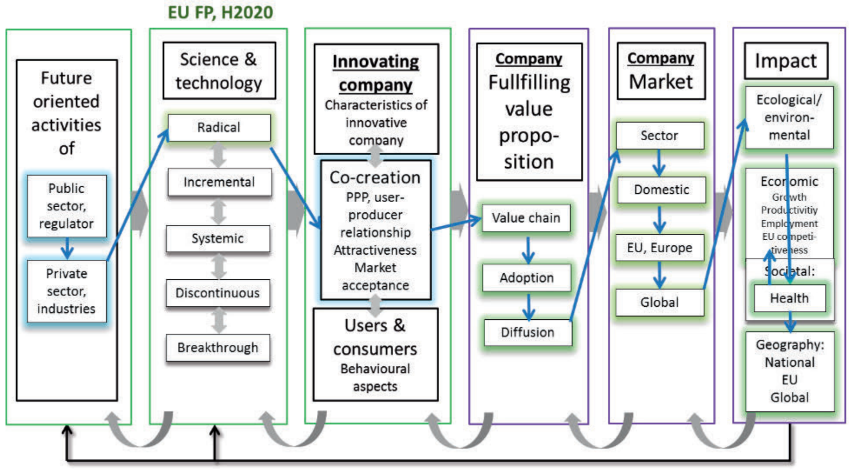


Figure 9. Innovation process pathway from RTD inputs throughout the innovation process phases to ultimate industrial and socio-economic outputs and impacts[65].

In the area of forest-based bioeconomy many studies and reports accentuate the importance of foresight studies.[66] As highlighted by the European Commission[67], knowledge, innovation and sustainable management are identified as core factors contributing to a shift towards a society relying strongly on renewable biological sources while achieving economic growth. Although governments play an important role in the encouragement and promotion of bioeconomy, companies and R&D organisations play core roles in the research, development and innovation of new products and processes.

Innovation refers to the introduction of new products (product innovation), production processes (process innovation) and management methods (organisational innovation). Innovations may be radical, breakthroughs, disruptive, systemic, discontinuous or incremental. Along the increased recognition of the role of innovation to economic and social development the concept and definition of innovation has

---

65 JIIP (Joint Institute for Innovation Policy), Joanneum Research, Tecnalia, TNO, VTT and Frost & Sullivan (2015) Final Report, Study on Contribution of the Framework Programmes to Major Innovations, European Commission, DG Research and Innovation, Directorate A. Framework Programme - Inter-institutional Relations, Unit A.5 Evaluation, April 2015.

66 Hurmekoski, E. and L. Hetemäki (2013) Studying the future of the forest sector: Review and implications for long-term outlook studies, Forest Policy and Economics (2013), http://dx.doi.org/10.1016/j.forpol.2013.05.005

67 EC (2012) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Innovating for Sustainable Growth: A Bioeconomy for Europe. {SWD(2012) 11 final}. Available online: http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf.

extended to service innovations, social innovations, behavioral innovations, etc.[68],[69] Innovations are created increasingly in a close interaction and co-creation of producers and users of emerging innovations, because in many businesses time to markets is a critical success factor in order to accelerate innovation to markets.[70] Co-creation of innovation takes into account various behavioural and experimental aspects of users and consumers of innovation. Value of new products is increasing via value chains and diffusion in markets. The final impacts of new products are ecological, societal and economic.

As in any industrial areas, also in forest-based bioeconomy patents pave the way to new innovative product and process technologies and consequently to new businesses. Due to the problems of definition of bioeconomy or forest-based bioeconomy, discussed at the beginning of this report, there is not available any clear and unambiguous statistical patenting data in areas of bioeconomy or forest-based bioeconomy.

The characteristics of innovation activities described above get support also from innovation studies related to bioeconomy area. Based on bioeconomy innovation case studies[71] the following key findings from their business ecosystem analysis were drawn: First, market access proved to be the key step in successful bioeconomy innovation besides the early engagement of end users in target markets as early as possible in the innovation development. Second, technology and services of bioeconomy offer global business opportunities, and the utilization of existing infrastructure lowers the commercialization threshold for novel bioeconomy innovations. Importance of complementary actors in the business ecosystems was also emphasized. Ensuring overall sustainability and holistic resource optimization across sectors is instrumental as bioeconomy innovations target resource-efficient use of valuable bioresources.

ICT, mobile technologies and related platform and cloud computing are of high importance in the modern forest-based bioeconomy ecosystems. For example, by wireless intelligence Ponsse Plc, the successful Finnish company manufacturing

---

68 OECD (2002), Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development, The Measurement of Scientific and Technological Activities, OECD. Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264199040-en.

69 Oslo Manual (2005) Guidelines for collecting and interpreting innovation data, Third edition, A joint publication of OECD and Eurostat (http://www.oecd-ilibrary.org/docserver/download/9205111e.pdf?expires=1439813910&id=id&accname=ocid46013614&checksum=703D0141F139C294185EE2474A4FEEC3).

70 Prahalad, C.K. & Ramaswamy, V. (2004) Co-creation experiences: The next practice in value creation. Journal of Interactive Marketing; Summer 2004; 18, 3.

71 Rönnlund, I., T. Pursula, M. Bröckl, L. Hakala, P. Luoma, M. Aho, A. Pathan, B. E.Pallesen (2014) Creating value from bioresources, Innovation in Nordic Bioeconomy, Nordic Innovation Publication 2014:01. Available online: http://www.nordicinnovation.org/Global/_Publications/Reports/2014/2014_01%20Innovation%20in%20Nordic%20Bioeconomy_final.pdf.

forest harvesting machines, has transformed traditional logging into wirelessly managed automated and data-intensive solutions for the whole value chain.[72],[73] These wireless applications enable optimal economic and environmental solutions over the entire value chain by minimizing the time usage at various stages and optimizing the harvest yields. In an effective management of forest-based ecosystem the key issue is how information is acquired and exchanged across the whole value chain from the procurement of wood in the forests, from the transport and logistical operations, to the industrial processing and to final products and consumption in markets.

3.2 Products and value chains in Finnish forest-based bioeconomy[74]

The forest-based bioeconomy builds on the traditional forest industry, since new bioproducts are in most cases extensions to existing product portfolios in Finland. The role of the traditional forest industry is crucial, because it forms a solid platform for the development of new innovative bioproducts. The production of traditional pulp generates valuable streams that can be utilised for new value-added products, i.e. traditional production is a prerequisite for the rise of new value-added products. The new bioproducts, such as wood-based textile fibres, provide possibilities for the eco-friendly fashion industry globally. For instance, the production of wood-based textile fibres may release cotton fields for food production. Forest-based biomass is not a limitless resource and it needs to be utilized it in a sustainable way and by developing technologies for the resource-efficient use of biomass and producing various products with different values and minimising waste. Figure 10 describes bioeconomy value chains in which bioeconomy utilizes clean technology in producing products and services in a more sustainable way.

72 Loikkanen, T. (2017a) Intelligent machinery for sustainable forestry, in: Lilja, K and K. Loukola-Ruskeeniemi (Eds.) (2017), 52–52. Available online: https://julkaisut.valtioneuvosto.fi/handle/10024/79985.

73 Loikkanen, T. (2017b) Evolving Engineering Ecosystems – Case Study of Finnish Forest Machine Industry, Research Report, VTT.

74 Section 3.2 draws largely on Lilja, K and K. Loukola-Ruskeeniemi (Eds.) (2017) Wood-Based Bioeconomy Solving Global Challenges, MEAE Guidelines and Other Publications 2/2017, Ministry of Economic Affairs and Employment. Available online: https://julkaisut.valtioneuvosto.fi/handle/10024/79985.

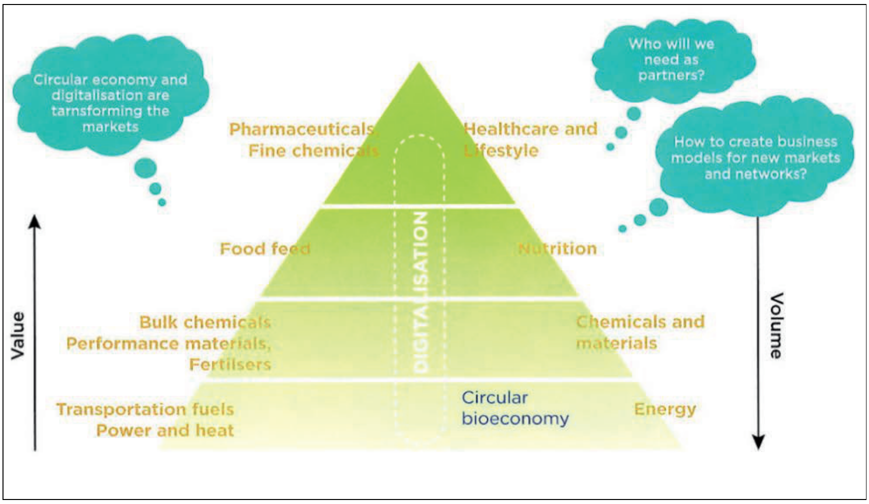


Figure 10. Bioeconomy value chains. The bioeconomy utilizes clean technology when sustainably producing products and services[75].

In forest-based bioeconomy value from raw material to end products and recycling originates and grows along life cycle stages between companies. Ecological resilience is a relevant element of value creation throughout the life cycle of raw-material and resource circulation. Industrial biotechnology applies biotechnology to the manufacture of products such as chemical compounds, including antibiotics, ethanol and citric acid, or proteins, including enzymes and antibodies. New service business opportunities will be created throughout value chains, for example, in services based on wood products and side streams.

Consumer awareness of bio-product options is essential as consumers ultimately choose which of the alternatives available are most suitable for them. As the scope of products, services and environments, in which wood as a raw material plays an important role, is widening at an accelerated pace, the role of consumers has to be taken into account in new ways.

Bioenergy is an integral part of the Finnish bioeconomy. Eighty per cent of wood-based bioenergy is produced using by-products and residues from harvesting and production operations of the forest industry. Most Finnish municipal centres outside the capital region use district heating plants, where pellets and wood residues are the main energy source.

75 Lilja, K and K. Loukola-Ruskeeniemi (Eds.) (2017) Wood-Based Bioeconomy Solving Global Challenges, MEAE Guidelines and Other Publications 2/2017, Ministry of Economic Affairs and Employment. Available online: https://julkaisut.valtioneuvosto.fi/handle/10024/79985.

In Finland, various actors in the forest sector are taking pioneering roles in the bioeconomy as part of new international knowledge, innovation and business ecosystems.[76] A major incentive in emerging ecosystems is that the sustainable use of all ingredients from wood will help to mitigate climate change and also solve other global challenges related to the diminishing availability of non-renewable resources. Section 3.3 gives concrete examples of forest-based bioeconomy innovations, products and businesses.

3.3 Finnish forest-based bioeconomy innovations and businesses

Forest-based bioeconomy is not only businesses of the future but already existing businesses of today. This section compiles seven examples of research and innovation driven forest-based bioeconomy businesses (of different size) in Finland. The innovations of selected companies represent value creation stages in the forest-based bioeconomy chain, starting from raw materials sourcing to primary and secondary processing of forest biomass and biomass components, towards separation and downstream processing, consisting also of service businesses.

3.3.1.1 Ponsse Plc[77]

The Finnish enterprise Ponsse Plc. produces innovative forestry machines and wireless automated data-intensive solutions that can optimise the needs in the entire biomass value chain. Wireless remote applications are also used in transporting machines between logging sites and, in maintenance, as well as diagnose services of machines worldwide. Since the 1970s, Ponsse has manufactured over 12,000 forest machines and 77 per cent of the turnover originates from exports. Ponsse´s export and service network covers 40 countries.

From 2010 till the end of 2016 Ponsse Plc. has invested EUR 56 million in R&D and approximately EUR 87 million in fixed assets. Ponsses´s passion in innovation is well manifested by bringing to the market technologically highly advanced harvester with the brand name “Scorpion”. Its development was launched in early phase of the economic recession 2008–2009. Ponsse swam against the tide: as the common reaction to recession was to cut R&D and other expenses, Ponsse decided to create a new harvester "without compromises". With selected partners a new harvester concept was generated which differs radically from competing products.

76 Lilja, K. and K. Loukola-Ruskeeniemi (Eds.) (2017) Wood-Based Bioeconomy Solving Global Challenges, MEAE Guidelines and Other Publications 2/2017, Ministry of Economic Affairs and Employment. Available online: https://julkaisut.valtioneuvosto.fi/handle/10024/79985.

77 The text is a condensed and slightly modified version of Ponsse article by Loikkanen (2017a) in Lilja and Loukola-Ruskeeniemi (Eds.) (2017) Wood-Based Bioeconomy Solving Global Challenges, MEAE Guidelines and Other Publications 2/2017, Ministry of Economic Affairs and Employment. Available at: https://julkaisut.valtioneuvosto.fi/handle/10024/79985.

After extensive user tests many new solutions were introduced that improve productivity and ergonomics. For example, the new crane solution offers for the driver visibility in all directions. Cabin levelling keeps the driver stable even in difficult terrains. The frame of the machine consists of three parts and the cabin is located in the middle frame enabling comfort for the driver at work. The stability of the machine is based on eight wheels and an active smart stabilisation system. Scorpion harvester has succeeded in the markets and has won several awards due to the design and material solutions. In addition to high technological quality of the machine. Ponsse has been a pioneer in wireless solutions which enable the management of logistics and transportation of biomass procurement over the entire value chain.

In effective forest management, the key issue is how the information is acquired and exchanged across the whole value chain from the procurement of wood in the forests, to the transport and logistical operations, and to industrial processing. Ponsse´s forestry machines have been equipped by PCs since 1993 and connected to Internet since 1997. Ponsse uses wireless applications also in its worldwide preventive remote operations, in maintenance services and in spare part deliveries for forestry machines, as well as for informing drivers that operate transportation carriages of machines. By wireless intelligence Ponsse has transformed traditional logging into wirelessly managed automated and data-intensive solutions for the whole value chain. Wireless applications enable optimal economic and environmental solutions over the entire value chain. It minimizes the time usage at various stages and optimizes the harvest yields. Real-time data is visualized for easy monitoring and decision-making from the logger to the fleet manager and to the services provided by Ponsse. Machines are equipped with monitoring operations informing where the machine is moving, whether it needs transportation carriage to change place, and what is the engine output and fuel consumption. As data is transferred to the cloud by Ponsse's Fleet Management application, the entrepreneurs can keep track of their machines. In spite of all pioneering solutions listed above, the continuous development and deployment of industrial internet applications are identified as the key future challenge of the company.

Close relationships to clients and direct involvement of users in the development and testing of machines are key issues in Ponsse´s culture. Ponsse nurtures innovative spirit, keeps technological competences in its own hands, and has a lean management organisation. All these features enable quick decisions ensuring rapid product development, agile sales, and effective operations and maintenance services worldwide. Ponsse has managed well in recent years in its niche markets worldwide. In 2016 Ponsse Group's turnover was EUR 517,4 million euro and operating profit EUR 55,2 million. The order book of machinery stood at the end of 2016 EUR 123.9 million. At the end of 2016 the total staff of Ponsse Group was 1435. Ponsse is listed on the Helsinki Stock Exchange. Ponsse, John Deere and Komatsu share more than 90 per cent - each one roughly one third – of global forest machine markets.

3.3.1.2 Paptic Ltd[78]

Paptic Ltd. was founded in April 2015 as a VTT spin-off company with the target of offering a sustainable and renewable alternative to plastic films. The first application area is carrier bags, while flexible packaging as a whole offers wide future growth potential. Non-degradable, poorly recyclable, easily littered and long-lasting plastic products cause extensive accumulation of problems and endanger marine ecosystems. About one trillion plastic bags are used every year, with 89% of them only once. Despite the urgency of the problem, no viable material alternative has been found until now. Paptic Ltd. addresses this global challenge and satisfies the needs of consumers, retailers and brand owners for sustainable carrier bags. The novel wood fibre-based material PAPTIC® combines the renewability of paper with the resource efficiency and functionality of plastics.

Once fully developed, PAPTIC® bags will be 100% biodegradable, renewable and recyclable. The patented PAPTIC® bags are the world's first economically sound and environment-friendly alternative to plastics bags. Although market entry is achieved through carrier bags, PAPTIC® is planning to enter the whole flexible packaging market expected to be worth 200 billion €. The business model for scaling up the production of PAPTIC® is based on utilization of existing and excessive paper industry infrastructure. Today PAPTIC® material is produced in a pilot-scale environment in Espoo. In order to speed up the scale-up, Paptic received from the European Commission (Horizon 2020) a grant of 2.2 million EUR in July 2016. Paptic Ltd. is currently conducting tests with a number of best-known brands and retailers in the world, with extremely favourable feedback from brand owners. The first deliveries of Paptic® Bags were made in June 2016 and the feedback both from the customers and consumers has been thoroughly positive.

3.3.1.3 Äänekoski bioproduct mill of Metsä Fibre Ltd[79]

Metsä Fibre built the first next-generation bioproduct mill in the world. Located in Äänekoski, Middle-Finland in the area of an existing pulp mill the new bioproduct mill is the largest investment of the forest industry in Finland. The mill will have an expected annual impact of more than EUR 0.5 billion on Finland's income.

---

[78] Source of PEPTIC Ltd. description: Kruus K. and T. Hakala (Eds.) (2017) THE MAKING OF BIOECONOMY TRANSFORMATION, VTT 2017. Available online: http://makingoftomorrow.com/ebook/.

[79] Text is based on: http://tappi.net/Detail.aspx?id=87602.

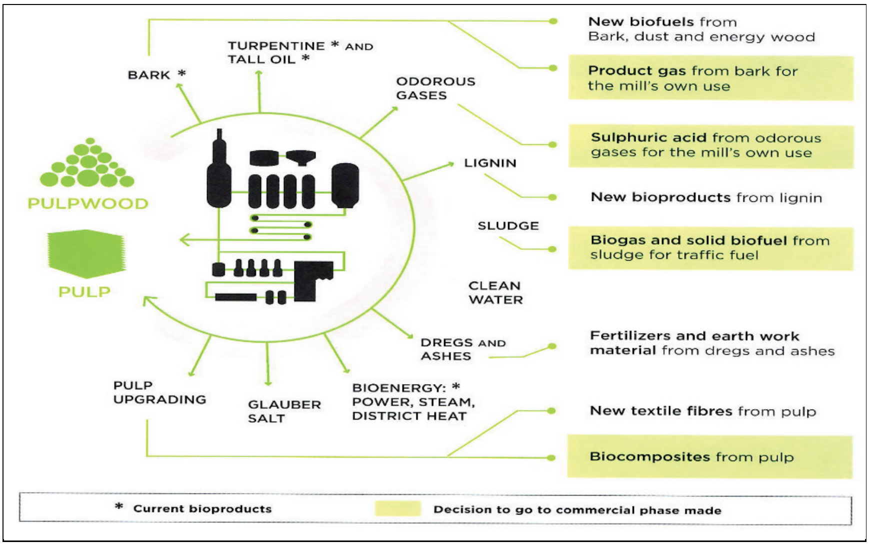


Figure 11. The scope of products in Äänekoski bioproduct mill. (Source: Metsä Fibre Ltd.)

When completed, the bioproduct mill will significantly increase the use of wood in Finland as a whole. The annual use of pulpwood will increase by around 4 million cubic meters (around 10 per cent) at the national level. The sustainable increase potential is 7 million cubic meters of softwood fiber and 4 million cubic meters of birch fiber. The wood will mainly be purchased in Finland.

In addition to high-quality pulp, the Äänekoski mill will produce a broad range of bioproducts, such as tall oil, turpentine, lignin products, bioelectricity and wood fuel. Potential new products created from production side streams include product gas, sulphuric acid, textile fibres, and raw ecosystem of bioeconomy companies that will develop and produce the bioproducts of the future from wood materials.

3.3.1.4 UPM GrowDex[80]

UPM's GrowDex® cellulose nanofibril hydrogel was recognized as a significant innovation with great future potential by the Chemical Industry Federation of Finland. The members of the award winning GrowDex team come from UPM and the University of Helsinki. The Chemical Industry Federation of Finland hands out the award every other year to innovations which are seen to be of great benefit to the well-being of both humans and the environment and which have the power to make a difference both in the everyday-life of people and as a commercial successes on an industrial scale.

[80] Source: https://www.upmbiofore.com/upm/upms-growdex-hydrogel-wins-an-innovation-award-by-the-chemical-industry-federation-of-finland/.

The GrowDex team was one of the two teams given the 2016 Innovation Award. The GrowDex® hydrogel is a result of interdisciplinary research by UPM and a team of researchers from the University of Helsinki's Department of Biopharmacy. UPM has commercialized GrowDex® for 3D cell culture applications such as pharmaceutical research and development. GrowDex® is biocompatible with human cells and tissues. The award given to the innovation is also a recognition to UPM for bravely moving into new areas of research and development.

"GrowDex® hydrogel is the first product for biomedical applications of the interdisciplinary research team of UPM and the University of Helsinki's Department of Biopharmacy. The role of the co-operation partners and Tekes has been significant as the research team started this project from basic research.

3.3.1.5 Spinnova Ltd[81]

Spinnova Ltd. a VTT spin-off company started operations in early 2015 to commercialize Fibre-to-Yarn technology globally. Spinnova meets the globally growing need for environmentally friendly, high-quality and low-cost textile yarn production. The demand for environmentally friendly textile products is increasing and currently there are no truly sustainable pathways to produce textile yarns. Increasing population, tightening legislation and scarcer natural resources will continue to increase this demand. Invented at VTT in 2011, the new-patented Fibre-to-Yarn technology allows simpler and more flexible production of bio-based, resource-efficient textile yarns with excellent recyclability and significantly lower production cost. Fibre yarn production uses virgin pulp fibres directly as yarn building blocks maintaining all the good properties of natural pulp fibres with no need for dissolution chemicals. Thus the technology provides economic and environmental alternative to cotton- and oil-based textile yarns. The developed technology uses a wet spinning process enabling the production of a wide variety of yarns from thin textile monofilaments to thick decorative yarns. Fibre yarn can be functionalized in many ways to meet the demands of different applications. Fibre yarns can be coloured, they can be made conductive and fibre yarn properties like strength, smoothness, stretch and hydrophobicity can be adjusted.

The most interesting market segment is apparel and textile products, with the objective to give cost efficient and sustainable alternative to cotton, oil and man-made cellulose-based yarns. Other very interesting market segments include medical applications, bio-composite reinforcements and even the traditional paper yarn market. In early 2015 Spinnova started to upscale the technology to industrial scale through industrial pilots. Building of a full-scale industrial production plant will be started in 2020–2022.

[81] Source of Spinnova Ltd. description: Kruus K. and T. Hakala (Eds.) (2017) THE MAKING OF BIOECONOMY TRANSFORMATION, VTT 2017. Available online: http://makingoftomorrow.com/ebook/.

SPINNOVA LTD IN A NUTSHELL

- 99% less water than cotton production
- 60% less production costs than cotton
- Up to 20% of global cotton usage could be replaced with Finnish harvesting surplus alone
- 1.95 M€ investment secured for first phase
- Commercialization plan:

2018: Production capacity of 300 tons/a

2020: The first industrial scale production plant with 30,000 tons/a capacity

3.3.1.6 Stora Enso Ltd mechanical laid paper mulch farming[82]

Reducing the need for pesticides, increasing growth, stabilizing soil temperatures and biodegradable, mulch paper is a boost for vegetable growers. Looking beyond traditional applications for paper, Stora Enso has developed a product for an entirely new market – mulch paper for vegetable growers. Mulch paper protects the soil and effectively combats weeds. It is intended for large-scale cultivation, inside or outside of greenhouses. It keeps weeds at bay in fields containing annual crops such as lettuce, cucumber, zucchini, cabbage and celery.

"The mulch paper reduces the need for pesticides, increases growth, stabilises temperature differences in the soil and is totally biodegradable. Vegetable growers avoid having to spend time and energy removing plastic from the field when the season is over. After the harvest, the mulch paper is ploughed in and returned to nature," says Dan Persson who works with innovation at Kvarnsveden Mill.

The mulch paper is made of spruce pulp and is the result of many years of cooperation between Kvarnsveden Mill and the Support Centre Mönchengladbach in Germany. It contains a higher share of kraft pulp so that the paper is stronger and has a longer resistance to moisture. The mulch paper is coated with a natural black pigment that prevents the sunlight from reaching the soil and thereby stops unwanted vegetation. Existing equipment has been used for the manufacture of the mulch paper at Kvarnsveden and no reengineering was required.

3.3.1.7 Arbonaut Ltd[83]

Arbonaut Ltd. produces detailed location specific data services on forestry resources, based on airborne laser scanning. Arbonaut is also the spin-off company from VTT: While Paptic and Spinnova have their roots in the research ecosystem of

---

82 Source: http://www.storaenso.com/newsandmedia/biodegradable-mulch-paper.

83 The text is based on Lilja, K and K. Loukola-Ruskeeniemi (Eds.) (2017) Wood-Based Bioeconomy Solving Global Challenges, MEAE Guidelines and Other Publications 2/2017, Ministry of Economic Affairs and Employment. Available online: https://julkaisut.valtioneuvosto.fi/handle/10024/79985.

the Finnish forest sector; Arbonaut has its roots in the ICT-sector. Arbonaut's managing director and owner, Tuomo Kauranne, tells[84] of the roots of the start-up 'We realised that with our technology we could measure two- and three-dimensional objects from aerial images. Initially, we created a new technology for the mobile phone industry. After the turn of the century, we developed the first ever map localisation phone in collaboration with the mobile phone manufacturer Benefon'. The story goes on: 'the recognition that the method could be applied in forestry management emerged as a result of forestry related computer programmes which we developed in collaboration with university researchers, placed in Joensuu, Finland. We realised that if we know the diameter of the crown of a tree, we can predict the tree's volume.' After describing the procedure for such a measurement process, Arbonaut began to produce machine vision software utilising the method.

The liDAR surveying method is at the heart of the technology, which has now replaced field measurements. 'We fly at the height of a couple of kilometres in an aeroplane and use laser beams to generate three-dimensional point cloud data on the object. On average, you have one data point per square metre, and on the basis of these points we use mathematical modelling for providing us reliable information on what the area consists of. We pretty much achieve accuracy down to a single tree,' explains Kauranne.

Now with operations on six continents, Arbonaut has gained clients around the world, including both forest companies and government authorities. 'Forest inventories provide valuable information to facilitate sustainable forestry management, and they also indicate when and where trees should be felled. Assessments of carbon stocks in tropical forests are currently an area of strong focus. We can monitor carbon storage development and provide reliable measurement processes at the national level and for certifications,' says Kauranne. According to him, the measurement results become a financial asset for the state when Arbonaut's method is used to demonstrate the amount of carbon dioxide that has been removed from the atmosphere, entitling the state to payments for carbon capture via forests under the Paris climate agreement.

3.3.1.8 Networks and platforms of Finnish bioeconomy communities

Seven examples of the Finnish bioeconomy businesses above illustrate well the extensive interests and achievements of Finnish companies in the development of innovative and commercialised forest-based bioeconomy activities and businesses. Industrial, R&D and policy communities have developed several networks and platforms in order to collaborate and develop various initiatives for the promotion of forest-based bioeconomy and sustainable technologies. For example, Cleantech Finland, with 250 member companies, is a hub of Finnish cleantech expertize and sustainable innovations.[85] BioeconomyFI is a common platform for the promotion of bioeconomy by The Ministry of the Environment, The Ministry Economic Affairs and

---

[84] Ibid.

[85] http://www.cleantechfinland.com/what-s-cleantech-finland.

Employment and Economy and The Ministry of Agriculture and Forestry.[86] The home page of BioeconomyFI includes versatile information of Finnish bioeconomy in different sectors including wood and forests. CLIC Innovation is an open innovation cluster with the mission of creating breakthrough solutions in bioeconomy, energy and cleantech. CLIC Innovation coordinates R&D&I project portfolios to construct systemic solutions, which are beyond the resources of individual operators.[87] The shareholders of the nonprofit CLIC Innovation Ltd include 30 companies and 17 universities and research institutions.

3.4 State-of-the-art of the forest-based bioeconomy

This section offers a qualitative assessment of the state-of-the-art of each FBA in terms of:

- Global production and demand in 2030 & 2050;
- Value network actors in the forest management; and
- Knowledge triangle benchmark: strategic objectives.

In addition, this sections provides a benchmark of the forest industry in selected countries and offers and panoramic overview of the current value networks in FBAs in Uruguay with a focus on:

- Innovation actors in forest-based bioeconomy in Uruguay;
- Research and university actors in in forest-based bioeconomy in Uruguay; and
- Institutional actors in forest-based bioeconomy in Uruguay.

In order to map the global value networks (GVN), key FBA actors were divided into three main categories according to their main role in the ecosystem. These categories are:

- Private or public company operating in forest sector;
- Institutional actor which operates in local environment or as global opinion leader related to forest industry;
- University and research organisation who are responsible of forest-based R&D.

The main information source for mapping of global actors was expert workshops organised with Luke and VTT experts. The experts were asked to list important global players in their fields from the three categories. Mainly, they were asked to name actors from the benchmark countries: Finland, Sweden, Canada, Australia, New Zealand, South Africa, Chile and Brazil. Few significant global players beyond these countries were also listed. Factiva news database acted as a secondary source for collecting actors from the relevant countries. The Factiva country actor lists were merged with expert lists, and actors were categorized similar to expert

86 http://www.bioeconomy.fi/.
87 https://clicinnovation.fi/.

lists. Thirdly, actors were identified from other sources, such as market reports[88] and web searches, during the information collection process.

In total, some 440 individual actors were identified in different FBA value chains, See Table 6.

Table 6. Sourced for identified actors.

Sources	Total*	Companies	Institutional players	R&D	Northern-hemisphere	Southern-hemisphere
Experts	164	43	7	22	234	150
Factiva	300	182	67	49		
Other	70	59	2	10		

*Note: an actor can be identified from multiple sources.

For the larger pulp and paper companies, different company divisions were treated as individual actors given their roles in different FBAs in the study. Given interlinkages of different FBAs, one actor may interact in different areas. In fact, this was usual in our data as 164 actors operated in more than one area. However, this also points out that majority of actors concentrate on specific operations or hold specific knowledge, as 276 actors were identified to one forest-based area only. Figure 12 shows the distribution of only those companies that originate from a benchmark country and does not count actors who originate outside benchmark countries (e.g. Uruguay) although they were identified important players in country's forest industry.

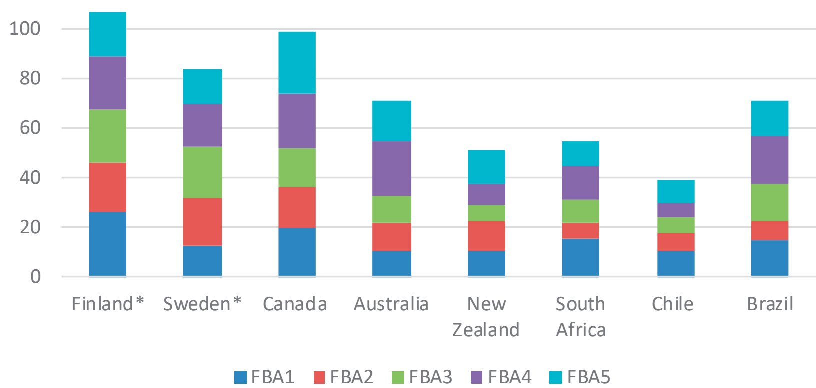


Figure 12. Distribution of actors identified in benchmark countries in different FBAs.

88 These reports include BCC Research reports (restricted access), Frost & Sullivan market analysis reports (restricted access), Global Forest Paper & Packaging Industry Survey 2016 edition survey of 2015 results by PwC, Canada & Pyrolysis report by Kutney, VTT report NWBC 2015, Tieto report.

In the subsequent value network descriptions, we follow innovation system[89] and helices[90],[91] approaches and categorize actors into four groups. In this study we use a framework of knowledge triangle, which bases on helix approach as well as innovation system that emphasizes the interaction between different types of innovation actors (Figure 13). These groups are **innovation/industry actor** (namely innovative companies who are commercializing innovations on market), **research** (namely public and private research organisations and laboratories), **universities for education and research**, as well as **institutional actors** who can be e.g. ministries, wood/forest associations. The last group of actors have influential role in setting regulations and society's attitudes and behaviour.

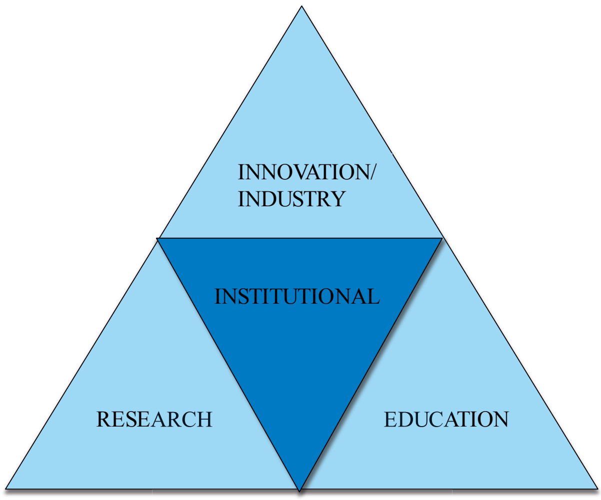


Figure 13. Knowledge triangle (+) approach.

Table 7 shows the distribution of the four actor categories in different countries. According to the different sources in this study, the largest number of companies come from northern hemisphere whereas the university-based research is relatively strong in southern hemisphere, in particular in Australia. Institutional players seem strong in Canada, and many of the southern hemisphere countries, such as Australia and New Zealand.

---

89 Sundbo, Jon (1998) The Theory of Innovation: Entrepreneurs, Technology and Strategy. Edward Elgar Publishing: Northampton, MA.

90 Etzkowitz, Henry & Leydesdorff, Loet (2000) The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research Policy, 29:2, 109–123.

91 Carayannis, Elias & Campbell, David (2014) Developed democracies versus emerging autocracies: arts, democracy, and innovation in Quadruple Helix innovation systems. Journal of Innovation and Entrepreneurship, 3:12.

Table 7. Distribution of actor categories in benchmark countries.

Geographic Areas		Innovation/ industry	Research	University	Institutional
Northern hemisphere	Finland	56	6	4	5
	Sweden	40	2	10	3
	Canada	42	3	9	11
Southern hemisphere	Australia	21	1	14	11
	New Zealand	9	1	4	12
	South Africa	13	3	7	10
	Chile	16	-	5	2
	Brazil	18	3	12	7

In distinction to previous breakdowns, Table 8 includes all actors identified, including those coming outside benchmark countries. This is because the experts identified additional actors outside the eight benchmark countries. In total, 80 actors originate from other than the original 8 eight benchmark countries: 21 of these actors are from the us, 40 are from different European countries, 7 are identified from Asia (e.g. China, Japan, Indonesia) and 8 from Latin America (from Argentina, Mexico and Colombia). Majority of these actors operate in industry (39 companies), and in research (29 research and university actors), the rest are institutional actors.

The main reason why all identified actors are included in the analysis is that majority of these companies are operating globally regardless of their country of origin, and the same applies to research, both academic and applied. Given that some of the actors are identified to be significant players in the forest-based bioeconomy area by more than one expert or source, it is justified to take these actors in the analysis.

Table 8. Different actor groups in FBAs divided by northern and southern hemisphere.

Type of Actors by Hemisphere		Forest management (FBA1)	Mechanical wood processing (FBA2)	Pulp-paper & new biomaterials (FBA3)	Biorefining (FBA4)	Bioenergy (FBA5)
Northern-hemisphere	Innovation/ Industry	33	50	55	46	52
	Research	9	3	4	6	6
	University	10	18	8	17	8
	Institutional	14	9	3	5	14
Southern-hemisphere	Innovation/ industry	30	33	35	30	35
	Research	4	2	4	5	3
	University	13	8	13	39	12
	Institutional	22	11	7	12	22

Figure 14 shows the number of different actors identified in each FBA.

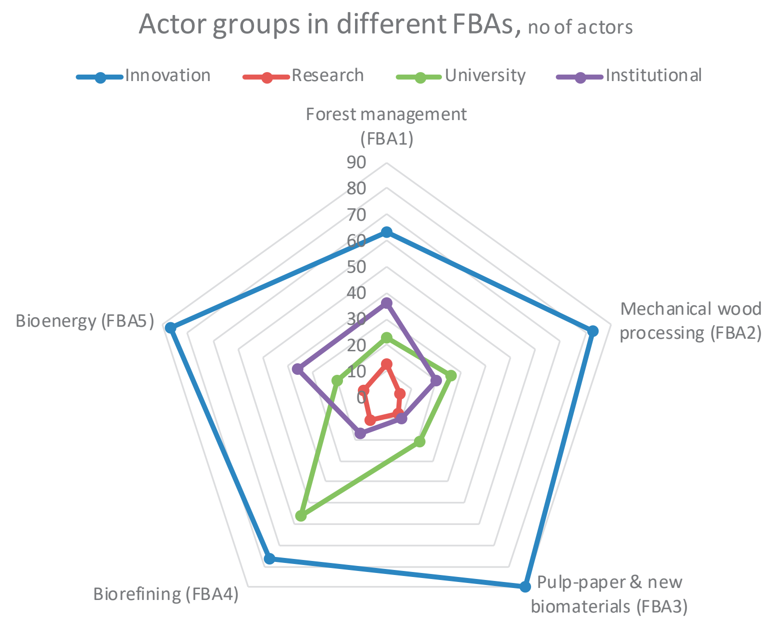


Figure 14. Ecosystem actors in different FBAs, global.

Figure 15 illustrates the division of ecosystem actors between northern and southern hemispheres. It is seen that the figures show similar pattern in the north and south. The only one deviating in shape is FBA4, namely biorefining.

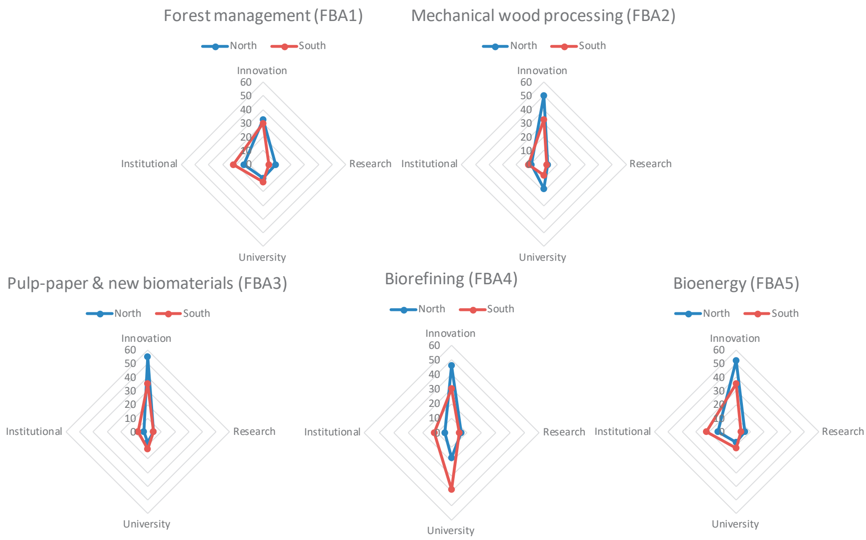


Figure 15. Division of ecosystem actors between northern and southern hemispheres in each FBA.

3.5 Global Value chains in Forest-based bioeconomy

A selected number of actors have been prioritized for the following analysis and illustrations. The following selection criteria has been followed: (1) actor is identified by VTT, Luke or Uruguayan experts; (2) actor is identified from multiple sources, e.g. report/s and expert/s. Variable ‘Count of sources’ in listings indicates simply frequency of sources in which the particular actor is mentioned.

The latter criterion excludes merely those actors identified only from Factiva. The results of Factiva analysis are reported separately. This way we narrow down focus on the most significant global forest value network players, in total *211 actors* for all of the FBAs.

3.5.1 FBA 1: Forest management

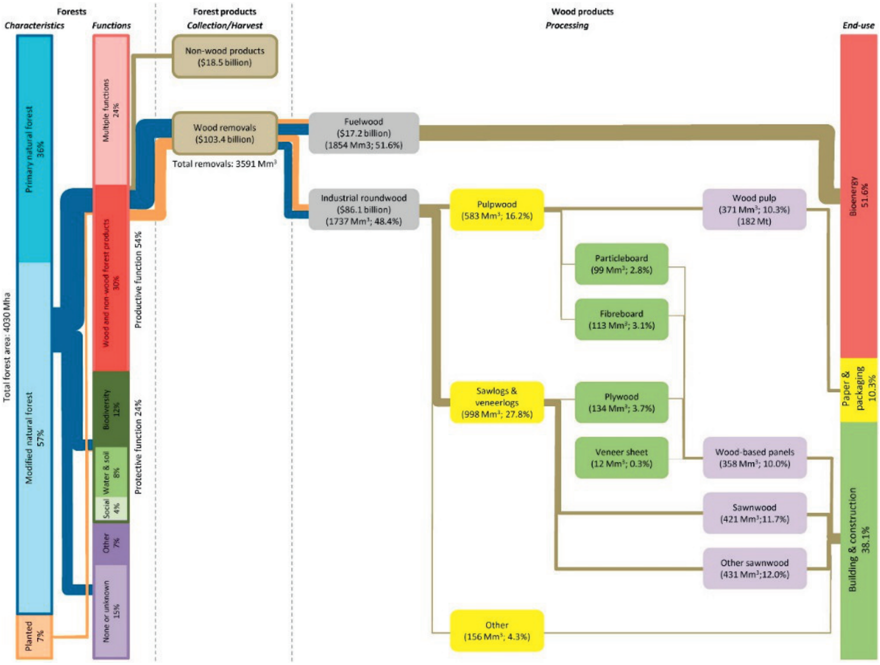


Figure 16. Global flow of wood, from forests to end-use.

Sankey map above illustrates the global flow of wood, from forests to end-use.[92] With data from FAO.[93]

Trends in global roundwood harvest and wood-products production from 1990 to today are shown below[94] based on data from FAO.[95].

[92] Ramage, Michel et al. (2017) The wood from the trees: The use of timber in construction. Renewable and Sustainable Energy Reviews, 68, 333–359.

[93] FAO. FAOSTAT dataset. Food and Agriculture Organization of the United Nations; 2015]. Forestry data for 2010. Wood removal data for 2013.

[94] Ramage, Michel et al. (2017) The wood from the trees: The use of timber in construction. Renewable and Sustainable Energy Reviews, 68, 333–359.

[95] FAO. FAOSTAT dataset. Food and Agriculture Organization of the United Nations; 2015]. Forestry data for 2010. Wood removal data for 2013.

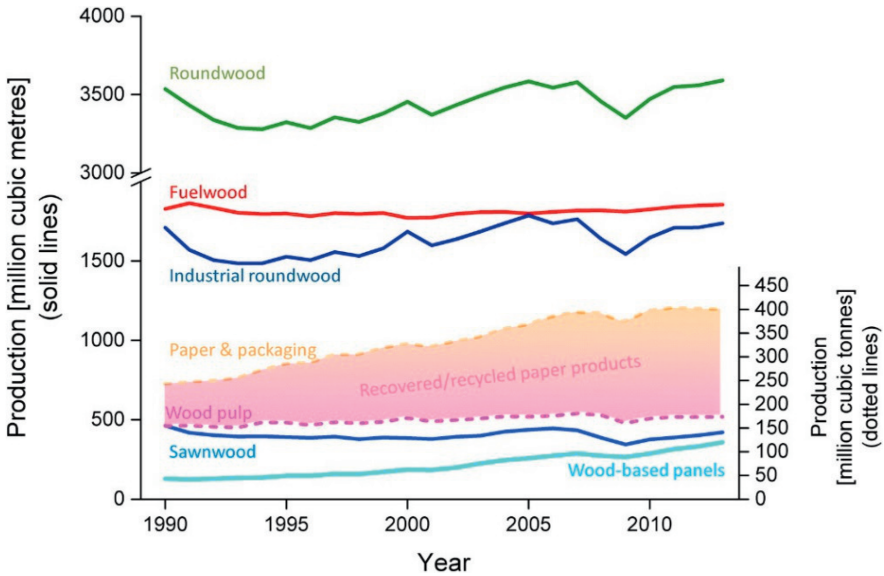


Figure 17. Trends in global roundwood harvest and wood-products production.

3.5.1.1 Value network actors in the forest management

Table 9; Table 10 and Table 11 (below) list the main knowledge triangle actors (innovation/industry; research and education), excluding institutional actors for whom similar analysis was not meaningful to perform.

Table 9. Innovation /Industry actors in FBA 1.

	Main focus area	Company/Innovation actor	Links to FBAs	Count of sources	Origin	Market
SILVICULTURE	Forest, pulp & paper	Stora Enso Oyj	5	4	Finland-Sweden	global
	Forest, pulp & paper	UPM-Kymmene Oyj	5	3	Finland	Global
	Forest, pulp & paper	Metsä Group	4	3	Finland	Europe
	Pulp (also forestry, paper and tissue)	CMPC (Compañía Manufacturera de Papeles y Cartones)	4	2	Chile	Mercosur
	Pulp, forest, wood, new biomaterials	Fibria Celulose, S.A.	3	2	Brazil	Global: Europe (36%), Asia (32%), North America (22%) and LatAm (10%)
	Forestry, wood boards for furniture and interior architecture	Masisa SA	3	2	Chile	Latin America; USA; Canada

	Main focus area	Company/Innovation actor	Links to FBAs	Count of sources	Origin	Market
	Forestry, pulp and paper; Packaging	Suzano Pulp and Paper /Companhia Suzano Papel e Celulose S.A.	3	2	Brazil	Global; China; USA, Switzerland, UK; Argentina
	Woodlands, Forest Products, Pulp, Paper & Paperboard, and Chemicals	Resolute Forest Products Inc.	3	2	Canada	USA; Canada
	Forest management	FORESTRY CORPORATION	2	2	Australia	
	Forestry	Celulosa Arauco y Constitucion SA, Forestry	1	2	Chile	Mercosur
	Forest management	VicForests	1	2	Australia	
	Forest operations	Metsä Forest (Metsä Group)	1	2	Finland	
	Forest biotechnology	FuturaGene plc (Suzano)	1	2	Brazil	Israel, China
	Forest management	UPM Wood sourcing and forestry	1	1	Finland	Austria, Estonia, Finland, Germany, Russia, Uruguay; USA. 14 countries
	Forest operations	HolmenSkog (Holmen)	1	1	Sweden	
	Forest operations	Sveaskog Ab	1	1	Sweden	
HARVESTING	Forest harvesting machines	JohnDeere Forestry Inc (Deere& Company)	2	3	USA	global
	Forest machines manufacturer, harvesters	Ponsse Oyj	2	3	Finland	global (sales offices - Europe: SE, NO, FR, UK, IR), USA, RU, HK, CN, (LatinAm: BR, UY)
	Digitalisation services	Tieto Oyj	1	2	Finland-Sweden	Europe
	Forest machines, thinning	Sampo Rosenlew Oy	1	1	Finland	RU, North America, Europe
	Forest inventory	Arbonaut Oy	1	1	Finland	Global (Lat. Am: Uruguay, Brazil,), Australia, South Africa
	Forest machines manufacturer, harvesters	Logset Oy	1	1	Finland	Global (Lat.Am: Chile, Brazil), Australia, Canada, USA, China, Japan
	Forestry information management	Savcor Oy	1	1	Finland	
LOGISTICS	Logistics	Rumo (part of Cosan)	1	1	Brazil	Latin America

Main focus area		Company/Innovation actor	Links to FBAs	Count of sources	Origin	Market
ROUND WOOD	Packaging paper and board, corrugated boxes, industrial sacks, timber in logs	Klabin SA	4	2	Brazil	Mercosur; USA and Austria offices
	Engineered wood products	West Fraser Timber Co Ltd	4	2	Canada	USA, CA
	Forest, pulp & paper	Canfor Corp	3	2	Canada	
	Lumber producer, sawmilling operation	Interfor Corp	2	2	Canada	CA, USA, China, Japan, France
	Forest Products, Pulp, Paper & Paperboard, and Chemicals	Tembec Inc (acquired by Rayonier Advanced Materials in 2017)	2	2	Canada-USA	
BIOMASS	Biodiesel	Neste Oyj	2	2	Finland	Finland, Netherlands, Singapore

Table 10. Research actors in FBA 1.

Main focus area		Research actor	Links to FBAs	Count of sources	Origin
SILVICULTURE	Forest consultancy; Biomaterials, Forest operations, wood products	FPInnovations	4	2	Canada
	Forest research	Finnish Forest Research Institute -Luke	2	2	Finland
	Forest-based research	Scion Research (a Crown Research Institute -CRI)	2	1	New Zealand
	Forest industry	Skogforsk	1	1	Sweden
	Forestry	Forest service - USDA (United States Department of Agriculture)	1	1	USA
FOREST INDUSTRY CONSULTING	Biomaterials	CSIR - Council of Scientific and Industrial Research	3	2	South Africa
	Forest industry management consulting	Pöyry Oy	2	2	Finland
	Forest consulting	Indufor Oy (Indufor Group)	1	1	Finland
	Forest management consulting	Simosol Oy	1	1	Finland

Table 11. Education actors in FBA 1.

Main focus area		University	Links to FBAs	Count of sources	Origin
SILVICULTURE	Forest management; wood and building technologies	University of British Columbia	4	3	Canada
	Plantation forestry; wood technology	University of Canterbury	4	2	New Zealand
	Forest science	Swedish University of Agricultural Sciences - SLU	4	2	Sweden
	Forestry, Biomaterials	University of Chile	2	2	Chile
	Forest sciences, bioprocessing	Sao Paulo State University	3	1	Brazil
	Forest ecosystems, forest management and forest-derived renewable materials	Oregon State University	2	1	USA
	Forest Ecology, Forestry of Temperate and Tropical Regions, Nature conservation and restoration, Forest Politics, Forest Management Planning, Wood Biology, Wood Technology, Remote Sensing, Geographic Information Systems, Hydraulics, Hydrology and Water Management	University of Ghent	1	1	Belgium
	Forest science and engineering	Federal University of Paraná	1	1	Brazil
	Forestry	Stellenbosch University	1	1	South Africa
HARVESTING	Digital solutions research, e.g. autonomous forest machines	Umeå University	4	2	Sweden
LOGISTICS	Bioenergy, logistics	Lappeenranta University	2	1	Finland
VALUE CHAIN OTHER	Wood and building technologies; biorefinery, bioenergy	University of São Paulo (USP)	5	3	Brazil
	Architecture, construction (wood)	University of Bío Bío	2	2	Chile

3.5.1.2 Knowledge triangle benchmark: strategic objectives

Company	Vision/Strategy	Products
Canfor Corp	To be the global leader in supplying diverse and innovative, quality wood-based products to our highly valued customers.	Forest: Dimension & specialty lumber.
CMPC	The company's mission is to produce and market in a sustainable manner – on the basis of man-made plantations – wood, pulp, paper and tissue products of first-rate quality that are competitive, add value for its stockholders and customers and create development opportunities for its employees and local communities.	Forestry: Different kinds of timber, based on the region.
Fibria Celulose, S.A.	At Fibria, innovation is present in all business areas. The company invests in the development of technologies and innovations aligned with its strategy of generating maximum value from its planted forests. This involves developing products and services capable of maximizing productivity, optimizing costs and anticipating trends and clients' expectations, while also offering opportunities to substitute fossil-based products in new markets. In this scenario, competitive innovation is a key company attribute	Forest/wood: Eucalyptus tree for pulp production.
Forestry Corporation	Heavy focus on regrowth forests.	Forest management done with ESFM philosophy. EFSM = Ecologically sustainable forest management.
Interfor Corp	Interfor is now one of the world's largest lumber providers. With annual capacity of 3 billion board feet from world-class facilities, we serve the needs of customers, strengthen local economies and build value for our employees and our shareholders. And now we're embarking on a bold new vision, capitalizing on opportunity and growing into an even more robust future.	Lumber: Structural lumber, industrial lumber, appearance lumber from a wide variety of trees.
JohnDeere Forestry Inc	Innovation means inventing, designing, and developing breakthrough products and services that have high appeal in the marketplace and strengthen customer preference for the JohnDeere brand. Innovation extends to using the latest technology to establish world-class manufacturing processes and applying the most advanced information technology tools and practices throughout the company.	Foresting machines; Collection of biomass: Skidders, feller bunchers, knuckleboom loaders, bunchers, swing machines, harvesters, forwarders.
Klabin SA	Klabin's management practices are guided by sustainable development and its management pursues integrated and responsible growth that combines profitability, social development and a firm commitment to environmental preservation.	Timber in logs: own demand raw material at Klabin's pulp and paper plants, the Forestry Unit is Brazil's largest supplier of wood logs originating from planted and certified forests (Pine and Eucalyptus).

Company	Vision/Strategy	Products
Masisa SA	Provide design, performance and sustainability for the creation of each furniture and interior environment in Latin America	Forestry: MASISA is looking to develop the synergies necessary to supply industrial plants by generating forestry products directly from the forest, as well as through recovering byproducts from the sawmill industry and third party clients that supply our forestry unit.
Metsä Group	Metsä Group is a responsible forest industry group whose core business consists of tissue and cooking papers, paperboard, pulp, wood products, and wood supply and forest services. According to our strategy, we focus our operations, investments and resources on areas where we have a clear competitive advantage and that offer good growth prospects	Forest: Metsä Group utilises wood raw material (Northern wood) to the full.
Neste Oyj	Our goal is to do more with less. That is why we continuously are searching for new renewable raw materials, such as waste and residues	n/a
Ponsse Oyj	Ponsse specialises in the production, sales and maintenance of forest machines designed for the cut-to-length method and in the related information systems. Ponsse constantly develops its products and services, keeping a close eye on the new features expected by the forest machine industry and entrepreneurs. Our mission is to contribute to our customers' success with productive and reliable Ponsse forest machines and services. It is our promise to be the "Logger's Best Friend".	Forest machines manufacturer, harvesters; collection of biomass: Harvesters, Forwarders, Dual Harwarders, Cranes & loaders.
Resolute Forest Products Inc.	At Resolute Forest Products, we are one team with one vision where: Profitability and sustainability drive our future.	n/a
Stora Enso Oyj	Our Purpose is doing good for people and the planet. Replace fossil-based materials with renewable solutions	Forest: Solid construction timber, Sawn and profiled wood products, post and beam construction.
Suzano Pulp and Paper S.A.	1. Structural competiveness: operating with low production costs. 2. Adjacent business: Three new fronts: fluff pulp from hardwood fiber, entering tissue market, launching lignin extraction. 3. Redesigning the industry: Seek proactive ways to consolidate or verticalize our operations, since we have a large volume of pulp that could be used to create a vertically oriented business and reduce the risks of product volatility.	Forestry: Sustainable growth through forestry research and development. Our forests are among the most productive in the world, and our practices are adapted to a variety of climates, soils and final wood applications. Through our biotechnology subsidiary Futuragene, we have developed the world's first genetically modified variety of eucalyptus.

Company	Vision/Strategy	Products
Tembec Inc / Rayonier Advanced Materials	Rayonier Advanced Materials creates one-of-a-kind cellulose specialties products from renewable resources.	n/a
UPM-Kymmene Oyj	Together we are building sustainable future based on versatile use of renewable wood biomass. Rooted in responsibility – driven by innovation.	Forest: used for pulp.
West Fraser Timber Co Ltd	We have a consistent and reliable business model that is based in efficiency and unwavering attention to cost management. We consistently reinvest in our operations to ensure our committed and dedicated staff has the right resources to compete and win in a challenging industry.	n/a

Vision and strategy documents and product categories were collected from company's web sources in June 2018. This information was searched for the most prominent actors in the forest-based area in question. The selection of the most prominent actors is based on the evaluation of two criteria indicated by the experts (1) how company is integrated in other forest areas (i.e. links to number of FBAs), and (2) the importance of an actor by expert sources (i.e. by how many different expert sources actor was mentioned [source here refers to Finnish or Uruguayan expert, or industry reports]).

The following listing shows selected company's strategy and the main products/services in the woodland management area.

3.5.2 FBA 2: Mechanical wood processing

The market for wood products is global and huge streams of goods are shipped between continents. Demand largely follows the general economic cycle and has been developing well. The market for wood products is strong in all the key territories. The construction industry is doing well in Europe and North American consumption has recovered. Asia is breaking new records and is dominated by the Chinese market, which is also seeing the fastest growth.[96]

The main bio products of sawmills are sawdust, chips, and bark.

3.5.2.1 Global production and demand in 2030 & 2050 in wood processing

The estimates presented in this section (and all the following FBAs) bases on the EFI-GTM model (the global forest sector model) which is a multi-regional and multi-period forest sector model that integrates forestry, forest industries, final demand

[96] Holmen (2017) Annual Report. Available at https://www.holmen.com/globalassets/holmen-documents/publications/annual-reports/holmen-annual-report-2017.pdf

for forest industry products and international trade in the products.[97] The model includes 61 regions covering the whole world.

Table 12. Assumed reference demands in the scenarios in selected years. World totals.

	Crunch			Bio-Inno			Bio-Stor		
	2020	2030	2050	2020	2030	2050	2020	2030	2050
Softwood sawn wood	284.8	296.4	307.8	300.7	350.8	461.1	310	336.8	384.9
Hardwood sawn wood	108.3	115.1	124.9	112	129.1	173.7	114.3	133.5	176.4
Plywood and veneer	102.7	106.4	108.1	107.9	125	162.1	131	178.7	272.8
Particle board and OSB	107	109.8	110.8	113.4	131.1	166.2	123.9	157.3	220.5
Other boards	101.4	104.1	102.9	107	123.4	154.4	134.4	197.3	322.3
Mechanical forest industry, Mm³	**704.2**	**731.8**	**754.5**	**741**	**859.4**	**1117.5**	**813.6**	**1003.6**	**1376.9**

Source: Kallio et al., 2015[98]

Table 13. Production of mechanical forest products in Europe and globally (mill cubic meters).

		Crunch			Bio-Inno			Bio-Stor		
	2010	2020	2030	2050	2020	2030	2050	2020	2030	2050
Europe										
Sawnwood	105	103	102	98	108	111	127	109	102	113
Other solidwood products	5	8	9	10	8	9	12	10	17	26
Particle board and other panels	54	43	37	28	48	47	43	53	57	54
Europe total	164	154	147	137	164	168	181	172	177	192
World										
Sawnwood	369	402	420	449	419	477	612	425	462	539
Other solidwood products	95	106	108	113	110	123	157	129	168	251
Particle board and other panels	175	207	211	209	216	243	293	246	330	468
World total	638	715	739	772	745	843	1061	800	960	790

According to Swedish Forest Industries Federation[99] the consumption of sawn softwood in 2016 was largest in Northern and central Europe. Also Canada and Chile consume relatively much of sawn softwood per capita.

97 Kallio, Lehtilä, Koljonen, Solberg (2015) Best scenarios for the forest and energy sectors – implications for the biomass market. Cleen Oy Research report no D 1.2.1.
98 Kallio, Lehtilä, Koljonen, Solberg (2015) Best scenarios for the forest and energy sectors – implications for the biomass market. Cleen Oy Research report no D 1.2.1.
99 See https://www.forestindustries.se/forest-industry/statistics/sawmill-industry/

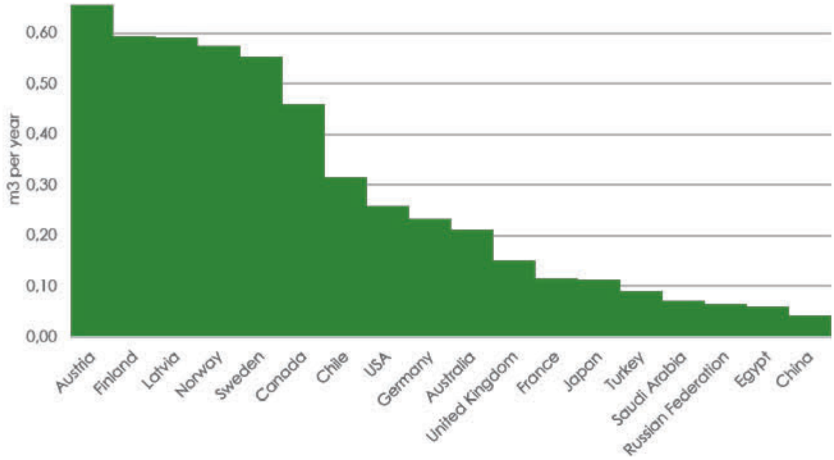


Figure 18. Consumption of Sawn Softwood 2016.

3.5.2.2 Value network actors in the mechanical wood processing

Table 14, Table 15 and Table 16 (below) list the main knowledge triangle actors (innovation/ industry; research and education actors) but excludes institutional actors for whom the similar analysis was not meaningful to perform.

Table 14. Innovation/industry actors in FBA 2.

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
SAWMILLING	Lumber producer, sawmilling operation	Interfor Corp	2	2	Canada	CA, USA, China, Japan, France
	Sawmill machinery	Raute Oyj	1	2	Finland	Latin America: Mexico, Chile, Brazil; Asia, USA, Canada, Europe, Russia
	Saw milling	Weyerhaeuser Inc.	1	2	USA	USAA, Canada
	Saw milling, bioenergy	Versowood Oy	2	1	Finland	
	Wood products; sawmills	Holmen Timber (Holmen)	1	1	Sweden	Scandinavia (main), UK, the rest of Europe, the Middle East and North Africa
	Sawmill machinery	Heinolan sahakoneet Oy	1	1	Finland	Europe, Russia, Asia (Japan, Korea)

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
	Sawmill machinery	Hewsaw / Veisto Oy	1	1	Finland	Sweden, the Baltic Countries, North America, Russia, Central Europe, Southern Hemisphere
	Sawmill	Nordanå Trä (Wood) AB	1	1	Sweden	Japan, China, Italy, Germany, Spain and the UK
SAWN TIMBER, WOOD CONSTRUCTION	Sawn timber and panels	Celulosa Arauco y Constitucion SA, Panels and sawn timber	4	2	Chile	North America; Latin America: BR, AR, CL
	Wood products	Södra Timber	1	1	Sweden	Scandinavia, UK, USA, North Africa
WOOD CONSTRUCTION	Wood products; LVL (laminated veneer lumber), plywood, wood construction	Metsä Wood (Metsä Group)	3	3	Finland	Domestic; Europe
	Wood products; plywood panels	UPM Plywood	1	3	Finland	Europe, Middle East and Africa
	Solid wood products (Remanufactured Wood, plywood, sawn wood)	CMPC (Compañía Manufacturera de Papeles y Cartones)	4	2	Chile	Mercosur
	Engineered wood products	West Fraser Timber Co Ltd	4	2	Canada	USA, CA
	Wood construction products; glulam& bioproducts	Setra Ab	3	2	Sweden	Europe, Asia (CN, JP), North Africa
	Wood-based panels; Oriented Strand Board	Norbord Inc	2	2	Canada	North America, Europe, Asia
	Engineered wood products; building materials manufacturer	Louisiana Pacific Inc.	2	2	USA	USA, Brazil, Chile, Australia, New Zealand
	Wood products, e.g. CLT	StoraEnso Wood Products	2	2	Sweden-Finland	Europe, Australia/NZ
	Wood products, Clue laminated timber -CLT	CLT Finland Oy	1	1	Finland	
WOOD PRODUCTS	Wood products; Furniture	IKEA Ab	2	3	Sweden	Global
	Wood boards for furniture and interior architecture	Masisa SA	3	2	Chile	Latin America; USA; Canada
	Wood products; wood protection	Bergs Timber Ab	1	2	Sweden	UK, USA, Scandinavia, the Middle East/North Africa
	Wood products, e.g. framing material to timbers, decking and siding	Western Forest Products Inc	1	2	Canada	

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
OTHER	Industrial recycling	Metso Oyj, Paper (Flow Control)	4	3	Finland	Europe 31%; North-America 32%; Asia and Pacific 15%

Table 15. Research actors FBA 2.

Main focus area	Research	Links to FBAs	Count of sources	Origin
Forest consultancy; Bio-materials, Forest operations, wood products	FPInnovations	4	2	Canada
Wood processing, biomaterials, biorefining, bioenergy	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	4	2	Australia
Wood protection, timber preservation	Consultant, Jack Norton Timber Protection	1	1	Australia
Bioeconomy	European Forest Institute - EFI	1	1	Finland
Research in wood	Forest Products Laboratory - USDA (United States Department of Agriculture)	1	2	USA

Table 16. Education actors in FBA 2.

Main focus area		University	Links to no of FBAs	Count of sources	Origin
WOOD CONSTRUCTION	Wood and building technologies; biorefinery, bioenergy	University of São Paulo (USP)	5	3	Brazil
	Forest management; wood and building technologies	University of British Columbia	4	3	Canada
	Wood processing, gasification; wood and building technologies	Chalmers University of Technology	2	3	Sweden
	Architecture, construction (wood)	University of Bío Bío	2	2	Chile
	Wood and building technologies	Technical University of Denmark	1	2	Denmark
	System analysis; wood and building technologies	Lund University	1	2	Sweden
	Wood and building technologies	Technical University of Munchen	1	1	Germany
	Wood and building technologies	Edinburgh Napier University	1	1	UK

Main focus area		University	Links to no of FBAs	Count of sources	Origin
	Wood and building technologies	ENSTIB, École Nationale Supérieure des Technologies et Industries du Bois	1	1	France
	Wood and building technologies	Mainz University of Applied Sciences	1	1	Germany
	Wood and building technologies	National University of Ireland	1	1	Ireland
	Wood and building technologies	Norwegian University of Science and Technology	1	1	Norway
	Wood and building technologies	University of Católica de Chile	1	1	Chile
	Wood and building technologies	University of Tecnológica Nacional	1	1	Argentina
	Wood and building technologies	University of Coimbra	1	1	Portugal
	Wood and building technologies	University of Santiago de Compostela	1	1	Spain
	Wood and building technologies	University of Bath	1	1	United Kingdom
	Wood and building technologies	University of L'Aquila	1	1	Italy
	Wood and building technologies	University of Politécnica de Madrid	1	1	Spain
	Wood and building technologies	University of Technology of Sydney	1	1	Australia
	Wood Science and Engineering	Luleå University of Technology	1	1	Sweden
	Wood and Building Technologies, Forestry and Wood	Växjö (Linnaeus) University	2	1	Sweden
WOOD PRODUCTS	Plantation forestry; wood technology	University of Canterbury	4	2	New Zealand
WOOD PRODUCTS	Wood technology, wood chemistry	University of Göttingen	2	1	Germany
WOOD PRODUCTS	Forest science and engineering; engineering of industrial wood	Federal University of Paraná	2	1	Brazil
OTHER	Wood Science	Wallenberg Wood Science Center (WWSC)	2	1	Sweden

3.5.2.3 Knowledge triangle benchmark: strategic objectives

The following listing states (if found in web search) company's strategy and the main products/services in the mechanical wood processing area.

Company	Vision/Strategy	Products
Celulosa Arauco y Constitucion SA, Panels and sawn timber	Renewables for a better life – We help improve people´s lives, developing forest products for the challenges of a sustainable world	Sawn timber: Appearance lumber, industrial furniture lumber, construction lumber and packaging & pallet lumber.
		Panels: Trupan MDF (radiata pine), Ultra particleboard, Duraflake particleboard, Fibrex HDF (High density fiberboard).
CMPC (Compañía Manufacturera de Papeles y Cartones)	The company's mission is to produce and market in a sustainable manner – on the basis of man-made plantations – wood, pulp, paper and tissue products of first-rate quality that are competitive, add value for its stockholders and customers and create development opportunities for its employees and local communities.	Solid wood products: Pulpwood logs, sawn pulpwood, sawn timber, refabricated wood, plywood board, long pulp fiber and short pulp fiber.
IKEA Ab	Becoming people & planet positive	Various products from "Low-cost materials"
Interfor Corp	Interfor is now one of the world's largest lumber providers. With annual capacity of 3 billion board feet from world-class facilities, we serve the needs of customers, strengthen local economies and build value for our employees and our shareholders. And now we're embarking on a bold new vision, capitalizing on opportunity and growing into an even more robust future.	Sawmilling operation: 18 mills and 3 woodlands.
Louisiana Pacific Inc.	n/a	Engineered wood products; building materials manufacturer: Exteriors, framing and panels & sheathing.
Masisa SA	Provide design, performance and sustainability for the creation of each furniture and interior environment in Latin America	Wood boards for furniture and interior architecture: MDP, MDF, MDF MR, Ecoplac, Thick PB, OLB, MDP MR, Melamine & painted boards and Décor panels
Metso Oyj, Paper (Flow Control)	Metso serves customers in the mining, aggregates, recycling, oil, gas, pulp, paper and process industries. Metso is well positioned in all of our customer industries, either globally or in a selected niche market. Our customers' and their customers' needs derive from certain global trends – urbanization of communities, ever increasing need for minerals and the growing demand for oil and gas – and are at the center of what drives us. We provide our customers with world-leading products and services built on technological excellence, experience and the highest safety standard. Our strategy targets higher profitability and lower volatility	Waste recycling: Waste to energy, Waste to fuel, Materials recovery, Mechanical biological treatment, Cement production.
Metsä Wood (Metsä Group)	Metsä Wood provides the premium-quality wood products for construction, industrial and distribution customers. Our aim is to be the best partner for these customers, opening up the almost endless possibilities of wood.	Wood products: Kerto® LVL – laminated veneer lumber, Birch plywood, Spruce plywood, Sawn timber, Finnjoist, Wood construction applications, Industrial applications, Nordic timber.
Norbord Inc	Thriving customer relationships are based on win-win outcomes. We are driven by this strategy, focusing on our key customers and working with them to ensure long-term mutual benefit. We will continue to improve our customer service, product and business development, supply chain effectiveness and technical support. So our customers continue to receive the best.	Wood-based panels; Oriented Strand Board: OSB: SterlingOSB3, SterlingOSB3 Tongue & Groove, SterlingOSB SiteCoat, SterlingOSB Fire Solutions, SterlingOSB BuildBoard, SterlingOSB RoofDek, SterlingOSB StrongFix.

Company	Vision/Strategy	Products
Setra Ab	Setra's sustainability policy builds on the sustainability issues that are most material to our business. It is our guiding principle in the work for a sustainable Setra. Our ambition is that sustainability should permeate our entire value chain.	Wood construction products; Glulam:
StoraEnso Wood Products	Our Purpose is doing good for people and the planet. Replace fossil-based materials with renewable solutions	Wood products: Building solutions (CLT), industrial components, modified wood, LVL, Pellets.
UPM Plywood	Together we are building a sustainable future based on versatile use of renewable wood biomass. Rooted in responsibility – driven by innovation.	Wood products; plywood panels: Coated smooth plywood, veneer, uncoated plywood, coated patterned plywood.
West Fraser Timber Co Ltd	We have a consistent and reliable business model that is based in efficiency and unwavering attention to cost management. We consistently reinvest in our operations to ensure our committed and dedicated staff has the right resources to compete and win in a challenging industry.	Engineered wood products: laminated veneer lumber (LVL) is manufactured from northern lodgepole pine.

The following listing shows selected research institutes' and universities' strategic objectives (the main research projects, areas, programmes and/or departments' focus) in the mechanical wood processing area.

Research organisation/ university	Project/programme/ research area	Source
FPInnovations	Advanced Building Systems Primary Wood Products Manufacturing Secondary wood products manufacturing	https://fpinnovations.ca/researchprogram/advanced-building-systems/Pages/default.aspx https://fpinnovations.ca/researchprogram/Pages/research-program-primary-wood-products-manufacturing.aspx https://fpinnovations.ca/researchprogram/Pages/research-program-secondary-wood-products-manufacturing.aspx
VTT Ltd	Smart cities (Smart energy)	https://www.vttresearch.com/services/sustainable-and-smart-city
Lund University	Timber Engineering and Wood Science Building Materials Building Physics Construction Management Structural Engineering Construction Sciences	http://www.kstr.lth.se/english/research/timber-engineering-and-wood-science/ http://www.byggnadsmaterial.lth.se/english/ http://www.byfy.lth.se/english http://www.bekon.lth.se/english/ http://www.kstr.lth.se/english/ http://www.byggvetenskaper.lth.se/english/
University of Bío Bío	Master in Architectural and Urban Heritage PhD in Architecture and Urbanism	http://postgrados.ubiobio.cl/Masters/40/Architectural_and_Urban_Heritage http://postgrados.ubiobio.cl/PhDs/1/Architecture_and_Urbanism/
Chalmers University of Technology	Centre for Housing Architecture Architecture and Planning Beyond Sustainability	https://www.chalmers.se/en/centres/cba/Pages/default.aspx https://www.chalmers.se/en/education/programmes/masters-info/Pages/Architecture-and-Planning-Beyond-Sustainability.aspx

Research organisation/ university	Project/programme/ research area	Source
	Architecture and Urban Design	https://www.chalmers.se/en/education/programmes/masters-info/Pages/Architecture-and-Urban-Design.aspx
	Design and Construction Project Management	https://www.chalmers.se/en/education/programmes/masters-info/Pages/Design-and-Construction-Project-Management.aspx
	Sound and Vibration	https://www.chalmers.se/en/education/programmes/masters-info/Pages/Sound-and-Vibration.aspx
	Structural Engineering and Building Technology	https://www.chalmers.se/en/education/programmes/masters-info/Pages/Structural-Engineering-and-Building-Technology.aspx
Technical University of Denmark	Construction and Mechanics	http://www.dtu.dk/english/research/research_areas/construction-and-planning
	DTU Civil Engineering	http://www.byg.dtu.dk/english
University of Canterbury	Wood Technology Research Centre	http://www.canterbury.ac.nz/engineering/schools/forestry/research/woodtech/
University of São Paulo (USP)	Architecture and Urbanism	http://www5.usp.br/english/education/undergraduate/courses-offered/architecture-and-urbanism/?lang=en
University of British Columbia	Peter Wall Institute for Advanced Studies/Soft Architecture	https://pwias.ubc.ca/videos/soft-architecture
	Faculty of Applied Science (Advanced manufacturing, clean energy, digital technologies, forest bioeconomy, architecture and landscape architecture, engineering)	https://research.ubc.ca/research-excellence/faculties-centres-institutes/faculty-applied-science

3.5.3 FBA 3: Pulp-paper / new biomaterial production chain

3.5.3.1 Global production and demand in 2030 & 2050 in pulp-paper and biomaterials

The estimates presented in this section (and all the following FBAs) bases on the EFI-GTM model (the global forest sector model), which is a multi-regional and multi-period forest sector model that integrates forestry, forest industries, final demand for forest industry products and international trade in the products.[100] The model includes 61 regions covering the whole world.

[100] Kallio, Lehtilä, Koljonen, Solberg (2015) Best scenarios for the forest and energy sectors – implications for the biomass market. Cleen Oy Research report no D 1.2.1.

Table 17. Assumed reference demand in the scenarios in selected years. World totals.

	Crunch			Bio-Inno			Bio-Stor		
	2020	2030	2050	2020	2030	2050	2020	2030	2050
Newsprint	20.1	19.4	20.2	20.2	19.4	20.2	20.1	19.4	20.2
Uncoated wood containing	13.2	12.6	12.9	13.3	12.9	13.2	13.2	12.6	13
Coated wood containing	11.7	10	10.3	11.7	10.1	10.4	11.7	10	10.3
Uncoated wood free	43.7	43.6	44.7	43.8	43.6	44.7	43.7	43.6	44.7
Coated wood free	23.2	21.2	21.5	23.2	21.3	21.7	23.2	21.2	21.6
Folding boxboard, WLC and other paperboard for packaging	59.7	67	77.9	61.8	73.7	91	59.7	68.1	79.7
Case materials	165.1	185.5	215.2	170.9	204	250.7	165.1	188.8	220.4
Household and sanitary papers	37.6	45.7	61.9	37.6	46.7	63.7	37.6	46.8	64
Other paper and paperboard	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7
Dissolving pulp and new fibers	7.2	9.7	17.5	9.1	35.1	73.7	8.3	14.8	37.1
Pulp and paper industry, Mt	**413.2**	**446.4**	**513.8**	**423.3**	**498.5**	**621**	**414.3**	**457**	**542.7**

Source: Kallio et al., 2015[101]

[101] Ibid.

Table 18. Production of pulp and paper products in the world, in million tons.

		Crunch			Bio-Inno			Bio-Stor		
	2010	2020	2030	2050	2020	2030	2050	2020	2030	2050
Printing and writing papers	143	113	105	104	112	104	101	112	104	100
Cartonboard and case materials	190	235	260	299	242	282	337	234	262	293
Household and sanitary papers	30	37	43	57	37	43	57	36	43	57
Other paper and paperboard	32	31	31	30	31	31	30	31	31	30
Paper and paperboard, Total	395	415	438	491	422	459	526	414	439	480
Sulfate & sulfite pulp	125	137	135	126	137	135	130	136	134	116
Dissolving pulp and new fibers	4	7	10	18	9	35	73	9	15	36
Sulfate pulp, dissolving and other fiber total	129	145	145	144		170	203	145	149	152

Source: Kallio et al., 2018[102]

We observe an increasing demand for both pulps that are driven by Chinese demand.

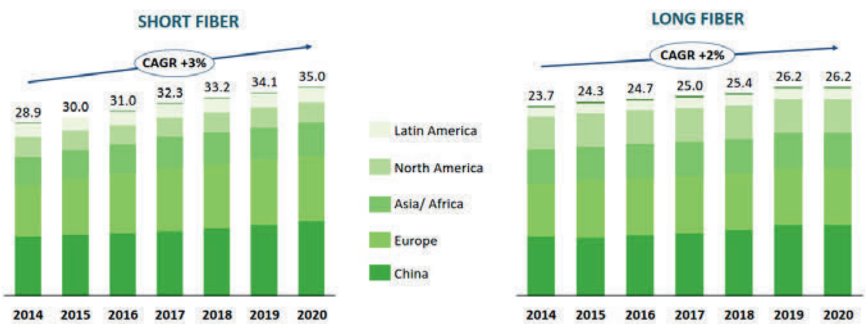
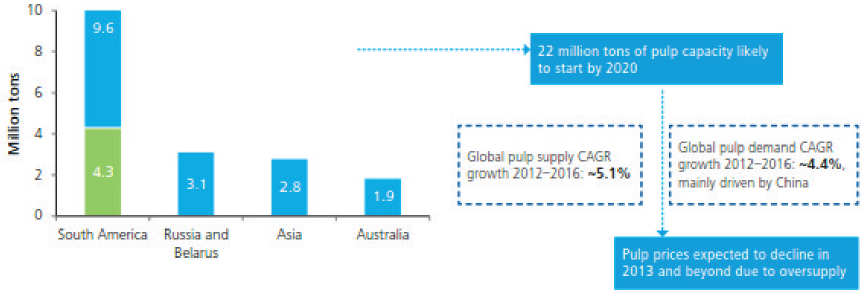


Figure 19. Global demand of pulp (Source: Klabin).

[102] Kallio, Lehtilä, Koljonen, Solberg (2015) Best scenarios for the forest and energy sectors – implications for the biomass market. Cleen Oy Research report no D 1.2.1.



Source: DTTL Global Manufacturing Industry group November 2012 analysis of data from Santander, *Chilean Pulp & Paper Sector: The Short-Term Illusion of Pulp Prices; Downgrading Copec and CMPC*, 28 March 2012

Figure 20. Estimated global pulp capacity additions by 2020 (Source: Deloitte report, 2013) – missing.

3.5.3.2 Value network actors in pulp-paper and biomaterials

Table 19, Table 20 and Table 21(below) list the main knowledge triangle actors (innovation/industry; research and education), excluding institutional actors for whom the similar analysis was not meaningful to perform.

Table 19. Innovation /Industry actors in FBA 3.

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
PULP	Pulp	Celulosa Arauco y Constitucion SA, Pulp	4	2	Chile	China (43%), Europe, Americas
	Pulp, biomaterials	Fibria Celulose, S.A.	3	2	Brazil	Global: Europe (36%), Asia (32%), North America (22%) and Latin America (10%)
	Pulp; biomaterials	Stora Enso Biomaterials	5	4	Sweden-Finland	Global
	Pulp	Metsä Fibre (Metsä Group)	2	4	Finland	Domestic, Russia
	Forest, pulp & paper	UPM Pulp	5	3	Finland	Global
	Pulp, packaging	Powerflute Oyj (Mondi, SA)	1	2	Finland	
	Dissolving pulp (euca)	Bracell ltd (incl. A mill Bahia Specialty Cellulose (BSC))	1	2	Brazil	China, Americas, Europe
	Pulp	Södra Cell	1	1	Sweden	
	Dissolving pulp	Sateri International Ltd	1	1	China	China

Category	Main focus area	Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
PROCESS TECHNOLOGIES & MACHINERY	Industrial recycling; Process industry valves (e.g. pulp & paper)	Metso Oyj, Paper (Flow Control)	4	3	Finland	Europe 31%; North America 32%; Latin America 7%; Asia and Pacific 15%
	Pulp & paper process equipment	ANDRITZ AG	3	2	Austria	Austria, Brazil, Canada, China, Finland, Germany, USA
	Biomass gasification technology, biorefining	Valmet Oyj	4	1	Finland	
PULP & PAPER	Pulp, paper and tissue	CMPC (Compañía Manufacturera de Papeles y Cartones)	4	2	Chile	Mercosur
	Pulp & paper, bioproducts	West Fraser Timber Co Ltd	4	2	Canada	USA, CA
	Pulp and paper; Packaging	Suzano Pulp and Paper /Companhia Suzano Papel e Celulose S.A.	3	2	Brazil	Global; China; United States, Switzerland, United Kingdom; Argentina
	Pulp & paper	Canfor Pulp Products Inc.	3	2	Canada	North America, Europe, Asia
	Pulp, Paper; Paperboard; chemicals	Resolute Forest Products Inc.	3	2	Canada	USA; Canada
	Pulp & Paper; Paperboard, Chemicals	Tembec Inc (acquired by Rayonier Advanced Materials in 2017)	2	2	Canada-USA	North America, France
	Pulp & Paper	Catalyst Paper Corporation	1	2	Canada	
	Pulp & Paper	Mondi Limited	1	2	South Africa	Central Europe, Russia, North America; South Africa
	Pulp & Paper	SAPPI Limited	1	2	South Africa	Southern Africa; North America
	Paper, papergrade pulp	Domtar Corporation	1	2	Canada	
	Pulp & Paper	APP Asia Pulp & Paper	1	1	Indonesia	
	Pulp & Paper	Sun Paper Group	1	1	China	
BIOMATERIALS	Bioproducts	Setra Ab	3	2	Sweden	Europe, Asia (CN, JP), North Africa
	Biorefinery; biomaterials for textile	Kaicell Fibers Oy	2	1	Finland	
	Biocomposite products	UPM Biocomposites	1	1	Finland	
PACKAGING	Packaging paper & board, corrugated boxes, industrial sacks	Klabin SA	4	2	Brazil	Mercosur; us and Austria offices
	Packaging; Fibre-based materials; specialty pulp	Ahlstrom -Munksjö Ltd	2	2	Finland-Sweden	Global

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
	Consumer Board; Corrugated Solution; Packaging paper	Billerudkorsnäs AB	1	2	Sweden	
	Packaging	Tetra Pak Ab	1	2	Sweden/ Switzerland	Global (Latin America: Argentina; Brazil; Chile
	Paperboard	Metsä Board (Metsä Group)	1	2	Finland	
	Packaging	Nefab Group AB (Nefab)	1	1	Sweden	
	Paperboard	Holmen Iggesund Paperboard (Holmen)	1	1	Sweden	
	Packaging	Evergreen Packaging Inc.	1	1	USA	USA, Asia, Middle East
	Packaging, paper	Visy Ltd	1	1	Australia	Australasia; Europe
	Packaging solutions & consumer board	Stora Enso packaging solutions & consumer board	1	2	Sweden-Finland	
PAPER	Paper	Holmen Paper	1	2	Sweden	
PAPER	Paper tissue	SCA - Svenska Cellulosa Aktiebolaget	1	2	Sweden	
PAPER	Paper	UPM Paper/Specialty papers	1	1	Finland	Europe, North America, Asia
PAPER	Paper	Stora Enso Paper	1	1	Sweden-Finland	
PAPER	Paper tissue	Metsä Tissue (Metsä Group)	1	1	Finland	
RECYCLING	Paper, packaging, tissues, recycling	Cascades Inc	1	2	Canada	

Table 20. Research actors in FBA 3.

Main focus area	Research	Links to FBAs	Count of sources	Origin
Forest consultancy; Biomaterials, Forest operations, wood products	FPInnovations	4	2	Canada
Natural products chemistry	INIA España	2	1	Spain
Cellulose derivatives	Instituto de Pesquisas Tecnologicas	2	1	Brazil
Wood processing, biomaterials, biorefining, bioenergy	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	4	2	Australia
Climate change; Biorefineries	Innventia AB /RISE	3	2	Sweden
Biomaterials	CSIR -Council of Scientific and Industrial Research	3	2	South Africa
Forest-based materials	VTT Ltd	3	2	Finland
Forest-based research	Scion Research (a Crown Research Institute -CRI)	2	1	New Zealand

Table 21. Education actors in FBA 3.

Main focus area		University	Links to FBAs	Count of sources	Origin
WOOD CHEMISTRY	Wood technology, wood chemistry	University of Göttingen	2	1	Germany
	Wood chemistry	University of Hamburg	2	1	Germany
BIOPRO-CESSING	Forest sciences, bioprocessing, bioenergy	Sao Paulo State University	3	1	Brazil
BIOMATERIALS	Wood and building technologies; biorefinery, bioenergy	University of São Paulo (USP)	5	3	Brazil
	Plantation forestry; wood technology; Chemical and Process Engineering	University of Canterbury	4	2	New Zealand
	Forest science; Forest Biomaterials	Swedish University of Agricultural Sciences -SLU	4	2	Sweden
	Biomaterials	University KU Leuven	3	1	Belgium
	Biorefineries. Fibrous Material	Universidad Nacional de Misiones	3	1	Argentina

Main focus area		University	Links to FBAs	Count of sources	Origin
	Wood Science; biomaterials	Wallenberg Wood Science Center (WWSC) joint with KHT &Chalmers	2	1	Sweden
	Wood and Building Technologies, Forestry and Wood, biomass	Växjö (Linnaeus) University	2	1	Sweden
	Forest ecosystems, forest management and forest-derived renewable materials	Oregon State University	2	1	USA
PULP	Pulp, biorefinery, bioenergy	University of Federal do Paraná	3	1	Brazil
PULP	Cellulose derivatives	University of Nacional del Litoral	2	1	Argentina
PULP	Pulp and paper	University of Federal de Viçosa	2	1	Brazil

3.5.3.3 Knowledge triangle benchmark: strategic objectives

The following listing states (if found in web search) company's strategy and the main products/services in the pulp/paper and new biomaterial production area.

Company	Vision/Strategy	Products
Ahlstrom - Munksjö Ltd	Expanding the role of fiber-based solutions for a sustainable everyday life.	Packaging: Food packaging and baking, non-food packaging, beverage packing & filter solutions.
		Speciality pulp: Kraft pulp.
ANDRITZ AG	Comprehensive and customizable products portfolio for special industries all over the world.	Pulp: Technology portfolio comprises equipment for woodyard, kraft pulp, dissolving pulp, mechanical pulp, deinked pulp, industrial grades (pulp).
		Paper: Primeline paper and board machines.
Canfor Pulp Products Inc.	To be the global leader in supplying diverse and innovative, quality wood-based products to our highly valued customers.	Pulp: Bleached & unbleached softwood pulp and fibre pulp. Paper: Bleached, coloured and unbleached kraft.
Celulosa Arauco y Constitucion SA, Pulp	Renewables for a better life – We help improve people´s lives, developing forest products for the challenges of a sustainable world.	Pulp: Bleached eucalyptus pulp, bleached radiata and taeda pine pulp, unbleached radiata pine pulp and unbleaced taeda pine pulp.

Company	Vision/Strategy	Products
CMPC	The company's mission is to produce and market in a sustainable manner – on the basis of man-made plantations – wood, pulp, paper and tissue products of first-rate quality that are competitive, add value for its stockholders and customers and create development opportunities for its employees and local communities.	Pulp: Bleached softwood kraft pulp, bleached eucalyptus kraft pulp and sack kraft paper.
		Paper: from wood pulp. Tissues: from Virgin and recycled fiber.
Fibria Celulose, S.A.	At Fibria, innovation is present in all business areas. The company invests in the development of technologies and innovations aligned with its strategy of generating maximum value from its planted forests. This involves developing products and services capable of maximizing productivity, optimizing costs and anticipating trends and clients' expectations, while also offering opportunities to substitute fossil-based products in new markets. In this scenario, competitive innovation is a key company attribute.	Pulp: hardwood pulp, but can be combined with different materials. Elemental Chlorine Free (ECF) and Totally Chlorine Free (TCF) processes.
		Biomaterials: biocomposites, biotechnology, cellulose nanocrystal. Forest/wood: Eucalyptus tree for pulp production.
Klabin SA	Klabin's management practices are guided by sustainable development and its management pursues integrated and responsible growth that combines profitability, social development and a firm commitment to environmental preservation.	Packaging paper & board: Kraft paper (4 variations), recycled paper (2 variations) and paperboard (4 variations).
		Corrugated boxes: all sorts of packaging according to customer's specification in various segments: foods, beverages, cosmetics, electric and electronic appliances, hygiene and cleaning, groceries and flowers, electric materials, chemicals and byproducts, clothing and footwear, glasses and ceramics.
		Industrial sacks: Variety of market segments like: civil construction, foods, chemicals, agribusiness, animal feed and others. Biodegradable, recyclable and produced with raw material from forests especially grown for this purpose.
Metso Oyj, Paper (Flow Control)	Metso serves customers in the mining, aggregates, recycling, oil, gas, pulp, paper and process industries. Metso is well positioned in all of our customer industries, either globally or in a selected niche market. Our customers' and their customers' needs derive from certain global trends – urbanization of communi-	Flow control: Installed base analysis, Maintenance supervision, On-call service, Valve repair, Resident - on-site expert, Metso service container, Valve spare parts, Start-up supervision, Valve technology training, Control performance evaluation service, ValveTriage service, Smart Device Check, Expertune PlantTriage software, Expertune PID Loop Optimizer.

Company	Vision/Strategy	Products
	ties, ever increasing need for minerals and the growing demand for oil and gas – and are at the center of what drives us. We provide our customers with world-leading products and services built on technological excellence, experience and the highest safety standard. Our strategy targets higher profitability and lower volatility.	
Metsä Fibre (Metsä Group)	The objective behind all our operations is to be the most sought-after provider of high-quality bioproducts and services that support our customers' business operations. We keep raising the bar for ourselves and constantly develop our operations, products and skills. Our operations are based on a fine-tuned and transparent process management model that is geared towards catering to our customers' needs. Thanks to our cost-efficient production of northern softwood pulp, we are well-poised to meet future challenges and generate added value for our shareholders. Continuous renewal is our response to changes in the global pulp markets.	Pulp: Multiple softwood, hardwood and bctmp pulps.
Resolute Forest Products Inc.	At Resolute Forest Products, we are one team with one vision where: Profitability and sustainability drive our future.	Pulp: Softwood pulp, hardwood pulp, Fluff pulp, NBSK pulp, RBK pulp. Paper: Tissue paper, newsprint, speciality paper.
Setra Ab	Setra's sustainability policy builds on the sustainability issues that are most material to our business. It is our guiding principle in the work for a sustainable Setra. Our ambition is that sustainability should permeate our entire value chain.	Bioproducts: Cellulose chips, Dry chips, Bark, Sawdust, Fuel mixes.
Stora Enso Biomaterials	Stora Enso Biomaterials utilises its renewable and non-food competing feedstock to develop and produce sustainable solutions.	Pulp: Wood pulp product lines cover both long and short fibres. These include Northern Bleached Softwood Kraft (NBSK) made from pine and spruce and Bleached Hardwood Kraft Pulp (BHKP) made from birch or eucalyptus. For hygiene applications, avariety of fluff pulp grades. Stora Enso also offer dissolving pulp for a wide range of applications.
		Biomaterials: In addition to wood pulp, Stora Enso is already producing lignin, which can be used for coatings and adhesives. Company sells tall oil

Company	Vision/Strategy	Products
		(Crude tall oil) and turpentine (Crude sulphate turpentine), valuable byproducts of the softwood pulp production process, which is used in various industries.
Suzano Pulp and Paper	1. Structural competiveness: operating with low production costs. 2. Adjacent business: Three new fronts: fluff pulp from hardwood fiber, entering tissue market, launching lignin extraction. 3. Redesigning the industry: Seek proactive ways to consolidate or verticalize our operations, since we have a large volume of pulp that could be used to create a vertically oriented business and reduce the risks of product volatility.	Pulp: for papers for sanitary purposes, paper for packaging, special papers, printing and writing paper. Paper: Uncoated, Paperboard (SBS solid bleached sulfate) and cut size.
		Packaging: For food, medicines, beverages, home and personal care products, etc.
Tembec Inc/ Rayonier Advanced Materials	Rayonier Advanced Materials creates one-of-a-kind cellulose specialties products from renewable resources.	Pulp & Paper: manufactures newsprint for publishers of daily newspapers and commercial printers, as well as controlled bulk paper for mass-market paperback book publishers and commercial printers. From High-yield hardwood pulp.
		Paperboard: manufactures lightweight Kallima® Coated Cover Paperboard used for a broad range of commercial printing, publishing and packaging applications.
UPM Pulp	Together we are building sustainable future based on versatile use of renewable wood biomass. Rooted in responsibility – driven by innovation.	Pulp: (Different pulp types from all of the following:) Bleached hardwood kraft pulp, bleached softwood kraft pulp, fluff pulp.
		Paper: Packaging and carton boards, Specialty papers, Woodfree uncoated and coated printing and writing papers, tissue, Magazine and fine papers, Speciality papers, Supercalendered papers, Lightweight coated papers, Woodfree speciality papers.
West Fraser Timber Co Ltd	We have a consistent and reliable business model that is based in efficiency and unwavering attention to cost management. We consistently reinvest in our operations to ensure our committed and dedicated staff has the right resources to compete and win in a challenging industry.	Pulp & papers: Bleached Chemical Thermo-Mechanical Pulp (BCTMP) pulps are used by paper manufacturers to produce printing and writing papers, paperboard products, tissue and towel products and a variety of other paper grades. The mechanical pulps are high yield pulps that require approximately half of the wood required by the traditional kraft pulping process. Northern Bleached Softwood Kraft (NBSK) is used by paper manufacturers to produce a variety of paper

Company	Vision/Strategy	Products
		products, including printing and writing papers and tissues.
		Bioproducts: biomass fuels such as bark, wood residuals and other wood co-products of our manufacturing process. Ongoing innovative areas of research are exploring new methods of using wood byproducts, including enhanced carbon and cellulose bio-composites. Also lignin.

The following listing states (if found in web search) research institutes' and universities' strategic objectives (the main research projects, areas, programmes and/or departments' focus) in the Pulp-paper / new biomaterials.

Research organisation/ university	Project/ programme/ research area	Source
CSIRO	Chemicals and fibres	https://www.csiro.au/en/Research/MF/Areas/Chemicals-and-fibres
CSIR -Council of Scientific and Industrial Research	Beneficiation of fly ash from pulp and paper mills: valorisation into heat-resistant geo-polymers	https://www.csir.co.za/beneficiation-fly-ash-pulp-and-paper-mills-valorisation-heat-resistant-geo-polymers
	Ultrasonic activation of dissolving wood pulp as a pre-treatment to alkali dissolution	https://www.csir.co.za/ultrasonic-activation-dissolving-wood-pulp-pre-treatment-alkali-dissolution
	Characterisation of pulp and paper mill sludge to establish the feasibility for beneficiation	https://www.csir.co.za/characterisation-pulp-and-paper-mill-sludge-establish-feasibility-beneficiation
FPInnovations	Bioproducts	https://fpinnovations.ca/researchprogram/Pages/bioproducts.aspx
	Market pulp	https://fpinnovations.ca/researchprogram/Pages/research-program-market-pulp.aspx
	Paper, packaging and consumer products	https://fpinnovations.ca/researchprogram/Pages/research-program-paper-packaging-consumer-products.aspx
	Pulp and paper	https://fpinnovations.ca/solutions-and-technologies/Pages/overview-pulp-and-paper.aspx
Innventia AB /RISE	Biorefining and pulping (The wood-based biorefinery, chemical pulping and bleaching, mechanical pulping, bioenergy)	http://www.innventia.com/en/Our-Expertise/Chemical-Pulping-and-bleaching/
	Paper and board (Stock preparation, paper chem-	http://www.innventia.com/en/Our-Expertise/Papermaking/

Research organisation/ university	Project/ programme/ research area	Source
	istry, forming, dewatering, drying, surface treatment - coating, paper mechanics, tissue paper) Packaging (Packaging development, production and converting, new packaging materials) New materials (Active materials, barriers and films, carbon fibres from lignin, composite materials, material design, nanocellulose, specialty cellulose for textiles)	http://www.innventia.com/en/Our-Expertise/Packaging/ http://www.innventia.com/en/Our-Expertise/New-materials/
VTT Oy	Bioeconomy and circular economy (Renewable chemicals, sustainable energy and fuels, biobased materials, valuable inorganics, healthy and sustainable food and beverages, key technology platforms for bioeconomy)	https://www.vttresearch.com/services/bioeconomy
Wallenberg Wood Science Center (Chalmers University of Technology & KHT)	The Materials Biorefinery Wood Nanotechnology Treesearch: Sweden's so far largest investment in fundamental research and knowledge and competence building in the field of new materials and speciality chemicals from forest raw material.	http://wwsc.se/research/the-materials-biorefinery/ http://wwsc.se/research/project-ii-processing-fundamentals/ http://wwsc.se/treesearch/
Swedish University of Agricultural Sciences-SLU	Biobased materials and fuels Department of Forest Biomaterials and Technology	https://www.slu.se/en/Collaborative-Centres-and-Projects/biobased-materials-and-fuels/ https://www.slu.se/en/departments/forest-biomaterials-technology/
University of Canterbury	The MacDiarmid Institute (Advanced Materials and Nanotechnology)	http://macdiarmid.ac.nz/
University of São Paulo (USP)	Lignocellulosis materials, paper and cellulose	http://dgp.cnpq.br/dgp/espelhogrupo/0883478982105894#linhaPesquisa

3.5.4 FBA 4: Biorefining for chemicals and energy products

3.5.4.1 Global production and demand in 2030 & 2050 in biorefining

The estimates presented in this section (and all the following FBAs) bases on the EFI-GTM model (the global forest sector model) which is a multi-regional and multi-period forest sector model that integrates forestry, forest industries, final demand for forest industry products and international trade in the products.[103] The model includes 61 regions covering the whole world.

Table 22. CCS (carbon capture and storage) and SNG (synthetic natural gas).

Technology	Feedstock(s)	Available	Investment cost (2030) €/kW(out)	Tech-nical life	Fuel output / feedstock (2030)
Biodiesel, integrated	wood	2020	2627	25	95 %
Biodiesel, integrated	black liquor	2030	2770	25	95 %
Biodiesel, non-integrated	wood, 2nd gen. crops	2020	2145	25	57 %
Biodiesel, non-integrated, CCS	wood, 2nd gen. crops	2030	2482	25	51 %
Biodiesel, non-integrated, CCS	black liquor	2030	3200	25	92 %
Biogasoline, non-integrated	wood, 2nd gen. crops	2030	2459	25	57 %
Biogasoline, non-integrated, CCS	wood, 2nd gen. crops	2030	2803	25	50 %
SNG, non-integrated	wood	2020	1682	25	72 %
SNG, non-integrated, CCS	wood	2030	1983	25	72 %
Heavy bio-oil, integrated	wood	2010	660	25	78 %
Ethanol	1st gen. crops	2010	1060	25	56 %
Ethanol, ligno-cellul.	residues, 2nd gen crops	2020	1990	25	42 %

Source: Kallio et al., 2015[104]

3.5.4.2 Value network actors in biorefining

Table 23, Table 24 and Table 25 (below) list the main knowledge triangle actors (innovation/industry; research and education), excluding institutional actors for whom the similar analysis was not meaningful to perform.

[103] Kallio, Lehtilä, Koljonen, Solberg (2015) Best scenarios for the forest and energy sectors – implications for the biomass market. Cleen Oy Research report no D 1.2.1.

[104] Ibid.

Table 23. Innovation/Industry actors in FBA 4.

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
BIOREFINING MACHINERY	Biomass and wood recycling; Refining (Gasification)	Metso Oyj, Paper (Flow Control)	4	3	Finland	Europe 31%; North America 32%; Latin America 7%; Asia and Pacific 15%
	Ligning technologies	ANDRITZ AG	3	2	Austria	Austria, Brazil, Canada, China, Finland, Germany, USA
	Biomass gasification technology, biorefining; ligning technologies	Valmet Oyj	4	1	Finland	
BIOREFINING	Pulp-based materials; biorefining	Stora Enso Biomaterials	5	4	Finland-Sweden	Global
	Pine oil production	Kaidi Finland Oy	2	2	Finland (Chinese owned)	
	Biorefinery; bioproduct for textile	Kaicell Fibers Oy	2	1	Finland	
	Biorefining	UPM Biorefining	1	1	Finland	
	Biorefinery; microcrystalline cellulose	Bioref Boreal Oy	1	1	Finland	
	Wood-based biochemicals; Ligning, wood-based cellulose nanofibril hydrogel	UPM Biochemicals	1	1	Finland	
BIOFUELS	Biofuels	Cosan (Conglomerate in energy & logistics)	2	2	Brazil	Brazil, Uruguay, Paraguay, Bolivia, UK
	Biodiesel	Neste Oyj	2	2	Finland	Finland, Netherlands, Singapore
	Biofuel power plants; CFB technology	Sumitomo Foster Wheeler Energia Oy	2	1	Finland	
	Forest biofuel	Neova Ab	1	1	Sweden	
	Biofuels	UPM Biofuels	1	1	Finland	
BIOENERGY	Renewable energy; CHP. Gasification	Nexterra Systems Corp.	2	2	Canada	Global, mostly North-America, UK, Japan (& Asia), Brazil

Table 24. Research actors in FBA 4.

Main focus area	Research	Links to FBAs	Count of sources	Origin
Wood processing, biomaterials, biorefining, bioenergy	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	4	2	Australia
Climate change; Biorefineries	Innventia AB /RISE	3	2	Sweden
Biomaterials	CSIR -Council of Scientific and Industrial Research	3	2	South Africa
Forest-based materials; Ligning technologies	VTT Ltd	3	2	Finland
Forest industry management consulting	Pöyry Oy	2	2	Finland
Bioenergy	Bioenergy La Tuque (BELT)	2	1	Canada
Bioethanol	CTBE - Brazilian Bioethanol Science & Technology Lab	2	1	Brazil
Natural products chemistry	INIA España	2	1	Spain
Cellulose derivatives	Instituto de Pesquisas Tecnologicas	2	1	Brazil
Biomaterials	The National Agricultural Technology Institute (INTA)	1	1	Argentina

Table 25. Education actors in FBA 4.

Main focus area		University	Links to no of FBAs	Count of sources	Origin
WOOD CHEMISTRY	Forestry, Biomaterials, chemistry	University of Chile	2	2	Chile
	Wood chemistry	University of Hamburg	2	1	Germany
	Plantation forestry; wood technology, Chemical and Process Engineering	University of Canterbury	4	2	New Zealand
BIOREFINING	Wood and building technologies; biorefinery, bioenergy	University of São Paulo (USP)	5	3	Brazil
	Biorefining	University of Concepción (Unidad de Desarrollo Tecnológico UDT)	2	3	Chile
	Biomaterials	University KU Leuven	3	1	Belgium

Main focus area		University	Links to no of FBAs	Count of sources	Origin
	Biorefineries. Fibrous Material	Universidad Nacional de Misiones	3	1	Argentina
	Pulp, biorefinery, bioenergy	University of Federal do Paraná	3	1	Brazil
	Forest sciences, bioprocessing, bioenergy	Sao Paulo State University	3	1	Brazil
	Cellulose derivatives	University of Nacional del Litoral	2	1	Argentina
	Pulp and paper	University of Federal de Viçosa	2	1	Brazil
	Biorefineries design	University of Campinas	1	1	Brazil
	Biomaterials	University of Girona	1	1	Spain
	Biorefineries	University of Maine	1	1	USA
	Biorefinery, bioenergy	University of San Pablo	1	1	Brazil
BIOFUELS	Bioethanol	University of Autonoma de Coahuila	2	1	Mexico

3.5.4.3 Knowledge triangle benchmark: strategic objectives

The following listing states (if found in web search) company's strategy and the main products/services in the biorefining for chemicals and energy products area.

Company	Vision/Strategy	Products
ANDRITZ AG	Comprehensive and customizable products portfolio for special industries all over the world.	Tailor-made solutions[105]
Cosan	Cosan focuses its investments on strategic industries, such as agribusiness, fuel and natural gas distribution, lubricants and logistics.	Biofuels from sugarcane, ethanol, biomass pellets from sugarcane straw and bagasse.
Kaidi Finland OY	Kaidi Finland Oy wants to enable premium quality pine oil production in Finland.	Pine oil production: From sustainable wood-based biomass and harvesting remains and even leftover bark from the forest industry. Pine oil can be used as a standalone product or as a blend with other petroleum/diesel products.
	Metso serves customers in the mining, aggregates, recycling, oil, gas, pulp, paper	Refining (gasification): Trunnion mounted ball valves.

[105] https://www.andritz.com/spectrum-en/news/tech-talk-lignin-removal

Company	Vision/Strategy	Products
Metso Oyj, Paper (Flow Control)	and process industries. Metso is well positioned in all of our customer industries, either globally or in a selected niche market. Our customers' and their customers' needs derive from certain global trends – urbanization of communities, ever increasing need for minerals and the growing demand for oil and gas – and are at the center of what drives us. We provide our customers with world-leading products and services built on technological excellence, experience and the highest safety standard.	Biomass and wood recycling: Stationary and mobile pre-shredders, fine shredders.
Neste Oyj	Our goal is to do more with less. That is why we continuously are searching for new renewable raw materials, such as waste and residues.	Biodiesel: Neste MY Renewable Diesel, produced 100% from renewable raw materials. 33% lower levels of fine particulates (and a smaller number of particulates in general), 9% less nitrogen oxides (NOx), 30% less hydrocarbons (HC), 24% lower carbon monoxide (CO) emissions, reduced levels of polyaromatic hydrocarbons (PAH).
Nexterra Systems Corp.	Our mission is to make the world cleaner and more sustainable by creating valuable energy and chemicals from local, renewable waste. Our goal is to help our customers reduce energy costs and become leaders in sustainability by delivering reliable renewable energy solutions.	Renewable energy; CHP.
		Gasification: core technology is a fixed-bed updraft gasification system in biomass which works in feedstocks of Wood (bark/chips, sawdust), Clean Construction and Demolition Debris, Biosolids from Sewage Sludge. Other potential feedstocks under development: RDF (Refuse Derived Fuel), Poultry Litter, Compost Material, Switchgrass, Agricultural Residues.
Stora Enso Biomaterials	Stora Enso Biomaterials utilises its renewable and non-food competing feedstock to develop and produce sustainable solutions. Stora Enso Biomaterials offers a variety of pulp grades to meet the demands of paper, board, tissue, textile and hygiene producers. The mission of Biomaterials is to find new, innovative ways to utilize the valuable raw material, wood while simultaneously running existing pulp and by-products businesses as efficiently as possible, based on customers' needs.	Pulp-based materials: dissolving pulp for a wide range of applications including textiles, pharmaceuticals, car tyres, cement, sponges, hair dye and food. Care product line contains a variety of fluff grades (Untreated, Semi-Treated, Treated, LKC and Low Mullen.
		Biorefining: tall oil (Crude tall oil) and turpentine (Crude sulphate turpentine), valuable byproducts of the softwood pulp production process, which is used in various industries. Also, Lignin and glucose. Biorefining concept[106].

[106] http://biomaterials.storaenso.com/Aboutus-Site/Pages/The-Stora-Enso-biorefinery-concept.aspx

The following listing states selected research institutes' and universities' strategic objectives (the main research projects, areas, programmes and/or departments' focus) in the biorefining for chemicals and energy products.

Research organisation/ university	Project/programme/ research area	Source
CSIRO	Chemicals and fibres	https://www.csiro.au/en/Research/MF/Areas/Chemicals-and-fibres
Innventia AB /RISE	Biorefining and pulping (The wood-based biorefinery, chemical pulping and bleaching, mechanical pulping, bioenergy)	http://www.innventia.com/en/Our-Expertise/Chemical-Pulping-and-bleaching/
CSIR	Biorefinery industry development facility	https://www.csir.co.za/biorefinery-industry-development-facility-0
VTT Oy	Bioeconomy and circular economy (Renewable chemicals, sustainable energy and fuels, biobased materials, valuable inorganics, healthy and sustainable food and beverages, key technology platforms for bioeconomy)	https://www.vttresearch.com/services/bioeconomy
University of Chile	Biochemistry Chemistry	http://www.uchile.cl/carreras/4986/bioquimica http://www.uchile.cl/carreras/4988/quimica
University of Canterbury	Chemical and processing engineering	http://www.canterbury.ac.nz/engineering/schools/cape/research/
University of São Paulo (USP)	Chemistry Biochemical Engineering	http://www5.usp.br/english/education/undergraduate/courses-offered/chemistry/?lang=en http://www5.usp.br/english/education/undergraduate/courses-offered/biochemical-engineering/?lang=en
University of Concepción UDT - Science, technology and innovation in bioeconomy. Departments: Biomaterials, Bioenergy, bioproducts, environment and services, technology management	Bioproducts research lines: Processes of chemical conversion of biomass; Lignocellulosic materials; Natural additives Biomass research lines: Containers and packaging; Bioplastics; Elastomeric Materials; Antimicrobial polymers	https://en.udt.cl/bioproducts/ https://en.udt.cl/biomaterials/

3.5.5 FBA 5: Bioenergy

3.5.5.1 Global production and demand in 2030 & 2050 in bioenergy

The estimates presented in this section (and all the following FBA) bases on the EFI-GTM model (the global forest sector model) which is a multi-regional and multi-period forest sector model that integrates forestry, forest industries, final demand for forest industry products and international trade in the products.[107] The model includes 61 regions covering the whole world.

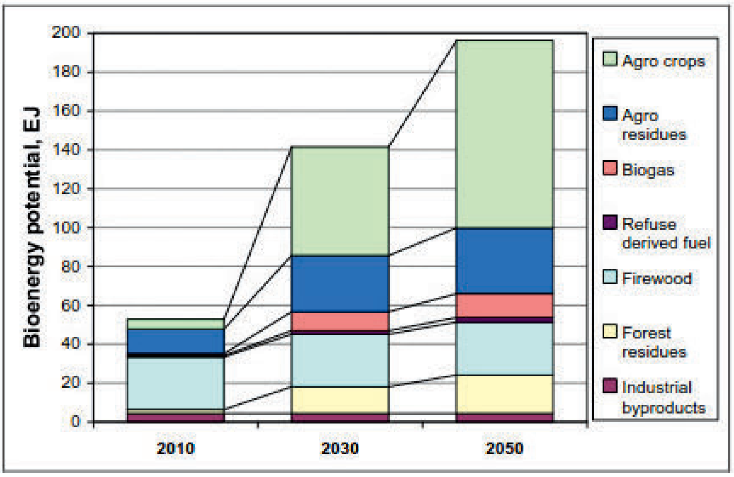


Figure 21. Assumed bioenergy potential on global level. (Source: Kallio et al., 2015)[108]

[107] Kallio, Lehtilä, Koljonen, Solberg (2015) Best scenarios for the forest and energy sectors – implications for the biomass market. Cleen Oy Research report no D 1.2.1.
[108] Ibid.

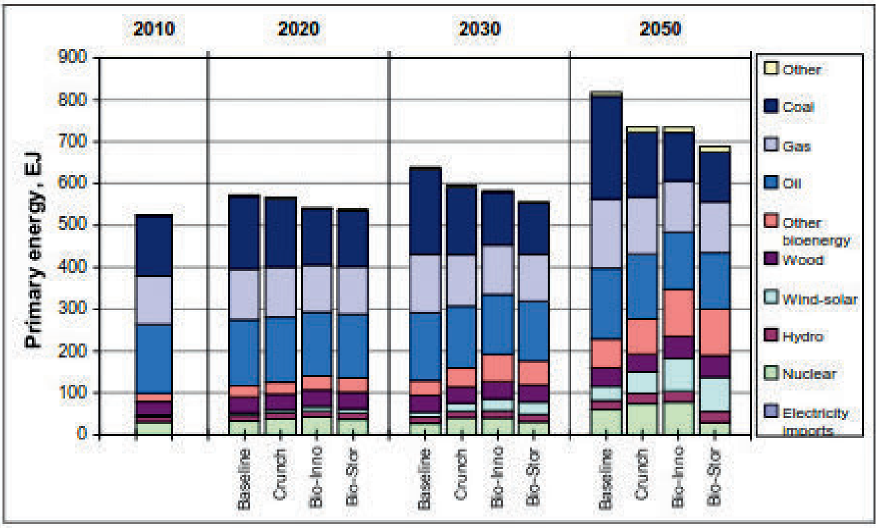


Figure 22. Global primary energy supply in the scenarios. (Source: Kallio et al., 2015)[109]

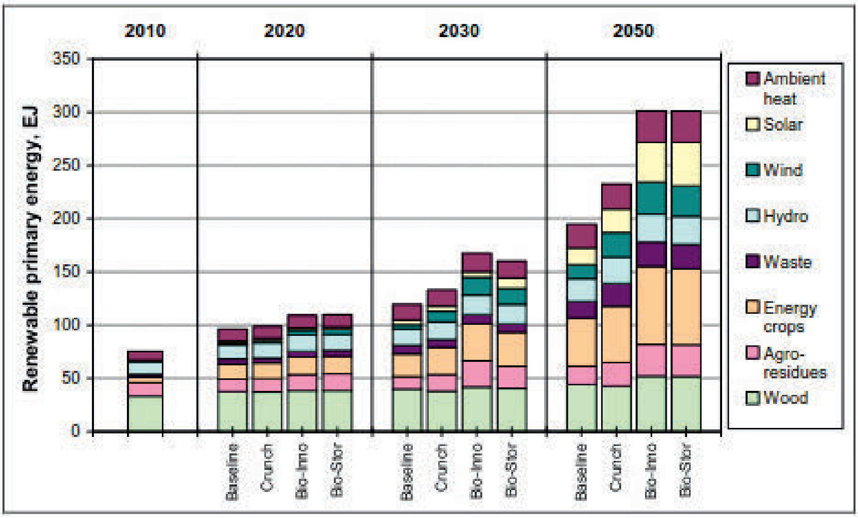


Figure 23. Global supply of renewable primary energy. (Source: Kallio et al., 2015)[110]

109 Ibid.
110 Kallio, Lehtilä, Koljonen, Solberg (2015) Best scenarios for the forest and energy sectors – implications for the biomass market. Cleen Oy Research report no D 1.2.1.

Table 26. Assumed demand for energy wood for heat, power and liquid fuels in the scenarios.

			2010	2020	2030	2040	2050
Finland	Crunch	h&p	15	26	26	28	31
		liq. fuels	0	4	9	19	16
		total	15	30	35	47	47
	Bio-Inno	h&p	15	26	28	32	27
		liq. fuels	0	3	11	13	9
		total	15	29	39	45	36
	Bio-Stor	h&p	15	27	27	27	24
		liq. fuels	0	3	7	13	18
		total	15	30	34	40	42
Europe	Crunch	h&p	152	172	203	243	250
		liq. fuels	0	14	35	63	74
		total	152	186	238	306	324
	Bio-Inno	h&p	152	238	261	258	242
		liq. fuels	0	13	30	176	230
		total	152	251	291	434	472
	Bio-Stor	h&p	152	238	265	255	225
		liq. fuels	0	14	38	177	287
		total	152	252	303	432	512
World	Crunch	h&p	458	975	1153	1219	1793
		liq. fuels	2	185	265	884	828
		total	460	1160	1418	2103	2621
	Bio-Inno	h&p	458	1283	1300	1250	1837
		liq. fuels	2	196	570	2130	2754
		total	460	1479	1870	3380	4591
	Bio-Stor	h&p	458	1244	1313	1498	1964
		liq. fuels	2	206	685	2250	3422
		total	460	1450	1998	3748	5386

Source: Kallio et al., 2015[111]

3.5.5.2 Value network actors in bio-energy

Table 27, Table 28 and Table 29 (below) list the main knowledge triangle actors (innovation/industry; research and education), excluding institutional actors for whom the similar analysis was not meaningful to perform.

111 Ibid.

Table 27. Innovation /industry actors in FBA 5.

	Main focus area	Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
BIO-MASS	Forest management	FORESTRY CORPORATION	2	2	Australia	
BIOMASS LOGISTICS	Forest harvesting machines; Collection of biomass (FBA5)	JohnDeere Forestry Inc (Deere& Company)	2	3	USA	Global
	Forest machines manufacturer, harvesters; collection of biomass	Ponsse Oyj	2	3	Finland	Global (sales offices - Europe: SE, NO, FR, UK, IR), USA, RU, HK, CN, (Latin America: BR, UY)
PROCESS TECHNOLOGIES	Biomass production technology -fluidized bed combustion technologies; ligning technologies	ANDRITZ AG	3	2	Austria	Austria, Brazil, Canada, China, Finland, Germany, USA
	Manufacturing, power plant	ABB Inc	1	2	Switzerland	
	Renewable energy (gasification)	Amec Foster Wheeler plc (UK) /John Wood Group PLC (UK)	1	2	UK (USA)	Latin America market of biomass power 8.5%
	Biomass gasification technology, biorefining; ligning technologies	Valmet Oyj	4	1	Finland	
	Biomass energy machinery (Gasification)	Metso Oyj, Biomass energy	1	1	Finland	Global, Europe, North America, Latin America 10% of biomass market
BIOENERGY SOLUTIONS	Biomass energy	Babcock & Wilcox Vølund A/S	1	1	Denmark	
	Biomass energy	Dresser-Rand	1	1	Germany	Latin America market in biomass power 12%
BIOENERGY-BIOMASS	Forest, pulp & paper; energy, pellets	Canfor Corp	3	2	Canada	
	Biomass residues, pellets, bioenergy	StoraEnso Wood Products	2	2	Sweden-Finland	FBA2: Europe, Australia/New Zealand
BIOENERGY-BIOFUEL	Biofuels	Cosan (Conglomerate in energy and logistics)	2	2	Brazil	Brazil, Uruguay, Paraguay, Bolivia and UK
	Biofuels; sawdust and ligning technologies for bioenergy	St1 Biofuels Oy	1	1	Finland	
	Biofuel power plants; CFB technology	Sumitomo Foster Wheeler Energia Oy	2	1	Finland	

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
BIOENERGY-BIO-OILS	Pine oil production	Kaidi Finland OY	2	2	Finland (in Chinese ownership)	
	Biocrude; Fast Pyrolysis technology, pyrolysis oil	Ensyn Inc	1	2	Canada	USA, Brazil
BIOENERGY-PULP	Packaging paper and board, corrugated boxes, industrial sacks	Klabin SA	4	2	Brazil	Mercosur; USA and Austria offices
	Bioenergy	UPM Energy	3	4	Finland	
	Pulp, bioenergy	Metsä Fibre (Metsä Group)	2	4	Finland	Domestic, Russia. In FBA2 local markets
	Pulp, forestry, paper and tissue, solid wood products	CMPC (Compañía Manufacturera de Papeles y Cartones)	4	2	Chile	Mercosur
	Pulp, forest, wood, new biomaterials; bioenergy	Fibria Celulose, S.A.	3	2	Brazil	Global: Europe (36%), Asia (32%), North America (22%) and Latin America (10%)
	Forestry, pulp and paper; Packaging	Suzano Pulp and Paper /Companhia Suzano Papel e Celulose S.A.	3	2	Brazil	Global; China; USA, Switzerland, United Kingdom; Argentina
	Forest Products, Pulp, Paper & Paperboard, and Chemicals	Resolute Forest Products Inc.	3	2	Canada	USA; Canada
	Bioenergy	Celulosa Arauco y Constitucion SA, Energy	1	2	Chile	Latin America (CL, AR, UY)
BIOENERGY-SAWMILL	Wood boards for furniture and interior architecture	Masisa SA	3	2	Chile	Latin America; USA; Canada
	Engineered wood products (e.g. laminated veneer lumber (LVL)); pulp & paper, bioproducts; bioenergy	West Fraser Timber Co Ltd.	4	2	Canada	USA, CA
	Engineered wood products; building materials manufacturer	Louisiana Pacific Inc.	2	2	USA	USA, Brazil, Chile, Australia, New Zealand
	Saw milling, bioenergy; use of sawdust in bioenergy in pellets	Versowood Oy	2	1	Finland	
GASIFICATION	Biomass combustion and gasification technologies	DP Cleantech	1	1	China	Asia, Latin America 21% mkt share of biomass power
	Renewable energy; CHP. Gasification	Nexterra Systems Corp.	2	2	Canada	Global, mostly North-America,

Main focus area		Company/ Innovation actor	Links to FBAs	Count of sources	Origin	Market
						UK, Japan (& Asia), Brazil
	Bioenergy; gasification	Enerkem Inc	1	1	Canada	
PELLETIZA-TION	Pellet production	Zilkha Biomass Energy LLC	1	1	USA	
TORREFAC-TION	Bioenergy; torrefaction	Airex Énergie Inc.	1	1	Canada	
	Bioenergy; torrefaction	Diacarbon Inc	1	1	Canada	

Table 28. Research actors in FBA 5.

Main focus area	Research	Links to FBAs	Count of sources	Origin
Forest consultancy; Biomaterials, Forest operations, wood products	FPInnovations	4	2	Canada
Wood processing, biomaterials, biorefining, bioenergy	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	4	2	Australia
Climate change; Biorefineries; bioeconomy	Innventia AB /RISE	3	2	Sweden
Forest-based materials; Ligning technologies, bioenergy technologies	VTT Ltd	3	2	Finland
Forest research; biomass	Finnish Forest Research Institute -Luke	2	2	Finland
Forest industry; bioenergy	Wood Resources International LLC	1	2	USA
Bioenergy	Bioenergy La Tuque (BELT)	2	1	Canada
Bioethanol	CTBE - Brazilian Bioethanol Science and Technology Lab	2	1	Brazil
Bioenergy	Sadc -Southern African Development Community	1	1	Southern Africa

Table 29. Education actors in FBA 5.

Main focus area		University	Links to FBAs	Count of sources	Origin
BIOMASS	Forest management; wood and building technologies; biomass	University of British Columbia	4	3	Canada
	Forest science, Forest Biomaterials; biomass	Swedish University of Agricultural Sciences -SLU	4	2	Sweden
	Biomaterials	University KU Leuven	3	1	Belgium
BIOREFINING	Biorefining	University of Concepción (Unidad de Desarrollo Tecnológico UDT)	2	3	Chile
	Biorefineries. Fibrous Material	Universidad Nacional de Misiones	3	1	Argentina
BIOENERGY-PULP	Pulp, biorefinery, bioenergy	University of Federal do Paraná	3	1	Brazil
BIOENERGY-GASIFICATION	Wood processing, gasification of biomass; wood and building technologies	Chalmers University of Technology	2	3	Sweden
BIOENERGY-BIOFUELS	Bioethanol	University of Autonoma de Coahuila	2	1	Mexico
BIOENERGY	Wood and building technologies; biorefinery, bioenergy	University of São Paulo (USP)	5	3	Brazil
	Bioenergy, logistics	Lappeenranta University	2	1	Finland

3.5.5.3 Knowledge triangle benchmark: strategic objectives

The following listing states (if found in web search) company's strategy and the main products/services in the bio-energy area.

Company	Vision/Strategy	Products
ANDRITZ AG	Comprehensive and customizable products portfolio for special industries all over the world.	Biomass production technology (Biomass pelleting technologies): Hammer mills, air & dust filters, pellet mills, conditioners, rotary valves, automation and process control, pocket feeder, air density separator and biomass handling technology. Fluidized bed combustion technologies: EcoFluind BFB boilers & PowerFluid CFB boilers. Automation systems for biomassa production (Load balancing increased lifetime, integrated lubrication control, cooling for control of critical process areas, exact mass temperature control).
Canfor Corp	To be the global leader in supplying diverse and innovative, quality wood-based products to our highly valued customers.	Energy/pellets: Sawmill residue conversion to wood pellets & industrial grade fuel pellets.
CMPC	The company's mission is to produce and market in a sustainable manner – on the basis of man-made plantations – wood, pulp, paper and tissue products of first-rate quality that are competitive, add value for its stockholders and customers and create development opportunities for its employees and local communities.	n/a
Fibria Celulose, S.A.	At Fibria, innovation is present in all business areas. The company invests in the development of technologies and innovations aligned with its strategy of generating maximum value from its planted forests. This involves developing products and services capable of maximizing productivity, optimizing costs and anticipating trends and clients' expectations, while also offering opportunities to substitute fossil-based products in new markets. In this scenario, competitive innovation is a key company attribute.	Bioenergy: Bio-oil, lignin. Forest/ wood: Eucalyptus tree for pulp production
JohnDeere Forestry Inc (Deere& Company)	Innovation means inventing, designing, and developing breakthrough products and services that have high appeal in the marketplace and strengthen customer preference for the John Deere brand. Innovation extends to using the latest technology to establish world–class manufacturing processes and applying the most advanced information technology tools and practices throughout the company.	Collection of biomass: Skidders, feller bunchers, knuckleboom loaders, bunchers, swing machines, harvesters, forwarders.
Klabin SA	Klabin's management practices are guided by sustainable development and its management pursues integrated and responsible growth that combines profitability, social development and a firm commitment to environmental preservation.	n/a
Masisa SA	Provide design, performance and sustainability for the creation of each furniture and interior environment in Latin America	n/a

Company	Vision/Strategy	Products
Metsä Fibre (Metsä Group)	The objective behind all our operations is to be the most sought-after provider of high-quality bioproducts and services that support our customers' business operations. We keep raising the bar for ourselves and constantly develop our operations, products and skills. Our operations are based on a fine-tuned and transparent process management model that is geared towards catering to our customers' needs. Thanks to our cost-efficient production of northern softwood pulp, we are well-poised to meet future challenges and generate added value for our shareholders. Continuous renewal is our response to changes in the global pulp markets.	Bioenergy: Bioproducts created from the side-streams of the pulp production process. Products such as biogas, biocomposites and fibre-based fabrics for example are already being developed together with partner companies.
Ponsse Oyj	Ponsse specialises in the production, sales and maintenance of forest machines designed for the cut-to-length method and in the related information systems. Ponsse constantly develops its products and services, keeping a close eye on the new features expected by the forest machine industry and entrepreneurs. Our mission is to contribute to our customers' success with productive and reliable Ponsse forest machines and services. It is our promise to be the "Logger's Best Friend".	Collection of biomass: Load scale, Multi-stemming, Variable load areas.
Resolute Forest Products Inc.	At Resolute Forest Products, we are one team with one vision where: Profitability and sustainability drive our future.	n/a
Suzano Pulp and Paper	1. Structural competiveness: operating with low production costs. 2. Adjacent business: Three new fronts: fluff pulp from hardwood fiber, entering tissue market, launching lignin extraction. 3. Redesining the industry: Seek proactive ways to consolidate or verticalize our operations, since we have a large volume of pulp that could be used to create a vertically oriented business and reduce the risks of product volatility.	n/a
West Fraser Timber Co Ltd	We have a consistent and reliable business model that is based in efficiency and unwavering attention to cost management. We consistently reinvest in our operations to ensure our committed and dedicated staff has the right resources to compete and win in a challenging industry.	Bioenergy: From sustainable & well-managed forestlands, Wood chips, sawdust and mill shavings sources from our mills, "Hog fuel" which is unprocessed mill wood fibre and bark pieces, Branches and other woody material resulting from harvesting, thinning or other forest management activities

The following listing shows selected research institutes' and universities' strategic objectives (the main research projects, areas, programmes and/or departments' focus) in the bio-energy area.

Research organisation/ university	Project/programme/research area	Source
Innventia AB/ RISE	Biorefining and pulping (The wood-based biorefinery, chemical pulping and bleaching, mechanical pulping, bioenergy)	http://www.innventia.com/en/Our-Expertise/Chemical-Pulping-and-bleaching/
FPInnovations	Biorefinery and energy	https://fpinnovations.ca/researchprogram/Pages/research-program-biorefinery-energy.aspx
CSIRO	Hydrogen Energy Systems Australia has access to vast energy resources through sun, wind, biomass, natural gas and coal, all of which can be used to produce hydrogen and/or the desired energy carrier compound.	https://www.csiro.au/en/About/Future-Science-Platforms
VTT ltd	Low carbon energy (Future energy systems, sustainable energy and fuels)	https://www.vttresearch.com/services/low-carbon-energy
Swedish University of Agricultural Sciences -SLU	Bio4Energy research environment SLU Biogas Center	https://www.slu.se/en/departments/forest-biomaterials-technology/research/ongoing-projects/bio4energy-ny/ https://www.slu.se/en/Collaborative-Centres-and-Projects/biogas-at-slu/
University of British Columbia	Biomass and Bioenergy Research Group at UBC Chemical and Biological Engineering Department The wood pellet research laboratory (BBRG)	https://biomass.ubc.ca/
Chalmers University of Technology	Sustainable Energy Systems Swedish Gasification Centre - node centre for indirect gasification of biomass	https://www.chalmers.se/en/education/programmes/masters-info/Pages/Sustainable-Energy-Systems.aspx https://www.chalmers.se/hosted/cigb-en
University of Concepción (Unidad de Desarrollo Tecnológico UDT)	Bioenergy research lines: Bio-oil as a platform for obtaining chemical products; Carbonaceous materials from pyrolysis with catalytic and agro-industrial applications; Development of modular technology for pyrolysis process; Energy densification of biomass; Decentralised electrical/heat generation systems (CHP); Thermal storage by phase change; Chemical storage of electrical energy; Hybrid and carbon-based materials	http://en.udt.cl/bioenergy/
University of São Paulo (USP)	Ph.D. Program in Bioenergy: cooperation between University of São	http://sites.usp.br/phdbioenergy/about-2/

Research organisation/ university	Project/programme/research area	Source
	Paulo (USP), University of Campinas (UNICAMP) and São Paulo State University (UNESP). Research group of bioenergy - GBio	http://www.iee.usp.br/gbio/

3.6 Forest industry in benchmark countries

This section introduces benchmark countries' forest industries and forest bioeconomy strategies. In some countries forest-based bioeconomy concept is more prominent (mainly in northern hemisphere countries) than in others. Comparative information was collected, e.g. in terms of statistics, as far it as possible, but due different practices in national statistical accounts, this information was not always available. Information search was performed in June-July 2018.

3.6.1 Finland

Figure 24 below illustrates the annual wood flows in Finland in 2013.

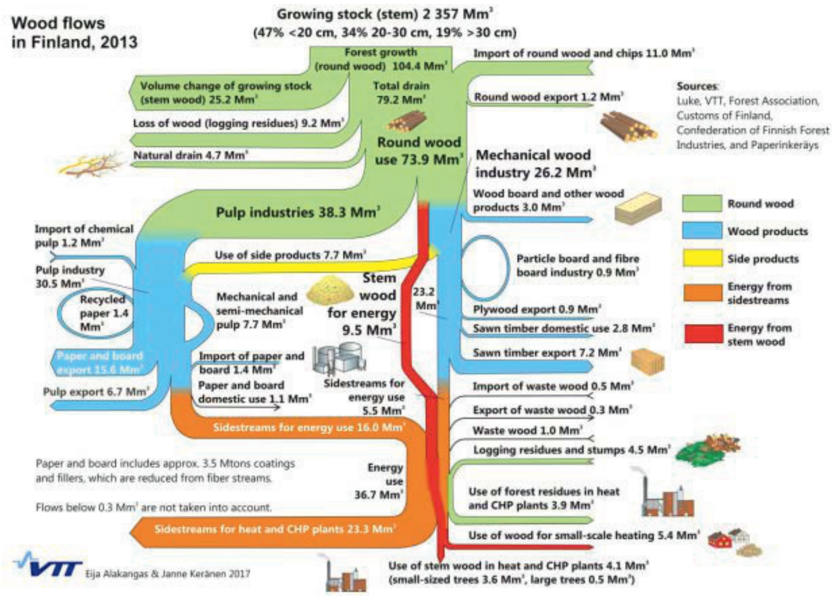
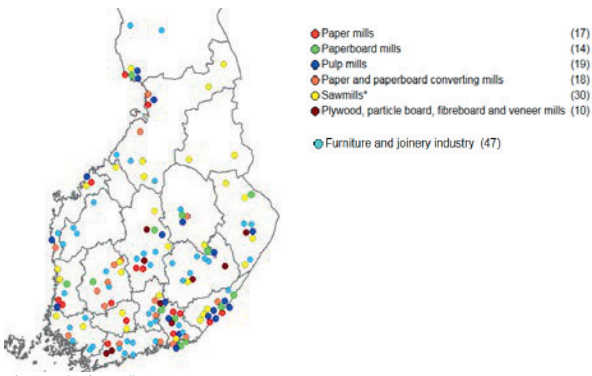


Figure 24. Wood flows in Finland 2013.[112]

The Finnish forest industry production plants are presented in picture (Figure 25) below. The picture shows number and location of different types of plants.



SOURCE: Finnish Forest Industries Federation; *FFIF members' sawmills, **Member companies of the Association of Finnish Joinery and Furniture Industries

Figure 25. Forest industry production plants in Finland.

[112] Source: Advanced forest energy concepts; Case studies from Finland. Alakangas et al. 2017. VTT Research Report.

Finland is also home to a number of near-term scheduled investments and expansions across the forest supply chain[113]). Investments are possible of the relative balance in supply and demand and the stable costs of wood.

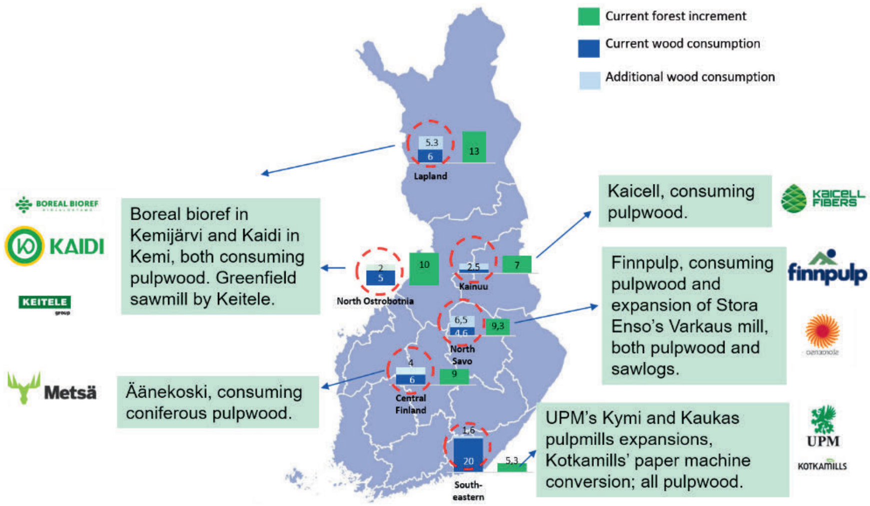


Figure 26. Forest investments in Finland.

The strategic goals of the Finnish Bioeconomy Strategy are:

1) **A competitive operating environment for the bioeconomy.**
   A competitive operating environment will be created for bioeconomy growth.
2) **New business from the bioeconomy.**
   New business will be generated in bioeconomy by means of risk financing, bold experiments and crossing of sectoral boundaries.
3) **A strong bioeconomy competence base.**
   The bioeconomy competence base will be upgraded by developing education, training and research.
4) **Accessibility and sustainability of biomasses.**
   Availability of biomasses, well-functioning raw material markets and sustainability of the use of biomass will be secured.

Vision for Finland: Sustainable bioeconomy solutions are the foundation of well-being and competitiveness in Finland (see more on Finnish Bioeconomy strategy[114].

Useful information sources which provide vast amount statistics of the magnitude of Finnish forest industry:

---

113 Forest Industry in Finland & Russia: Opportunities & Challenges, March 20, 2018, Vasylysa Hänninen https://induforgroup.com/forest-industry-in-finland-russia-opportunities-challenges/

114 http://biotalous.fi/wp-content/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf

- Finnish Forest Industries, https://www.forestindustries.fi/
- Finnish Forest Association, https://www.smy.fi/en/
- The Finnish Sawmills Association, https://www.sahateollisuus.com/en
- Finnish bioeconomy, http://www.bioeconomy.fi/wood-and-forest/

3.6.2 Sweden

The picture below (Figure 27) illustrates the Wood Flow for the forest industries in Sweden.[115]

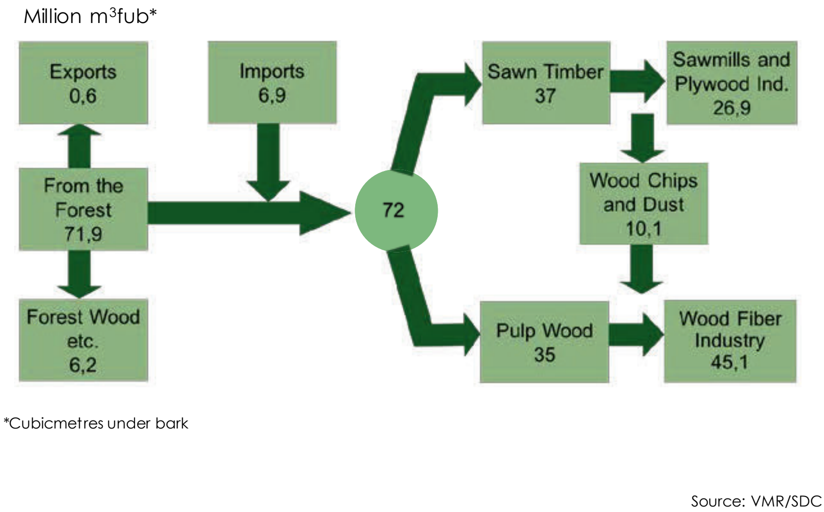


Figure 27. Wood flow for the Forest industries.

The size of Swedish forest industry is indicated by the amount of members of the Swedish Forest Industries Federation:[116]

- 50 pulp and paper mills
- 120 sawmills
- 40 companies closely connected to the production of pulp, paper or timber goods.

Swedish bioeconomy strategy states the following priority areas in R&D:[117]

1) The replacement of fossil-based raw materials with bio-based raw materials

---

115 https://www.forestindustries.se/forest-industry/statistics/swedish-forests

116 https://www.forestindustries.se/forest-industry/facts-and-figures

117 See Swedish Strategy for a Bio-based Economy http://www.formas.se/PageFiles/5074/Strategy_Biobased_Ekonomy_hela.pdf. See also Swedish Wood - a department within The Swedish Forest Industries Federation. Swedish Wood is supported by the Swedish sawmill and glulam industries. https://www.swedishwood.com/about_us/ and Swedish Forest industry Federation. https://www.forestindustries.se/

2) Smarter products and smarter use of raw materials
3) Change in consumption habits and attitudes
4) Prioritisation and choice of measures
5) Swedish Research and Innovation.

A good practice from Sweden are cluster initiatives which include the development of infrastructure and pilot plants and co-location of company R&D on university campuses. One of the strongest clusters in Sweden is Paper Province cluster[118] which has transformed it from paper and pulp to forest bioeconomy cluster. Cluster works in the field of forest-based bioeconomy in Värmland and the surrounding regions. It has over 100 member companies of which 10% are start-ups.

To support clusters in regional development, government of Sweden has set up a test bed network of open innovation platforms for companies to test and pilot their products. New test bed for developing green technologies, called LignoCity, was set up originally in 2007 as a test environment for LingoBoost technology, in collaboration with Innventia (RISE), Nordic Paper (a Norwegian company operating in Sweden and Norway) and Paper Province cluster. LingoCity is an open platform for companies can develop and scale up technology that refines lignin to new climate-friendly fuels, chemicals and materials.

3.6.3 New Zealand

A picture below (Figure 28) shows wood flow for New Zealand in 2013.

[118] http://paperprovince.com/)

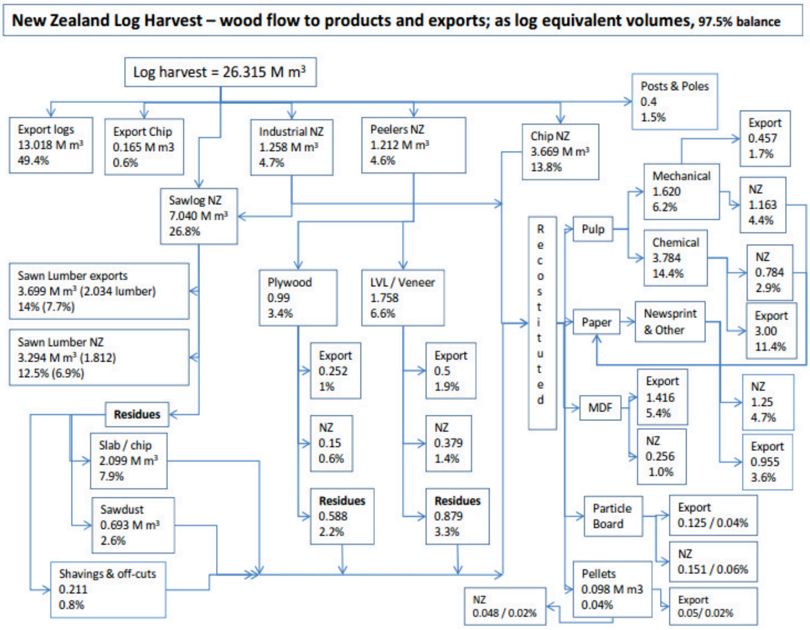


Figure 28. New Zealand wood flow.[119]

Forestry in New Zealand is geared to both domestic and export demand. Some 44% of harvested logs and varying percentages of processed forest products are destined for world markets. Australia, China, Japan, the Republic of Korea, the USA, Indonesia and India account for more than 80 per cent of the value of these exports. Apart from logs, exports include sawn timber, wood chips, panels, pulp and paper and other products.[120]

NZIER[121] presents in a recent report the following key facts about the contribution of forestry to New Zealand.

119 Source: WoodScape Study – Technologies and Markets February, 2013.

120 Source: https://www.nzfoa.org.nz/plantation-forestry

121 NZ Institute of Economic Research -NZIER (2017) Plantation forestry statistics Contribution of forestry to New Zealand NZIER report to New Zealand Forest Owners Association & New Zealand Farm Forestry Association funded by the Forest Growers Levy Trust Inc. https://www.nzfoa.org.nz/resources/file-libraries-resources/discussion-papers/602-nzierreport-2017/file

New Zealand's Primary Sector Science Roadmap highlights the following areas of importance that science needs to support:

1) Sustaining, protecting and adapting our natural resources
2) Growing productivity and profitability with environmental, social and cultural acceptability
3) Integrating primary production systems, people, communities and values
4) High-value products for consumers.

To the four areas science needs to support, roadmap has identified 8 research themes. See more of Strengthening New Zealand's bioeconomy for future generations.[122]

A more specific New Zealand Forest Growers' Science and Innovation Plan[123] in 2015 lists the following research objectives:

- Protect forest assets and markets from adverse factors
- Improve productivity and uniformity within and between trees
- Sustain and enhance forestry's licence to operate
- Improve efficiency and safety in operations and supply chain logistics
- Ensure species options for diversity of sites and markets.

These identified five key research objectives to help transform plantation forestry from a log production business to the starting point of a market led and automated capital intensive manufacturing industry.

Additional strategic objectives are set in New Zealand forest and wood products industry strategic action plan.[124] This offers objectives for 2020, and new plan is in progress at Woodco Association.

Useful information sources:

- Bioenergy Association, https://www.bioenergy.org.nz
- New Zealand Forest Owners Association, https://www.nzfoa.org.nz/
- The Wood Council of New Zealand (Woodco), http://woodco.org.nz/.

122 https://www.mpi.govt.nz/dmsdocument/18389/loggedIn
123 https://www.nzfoa.org.nz/resources/file-libraries-resources/research-science-technology/574-s-and-i-2015/file
124 http://woodco.org.nz/images/stories/pdfs/ForestWood_Strategic_Action_Plan.pdf

3.6.4 Australia

According to FIAC[125], Australia's forest industry comprises businesses involved in growing and harvesting trees, processing wood and wood fibre, manufacturing pulp, paper and engineered, reconstituted and solid wood products, and businesses that export, import, wholesale and retail forest products. The industry also includes organisations that employ forestry and forest product-related researchers. Figure 29 below shows exports of Australian forest industry in 2014.

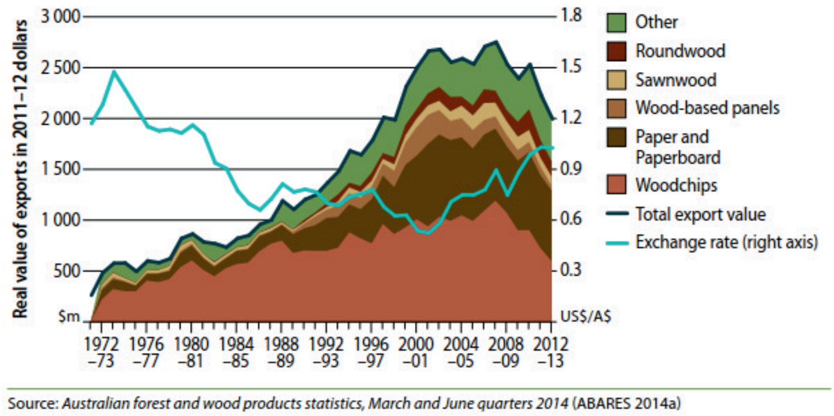


Figure 29. Forest product exports in Australia.[126]

Australia's does not have a forest-based bioeconomy strategy as such. A national forest industry plan is in progress but forest associations and other relevant actors have outlined their strategic objectives to rush this work. For example, the role of forest residues in bioenergy are described in 'Opportunities for Primary Industries in the Bioenergy Sector – National Research, Development and Extension Strategy'[127].

More specific strategic objectives are offered by Forest Industry Advisory Council (FIAC)[128] in 2016. Council states eight strategies for transforming Australian's forest product industry by 2050:

1) Preserve the existing productive forest estate
2) Optimise forest management by focusing on strategic regions
3) Expand the productive forest estate in strategic regions
4) Discover new and enhanced ways to use wood fibre
5) Develop technologies to commercial scale

[125] http://www.agriculture.gov.au/forestry/industries/fiac/transforming-australias-forest-industry
[126] Source: Commonwealth of Australia, 2015
[127] https://www.agrifutures.com.au/wp-content/uploads/publications/14-056.pdf
[128] http://www.agriculture.gov.au/forestry/industries/fiac/transforming-australias-forest-industry

6) Promote and enable market adoption
7) Promote the industry as being environmentally friendly and socially responsible
8) Broaden community support for the industry.

Additional points are found in Australian forest product association's (Ausfpa) report[129] to national forest industry plan. [130]

Informative studies:

- Utilisation of plantation eucalypts in engineered wood products, James R B Hague, 2013. http://www.fwpa.com.au/images/processing/PNB290-1112_uses%20of%20plantation%20Euc%20eng%20wood%20products.pdf

- Processing methods for production of solid wood products from plantation-grown Eucalyptus species of importance to Australia, Russell Washusen, 2013. http://www.fwpa.com.au/images/processing/PNB291-1112A_processing_methods_for_SW_products_euc_plantations.pdf

- Overcoming Psychological Barriers to Widespread acceptance of Mass Timber Construction in Australia, Paul Kremer and Mark Symmons, 2016 http://www.fwpa.com.au/images/marketaccess/2016/Final_Report_Web_PNA309-1213_.pdf

- Commonwealth of Australia 2015, Meeting Market Demand: Australia's Forest Products And Forest Industry, Forest Industry Advisory Council, Department of Agriculture. https://www.google.fi/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiaku-8h-XbAh-WKJJoKHXo8AAAQFggmMAA&url=http%3A%2F%2Fwww.agriculture.gov.au%2FSiteCollectionDocuments%2Fforestry%2Ffiac-issues-paper.pdf&usg=AOvVaw0VKC2OyeLl2zMBOuskn4Q8

3.6.5 Canada

In terms of production, Canada is the second-largest exporter of forest products in the world.[131]

Canadian industry by the numbers (Source: Statistics Canada, 2016). [132]

---

[129] http://ausfpa.com.au/publications/towards-a-national-forest-industries-plan-key-industry-asks/

[130] Other sources include: AFPA, http://ausfpa.com.au/about/; Forest and Wood Products Australia, http://www.fwpa.com.au; Forest Industry Advisory Council (FIAC), http://www.agriculture.gov.au/forestry/industries/fiac; and Timber NSW, http://timbernsw.com.au

[131] Canadian Council of Forest Ministers (2017). Forest Bioeconomy Framework for Canada. https://www.ccfm.org/pdf/10a%20Document%20-%20Forest%20Bioeconomy%20Framework%20for%20Canada%20-%20E.pdf

[132] See https://www.statcan.gc.ca/eng/start

Key Figures	Total Exports by Product
Forest Sector Revenues (2015): $67 Billion	Pulp: $7.6 Billion
Forest Sector GDP: $21.8 Billion	Paper: $9.5 Billion
Share of GDP: 1.3%	Wood: $17.5 Billion
Share of Manufacturing GDP: 12.5%	Total Exports: $34.6 Billion
	Trade SurplUSA: $23.3 Billion

Canadian Council of Forest Ministers Innovation Committee launched a comprehensive approach for increasing and accelerating bio-based activities in Canada. Their report 'Forest Bioeconomy Framework for Canada'[133] represents several objectives under four pillars to make Canada a global leader in the use of forest biomass for advanced bioproducts and innovative solutions. These set objectives are:

1) Advance green employment in forest sector
2) Promote partnerships with indigenous peoples to co-create innovations for forest bioeconomy
3) Establish effective standards for forest biomass resources and advanced bioproducts
4) Enhance data collection and management on bioeconomy
5) Coordinate outreach and marketing of forest bioproducts
6) Support bioeconomy procurement programs
7) Develop effective and updated regulations to maximize market opportunities for forest bioeconomy
8) Facilitate an innovation ecosystem in use of forest biomass
9) Support continued research, development, and deployment in forest sector transformation
10) Develop innovative financial mechanisms for forest bioeconomy.

In addition, Canada has introduced 26 federal level initiatives in 2015 to boost forest sector innovations. [134]Canadian Council of Forest Ministers Innovation Committee has created an innovation action plan for Canadian forest industry.[135] The identified actions centralise on three pillars: collaborate, engage and mobilise.

Figure 30 illustrates Canadian forest sector innovation systems[136]. The Canadian Wood Fibre Centre (CWFC) together with FP innovations are the main actors in forest innovation. Since 2007, the Government of Canada has been supporting ini-

[133] Ibid.
[134] Forest Sector Innovation in Canada 2015 cled fibre-based biorefineries ustry 2016 ()we have subcontracted. ources from VTT and, in particular, FBA 1 and 2 require addihttps://www.ccfm.org/pdf/CCFM%20Innovation%20Compendium%20August%2017%20EN%202015.pdf
[135] http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/37112.pdf
[136] https://www.ccfm.org/pdf/CCFM%20Innovation%20White%20Paper%20-%20May%2028%202015%20-%20English.pdf

tiatives that foster innovation and create new market opportunities for Canada's forest sector via The Forest Innovation Program (FIP).[137] Futures Bio-Pathway projects that started in 2011 focused Canada strongly towards bio-refining and bioenergy.[138]

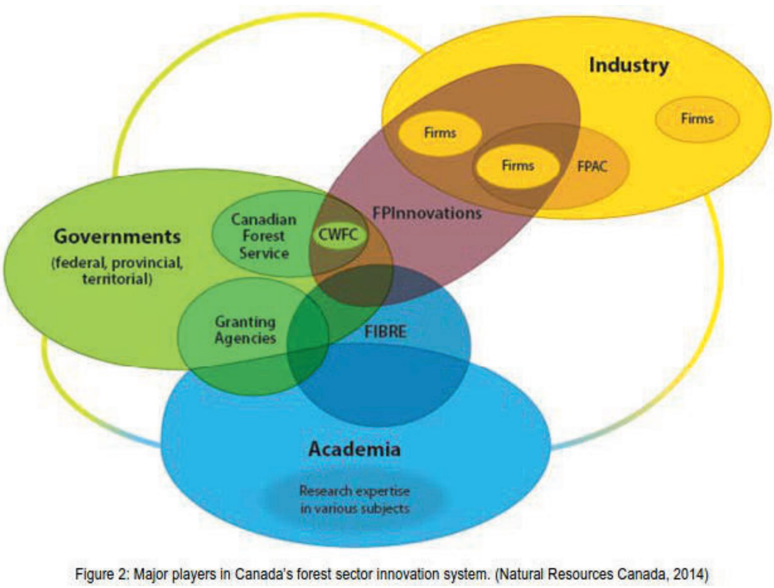


Figure 30. Canadian forest sector innovation system.[139]

Information sources:

- Canadian Council of Forest Ministers, https://www.ccfm.org/english/
- The Forest Products Association of Canada (FPAC), http://www.fpac.ca/
- Canadian Institute of Forestry, http://www.cif-ifc.org/about/
- For wood construction in British Columbia, https://www.naturallywood.com/.

3.6.6 South Africa

Figure 31 illustrates South African hardwood and softwood plantation areas by use. 73% of softwood goes to sawlogs, while 87% of hardwood ends up as pulpwood.

137 http://www.nrcan.gc.ca/forests/federal-programs/13137
138 http://www.fpac.ca/wp-content/uploads/BIOPATHWAYS-II-web.pdf
139 Canadian Council of Forest Ministers (2017). Forest Bioeconomy Framework for Canada. https://www.ccfm.org/pdf/10a%20Document%20-%20Forest%20Bioeconomy%20Framework%20for%20Canada%20-%20E.pdf

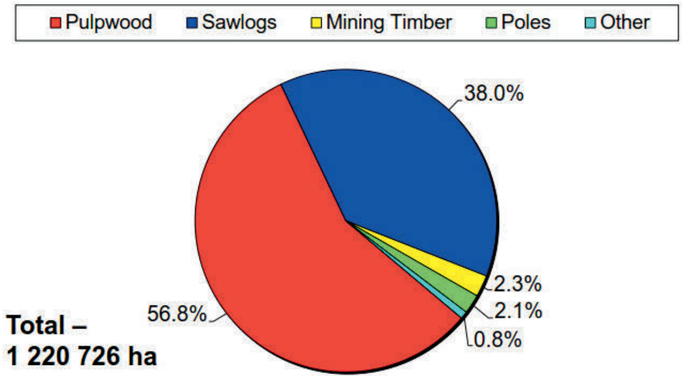


Figure 31. South African plantation areas by use.[140]

Figure 32 illustrates in turn South African hardwood and softwood roundwood by use. Also, the majority of round softwood goes to sawlogs, and the most of hardwood ends up as pulpwood.

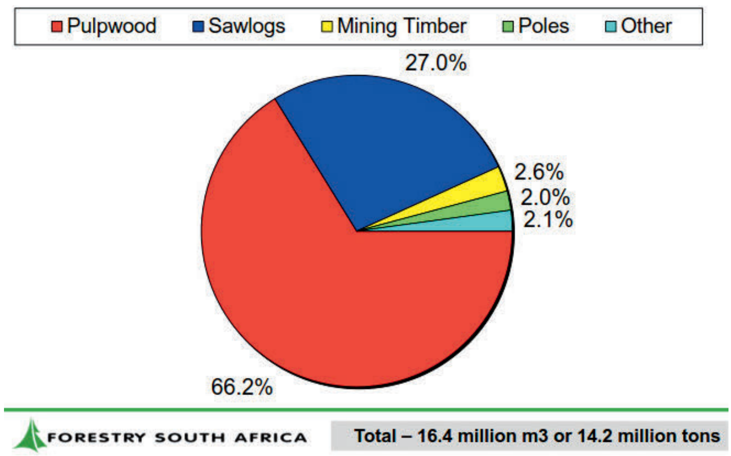


Figure 32. South African roundwood use.

The South African forest products industry constitutes of:

- Total number of processing plants: 151
    - 75 sawmills
    - 35 pole plants
    - 17 pulp, paper & board mills

[140] Godsmarck, R., (2017). South African Forestry and Forest Products Industry 2016. http://www.forestry.co.za/uploads/File/industry_info/statistical_data/new%20lay-out/South%20African%20Forestry%20&%20Forest%20Products%20Industry%20-%202016%20(R).pdf

- 1 Match Factory
- 2 Veneer Plants
- 4 Charcoal Plants
- 17 Mining Timber Mills.

The bioeconomy strategy of South Africa has not a strong focus on forest or wood-based products but concentrates largely to biotechnology applications.[141] However, forest focused objectives are presented in the Forestry 2030 Roadmap[142].

The Roadmap states the following strategic objectives:

1) Facilitate improved timber availability and secure supply of timber to ensure sustainability of entire timber value chain;
2) Increase the contribution of all types of forests and related goods and services to the quality of life of South Africans with particular focus on rural and disadvantaged communities;
3) Promote conservation of forest biological diversity, ecosystems and habitats, while promoting the fair and equitable distribution of their economic, social, health and environmental benefits;
4) Facilitate skills development, awareness raising and information sharing with a view to enhance the profile of forestry as a sector;
5) Implement innovative ways to enhance and streamline the regulatory environment to assist the sector to be compliant while reaching its potential in terms of sustainable development;
6) Create enabling institutional and financial arrangements for sustainable forest management;
7) Maintain the South African forest sector as a knowledge-based enterprise, adapt to addressing constraints to growth in the sector and managing the risks to growth;
8) Strengthen international and regional partnership in order to enhance sustainable forest management.

Information sources:

- Sawmilling South Africa (SSA), http://www.sawmillingsouthafrica.co.za/
- Forestry South Africa (FSA), http://www.forestry.co.za
- The paper manufacturers association, http://www.thepaperstory.co.za/
- Institute for Timber Construction, http://itc-sa.org/.

3.6.7 Brazil

Figure 33 (below) shows the quantity and value of Brazilian forest industry production.[143]

141 The Bio-economy Strategy, Department of Science and Technology, South Africa (2013).
142 http://extwprlegs1.fao.org/docs/pdf/saf149602.pdf
143 Source: http://snif.florestal.gov.br/en/estatisticas-florestais

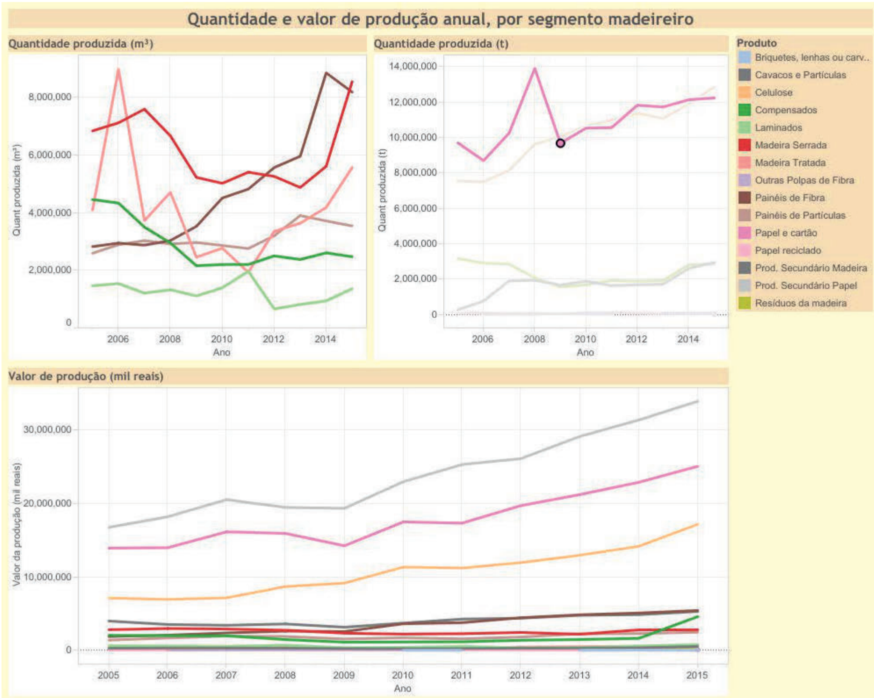


Figure 33. The quantity and value of Brazilian forest industry production.

Figure 34 (below) shows the extraction of Brazilian forest non-wood products.[144]

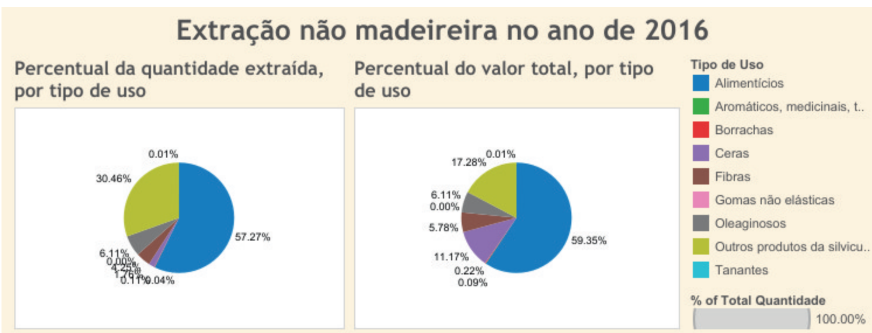


Figure 34. The extraction of Brazilian forest non-wood products.

[144] Source: http://snif.florestal.gov.br/en/estatisticas-florestais

According to German Bioeconomy Council (2015)[145], Brazil has no official bioeconomy strategy. For this reason, only secondary sources which have English summaries have been used.

Examples of main initiatives in Brazilian bioeconomy are[146]:

- Chemistry Industry Development Plan (2015): to promote projects in technological development and investment in the manufacture of chemical products.
- Brazilian Company of Industrial Research and Innovation (EMPAPII) outlines actions on bioeconomy: Biocontrol and biotechnological processes in the sustainable management of agricultural pests; Biomass Processing; Renewable Chemistry; Green Chemistry; Environmental Biotechnologies Applied to the Recovery of Contaminated Areas and to the Valorization of Waste from the Industrial Sector; and Development and Scale-up of Biotechnological Processes.
- SENAI Institute of Innovation – ISI: Support program for increase the Brazilian industrial competitiveness, with more than 150 projects in biomass, biosynthetics and biotechnology.

Initiatives emphasise bioenergy and development of the (agricultural) biotechnology sector, which are both strong areas of Brazil.

Information sources:

- About agroforestry, see Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA), https://www.embrapa.br/en/tema-integracao-lavoura-pecuaria-floresta-ilpf
- Serviço Florestal Brasileiro, http://www.florestal.gov.br/ & http://snif.florestal.gov.br/en/
- Pulp and Paper Technical Association of Brazil (ABTCP), http://www.abtcp.org.br/.

3.6.8 Chile

Illustration (Figure 35) shows Chilean wood products flow in 2016.[147]

[145] https://biooekonomie.de/sites/default/files/brazil.pdf
[146] http://www.fapesp.br/eventos/2017/6dialogue/08-11-17/15h45_Bruno_Nunes.pdf
[147] Chilean Forestry Sector 2017, https://wef.infor.cl/index.php

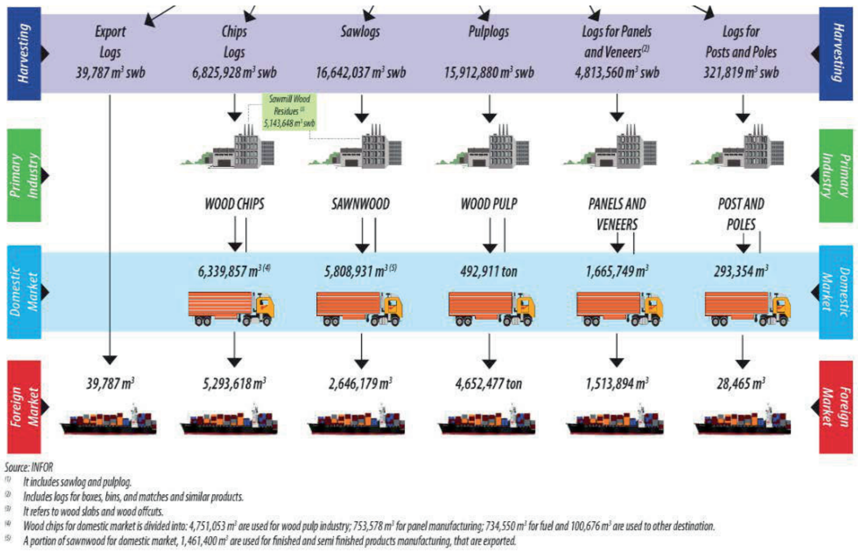


Figure 35. Chilean wood products flow in 2016.

Figure 36 shows Chilean forest exports of main products in 2016[148]

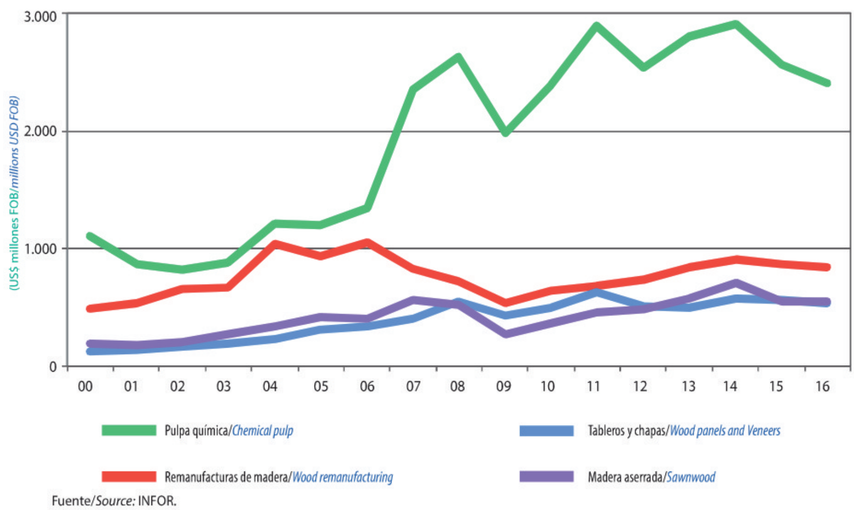


Figure 36. Chilean forest exports of main products in 2016.

Forest-based bioeconomy was not found for Chile, but other strategic documents exist that set objectives for Chilean forest sector development. One these is a Forest

148 Ibid.

Policy 2015–2035 by CONAF[149]. The forest policy has been structured around four strategic axes, each one of them disaggregated into objectives of impact and outcome objectives. The strategic axes are:

1) Setting up a public forest institute for forestry.
2) Boosting silviculture, industrialization and the integral use of forest resources.
3) Generating the necessary conditions and instruments for forest development to reduce social and technological gaps.
4) Conserving and increasing nation's forest heritage.

Another forest sector related document is a Chilean wood energy strategy[150] which has the following strategic objective:

To promote the sustainable production and efficient use of forest biomass as a non-conventional renewable energy, to contribute to the country's energy security and independence, through the inclusion and delivery of skills to small owners of native forests, plantations and micro-enterprises in the sector.

Creation of the wood energy strategy ensures (1) the sustainability of the forest resource and the supply of firewood and biomass in the long term; (2) strengthening of the promotion of the inclusion of small and medium producers and the professionalization of the sector and the quality of the product; and (3) implementation of a firewood traceability model, which will improve and strengthen CONAF's current regulatory and oversight role in forestry.

Information sources:

- CONAF - Corporación Nacional Forestal, http://www.conaf.cl/nuestros-bosques/
- Corporación Chilena de la Madera, http://www.corma.cl/about-us
- INFOR - Instituto Forestal, https://www.infor.cl/.

3.7 Current FBA value networks in Uruguay

This section describes value networks in Uruguay and it uses similar categorisation of knowledge triangle actors than global benchmark in section 3.5. The background information of the total Uruguayan value network actors is provided in Table 30 and Figure 37.

149 http://www.conaf.cl/wp-content/files_mf/147204722435024LIBRO.pdf

150 http://www.conaf.cl/wp-content/files_mf/1456844180EstrategiaDendroenerg%C3%ADa_CONAF20152030.pdf

Table 30. Different actor groups in each FBA in Uruguay.

FBA ecosystem actors in Uruguay	Forest management (FBA1)	Mechanical wood processing (FBA2)	Pulp-paper & new biomaterials (FBA3)	Biorefining (FBA4)	Bioenergy (FBA5)
Innovation/industry	16	17	3	2	7
Research	2	2	2	2	1
University	4	5	4	2	0
Institutional	3	3	5	2	2

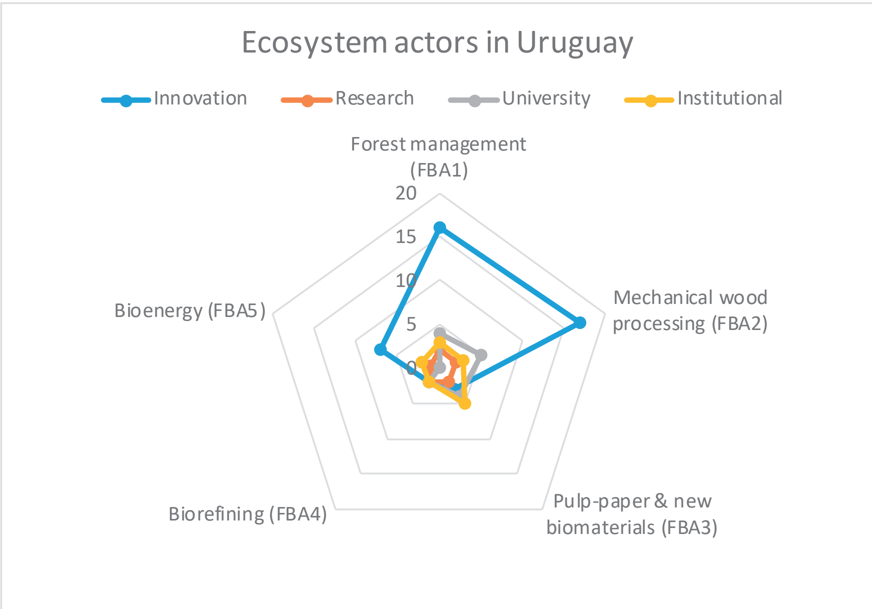


Figure 37. Distribution of different ecosystem actors in Uruguay.

3.7.1.1 Innovation/industry actors in forest-based bioeconomy in Uruguay

The following section introduces innovation/industry actors in Uruguayan forest-based bioeconomy (in all FBAs). Innovation actor in here refers to companies operating in forest industry regardless of their innovation capacity. In the context of innovation system, industry's role is to adopt and commercialise innovations.

3.7.1.1.1 FBA 1 - Forest management value network actors in Uruguay

Table 31. Value network actors in forest management in Uruguay.

Main focus area		Company/ Innovation actor	Links to FBAs	Market	Importance in value chain	Power	Main supply chain activity
SILVICULTURE	Forest management, chips exports	Forestal Atlántico Sur	1	domestic	low	Medium	Move, sell
	Forest management, chips exports	Foresur	1	domestic	low	Medium	sell
	Logs sale; Forestry Financial Trust	Bosques del Uruguay	1	domestic	low	Small	sell
	Logs sale; Logs, poles, forestry services	IDALEN SA	1	domestic	low	Small	sell
	Pulp; Cellulose	UPM - Forestal Oriental	3	global	high	High	Buy, make
	pulp	Montes del Plata	4	global			
BIOMASS	Energy; Petroleum, cement	ANCAP	4				
ROUND WOOD	Logs export	Muradir SA	1	domestic		Small	sell
	Wood products	URUFOR - COFCOFUSA	3	domestic	medium	Medium	make, sell
	Logs export	TLG-SA	1	MERCOSUR	low	Small	sell
	Wood products; Plywood and veneer	Lumin (BTG Pascual) (prev. Uruply SA)	3	regional	medium	Medium	make
	Wood products; Boards and chips	FYMNSA	3	domestic	medium	Medium	make
	Wood products; Boards and poles	Forestal Caja Bancaria	2	domestic	low	low	make
	Wood products; Treated wood, poles	Matra SA	2	domestic	low	low	make
	Wood products; Treated wood for construction, poles, round wood for export	Arazatí	2	domestic	low	low	make
	Wood products; Treated wood	Madex	2	domestic	low	low	make

3.7.1.1.2 FBA 2 - Mechanical wood processing value network actors in Uruguay

Table 32. Value network actors in mechanical wood processing in Uruguay.

Main focus area		Company/ Innovation actor	Links to FBAs	Market	Importance in value chain	Power	Main supply chain activity
SAWMILL-ING	Wood products	URUFOR - COFCOFUSA	3	domestic	medium	Medium	make, sell
WOOD PRODUCTS	Wood products; Clear, standard and pallet boards	Frutifor	2	regional	medium	Medium	make
	Wood products; Treated wood, low scale furni-tures	Cerro Pelado	1	domestic	low	low	make
WOOD CONSTRUCTION	Wood products; Plywood and ve-neer	Lumin (BTG Pascual) (prev. Uruply SA)	3	regional	medium	Medium	make
	Wood products; Boards and chips	FYMNSA	3	domestic	medium	Medium	make
	Wood products; boards	Tingelsur S.A.	1	domestic	medium	low	make
	Wood products; boards	JCE	1	regional	low	low	make
	Wood products; Boards and poles	Forestal Caja Bancaria	2	domestic	low	low	make
	Wood products; pallets	IMNsur	1	domestic	low	low	make
	Wood products; Treated wood, poles	Matra SA	2	domestic	low	low	make
	Wood products; Treated wood for construction, poles	Oxipal	1	domestic	low	low	make
	Wood products; Treated wood for construction, poles, round wood for export	Arazatí	2	domestic	low	low	make
	Wood products; Treated wood	Lidenor	1	domestic	low	low	make
	Wood products; Treated wood	Madex	2	domestic	low	low	make
	Wood construc-tion;	Maguinor Maderas	1	domestic	low	low	make

3.7.1.1.3 FBA 3 - Pulp-paper & new biomaterials value network actors in Uruguay

Table 33. Value network actors in pulp-paper & new biomaterials in Uruguay.

Main focus area	Company/ Innovation actor	Links to FBAs	Market	Importance in value chain	Power	Main supply chain activity
Pulp; Cellulose	UPM - Forestal Oriental	3	global	high	High	buy, make
pulp	Montes del Plata	4	global			

3.7.1.1.4 FBA 4 - Biorefining value network actors in Uruguay

Table 34. Value network actors in biorefining in Uruguay.

Main focus area	Company/ Innovation actor	Links to FBAs	Market	Importance in value chain	Power	Main supply chain activity
Energy; Petroleum, cement	Ancap	2				

3.7.1.1.5 FBA 5 - Bioenergy value network actors in Uruguay

Table 35. Value network actors in bioenergy in Uruguay.

Main focus area		Company/ Innovation actor	Links to FBAs	Market	Importance in value chain	Power	Main supply chain activity
Bioenergy-sawmill	Wood products	URUFOR - COFUSA	3	domestic	medium	Medium	make, sell
	Wood products; Clear, standard and pallet boards	Frutifor	2	regional	medium	Medium	make
	Wood products; Plywood and veneer	Lumin (BTG Pascual) (prev. Uruply SA)	3	regional	medium	Medium	make
	Wood products; Boards and chips	FYMNSA	3	domestic	medium	Medium	make
Bioenergy - pulp	Pulp; Cellulose	UPM - Forestal Oriental	3	global	high	High	buy, make
	Pulp	Montes del Plata	4	global			
Energy	Energy; Petroleum, cement	Ancap	2				

3.7.1.2 Research and university actors in in forest-based bioeconomy in Uruguay

The following section introduces research and university actors in Uruguayan forest-based bioeconomy (in all FBAs).

Table 36. Value network research and university actors in Uruguay.

Main focus area	Research/ University	FBA 1	FBA 2	FBA 3	FBA 4	FBA 5	Location
Research, undergraduate and graduate degrees	Faculty of Engineering - UDELAR		x	x	x		Montevideo
Research, undergraduate and graduate degrees	Faculty of Agronomy - UDELAR	x	x	x	x		Montevideo
Research, undergraduate and graduate courses	Faculty of Architecture - UDELAR		x				Montevideo
Undergraduate vocational degree (in technical degree in forestry)	University of the Firm (UDE)	x					Montevideo
Undergraduate vocational degree (in forestry and forestry technologies	University of Work (UTU)	x	x	x			Montevideo
Undergraduate degree	Technological University (UTEC)	x		x			Paysandú
Research and graduate degree	ORT University		x				Montevideo
Research and providing technical support for producers	National Institute for Agricultural Research (INIA)	x	x	x	x		Tacuarembó
Research and testing for production	Technological Laboratory of Uruguay (LATU)	x	x	x	x	x	Montevideo

3.7.1.3 Institutional actors in forest-based bioeconomy in Uruguay

The following table lists institutional actors in Uruguayan forest-based bioeconomy (in all FBAs).

Table 37. Value network institutional actors in Uruguay.

Main focus area	Institutional	FBA 1	FBA 2	FBA 3	FBA 4	FBA 5
Plantations and native forest, territorial ordering, sustainability	Ministry of Livestock, Agriculture and Fisheries (MGAP)	x				
Sawmills, pulp mills, energy	Ministry of Industry, Mining and Energy (MIEM)		x	x		x
Environmental and housing policies	Ministry of Housing, Territorial Organization and Environment (MVOTMA)	x	x	x		x
Infrastructure, public works	Ministry of Transportation, and Public Works (MTOP)	Not FBA specific				
Planning	Office of Planning and Budget (OPP)	Not FBA specific				
Investment attraction	Uruguay XXI			x		
Union, workers right	Union of Wood Industry (SOIMA)	Not FBA specific				
Industry Association	Society of Forestry Producers (SPF)	Not FBA specific				
Industry Association	Association of Wood-Processing Industries (CIPROMA)		x			
Industry Association	Association of Wood Industries of Uruguay (ADIMAU)	Not FBA specific				
a South American trade bloc	Mercosur	x		x	x	

3.8 Forest- and wood-based products

As part of Task 1 and 2, an exercise to rate the Top 10 forest products was performed in Montevideo workshop in May 2018 and replicated with Finnish experts in June 2018.

Figure 38 shows the most important wood-based products for Uruguay in future in terms of the following two criteria: (1) productive transformation; and (2) wealth creation. These products were assessed in stakeholder workshop in Montevideo, in May 2018. In total 18 respondents ranked the 10 most important products according to the two criteria. The respondents represent the following actors: government 3, business 4, civil society 1, research and education 4, and 6 of the respondents did not state their background. Ranking of products is based on points received by a product; 10 points were given to the most potential product in descending order to 1. Scores for productive transformation and wealth creation were summarized that gave the most important product (a CLT) a total score of 170.

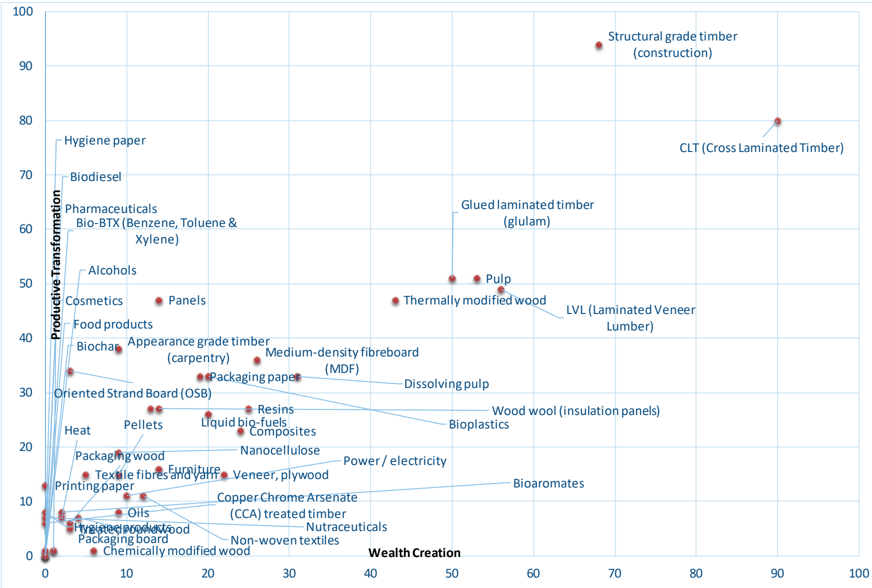


Figure 38. Assessment of forest- and wood-based products for Uruguay.

Table 38 shows the scores for the highest and lowest potential products for Uruguay.

Table 38. Products of the most and the least potential in Uruguay.

URUGUAY (n = 18)	**Total Score**	**Productive Transformation Total**	**Wealth Creation Total**
Products with the most potential			
CLT (Cross Laminated Timber)	170	80	90
Structural grade timber (construction)	162	94	68
LVL (Laminated Veneer Lumber)	105	49	56
Pulp	104	51	53
Glued laminated timber (glulam)	101	51	50
Thermally modified wood	90	47	43
Dissolving pulp	64	33	31
Medium-density fibreboard (MDF)	62	36	26
Panels	61	47	14
Bioplastics	53	33	20
Products with the least potential			
Copper Chrome Arsenate (CCA) treated timber	6	6	0

URUGUAY (n = 18)	Total Score	Productive Trans-formation Total	Wealth Creation Total
Pharmaceuticals	2	1	1
Untreated round wood	2	1	1
Hygiene paper	1	1	0
Biodiesel	1	1	0
Alcohols	0	0	0
Bio-BTX (Benzene, Toluene & Xylene)	0	0	0
Biochar	0	0	0
Food products	0	0	0
Cosmetics	0	0	0

Similar evaluation of the most potential forest-based products was performed by Finnish experts (Table 39). A clear difference is seen in the evaluations. Uruguayans' prefer several mechanical wood products whereas advanced forest countries see forest bio-based products impactful by 2013. Mechanical wood products, which are seen in both lists, are: 1) CLT and 2) Structural grade timber (construction). Also pulp and bioplastics are found important in both evaluations. In turn, very distant views are offered for (forest-based) food products and importance of hygiene paper.

Other links in the two listings are also seen. For example, wood-based textile fibres and yarn require dissolving pulp that is evaluated as a potential product for Uruguay.

Table 39. Products of the most and the least potential in Finland and other leading forest countries.

Rank	FINLAND (n = 2)	Total Score	*Productive Transfor-mation*	*Wealth Cre-ation*
1	Bioplastics	23	10	13
2	Nanocellulose	22	16	6
3	Food products	22	16	6
4	Textile fibres and yarn	17	7	10
5	CLT (Cross Laminated Timber)	15	8	7
6	Hygiene paper	14	4	10
7	Structural grade timber (con-struction)	12	5	7
8	Packaging board	12	0	12
9	Pulp	10	0	10
10	Liquid biofuels	10	5	5

3.8.1.1 Assessing the future markets

Table 40 shows the market size for some prioritised forest-based products. The information was collected from publicly available web sources and estimates are indicative only, as more profound market research requires more resources. The estimations were made in June 2018.

Table 40. Market potential of top ranked products.

Forest-based products	Future global market potential	Source
CLT (Cross Laminated Timber)	USD 2.07 billion by 2025	Grand view research[151]
	USD 2,332.1 Mn by 2025	Transparency market research[152]
LVL (Laminated Veneer Lumber)	USD 3.5 Billion by 2022	Researchandmar-kets.com (original source unknown)[153]
	USD 5.5 Billion by 2023	IMARC group[154]
Pulp	Revenues from the sales of pulp USD 60,000 mn by 2026	Transparency market research[155]
Glued laminated timber (glulam)	USD 9.53 billion by 2026	Statistics MRC[156]
Medium-density fibre-board (MDF)	USD 34 Billion by 2022	IMARC group[157]
Panels	USD 174.55 billion by 2025	Report linker (original source unknown)[158]
Bioplastics	USD 35.47 billion in 2022	Zion market research[159]
Nanocellulose	USD 1 billion by 2024	Global Market In-sights[160]
Textile fibres and yarn	USD 39 billion by 2024 (all cellulose fibres)	Global Market In-sights[161]

151 https://www.grandviewresearch.com/press-release/global-cross-laminated-timber-market
152 https://www.prnewswire.com/news-releases/global-cross-laminated-timber-market-to-reach-us-23321-mn-by-2025-production-of-cross-laminated-timber-in-europe-and-north-america-likely-to-offer-attractive-market-opportunities-678751103.html
153 https://www.researchandmarkets.com/reports/4535111/laminated-veneer-lumber-market-global-industry
154 https://www.imarcgroup.com/laminated-vaneer-lumber-market
155 https://www.transparencymarketresearch.com/pressrelease/pulp-market.htm
156 https://www.reuters.com/brandfeatures/venture-capital/article?id=29914
157 https://www.imarcgroup.com/global-medium-density-fibreboard-market
158 https://www.reportlinker.com/p05445420/Wood-Based-Panel-Market-Size-Share-Trends-Analysis-Report-By-Product-By-Application-And-Segment-Forecasts.html
159 https://globenewswire.com/news-release/2018/01/16/1289496/0/en/Global-Bio-Plastics-Market-Will-Reach-USD-35-47-Billion-by-2022-Zion-Market-Research.html
160 https://globenewswire.com/news-release/2018/03/08/1418152/0/en/Nanocellulose-Market-to-exceed-1bn-by-2024-Global-Market-Insights-Inc.html
161 https://www.gminsights.com/pressrelease/cellulose-fiber-market

4. Visions for forest-based bioeconomy areas in Uruguay

The Uruguayan government and the FBA-Uruguay project Governance Group decided to embrace the overall vision for the forest-based bioeconomy in Uruguay created by the Council of Forest and Wood Industries (CSFM, for its Spanish acronym). The Council was created by entrepreneurs, workers and technicians from the private and public sector to provide institutional and strategic support to forest-based bioeconomy initiatives in Uruguay.

4.1 Overall vision for the forest-based bioeconomy in Uruguay

> *To be a forestry-based bioeconomy chain leader in the incorporation of new technologies and innovative process, which maximizes the efficient use of resources through a diversified production, contributes to economic growth and decentralized social development by promoting environmental sustainability (CSFM, 2018).*

4.2 Visions by forest-based bioeconomy areas (FBAs)

	**FBA1 Vision for Foresight management** There is a quality forest base that adapts to the sector requirements, through sustainable forest management of both plantations and native forest and promotes the development of new entrepreneurial ecosystems.
	**FBA2 Vision for Mechanical wood processing)** The industry of mechanical transformation of wood makes an efficient, innovative and integral usage of the wood resource, boosted by construction demand and embedded in global value chains.
	**FBA3 Vision for Fibre-based biomaterial processing** Production of different types of cellulose pulp operates under the highest environmental and efficiency standards, achieving strong linkages with the mechanical transformation industry, biorefinery and production of fibres, paper and paperboard.

	**FBA4 Vision for Biorefining for chemicals and energy products)** The biorefinery and the development of bioproducts has diversified and maximized the use of waste, side-streams and residues of wood, generating an alternative to the petrochemical matrix; supported by a strong development of local research and innovation.
	**FBA5 Vision for Bioenergy** The use of side-streams and residues of wood, integrated within the forestry value chain, supplements the renewable energy matrix of the country.

5. Strategies, policies, regulations and action roadmaps for the future

Part 5, structured around six sections, discusses strategies, policies, regulations and action roadmaps for selected forest-based bioeconomy areas. Section 5.1 introduces to the strategies and rationale of public policies in the transition towards forest-based bioeconomy, Section 5.2 introduces to the MLP framework and public policies in transition towards bioeconomy, Section 5.3 describes policy strategies of forest-based bioeconomy in the OECD and in the European Union, and in selected individual countries, as well as some comparisons made of bioeconomy strategies and policies in selected countries. Section 5.4 describes the top 15 opportunity pathways (OP) for the five forest-based bioeconomy areas in Uruguay. Section 5.5 provides a systematic analysis and panoramic overview of the five main Action Roadmaps (AR). Finally, Section 5.6 highlights the need for a concerted multi-stakeholder effort to act upon the over 500 recommendations structured around their main implementation dimensions (i.e. context, people, process and impact) and recommended implementation timeframes (by 2020, 2025 or 2030). Only the partial or complete implementation of the suggested actions would allow Uruguay to benefit from the identified strategic openings by 2040, 2050, and beyond.

5.1 Public policies in transition towards forest-based bioeconomy

The rationale of public intervention in research and innovation activities has theoretical and empirical argumentation lines, although, ultimately, public intervention and investments in research and innovation activities get legitimacy from empirical socio-economic or ecological impact evidence.[162] Impact evidence is produced by evaluation and impact assessment exercises in order to legitimize the use of taxpayers´ money to public R&D activities. The debate in the argumentation of public intervention in research and innovation activities has proceeded from market and system failures to transformational failures as described below. These argumentation lines give legitimacy to public intervention also in areas of bioeconomy and forest-based bioeconomy.

The traditional argument in the economic literature for public intervention in R&D and innovation is given by the theory of market failures: Market system does not invest enough and optimally in research funding as compared to societal needs.[163] The reasons of market failure are indivisibility and appropriability of created new

[162] Loikkanen, T. and N. Rilla (2014) Towards Evidence Based Impact Assessment of Science, Technology and Innovation Policies on a Basis of Systematically Collected Innovation Data, in: Proceedings, Conclave of Scientists of Science, Technology and Innovation Policy: Foresight, Growth, Roadmaps, Sectoral Impact Assessment and Alliances, Edited by Dr. Mohsin U Khan, Zaheer Science Foundation, India.

[163] Arrow, K. (1962). Economic welfare and the allocation of resources for innovation. In R. R. Nelson, The Rate and Direction of Innovative Activity: Economic and Social Factors (pp. 609–626). NBER Press.

knowledge and information asymmetry. Societal needs areas are related to public goods and externalities, being wholly or partly external to price and market system. Examples of such areas are environmental protection, occupational health and safety, meteorological services, or defence. Missing or failing market areas may relate to technological, economic or societal infrastructures, such as transportation, energy or communication. In competing with fossil fuel-based products and production processes, bio-based substitutes are encumbered by market failures, such as the limited internalisation of environmental costs of fossil fuel use.[164] At the same time, investments in innovative bioeconomy pathways are associated with knowledge and learning spillovers, which, as positive externalities, result in lower levels of innovative activities than socially optimal.

Additional market failure based arguments for public research funding are an exceptionally long time horizon in societal problem solving surpassing conventional enterprise horizon, knowledge and learning spillovers (positive externalities), and research requiring critical mass and big R&D facilities, like aeronautical and space research. Besides market failure, another argumentation line for innovation policy rationale exists: public intervention in research and innovation activities is needed for the sake of ”system failures”, failures in policy planning and policy-making, etc.[165]

Weber and Rohracher[166] extend the failure argumentation to transformational system failures. The background of transformational system failures is both in the policy debate in the search of research, technology and innovation based solutions to societal challenges[167] and research on multi-level perspective of sociotechnical transitions.[168] Weber and Rohracher (ibid.) propose a comprehensive framework that allows legitimizing and devising policies for transformative change drawing on a combination of market failures, structural system failures and transformational system failures. They suggest a set of guiding rationales for underpinning a broader approach to innovation policy that is geared towards inducing and realizing long-term processes of transformative change towards sustainability. With these rationales they try to reconcile structure-oriented innovation system approaches with the multi-level perspective of sociotechnical transitions.

The multi-level perspective offers several argumentation lines that are relevant and valuable for devising policies in support of goal-oriented transformative

---

[164] Hagemann, N. et al. (2016) Possible Futures towards a Wood-Based Bioeconomy: A Scenario Analysis for Germany, Sustainability 2016, 8, 98; doi: 10.3390/su8010098. Available online: www.mdpi.com/journal/sustainability.

[165] Woolthuis, R.K., Lankhuizen M.and Gilsing V. (2005), A System Failure Framework for Innovation Policy Design. Technovation, 25(6), pp. 609–19.

[166] Weber, K.M. and H. Rohracher (2012) Legitimizing research, technology and innovation policies for transformative change. Combining insights from innovation systems and multi-level perspective in a comprehensive ‘failures’ framework, Research Policy 41 (2012) 1037–1047.

[167] Era Expert Group (2008) Challenging Europe’s Research: Rationales for the European Research Area (ERA), European Commission. Available online: https://ec.europa.eu/research/era/pdf/eg7-era-rationales-final-report_en.pdf.

[168] Geels, F. and Schot, J. (2007) Typology of sociotechnical transition pathways, Research Policy 36 (2007) 399–417.

change.[169] First, it explicitly focuses on the goal-orientation of system transformations. Second, while the innovation systems approaches tend to emphasize the supply side of innovation only and neglect the production and consumption side of system transformations; this is represented prominently in the multi-level literature. Third, as a consequence of their emphasis on transformative change, the multi-level perspective also takes the need for better coordination between research, technology and innovation policy on the one hand and other relevant policies on the other more prominently into account than the innovation systems literature. Fourth, the multi-level perspective recognizes the importance of reflexivity for the shaping of long-term transformation paths. These four arguments – as derived from the multi-level perspective – have been reformulated as transformational system failures. Together with the well-established market and structural system failure arguments, Weber and Rohracher (ibid.) provide a comprehensive framework for legitimizing research, technology and innovation policies for a transformative change.

In conclusion, the creation of, and transition towards the sustainable forest-based bioeconomy contains many features of market, system and transformational failures, giving legitimacy to public intervention and promotion of bioeconomy, in general, as well as of forest-based bioeconomy, in particular.

5.2 MLP framework and public policies for bioeconomy transitions

The transition towards bioeconomy and forest-based bioeconomy can be supported by applying and developing appropriate supporting frameworks and policy instruments. The "arsenal" of traditional policy instruments is extensive and can still be applied in the promotion of bioeconmy of the future. The future oriented long-term ecological and socio-economic transitions (or transformations) have been analysed extensively within Multi-Level Perspective (MLP) framework since the early 2000s.[170] By applying MLP framework, for example, Bosman and Rotmans[171] analyse strengths and weaknesses of the transition towards bioeconomy in Finland and The Netherlands. In the multi-level context MLP-based analysis consists of three levels, landscape, socio-technical regime and niche innovations: in the niche-level innovative practices are developed, the regime-level provides structure and stability to a system, and the landscape level comprises long-term trends and exogenous events that might put pressure on the regime. The analysis consists of the system transition from the current regime to the new regime, as illustrated in Figure 39.

169 Weber, K.M. and H. Rohracher (2012) Legitimizing research, technology and innovation policies for transformative change. Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework, Research Policy 41 (2012) 1037–1047.

170 Geels, F. and Schot, J. (2007) Typology of sociotechnical transition pathways, Research Policy 36 (2007) 399–417.

171 Bosman, R.; Rotmans, J., (2016) Transition Governance towards a Bioeconomy: A Comparison of Finland and The Netherlands. *Sustainability* 2016, *8*, 1017.

Transitions can occur when developments at these three levels align[172],[173],[174]. The planning and implementation of actions in transition process will be carried out in collaboration of all key actors and stakeholders.

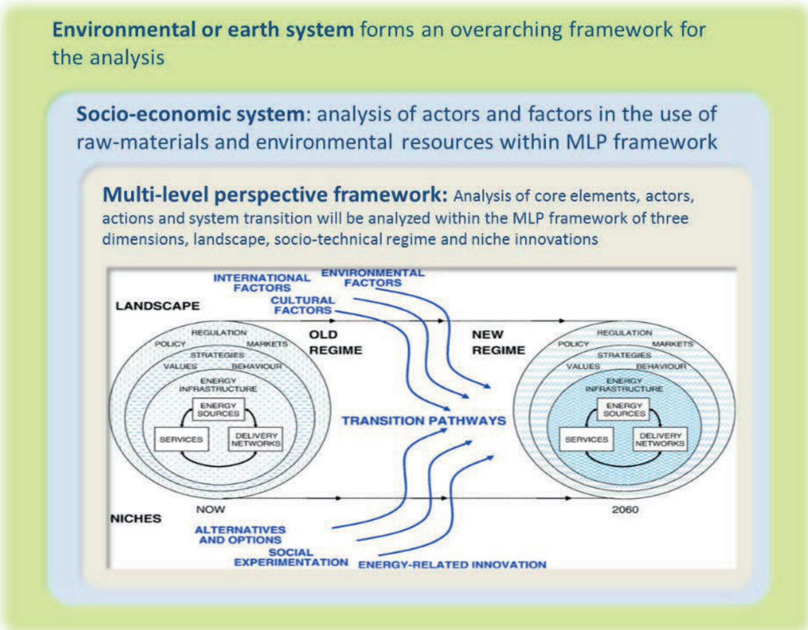


Figure 39. Analysis of core elements, actors, actions and system transition within MLP-framework[175].

According to Bosman and Rotmans[176] the transition to a bioeconomy is a complex process. It is the result of a co-evolution of economic, technological, institutional, cultural and ecological developments at different scale levels. Transformative changes may take decades (25–50 years) and require both radical and incremental innovations. Transitions (including in bioeconomy) involve multiple possible visions, transition pathways and challenging the status quo, thus face fierce resistance from vested interests in the energy, petro-chemical, agriculture and forestry sectors.

172 Ibid.

173 Geels, F. and Schot, J. (2007) Typology of sociotechnical transition pathways, Research Policy 36 (2007) 399–417.

174 Foxon, T. J., Hammond, G.P. and Pearson, P.J.G. (2010) Developing transition pathways for a low carbon electricity system in the UK. Technological Forecasting and Social Change vol. 77 no. 8, pp. 1203–1213.

175 Original source from Foxon et al. 2010 is adapted into the framework of the on-going EU 7FP project RECREATE funded by the European Commission (http://www.recreate-net.eu/dweb/).

176 Bosman, R.; Rotmans, J., (2016) Transition Governance towards a Bioeconomy: A Comparison of Finland and The Netherlands. *Sustainability* 2016, *8*, 1017.

The literature on transitions separates the understanding transition processes, referred to as transition dynamics, and understanding how actors (aim to) influence or steer transition processes, transition governance or transition management.[177] In transition dynamics, different levels in time and functional or geographical aggregation can be distinguished, which have resulted in 'multi-phase' and 'multi-level' frameworks. The multi-phase concept focuses on the direction, speed and size of transitions, and it describes a transition through time as an S-shaped curve. The S-curve goes through four phases, (1) pre-development (incubation, with the diversity of experimentation activities when small changes take place in a system but in the background and are not yet visible), (2) Take-off the process of transition (structural changes gain momentum and this is the ignition of a transition), (3) Acceleration of the change process with the increasing returns of economies of scale that support the diffusion of new solutions and lead to structural changes which gain speed and become visible, and (4) Stabilisation with the decreases in the speed of societal change, in which a new state of dynamic equilibrium is reached).[178],[179] According to Bosman and Rotmans[180] transition management provides a framework within which to analyse and influence transitions in terms of direction and pace. Transitions are characterised by alternating periods of fast and slow change, together forming a strongly non-linear process.

The development of niche level innovations in MLP-framework – their impacts on the shift from the current regime to the new regime – play an important role in the transition process. Innovations develop stepwise from research and development stage via demonstrations and pre-commercial stages to fully commercial stage, as described in Figure 40 below.

Figure 40 shows the commercial maturity of some new and renewable energy technologies in relation to their transition to the market in the United Kingdom.[181]

---

[177] Ibid.

[178] Ibid.

[179] Könnöla, T., Carrillo-Hermosilla, J. and Loikkanen, T. (2013) Governance of energy system transition: theoretical framework and empirical analysis in Europe, International Journal of Transitions and Innovation Systems, 2013, 3 (1):50–69.

[180] Bosman, R.; Rotmans, J., (2016) Transition Governance towards a Bioeconomy: A Comparison of Finland and The Netherlands. *Sustainability* 2016, *8*, 1017.

[181] Foxon, T. J., Gross, R., Chase, A., Howes, J., Arnall, A., Anderson, D. (2005). "UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures," Energy Policy, Elsevier, vol. 33(16), pages 2123–2137, November.

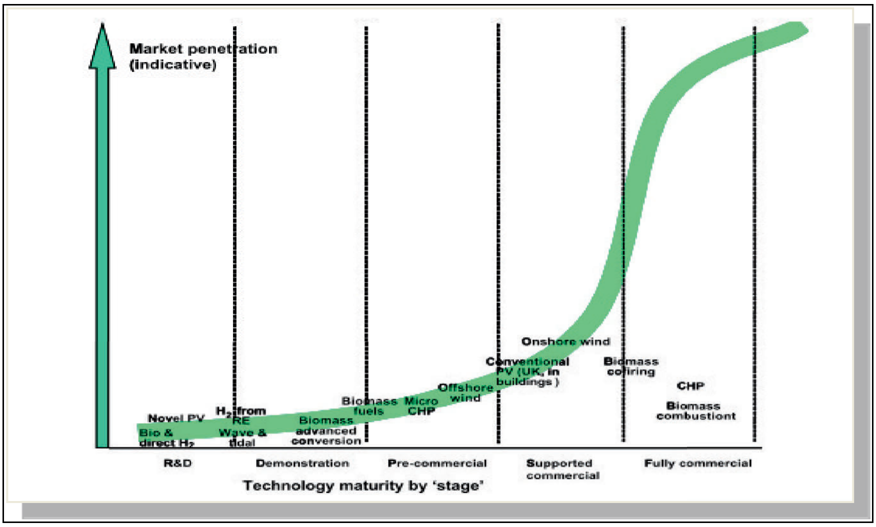


Figure 40. Technology maturity by stage.[182]

Foxon et al.[183] separate (1) basic and applied R&D, (2) demonstrations (early prototypes with a view to later developing full scale facilities), (3) pre-commercial phase by which the demonstration phase technologies have already been produced in some of the full scale units, (4) a subsidized commercial phase, which already has more commercially-oriented enterprises supported, and (5) commercial technology, which compete with one another in a wider regulatory framework, already subsidies from the state. Besides the commercial maturity of renewable energy technologies, policy instruments can be used correspondingly along different maturity stages of technologies.[184] In the promotion of bioeconomy and forest-based bioeconomy the encouragement of innovation through regulation and public innovative procurement is getting stronger. The Paris Climate Agreement, adopted in December 2016, accelerates the development of technologies limiting greenhouse gas emissions. Moreover, as digitalisation enables the modernization of industrial and public sector structures, policy measures can be targeted to develop the necessary digital platforms and experimental environments.

With respect to policy measures, on a general level, Hetemäki concludes that, although it is very unlikely that there is one overarching policy, which can solve the challenges and create opportunities, strong emphasis needs to be placed on the

[182] Foxon, T. J., Hammond, G.P. and Pearson, P.J.G. (2010) Developing transition pathways for a low carbon electricity system in the UK. Technological Forecasting and Social Change vol. 77 no. 8, pp. 1203–1213.
[183] Foxon, T. J. et a. (2005).
[184] Ibid.

carbon price.[185] In one way or another, it is an essential tool in tackling climate change, and also provide incentives for economies and sectors (including the European forest-based sector) to transform to the new bioeconomy. Innovation becomes substantial in a bioeconomy as new technologies and products are needed. It demands a specific policy setting allowing learning across sectors, balancing public support, technology push, and market pull, e.g. by environmental standardization and labelling or via green public procurement.[186] In the context of forest-based bioeconomy, integrated forest and environmental management becomes relevant in the bioeconomy, when striving not only for efficient but also at the same time sustainable resource use and environmental protection, taking into account the provision of diverse ecosystem services from forests. The core challenges in the context of integrated forest management in the bioeconomy are the identification of political and economic trade-offs and conflicting interests of stakeholders in using forests, the assessment of the economic values of forest ecosystem services and biodiversity protection, and the provision of incentives for corporate social responsibility and green consumerism.[187]

Section 5.1 above presents argumentation lines of policies in the promotion of bioeconomy or forest-based bioeconomy. Policy-makers can use a range of potential policy instruments like R&D support, market development policies (e.g. support to niche market), long-range targets and obligations, financial incentives (e.g. capital subsidies, tax credits, hypothecation of revenues). Foxon et al.[188] identify three benefits of these policies: creation of options to tackle environmental problems (options value); reducing the long-term cost of mitigation and increase environmental returns (by reducing mitigation costs); and the innovations they induce may bring economic benefits in their own right (sometimes called positive externalities). Effective policy should also understand innovation as a system and recognise that the technologies considered are diverse and face different challenges. It is hence important that policy supports innovation through its various stages, targeted if necessary to address specific barriers in the innovation cycle (Figure 41).

---

185 Hetemäki, L. (Ed.) (2014) Future of the European Forest-Based Sector: Structural Changes Towards Bioeconomy. European Forest Institute. Available online: file:///C:/Users/torst_000/Downloads/Hetemaki_Ed_thinkforest_brief_future_of_european_fbs_and_bioeconomy_2014.pdf.

186 Kleinschmit, D., Lindstad, B. H., Thorsen, B. J., Toppinen, A., Roos, A., & Baardsen, S. (2014). Shades of green: a social scientific view on bioeconomy in the forest sector. Scandinavian Journal of Forest Research, 29(4), 402–410. Available online: http://macroecointern.dk/pdf-reprints/Kleinschmit_SJFR_2014.pdf.

187 Ibid.

188 Foxon, T. J., Gross, R., Chase, A., Howes, J., Arnall, A., Anderson, D. (2005). "UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures," Energy Policy, Elsevier, vol. 33(16), pages 2123–2137, November.

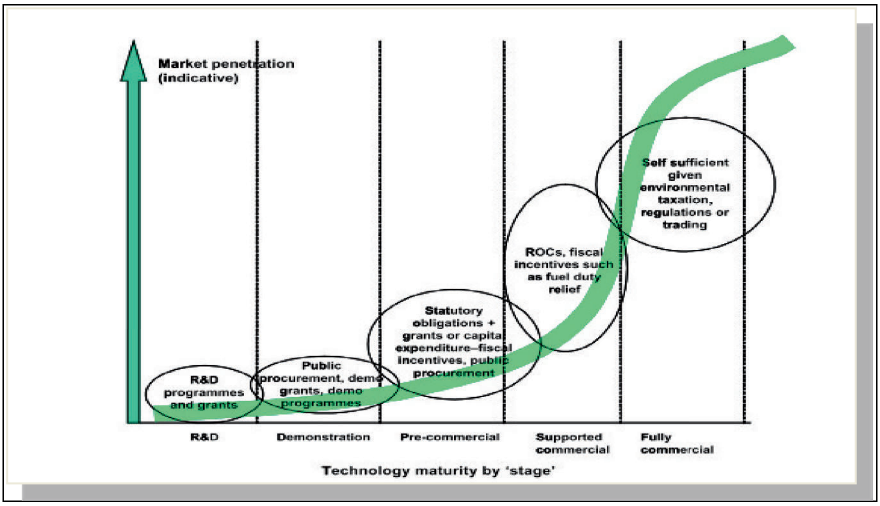


Figure 41. Examples of renewable policy development Instruments for the development of a renewable energy technology maturity curve.[189]

Figure 41 is an idealised picture showing different types of policy instrument on the graph of market penetration against technology maturity. Accordingly, the maturity by stage logic fits also to the policy instruments in the promotion of bioeconomy or forest-based bioeconomy areas. Policy instruments are interacting; for example, niche market support may promote further R&D. A successfully performing technology would then be able to progress smoothly from the early stages to the final stage where it can compete without direct support (given, for example, a generally supportive environmental tax or trading scheme). As Foxon et al.[190] conclude, there are several elements to a policy, and instruments need to vary with the phase of a technology's development; policies should however take into account technological and institutional factors threatening to lead to 'lock-in' of existing carbon-based technologies.

The transition towards bioeconomy and forest-based bioeconomy related strategies and policies can be facilitated by support from research. The majority of bioeconomy research have been carried out predominantly within natural and engineering sciences. The transition towards bioeconomy involves however economic, social and policy challenges. OECD[191] accentuates that the social analysis is necessary in order to guide policymaking towards bioeconomy.

[189] Ibid.
[190] Ibid.
[191] OECD (2009) The Bioeconomy to 2030: Designing a Policy Agenda. Main findings and policy conclusions. Available online: http://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/42837897.pdf.

5.3 Common strategies and policies of the forest-based bioeconomy

Many transnational organisations and individual countries have specific and integrated bioeconomy strategies and policies containing versatile facets of the bioeconomy and forest-based bioeconomy. The International Futures Programme (IFP) of the Organisation for Economic Co-operation and Development (OECD) embarked on a two-year project to design a bioeconomy policy agenda for governments in 2005.[192] The results of the project were published in 2009 and the main titles of conclusions are presented in the Box below.

THE PRINCIPLE POLICY CONCLUSIONS OF THE OECD´S BIOECONOMY REPORT 2009:

1. Prepare the foundation for the long-term development of the bioeconomy
2. Reverse the neglect of agriculture and industrial biotechnologies
3. Prepare for a costly but beneficial revolution in healthcare
4. Turn the potentially disruptive power of biotechnology to economic advantage
5. Reduce barriers to biotechnology innovation
6. Promote the integration of biotechnology research across commercial applications
7. Create an ongoing dialogue among governments, citizens and firms

The early bioeconomy initiative of the OECD with its recommendations have encouraged the member countries of the OECD to start national strategic and policy activities in bioeconomy and forest-based bioeconomy. Section 3.3 considers first bioeconomy strategies of the European Union, and, second, national bioeconomy strategies and policies in selected countries and, third, selected studies comparing bioeconomy strategies and policies of individual countries.

5.3.1 Bioeconomy strategy of the European Union

Europe is considered a world leader in the bioeconomy and an important precondition to keep this role and a further expansion of bioeconomy industries is supportive and smart regulation. For example EU legislation has been in place since the 1990s to cover the contained use of genetically modified micro-organisms. The Member States of the EU are required to take all measures necessary in order to avoid the contained use of genetically modified micro-organisms (GMMs) having negative consequences on human health and the environment.

The EU adopted its bioeconomy strategy in 2012. It is estimated that direct research funding associated to the Bioeconomy Strategy under Horizon 2020 could generate about 130,000 jobs and €45 billion in value added in bioeconomy sectors

[192] OECD (2006) The Bioeconomy to 2030: Designing a Policy Agenda. Available online: http://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/thebioeconomyto2030designingapolicyagenda.htm.

by 2025.[193] The EU strategy is linked to Horizon 2020, the EU Framework Programme for research 2014–2020. Funding for research, development and innovation is expected to improve European competitiveness and growth and create new jobs. The programme provides funding for food safety, sustainable agriculture and marine research, shipping and inland waters. Funding is also granted to safe, clean and efficient energy production, climate actions, resource efficiency and raw materials. The policy framework of the European bioeconomy consists of a multitude of regulations and strategies from several policy areas, including the Common Agricultural Policy, the EU Forest Strategy, the Common Fisheries Policy, the Blue Growth Agenda, the new EU framework for aquaculture, quality schemes for agricultural products and foodstuffs, food and feed safety regulations, the Renewable Energy Directive (RED), the 2030 policy framework for climate and energy, standards, certification and labelling for bio-based products and the Circular Economy Package.

In order to support the EU Bioeconomy Strategy the JRC established the Bioeconomy Observatory.[194] The establishment of the Observatory is part of the implementation of the EU Bioeconomy Strategy 2012, described above. The Bioeconomy Observatory, as the Strategy does, focuses on three main pillars:

- "Research" (investments in Research, Innovation and Skills)
- "Policy" (reinforced policy interaction and stakeholder engagement)
- "Markets" (enhancement of markets and competitiveness in bioeconomy).

In partnership with the EU and through cooperation with the Standing Committee on Agricultural Research (SCAR) the Member States provide comprehensive and authoritative data and information on bioeconomy to the Bioeconomy Observatory. The observatory was carried out in collaboration of DG-JRC (IPTS, Sevilla) and SCAR. The general objective was to collect at individual Member State level and on the basis of a preliminary questionnaire prepared by the JRC and SCAR quantitative data and qualitative information especially of national bioeconomy research activities and national bioeconomy policy initiatives from the EU Member States.

5.3.2 Examples of national bioeconomy strategies and policies

Among the countries having official governmental bioeconomy policy strategies are:

- Finland: The Finnish BioEconomy Strategy (2014)
- Germany: the national policy strategy BioEconomy (2014) and National research strategy BioEconomy 2030 (2010)

---

[193] EC (2012) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Innovating for Sustainable Growth: A Bioeconomy for Europe. {SWD(2012) 11 final}. Available online: http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf.

[194] Langeveld, J.W.A. (2015): Results of the JRC-SCAR Bioeconomy survey. BIOMASS RESEARCH REPORT 1501, Biomass Research, Wageningen. Available online: https://www.scar-swg-sbgb.eu/lw_resource/datapool/_items/item_24/survey_bioeconomy_report1501_full_text.pdf.

- The Netherlands: Framework memorandum on the Biobased Economy (2012)
- South Africa: The BioEconomy strategy (2013)
- Sweden: Swedish Research and Innovation Strategy for Biobased Economy (2012)
- USA: The National Bioeconomy Blueprint for the USA (2012)
- Canada: The Canadian Blueprint: Beyond Moose and Mountains (2008)
- Australia: Biotechnology and Australian Agriculture: Toward the Development of a Vision and Strategy for the Application of Biotechnology to Australian Agriculture (2008).

According to results of Bioeconomy Observatory, nine EU Member States are implementing a Bioeconomy strategy. Flanders, Germany, Finland and Sweden have developed a full strategy, and Switzerland, Denmark, Estonia, the Netherlands and Wallonia implement a partial strategy. Large differences exist in the implementation of a Bioeconomy policy and a limited number of countries have installed such a policy, a bioeconomy advisory board or an implementation agency. In some other cases, one or two ministries have been assigned the lead in the development of a Bioeconomy policy. Generally, a small number of countries seem to implement a full package (strategy, board, agency, policies, and dedicated R&D programmes). Moreover several countries have governmental interest in the bioeconomy, national blueprints, green economy strategies, or biobased industry strategies. The Bioeconomy Observatory of the EU gives more detailed data of bioeconomy strategies and policies in Member States of the EU.

The following short overview gives basic data of bioeconomy and forest-based bioeconomy strategies and policies in selected countries. Due to the long history in the forest industry, Finland has much to offer for the formation of the new biobased industrial field. The forest industry develops new bio-based products the share of which is estimated in the Finnish Bioeconomy Strategy to increase to one half of Finnish export earnings in this sector by 2030. Finnish competence areas will also include biochemical methods, pulping technologies and enzyme production for the refining of biomass. Various combinations of process chemistry and bio and nano technologies are expected to raise to completely new production technologies and biomaterials. Strong expertise in wood biomass harvesting technologies, logistics and refining can be further developed by utilising ICT solutions.

In Finland, sustainably managed and certified forests are monitored by using digitalised data bases, which serve forest owners and wood markets. In the national innovation system, new concentrations of academic knowledge and competence have been formed in forest-based bioeconomy areas in order to facilitate radical product innovations and accelerate the transition of new business ideas from basic research phase to commercialisation. Pilot facilities are available for multiple technologies and production processes, complemented with globally recognised knowledge intensive services.

The start-up boom which started in Finland in the early 2000s from the ICT- and game industry sectors has entered also to the biobased industrial field.

Figure 42 presents the vision and strategic goals of the Finnish Bioeconomy Strategy[195].

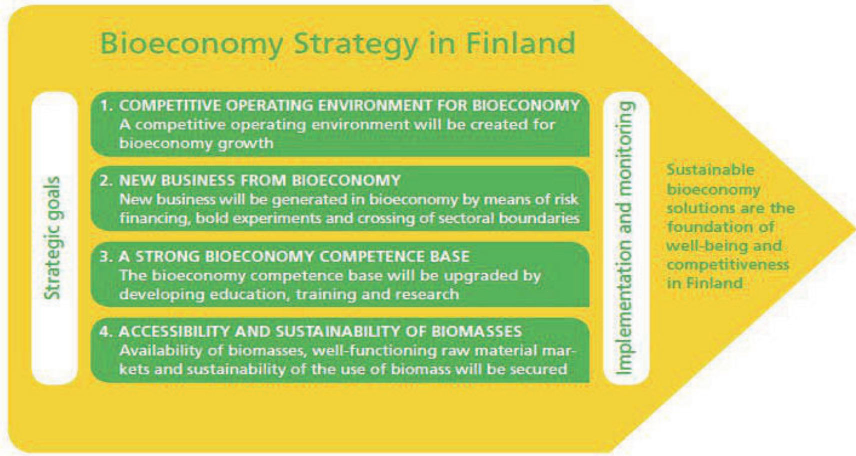


Figure 42. Vision and strategic goals of the Finnish Bioeconomy Strategy.

The objective of the Bioeconomy Strategy of Finland is to increase the output of the national bioeconomy to EUR 100 billion by 2025 and to create 100,000 jobs. It is estimated that till 2025 the Finnish bioeconomy could experience an annual growth rate of some 4%. This means that the bioeconomy output would increase from its current level of EUR 60 billion to EUR 100 billion.

The official governmental bioeconomy policy strategy contains concrete objectives, focused actions, activities, measures and targets, as well as responsibilities of ministries, research institutes and agencies in the implementation of the bioeconomy strategy. The box below presents the goals, policies and measures of the Finnish bioeconomy strategy in more detail.

Strategic goals, policies and measures of Finnish bioeconomy strategy

1. A COMPETITIVE OPERATING ENVIRONMENT FOR THE BIOECONOMY: A COMPETITIVE OPERATING ENVIRONMENT IS CREATED FOR THE BIOECONOMY

1.1. Anticipating the global demand for bioeconomy solutions and preparing roadmaps

1.2. Developing steering methods to support new bioeconomy solutions

1.3. Providing incentives for the replacement of non-renewable natural resources by renewable ones in public procurement

1.4. Promoting demand for bioeconomy products and services

[195] Finnish Bioeconomy Strategy (2014) Sustainable growth from bioeconomy, Finnish Bioeconomy Strategy. Available in: http://www.bioeconomy.fi/facts-and-contacts/finnish-bioeconomy-strategy/.

1.5. Promoting the standardisation and certification of bioeconomy solutions

1.6. Smart green urban regions as development environments for bioeconomy solutions

1.7. Incorporating the bioeconomy in Finland's country image

2. GENERATING NEW BUSINESS FROM THE BIOECONOMY: NEW BUSINESS WILL BE GENERATED FROM THE BIOECONOMY BY MEANS OF RISK FINANCING, BOLD EXPERIMENTS, A STRONG DOMESTIC MARKET AND THE CROSSING OF SECTORAL BOUNDARIES

2.1. Increasing equity financing and innovation inputs in the bioeconomy

2.2. Funding piloting and demonstrations projects of new bioeconomy solutions

2.3. Developing bioeconomy cooperation platforms across sectoral boundaries

2.4. Promoting immaterial value creation to increase the added value of products and services

3. CREATING A STRONG BIOECONOMY COMPETENCE BASE: DEVELOPING THE BIOECONOMY COMPETENCE BASE BY UPGRADING EDUCATION, TRAINING AND RESEARCH

3.1. Developing education content to train bioeconomy experts

3.2. Creating preconditions for bioeconomy through research

4. ACCESSIBILITY AND SUSTAINABILITY OF BIOMASSES: SECURING THE AVAILABILITY OF RENEWABLE NATURAL RESOURCES, WELL-FUNCTIONING RAW MATERIAL MARKETS AND SUSTAINABILITY OF RAW MATERIAL USE

4.1. Ensuring the possibilities of using biomasses and their availability for the needs of a growing bioeconomy

4.2. Making more efficient use of knowledge related to biomass resources

Source: The Finnish Bioeconomy Strategy (2014).

Over one half of Finland's bioeconomy relies on forests. Timber is more important for Finland than for any other country in Europe. In the bioeconomy, however, conventional boundaries between sectors will be blurred, and new kind of cross-sectoral cooperation is being created. The bioeconomy based on sustainable exploitation of forests will result in symbiotic relationships between the forest, energy, technology, chemical and construction industries. Besides national level impacts, the decentralised and resource-efficient bioeconomy solutions can improve self-sufficiency on regions and locations where raw-material is produced and processed.

In Germany, the German federal government started the implementation of a biobased economy already in 2009/2010 by establishing a National BioEconomy Research Strategy and a National Bioeconomy Council. The main bioeconomy initiatives are the National Policy Strategy Bioeconomy[196] and National Research

[196] National Policy Strategy Bioeconomy (2014) https://www.bmel.de/SharedDocs/Downloads/EN/Publications/NatPolicyStrategyBioeconomy.pdf?__blob=publicationFile

Strategy Bioeconomy 203.[197] The German bioeconomy strategy highlights striving for self-sufficiency in energy and raw materials. Germany will also invest strongly in developing green technology. The strategy priorities include energy and material efficiency, environmentally friendly energy production and storage, sustainable water supply, sustainable transport, and waste processing and recycling. In line with the EU's vision for a sustainable bioeconomy Germany has adopted several national strategies supporting the transition. The wood-based bioeconomy is supported as part of German strategies, as well as through the establishment of a German "Excellence Cluster BioEconomy" referring mainly to woody biomass and supporting knowledge exchange between industry and science in order to develop sustainable bioeconomy processes and products.[198]

In **the Netherlands** The Dutch bioeconomy strategy focuses on the chemical and energy sectors, with the main focus on securing the availability of biomasses for these fields. **Sweden** aims to reach by the bioeconomy strategy zero greenhouse gas emissions by 2050. Opportunities provided by green growth are high on the agenda, alongside with the climate-related targets. Among other things, Sweden will strive to determine the value of ecosystem services and to analyse the problems that environmental and climate challenges may pose for society. In **Norway** the Norwegian government has drawn up a biotechnology strategy that emphasises stronger research efforts. The Bioeconomy Observatory gives detailed state-of-the-art information of the bioeconomy and forest-based bioeconomy in the Member States of the EU.[199]

5.3.3 Examples of country comparisons in bioeconomy strategies and policies

Comparisions and benchmarking studies of bioeconomy and forest-based bioeconomy strategies and policies between individual countries are important for mutual learning in developing strategies and planning and implementing policies in bioeconomy areas. Below we make a short overview on Staffas et al.[200] and Meyer[201] comparing bioeconomy strategies and policies of several individual countries, and Bosman and Rotmans[202] comparing national bioeconomy strategies and policies in

---

197 National research strategy Bioeconomy 2030 (2010) https://www.pflanzenforschung.de/files/4514/7886/1937/German_bioeconomy_Strategy_2030.pdf

198 Bioeconomy Cluster (2016). Available online: http://en.bioeconomy.de.

199 Langeveld, J.W.A. (2015): Results of the JRC-SCAR Bioeconomy survey. BIOMASS RESEARCH REPORT 1501, Biomass Research, Wageningen. Available online: https://www.scar-swg-sbgb.eu/lw_resource/datapool/_items/item_24/survey_bioeconomy_report1501_full_text.pdf.

200 Staffas, L., M. Gustavsson and K. McCormick (2013) Strategies and Policies for the Bioeconomy and Bio-Based Economy: An Analysis of Official National Approaches, Sustainability 2013, 5, 2751–2769. Available online: file:///C:/Users/torst_000/Downloads/sustainability-05-02751-v3.pdf.

201 Meyer, R. (2017) Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates, Sustainability 2017, 9, 1031; doi:10.3390/su9061031.

202 Bosman, R.; Rotmans, J., (2016) Transition Governance towards a Bioeconomy: A Comparison of Finland and The Netherlands. *Sustainability* 2016, *8*, 1017.

The Netherlands and Finland. Corresponding studies have been made with narrower scope of forest-based bioeconomy, in which the scope has been narrower, as in such as Lindstad et al.[203] which considers forest-based bioenergy policies in five European countries and especially interactions between national and EU policies.

The aim of the Staffas et al. (ibid.) study was to clarify similarities and differences between bioeconomy strategies and policies. The analysis presents a comparative overview of the strategies and policies for developing a bioeconomy in the EU, USA, Canada, Sweden, Finland, Germany and Australia. The authors conclude that the main emphasis in bioeconomy strategies and policies is often in enhancing the national economy and in providing new employment and business possibilities, whereas the aspects of sustainability and resource availability are addressed only to a limited extent in many documents. Moreover they conclude that bio-based economy and bioeconomy are often used as buzzwords or technical fix for the challenge of taking steps in the transition away from fossil fuels.

A recent and systematic comparative analysis of official bioeconomy strategies of the EU, Germany, OECD, Sweden and the USA with regard to their context, visions and guiding implementation principles is offered by Meyer[204]. The study assesses the relationship between these bioeconomy strategies and important scientific and societal debates around bioeconomy. The study concludes with five major stumbling blocks for the further development of the bioeconomy: (1) there is the risk of disappointment because far-reaching promises of the strategies are difficult to achieve; (2) the bioeconomy is not the only way to a low carbon economy so alternatives could impede the desired development; (3) persistent conflicts between the different uses of biomass for food, material and energy production could lead to unstable policy support with short-term shifts; (4) a broader success of new bioeconomy value chains could trigger new societal conflicts over bioeconomy if efficiency gains, cascading use, residue use and sustainability certification are not sufficient to ensure a sustainable supply of biomass; and (5) the acceptance of bioeconomy could be compromised if bioeconomy policies continue to ignore the ongoing societal debates on agriculture and food. Meyer[205] concludes that almost all strategies expect the bioeconomy, make an important contribution to societal or global challenges. The set of expectations in the strategies can be clustered into two basic visions biotechnology-centred vision, first life science and biotechnology as drivers of innovation, and, second, transformation-centred vision: shift to a bio-

---

[203] Lindstad, B.H., T. Pistorius, F. Ferranti, G. Dominguez, E. Gorriz-Mifsud, M. Kurttila, V. Leban, P. Navarro, D.M. Peters, S. Pezdevsek Malovrh, I. Prokofieva, A. Schuck, B. Solberg, H. Viiri, L. Zadnik Stirn, J. Krc (2015) Forest-based bioenergy policies in five European countries: An explorative study of interactions with national and EU policies, Biomass and bioenergy 80 (2015), 102–113. Available online: https://www.researchgate.net/profile/Spela_Pezdevsek_Malovrh/publication/277007325_Forest-based_bioenergy_policies_in_five_European_countries_An_explorative_study_of_interactions_with_national_and_EU_policies/links/557e6f5908aeb61eae247ff1.pdf.

[204] Meyer, R. (2017) Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates, Sustainability 2017, 9, 1031; doi:10.3390/su9061031.

[205] Meyer, R. (2017) Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates, Sustainability 2017, 9, 1031; doi:10.3390/su9061031.

based economy global challenges. The biotechnology-centred vision sketches a future where new findings in life science and the resulting technologies and innovations lead to economic growth, improved international competitiveness and additional jobs. The transformation-centred vision presents bioeconomy as an answer to global challenges such as climate change, food security and the finite nature of and dependence on fossil fuels.

Bosman and Rotmans[206] analyse how the transition toward a bioeconomy takes shape in Finland and The Netherlands and what kind of roles does transition governance employed in these countries in terms of strengths and weaknesses. The research method of the authors involved comparative qualitative case study analysis through action research. The study contains also a careful analysis of the key issues in the economic state-of-the-art and recent trends in both countries (industrial and energy structures, export and import, employment, competences). The aim of the study is not to problematise the bioeconomy itself but to provide insights into how two different countries with high bio-ambitions but different starting points understand, shape and govern the transition towards the bioeconomy. Main difference between the two countries analysed is that the Finnish economy is dependent mainly on forestry, metals, engineering, telecommunications, and electronics, and the Dutch economy on food processing, chemicals, petroleum refining, and electrical machinery. The authors of the study conclude with an integrated assessment of the biobased transition and the way it is governed in both countries, as well as the lessons to be learned from both approaches.

The governance approach of the bioeconomy in The Netherlands focuses on co-creation of a long-term vision that informs for short-term action, and on facilitation of bottom-up regional clusters and promoting radical innovation through cooperation between vested players and frontrunners. Finland is adopting a more traditional top-down governance strategy, which focuses on the shorter-term economic opportunities and incremental innovation that keep the overall structure of existing industries intact. Finland also lacks a coherent long-term vision, the current vision is government-led and has 2025 as its target year, which in transition terms is a relatively short time frame. With regard to the governance of the transition Dutch government acts as a facilitator while the Finnish government acts more as a director of the transition.

Table 41 below summarises the main insights from the comparison of the Dutch and Finnish transitions and governance approaches by Bosman and Rotmans.[207] The left hand row of Table below lists also the key criteria of the bioeconomy comparison of these countries.

---

[206] Bosman, R.; Rotmans, J., (2016) Transition Governance towards a Bioeconomy: A Comparison of Finland and The Netherlands. *Sustainability* 2016, *8*, 1017.
[207] Ibid.

Table 41. Summary of the comparison of the Dutch Biobased Economy and the Finnish Bioeconomy Transitions[208].

	Dutch Biobased Economy	Finnish Bioeconomy
Transition	Fossil to biobased	Bulk to specialty
Drivers	Chemistry sector/government	Bioeconomy and innovation in genes
Urgency	Rather high	Average
Phase	Pre-development	Just before take-off
Regime	Economic topsectors	Powerful silo structure
Niches	Systematic experimentation	Many unconnected pilots
Vision	Co-created vision for 2050	Government-led vision for 2025
Governance	Transition governance	Traditional top-down
Scale	Regional	National
Approach	Conceptual, network-based	Practical, sector-based
Focus	Radical innovation	Incremental innovation
Government	Facilitator	Director

The authors assess that in transition phases The Netherlands is in the predevelopment phase, while Finland is assessed to be just before take-off phase. The regime in The Netherlands is made up of the economic top-sectors that work together with the Dutch government on strengthening their already strong positions. In Finland the regime is characterised by a powerful silo structure that hampers innovations that cut across these silos, such as in the bioeconomy. The niches are connected in The Netherlands through regional clusters, a coherent vision, and transition pathway development, which provides coherence and a shared goal. In Finland the pilots are numerous but disconnected, with various experiments going on at many different places, often without being aware of each other.[209]

From Sections 4.1 to 4.3 above the following three main conclusions can be drawn: First, they help to present the rationale for public policies in the transition towards the sustainable bioeconomy. Bioeconomy in general and forest-based bioeconomy, in particular, contain many features of market, system and transformational failures, which give legitimacy to public intervention and promotion. Second, the sections introduce the MLP framework and public policies, as well as some common instruments promoting the transition towards bioeconomy and forest-based bioeconomy. Third, they present common policy strategies of bioeconomy in the OECD, in the European Union, and in selected individual countries advanced in bioeconomy and forest-based bioeconomy areas, and examples of country comparisons in bioeconomy strategies and policies in selected countries.

Sections 4.4 to 4.6 will first describe the 15 opportunity pathways (OP) for Uruguay; then provide a systematic analysis and panoramic overview of the five main Action Roadmaps (AR); and present over 500 recommendations in the action roadmaps, which are structured around their implementation dimension (i.e. context, people, process and impact) and implementation timeframe (by 2020, 2025 or 2030).

[208] Source: Bosman, R.; Rotmans, J., (2016) Transition Governance towards a Bioeconomy: A Comparison of Finland and The Netherlands. *Sustainability* 2016, *8*, 1017.
[209] Ibid.

5.4 Forest-based opportunity pathways in Uruguay

Fifteen Opportunity Areas were initially identified by VTT and LUKE experts and these have later been validated in several workshops and expert meetings. This validation process led to their fully-fledged assessment and further development into Opportunity Pathways (OPs), as well as their prioritization of into three groups, from the ones that Uruguay should treat by 2050 with *higher focus* (**G1**); with *medium focus* (**G2**); or with *lower focus* (**G3**). After drafting of OPs, these were discussed, together with critical and political issues, in a workshop organised in Montevideo in May 2018 with over 60 local stakeholders. Six of the opportunity pathways received remarkably more attention in terms of insights from the Montevideo workshop, while in a follow-up workshop with VTT and LUKE experts in June 2018 the other nine OPs were further discussed. Insights were described in four categories: industry/innovation, research, education and institutional needs in Uruguay. Based on Uruguayan workshop institutional needs were raised important to address in Uruguay to develop forest-based bioeconomy.

A final prioritisation was made in workshop organised in Montevideo in October 2018. Given the high number of opportunity pathways, a new prioritisation from high to low focus was created. Within this categorisation three OPs were selected as those requiring the highest focus from Uruguayan stakeholders in order to materialise (Table 42). In other words, these opportunity pathways were seen the most prominent for Uruguay to attain by 2050. Following similar logic, six OPs were evaluated to be attainable but with less intensity than the above three. Therefore, they were categorised with medium focus. Whereas six important but currently the least appealing OPs in turn will be treated with less attention in forest-based bioeconomy action roadmap for 2050.

Table 42. Opportunity pathways in forest-based bioeconomy areas in Uruguay by 2050.

OPPORTUNITY PATHWAY (OP)	CODE
HIGHER FOCUS (G1)	
Adaptation of competitive sawn wood and plywood products (including standards) to international and domestic building with wood markets and distribution channels (for both pine and eucalyptus).	FBA2_OP3
Encourage large companies to consider investments also in other type pulp mills, such as pine kraft pulp, eucalyptus dissolving pulp and eucalyptus NSSC pulp mills.	FBA3_OP2
Encourage the creation of networks to joint utilisation of different residues and wastes from forest industry and other sectors, to produce different bio-chemicals, materials and biofuels.	FBA4_OP2
MEDIUM FOCUS (G2)	
Implementing and maximizing the output value of the present forest resource, which is currently underutilized plantations (e.g. pine) and ascertaining the quality of logistics infrastructure (harvesting, roads and bridges, wood terminals).	FBA1_OP2

OPPORTUNITY PATHWAY (OP)	CODE
Developing environmental research/education programmes, policies, regulations and cross-sectoral investment strategies aimed to promote the use of native forests for new (non-wood-based) ecosystem services, pharmaceutical and food products.	FBA1_OP1
Supporting and ascertaining an attractive investment environment for large international companies in sawmill, plywood mill and thereafter to engineered and modified wood products manufacturing, this should support also local SME activity in mechanical wood processing.	FBA2_OP1
Supporting local SMEs (including university spin-offs) to develop novel cellulose-based products and materials from the currently produced eucalyptus pulps.	FBA3_OP3
Investments in the separation of lignin and hemicellulose-based by-products from pulping operations and their further conversions to marketable (domestic, international) intermediates or end-products, such as lignin for plywood adhesives or dispersants.	FBA4_OP1
As a case-by-case alternative, white or torrefied pellet production from wood processing side streams. Pellets improve storage life of forest biomass and can be used both in Uruguay's industries and private and public buildings for energy or exported.	FBA5_OP2
LOWER FOCUS (G3)	
Creating and supporting local entrepreneurial networks or entrepreneurs and supporting the supply of competent labour in forest management and timber harvesting (education, economic incentives, stakeholder relationships).	FBA1_OP3
Proof-of-concepts and incentives to wood-based panel industries and related bioenergy and biorefining areas to convince investors and companies about the opportunities of competitiveness, profitability and business volume.	FBA2_OP2
Promotion of the investments by large companies for the manufacture of different paper and paperboard grades, using locally produced kraft pulps.	FBA3_OP1
With the help of further R&D resources, finding value-added material and chemical applications for wood barks available from the saw mills.	FBA4_OP3
Seizing opportunities for small-to-medium scale Combined Heat and Power (CHP) plants at new and existing mechanical wood processing sites and biorefineries.	FBA5_OP1
Improvement of solid or liquid FT-synthetic fuels together with a production of hydrogen and advanced biofuels such as bio-oil, biofuel and renewable diesel.	FBA5_OP3

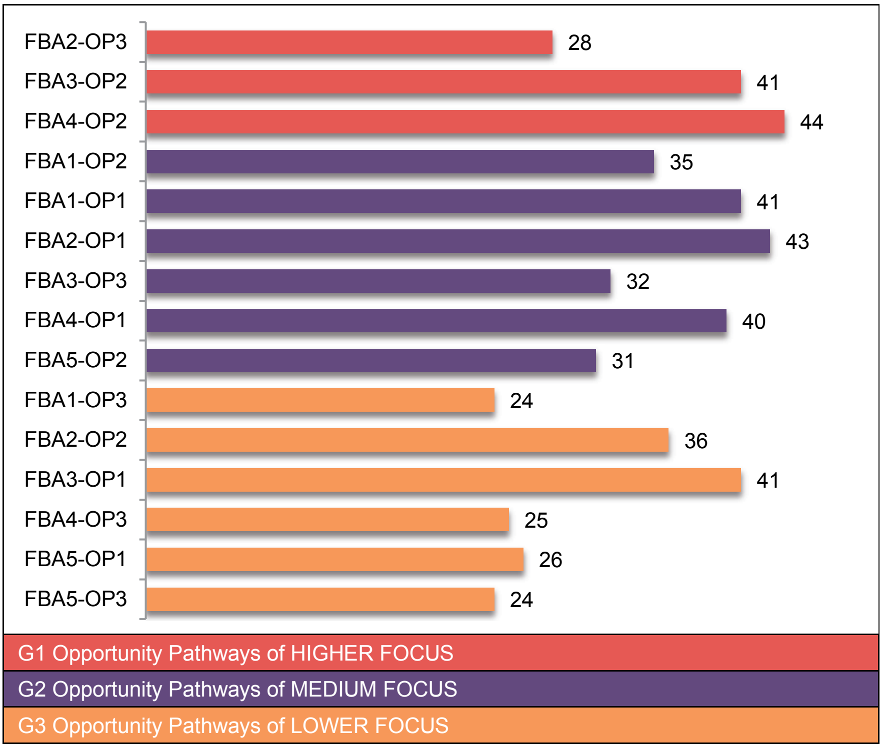
The following sections provide a more detailed description and assessment of the opportunity pathways (OPs) in terms of:

- Key recommendation
- Background
- Key enabling actions
- Key reactions from stakeholders and experts
- Innovation/business needs
- Research needs
- Education needs

- Institutional needs.

For each of the 15 OPs an action roadmap was also co-created with the active engagement of Finnish and Uruguayan FBA experts and key stakeholders. A total of 511 recommendations were generated and consolidated into five action roadmaps by FBA (see also Section 4.8).

Table 43. Number of OP-specific recommendations (actions) by focus level.



5.5 Forest-based bioeconomy opportunity pathways of higher focus

5.5.1 Fostering EWP and wood-based building (FBA2_OP3)

Recommendation: To adapt competitive sawn wood and plywood products (including standards) to international and domestic building with wood markets and distribution channels (for both pine and eucalyptus).

Background:

Improving sawmill industry to increase production of engineered wood products (EWP) in Uruguay is seen highly essential and urgent. Regional market potential is foreseen positive if current dubious attitude to wood-based construction in Uruguay and neighbouring region (except Chile) will be transformed. Potential for export market exists, but requires simultaneous development of domestic wood-based construction sector. The potential of EWP is locally recognised in four products, CLT, LVL, structural grade timber for construction, and glulam, which were among the five most potential forest-based products in Uruguayan ranking of different forest products. Another important driving force for developing EWP sector is a foreseen underutilisation of wood, mainly pine, resources. Third driver is the potential of side streams of sawmill industry (e.g. sawdust, chips) that offer potential for transformation into higher value added products (e.g. pellets) if raw material is produced in great quantities. Chips can be used in pulp making or, if not logistically feasible in pulping process, those can be used to produce bioenergy.

The benefits of different EWP, manufactured from laminated timbers, adhesives and other materials, include increased dimensional stability, more homogenous mechanical properties and greater durability. Therefore, products such as CLT, GLT, LVL, are widely used in construction sector. For instance, CLT and glulam are suitable for interior and exterior usage, whereas LVL is for interior usage[210]. Construction sector products are mainly made of softwood. In general, modular wood construction offers benefits such as reduced waste, lower costs, and shorter installation programs. Wood is structurally efficient material, for instance in roofs, some bridges and the gravity load resisting system of tall buildings. In these structures a high proportion of the load to be resisted is the self weight of the structure itself. For wooden buildings taller than 10 stories, the only proven construction system to date is the external glulam frame supporting internal CLT units.

Research avenues in softwood EWP are new joining methods, e.g. welding of timber via high frequency oscillating or linear friction of adjacent wood surfaces as a replacement for wet adhesives, and improving the stiffness and strength to weight ratios of engineered softwood products[211]. The surface properties can be modified form different functionalities by vinyl monomer impregnation or atmospheric pressure plasma technologies[212]. Also seismic performance of taller wood structures is an active area of research. It is sensible to use wood resources for construction products whose lifespan is long, from over 30 years to even over 100 years, and which can be re-used as e.g. wood plastic composites, or down-cycled into either pulp or fuel.

210 Ramage, M.H. et al. (2017). The wood from the trees: The use of timber in construction. Renewable and Sustainable Energy Reviews, 68, 333–359.
211 ibid.
212 Dimitrakellis, P., & Gogolides, E. (2018). Hydrophobic and superhydrophobic surfaces fabricated using atmospheric pressure cold plasma technology: A review. Advances in colloid and interface science, 254, 1–21.

CLT market is dominated by Europe, as it constituted approximately 90% of the global CLT production in 2015 (a volume of 0.6 million cubic meters)[213]. North American market shows increase in demand due to adoption of a new product standard for CLT by the International Building Code in 2015. The large timber companies have recognized the potential of CLT that shows in several planned, or recently started production installations[214]. Demand for CLT is expected to increase as market participants realize its benefits as a replacement for traditional building materials, such as steel and concrete, in high-rise building construction. One of the downsides is that current hype in CLT can lead to a major global gap in expertise. For instance, also Australian wood product manufacturers have recently engaged in CLT production[215]. It has been reported that CLT industry is still relatively young and production volumes relatively small due to customised production[216]. Furthermore, entering to CLT sector successfully requires extensive involvement along the value chain.

It is estimated that CLT and LVL production constitutes 10.7% of total wood adhesives market by 2024 while particleboard remains as the main application area (33.3% in 2024)[217]. Hardwoods are considered ideal for high-quality LVL production, which finds several applications in the building & construction industry (e.g. in beams, headers, and rim boards). Although CLT usage is increasing in particular in Europe and North America, Latin America and the Middle East are currently exploring CLT usage whereas demand for LVL in the building & construction industry in the region is relatively mature[218]. In Europe, a trend toward pre-fabricated housing offers new growth opportunities for the LVL segment, in particular in Scandinavia and UK[219]. However, LVL utilization in Europe is lower than in North America. A worrying trend in Europe for wood-based construction is lack of skilled labour which drives solutions like off-site pre-fabricated construction. LVL has gained importance as substitute for glulam due to its higher structural (e.g. strength-to-weight ratio) and mechanical properties, as well as and lesser installation space for structural frame applications. In addition, LVL proves to be more cost-effective than glulam as less wood is required to manufacture an LVL component compared to glulam.

One good example from EWP industry is a Finnish Metsä Wood's LVL mill that is 100% self-sufficient in energy as it uses its side streams of sawdust, chips and bark for bioenergy[220]. Company dominates European mature LVL market by 80%

---

213 Frost & Sullivan, 2016. North American and European Engineered Wood (EW) Market, Forecast to 2022.

214 https://www.timber-online.net/wood_products/2018/11/CLT-production-2017-growing-market.html

215 https://greenmagazine.com.au/australias-first-cross-laminated-timber-manufacturing-plant/

216 Muszynski, L. et al. (2017) Insights into the Global Cross-Laminated Timber Industry. BioProducts Business, 2(8), 77–92. http://biobus.swst.org.

217 Frost&Sullivan (2018) Analysis of Global Wood Adhesives Market, Forecast to 2024.

218 ibid

219 Frost & Sullivan., 2016. North American and European Engineered Wood (EW) Market, Forecast to 2022.

220 https://www.metsawood.com/global/news-media/articles/Pages/100-bioenergy.aspx

market share[221]. Another example representing innovativeness in traditional wood construction is a patented WLT building system which was created and developed by Finnish woodworking expert Aalto Haitek Ltd.[222] Its timber building technology, based on unique wave structure, is healthy, sustainable and additive free, and suits in building as well as larger infrastructure projects, like bridges.

Key enabling actions:

- Supporting wood-based panel manufacturing (as part of an industrial policy) (PI-03)
- Developing expertise in structural and architectural design of large-scale wooden buildings (office, residential, commercial) (CI-06)
- Developing the (local) demand and supply for wood-based construction products to make the sector as competitive as traditional construction (CI-02)

Key reactions from stakeholders and experts:

Main barriers in developing sawmill industry in Uruguay are lack of wood-based construction regulation and attitudes to wood-based construction over dominant construction materials and methods. Regulative barriers exist in EWP manufacturing requirements, structural calculation codes, and limitations in wood construction just to name few examples. Progress of EWP production relates strongly to supply of raw material (i.e. different types of wood) and logistics. For sawmill industry to be lucrative, utilisation of residues locally is one of the key issues to be solved. use of residues demands cluster approach to create synergies in industry. Regional operators for sawmill residues are very few (one potential in Argentina) and transporting to neighbouring countries is seen unprofitable. Currently, sawmills use only domestic raw material, which gives room for importing wood in case manufacturing increases in future.

Major concern is Uruguay lagging behind in EWP sector because of low innovation capacity and sluggish renewal of sector. Imports may take over domestic production. Without a defined articulation in industry and academia, ready-made solutions will be adopted from abroad. To increase the wood-based construction in Uruguay, country needs to intensify knowledge in academia and industry as well in general public with trainings. One of the central areas to improve utilisation of domestic goods is to develop standardisation and certification systems for sawn products and manufacturing, also for products in wood-based construction. Uruguay could profile itself as leading Latin American country in wood-based construction. For example, setting up a regional fair for wood-based housing replicating a Nordic tradition of Housing Fair[223] and demonstrations in pilot buildings may bring desired

221 Frost & Sullivan, 2016. North American and European Engineered Wood (EW) Market, Forecast to 2022.
222 https://www.aaltohaitek.fi/frontpage
223 http://asuntomessut.fi/english/what-is-a-housing-fair/

visibility. Chilean wood-based industry is the only severe competitor in the region now that gives room for Uruguay to advance in the sector. However, current ambiguity created by Mercosur should be solved for potential EWP trade.

Promoting of wood-based construction is essential, not only to take into account single-family houses but larger construction projects as well. Development of industrial base for wood-based construction is seen one of the priorities. From an environmental impacts' perspective, wood-based construction has direct influence to carbon dioxide emissions as increased wood utilisation (in mechanical processing and construction) binds carbon dioxide into wood structures.

Innovation/business needs:

Certification of EWP in smaller and larger scale (e.g. wooden bridges) are urgent needs in business and innovation to materialise in Uruguay. For innovation to take place in structural and architectural design of large-scale wooden buildings, expertise is needed, for instance, in wood drying and thermally and chemically treated wood processes. Domestic production in many areas of EWP is missing. Given the low national competence level in wood-based construction, systemic development of industry is important. This applies to training of industry and end-users, setting research agendas in collaboration with private sector and research institutions as well as developing domestic market in terms of prices and wood-based standards, and most of all commercial channels (domestic and international) for EWP. Adoption of wood-construction requires changes in wood-based materials and design but simultaneously ensuring of stable quality in production. Piloting of CLT, and possibly LVL, mill would give EWP industry, and other stakeholders (like related sectors, investors, consumers and decision makers), a positive signal of the market prospects.

Research needs:

Development of EWP industry in Uruguay demands strong RTDI collaboration (domestic and international) that involves larger companies and integrates international expertise. In addition to R&D competences, parallel concentration is needed in development of testing and standardisation services and marketing and branding competences.

In general, concentration on research areas that are not yet on market to improve innovativeness should be prioritised. For instance, setting up research and testing in exploitation of lignin in EWPs (such as substitute for glues in structural wood production, is one potential area).[224] Other potential areas include exploring non-traditional raw materials and products (e.g. oak). In the context of EWP, it is important to research and develop local adhesives and different types of preservatives

[224] For example CatLignin technology developed by VTT enables decreasing the carbon footprint and improve the ecology of resin glues significantly. Resin glues are used in many wood products, such as plywood, hardboard, chipboard and laminated wood.

linked to biorefining. To ensure supply and versatility of raw material in wood-based construction, research for preservation of local conditions (species, pests, fungi, climate) should be sustained. Devoting research efforts to quality of wood raw material (incl. other species than eucalyptus and pine) as construction material is important, but quality issues should be considered in education and regulation too. So far, modern wood engineering has largely concentrated on a few softwood species. Moreover, a need to set up a national research programmes on mechanical properties of wood is recognised.

Education needs:

Lacking tradition in wood-based construction creates large demands in Uruguayan education system. Education and training is seen needed in both industry, e.g. to classify sawn products by standards and increase knowledge of wood-based construction and different EWP, and in academia to enhance understanding in wood-construction technologies. Therefore, simultaneous occupational, vocational and university education development is essential.

It is recognised that in order to support EWP manufacturing as part of an industrial policy, one needs to approach engineering with stronger forestry focus. Developing expertise in structural and architectural design in turn requires for instance, technical training in construction carpentry and intensifying knowledge of the quality of wood. It is also essential to break the cultural barrier regarding use of wood in construction in academia, and make investments to increase training in wood architecture. To create local competences, wood-based construction should be included in both national university/ies curricula and university careers. An example would be to set up a programme that offers a degree between different universities. Courses offered should be focused and on-site and remote learning for SME entrepreneurs ensured. Overall, learning by doing approach in R&D should be applied. Besides technological and technical competencies, it is equally important to improve business, entrepreneurship, marketing and sales skills.

Institutional needs:

Creating a domestic market and demand for EWP is a priority for sawmill and plywood industries to evolve in Uruguay. Various regulative improvements are foreseen for forming of EWP manufacturing industry in Uruguay: such as norms for manufacturing requirements and seals of structural certification, or standardization of preservation standards. Similarly, reducing obstacles to wood-based construction requires institutional actions. There is a need to promote wood construction driven by energy efficiency and developing wood construction minimum shares. In addition, certification of wood according to use is needed. Benchmarking of neighbouring countries (mainly Chile and Argentina) in good practices for wood-construction standards is needed, e.g. in lightweight framing of wood. But, also streamlining bureaucracy and institutional systems in construction are needed on the governmental side. For domestic wood supply, modernisation of transport infrastructure and improvement in state purchases containing national wood are needed. To develop EWP and wood-construction industries, incentives to local investments are highly needed. Private sectors' investment readiness should be supported with public procurement in wood-based construction, e.g. schools, bridges, public buildings. If Uruguayan companies are not willing to invest in EWP manufacturing, development of domestic market stagnates. Building of public wood-based buildings to raise awareness, promote and demonstrate viability of wood-based construction would show the needed commitment.

5.5.2 Increasing types of pulp produced (FBA3_OP2)

Recommendation: Encourage large companies to consider investments also in other type of pulp mills, such as pine kraft pulp, eucalyptus dissolving pulp and eucalyptus NSSC pulp mills.

Background:

Currently, there are two pulp mills in Uruguay both producing bleached eucalyptus kraft pulp. Montes del Plata mill jointly owned by Arauco (Chile) and Finnish-Swedish Stora Enso started its operation in 2014 and has annual capacity of 1.4 million tons of pulp. UPM, headquartered in Finland, has produced pulp at the Fray Bentos mill since 2007 with annual capacity of 1.3 million tons of pulp. UPM has also signed an investment agreement with the Government of Uruguay in November 2017 related to a potential construction of new pulp mill in location close to the city of Paso de los Toros in central Uruguay. In past, a smaller mill (Pamer) using neutral sulphite semichemical (NSSC) process produced paperboard and market pulp but is no longer in operation. In Uruguay, it is now justified to consider further chemical or semi-chemical pulping processes and products to increase the choice of high-volume, market-driven products from the current wood raw materials, including the under-utilised pine wood resources. Among the most potential such products are eucalyptus dissolving and NSSC pulps, and pine kraft pulp. Additional products worth consideration might include fluff pulps from pine, potentially also from eucalyptus. Global and Latin American market outlooks seem to be promising for all of these pulps in various end-uses[225]. Important driving forces include increased local and global demand for fibre-based packages, cellulosic textiles and other cellulose products, and different biobased raw materials for chemical industry. Furthermore, the separation of various by-products could be integrated to the potential novel pulping operations, to provide raw materials for different chemical, material and even food sectors.

The global dissolving pulp capacity has steadily increased during the past 15 years and has reached the level of 9 million tons, with further capacity increases

[225] Pöyry, World Paper Markets up to 2030.

expected for the coming years[226]. Although there are dozens of producers, only two of them (Bahia Specialty Cellulose and Jari Celulose in Brazil) operate in Latin America, using eucalyptus raw material. In addition, Arauco in Chile has recently announced a dissolving pulp project at one of their pulp mills[227]. Dissolving pulp can be produced by sulphite and prehydrolysis kraft processes (from softwood and hardwood); most of the recent capacity increases are based on the conversion of existing paper grade kraft lines to the dissolving pulp lines[228] (including the Jari and Arauco projects). Although no new sulphite pulp mills have been constructed during the past 35 years, a large industrial consortium in Sweden is currently evaluating possibilities for a new sulphite dissolving pulp production, integrated with the recovery of different by-products[229]. The main application areas of dissolving pulp include textiles and specialty chemical derivatives for a large number of different materials uses, ranging from food additives to explosives (see FBA3_OP3)[225].

In Uruguay, dissolving pulp production could apparently be based on a new prehydrolysis kraft line with a moderate capacity, as there are no current announced plans for the conversion of the existing lines to the dissolving pulp production. This may be realised by a new player or one of the currently operating forest companies. There are also other, emerging potential technologies for the production of dissolving pulp and textile fibres, by using paper grade pulps. Finnish company Metsä Group and Japanese Itochu Corporation announced in October 2018 a joint venture on a demonstration project to study direct dissolution of paper grade pulp using a novel solvent for the pulp dissolution stage[230]. The new technology is estimated to be more environmentally friendly than the textile fibre production technologies currently in use. After the demo phase (2–3 years), technical and economic realities of building a clearly larger plant in Finland in the future will be evaluated. Other potential future options include removal of hemicelluloses from paper grade pulps by controlled post-treatment steps. These types of technologies are still under development[231].

The global NSSC pulp production is c. 5–6 million tons, with some recent increase after a period where the production slightly declined[225],[232]. The pulp (produced only from hardwood) is used almost exclusively for the production of fluting for corrugated containerboards, often together with some recycled fluting. Pure NSSC fluting is, however, usually ranked very high for packaging for demanding

---

226 R. Young, Global trends in dissolving pulp. Spectrum 2017:36, 52–53.

227 https://www.arauco.cl/mo/arauco-to-materialize-significant-innovation-at-its-valdivia-pulp-mill-allowing-the-company-to-enter-new-markets.

228 Hawkings Wright Ltd, Pulp market outlook and the growing influence of the viscose sector. Europulp/Utipulp, Barcelona, 14th September 2017.

229 http://www.processum.se/en/sp-processum/information/news-archive/2380-positive-result-from-feasibility-study-flagship-biorefinery.

230 http://news.cision.com/metsaliitto-osuuskunta/r/metsa-group-and-itochu-establish-a-joint-venture-that-builds-an-industrial-demo-plant-to-produce-woo,c2632127.

231 M. Borrega et al., Birch wood pre-hydrolysis vs pulp post-hydrolysis for the production of xylan-based compounds and cellulose for viscose application. Carbohydrate polymers, 190 (2018), 212–221.

232 Index Box, World, Semi-chemical fluting - market analysis, forecast, size, trends and insights, 2018.

circumstances and tough requirements endured over long periods of time, typically for packing and transporting delicate goods like fruit, vegetables and other food products. Most of the NSSC fluting production takes place in North America, where International Paper is the key producer. Other important global players include Stora Enso, Powerflute, BillerudKorsnäs, Mondi, Sappi, and Georgia-Pacific. In Latin America, there is apparently no current NSSC fluting production, and thus the containerboard production is mainly based on the use of recycled fluting and some imported NSSC fluting. From the total global NSSC fluting production, c. 1.5 million tons enter the cross-border trades[225]. High quality NSSC fluting from the Nordic countries is expected to continue to strengthen their role in the global markets.

In Uruguay, the NSSC pulp production from eucalyptus for demanding packaging uses could be either integrated into the kraft pulp mills (either current or new), or that could be realised in stand-alone NSSC mills. Although the integrated systems are common, there are also examples on well-operating, separate NSSC mills. The current stand-alone NSSC mills require may have production capacities up to 300,000 tons. For the cooking chemicals, there are currently two main options, either sodium and ammonium sulphites. Of them, the ammonium-based process requires a stand-alone installation (like Powerflute in Finland) and sufficient supply of ammonium water for the cooking chemicals production. Otherwise, the processes are based on well-established technologies. A number of NSSC pulp mills have demonstrated that they can also contribute to chemical industry by recovery of useful by-products for different uses. So far, acetic acid has earlier been isolated at some mills, although highest potential is found within lignosulphonates. Today, tens of thousands of tons of eucalyptus-based lignosulphonates are being isolated at Sappi's Tugela mill in South Africa[233]. To establish something like that in Uruguay would make the corresponding mill the first source of valuable lignosulphonates in Latin America, after the closure of the Melbar lignosulphonate plant and the sulphite pulp mill in Brazil in 2012. Needless to say, that would also reduce the need for imported lignosulphonates in the region.

The third potential new pulping option, production of pine kraft or kraft-polysulphide pulp, would open new routes for the multi-purpose use of currently underutilised or simply exported pine wood logs. According to a recent study[234], a mill producing 250,000 tons/a of high-yield kraft pulp mill could be fed for many years to come, using secondary log parts available from the present plantations. At the same time, the high-quality wood sections would be used for the engineered wood products. Different potential options can be seen for the pine kraft pulp production, for example, in the form of bleached paper grade market pulp or different packaging materials. There is currently somewhat more demand than supply (c. 28 million tons) for the bleached softwood kraft pulp[235], the main producers being including International Paper, Koch Ind., Arauco, Domtar and Metsä Fibre. There are already,

233 https://www.sappi.com/tugela-mill.

234 University of the Republic for OPP Project "Forest based bioeconomy in Uruguay by 2050": Forest Based Bioeconomy Areas, Strategic products from a technological point of view.

235 ENCE, delivering value, delivering commitments. September 2018.

however, announced projects for new softwood pulp capacity, especially in Finland (4 projects, total >3 million tons) and Russia (2 projects, c. 2 million tons). Although they all would not be realised in new future, more softwood pulp can be expected to the markets from these sources.

In terms of different packaging applications, softwood kraft pulp can be used for the manufacture of sack paper and kraftliners for containerboards. According to the Pöyry report[225], global production of sack paper is c. 5 million tons. Of this, Latin America produces 14% of this but uses 17%. By 2030, the global production is predicted to reach the level of 5.7 million tons, including steadily increased consumption in Latin America. The main producers include Mondi, BillerudKorsnäs, Klabin, and SmurfitKappa, among others. In Latin America, especially in Brazil, the dominating end-user sector in the paper sacks is building materials. Other important sectors include agricultural products, chemicals and fertilisers.

The kraftliners constitute c. 20% of containerboard furnish material in Latin America, the main material being recycled linerboard[225]. Today, import deficit of containerboard to Latin America is nearly 3 million tons, and this is expected to reach the level of nearly 3.5 million tons by 2030. To decrease this deficit, more local production is required. For that, the simultaneous production of fluting and liners would open interesting opportunities to strengthen the country's role in the packaging material industry. Most of the containerboard import is today shipped from North America (more than 2 million tons).

As already mentioned, the well-planned use of the pine wood resources could serve both the (packaging) paper industry and mechanical wood sector. A number of additional, potential benefits are also apparent. The use of softwood raw material would give access to two by-products (pine chemicals) that are not available from eucalyptus: sulphate turpentine (yield 3–4 kg per ton of pulp) and tall oil (yield 30–40 kg) for further valorisation to be used by chemical industries. Today, the global pine chemicals market represents c. 4 billion USD and it is expected to grow by 4–5% per annum in the coming years[236,237]. This sector includes 1.7 million tons of crude tall oil distillation capacity, of which 3% is covered by Latin America's sole distillation plant in Brazil. From tall oil, valuable phytosterols can also be recovered as is done in Brazil at one plant. The global sulphate turpentine production is 180,000 tons, of which 165,000 tons are being produced in North America and Europe, with only a small production volume in Latin America. Nearly similar amounts of so-called gum turpentine are collected from living trees, with the estimated figures of 190,000 and 25,000 tons for the global and Brazilian production, respectively.

In addition to the pine chemicals, softwood lignin for wood adhesives and many other uses can also be recovered as a by-product from pine kraft pulping. Today, there are five kraft lignin plants in operation, the capacities ranging from 10,000 to 50,000 tons (four of them are based on softwood lignin). Furthermore, pine bark offers potential sources for tannins and other constituents, further increasing the

[236] M. Baumassy, The tall oil industry: 100 years of innovation. 2014 PCA International Conference.

[237] K.A. Ukkonen, Pine chemicals - global view. 2016 PCA International Conference.

potential contributions to the chemical industry. Recent Chilean achievements in the improved bark extraction process have resulted in an optimistic view of having several bark processing plants in operation in Chile during the coming years[238].

Depending on the future market situation, the potential pine kraft pulp production can also be designed to meet other types of final products. These include the production of dissolving pulp, normal paper grade pulp, and fluff pulp for different hygiene products where increasing markets can be seen. There are currently three fluff pulp producers in Latin America: Arauco (pine), Klabin (pine) and Suzano (eucalyptus), two last ones having started very recently. According to a recent study, global fluff pulp capacity and demand today are 6.8 and 5.8 million tons, respectively[239]. The leading producers include Georgia-Pacific, Weyerhaeuser, International Paper, and Domtar.

The realisation of all the above pulping opportunities can be based on well-established technologies and process design and should be manageable by local or international forest companies, or by new players. There are, however, certain novel technologies also evolving that may become industrially available in near future. Depending on the case, different strategies will apparently be required to scan the existing and future local and international clients and the corresponding value chains. The current large forest industry companies operating in the country or in Latin America in general are expected to have access to all human resources required for feasibility studies, deeper design and construction of any of the addressed pulping operations. Naturally, the companies already operating in the country obviously have the deepest knowledge and expertise in managing such projects, although there are also several (other) forest companies that have expertise in operating in several Latin American countries. For the relevant research questions on the raw material characterisation, process optimisation, product tests and related questions, local university expertise should in most cases be sufficient.

Key enabling actions:

- Integrating wood-based biorefining into large-scale pulp and paper mills (CI-09)
- Developing integrated mills (for pulp and by-products, for paper & packaging, for kraft & fluting pulp) (CI-08)
- Producing reinforced fibres to meet the global demand for card/paperboards in packaging (e.g. recyclable packages in food industry). Substituting most petrochemical based products (such as plastics) with bio-based products (CI-10)

[238] A. Berg and F. Guzman, A novel process for biomass extraction: the basis for a pine bark biorefinery. 8th Nordic Wood Biorefinery Conference, Helsinki, October 22–25, 2018, Proceedings, p. 105–109.

[239] Smithers Pira, The future of fluff pulp to 2022.

Key reactions from stakeholders and experts:

Increasing the number of pulp types or grades produced addresses, at least partly, the strong need to diversify forest sector activities in order not to become too dependent on only one tree species or only pulp as end product in Uruguay. Producing different grades of pulp from eucalyptus but also from pine would lessen vulnerability for global demand fluctuations in specific types of pulp for the country as a whole. At the same time, it would allow product diversification offering path to new markets and market segments, which still can be relatively small but growing - such as pulp for textile applications. Producing soft paper, packaging and textiles are seen as a desirable goal for evolvement in the pulp industry. Furthermore, certain options (such as pine kraft pulping) would give access to new by-products, especially softwood lignin and pine chemicals (tall oil and turpentine) to strengthen raw material choices for the national chemical industry and other sectors. The need for more detailed feasibility and market studies are, however, among the first actions to be taken.

Innovation/business needs:

Take advantage of the existence of large cellulose plants to develop local cases of technological applications to create value-added by-products from side-streams of pulping process (e.g. lignin). The existing pulp mills and possible new mill(s) in future provide a springboard for developing integrated mills in Uruguay. Depending on industrial actor's focus and decisions, integrated mills can focus on pulp and by-products, on paper and packaging, on kraft and fluting pulp to name a few.

How realistic and attainable goal integrated mill(s) is depends ultimately on decisions of the companies operating the pulp mills – decisions about changes in mills, e.g. adoption of integrated mills, are done typically on board level. Therefore, it seems important to find and frame areas in which national and companies' interests align and provide compelling business case. Large companies' active in pulp industry make decisions to invest with a long-time horizon and careful assessment of global market trends; products are market driven and companies producing pulp are looking for a business with clear market share in future. Scale/production capacity of mills is nowadays also an important parameter in competition. Regarding operating environment, infrastructure and efficient logistics, geographical vicinity of plantations to pulp mills, and level of education are important factors for industry actors. Innovation could be driven by using innovation platform perspective.

Research needs:

Wider variation of pulp grades produced in Uruguay sets requirements for domestic research and development capabilities but current competence level provides a sound basis for development. To get optimal quality of raw material requires long-term competence development and commitment in R&D. Because of this, sufficiency of current competences may turn out a challenge in Uruguay, though (link to education needs).

Areas in which there were identified research needs include the properties of Uruguayan pine (Pinus taeda) for paper production, improvement of species genetics and search for new varieties, using pulpwood as raw material for cellulose and cellulose fibres in textiles and development of alternative by-products using lignin obtained from pulping process (lignin separation as part of this). Encourage research partnerships/collaboration between universities/research institutes and forest sector companies present in Uruguay. This would support emergence of close to market solutions

Education needs:

As in all the other opportunity pathways, education is a key factor regarding long-term outlook for increasing types of pulp produced in Uruguay. There is a need to generate and strengthen knowledge base in new technologies and products related to various grades of pulp, thus providing expertise and competence required for making possible production a wider range of products from wood-based raw material. Active search for different uses of pulp grades and side-streams of pulping process can create opportunities for entrepreneurial activities and offering people training for entrepreneurship during their initial education may lower threshold for setting up new businesses.

Institutional needs:

As noted above, increasing types of pulp produced in Uruguay is a question, which needs to be addressed jointly with the industrial actors. Whatever decisions are made regarding pulp grades/types, they have a direct impact on range of opportunities available in producing high-value products in biorefining and bioenergy. Government can however use a mix of policy measures and regulation to create favourably legal and operation environment and demand for products using pulp as a raw material for new products. Government can foster transition from petrochemical/fossil based products to bio-based products, generate an enabling regulatory framework for production and conditions to attract investments related to short fibre. To proceed it is important to involve stakeholders such as the public petrol company and generate alliances with the pulp mills plants for the production of biorefineries. Uruguay Government needs also explicate their forest-based objectives to 2050 with the companies operating the pulp mills in the country in order to create win-win situations.

5.5.3 Encouraging networking in the use of forest industry residues and wastes (FBA4_OP2)

Recommendation:

Encourage the creation of networks to joint utilisation of different residues and wastes from forest industry and other sectors, to produce different biochemicals, materials and biofuels.

Background:

Like other industrial sectors, the forest industry operations produce a variety of different solid inorganic and organic residues and wastes at different processes[240,241,242]. In addition to these solid streams or fractions, there are also many different liquid process streams containing additional, dissolved residual materials offering opportunities to develop advanced biorefinery-type systems (e.g. FBA3_OP2 and FBA4_OP1). In this opportunity, the main focus will be in the solid residues and wastes and in the creation of innovation networks to address their management between different sectors for new solutions, thus converting the residues and wastes to useful raw materials. This type of development will require the development of innovative symbiosis solutions between different industrial sectors and other stakeholders. If successful, it will have positive impacts on sustainability and efficiency of the use wood and other biomasses as well as unrenewable raw materials. For successful solutions, at least most of the currently identified residues and wastes should obviously be valorised close to the sites where they are formed or generated. By taking into account the main types of the residues and wastes, i.e. inorganic and organic (lignocellulose-based) materials, it is suggested that separate innovation networks will initially be set up for both of them.

Examples of the inorganic solid residues or wastes from forest industry include green liquor dregs, recovery boiler fly ash, lime mud and slaker grits from the pulp mills, and ashes from biomass combustion. Organic solid residues or wastes from forest industry include bark, harvesting residues, sawdust and different residues from plywood manufacture and other mechanical wood industry, fibre clay and deinking sludge from paper mills, and biosludges from wastewater treatment. Recovered wood and paper can also be included here as wastes. Wood bark as a source of chemicals is more specifically addressed in FBA4_OP3.

For the main inorganic residues there are already several tested and applied means of uses, such as fertilisers, landfilling, cement or concrete manufacture, and

240 Monte, M. C., Fuente, E., Blanco, A., & Negro, C. (2009). Waste management from pulp and paper production in the European Union. Waste management, 29(1), 293–308.

241 Watkins, G., Makela, M., & Dahl, O. (2010). Innovative use potential of industrial residues from the steel, paper and pulp industries–a preliminary study. Progress in Industrial Ecology, An International Journal, 7(3), 185–204.

242 Simão, L., Hotza, D., Raupp-Pereira, F., Labrincha, J. A., & Montedo, O. R. K. (2018). Wastes from pulp and paper mills. A review of generation and recycling alternatives. Cerâmica, 64(371), 443–453.

road construction. Of the inorganic fractions, the most challenging one in terms of valorisation is green liquor dregs due to the presence of soluble compounds and various heavy metals of environmental concern[243]. Therefore, pulp and paper companies are actively searching for the sustainable solutions for the disposal and valorisation of the dregs. In Brazil alone, more than 250,000 tons of green liquor dregs are annually generated, and the figure for lime mud and slaker grits is even higher. Many kraft pulp mills (especially softwood pulp mills recovering tall oil) also recover and dispose recovery boiler fly ash (crude sodium sulphate) in varying amounts, especially if there is no chloride control process installed.

Substantial amounts of different inorganic residues and wastes are also generated in mining, minerals, metals and glass industries, and in the related areas. For the development of sustainable management and application means for the inorganic wastes from the forest industry, collaboration with such sectors may result (case by case) in novel and even profitable solutions, as recent examples from Europe demonstrate[244,245,246]. There are also successful examples on the development of sustainable products (such as fertilisers) by combining inorganic residues with biosludges from pulp and paper mill wastewater plants. It is therefore justified to expect that via extensive networking and joint innovation programmes a number of similar symbiosis cases can also be identified and realised in Uruguay. As the current applications typically represent relatively low value uses, one of the main challenges will be related to the need of new, value-added innovations and invention of marketable specialty products.

The list of potential solid organic wastes from the forest industry covers a wide range of different materials; this is naturally largely expanded by integration of different agro-based residues as well. For the pulp mill sludges, usually listed applications are found in agriculture, construction and energy use, including the combustion in the recovery boilers[247]. The production of various chemicals, materials (e.g. bioplastics) and biofuels (e.g. bioethanol and biogas) have also been extensively studied but only little realised so far. The other materials include fractions from harvesting (including eucalyptus bark typically left on the plantations), debarking of softwood, and mechanical processing residues (including sawdust and sander dusts).

---

[243] Golmaei, M., Kinnarinen, T., Jernström, E., & Häkkinen, A. (2018). Extraction of hazardous metals from green liquor dregs by ethylenediaminetetraacetic acid. Journal of environmal management, 212, 219–227.

[244] Watkins, G., Husgafvel, R., Pajunen, N., Dahl, O., & Heiskanen, K. (2013). Overcoming institutional barriers in the development of novel process industry residue based symbiosis products–Case study at the EU level. Minerals Engineering, 41, 31–40.

[245] Pajunen, N., Watkins, G., Husgafvel, R., Heiskanen, K., & Dahl, O. (2013). The challenge to overcome institutional barriers in the development of industrial residue based novel symbiosis products–Experiences from Finnish process industry. Minerals Engineering, 46, 144–156.

[246] Husgafvel, R., Nordlund, H., Heino, J., Mäkelä, M., Watkins, G., Dahl, O., & Paavola, I. L. (2016). use of Symbiosis Products from Integrated Pulp and Paper and Carbon Steel Mills: Legal Status and Environmental Burdens. Journal of Industrial Ecology, 20(5), 1187–1198.

[247] Romaní, A., Michelin, M., Domingues, L., & Teixeira, J. A. (2018). Valorization of Wastes From Agrofood and Pulp and Paper Industries Within the Biorefinery Concept: Southwestern Europe Scenario. In Waste Biorefinery (pp. 487–504).

Apart from the use as a source of chemicals (see FBA4_OP3), barks can find applications for example in energy production, agriculture, manufacture of boards, and water or gas cleaning[248]. The applications may depend, however, very much on the physical and chemical nature of the barks. Sawdust is currently used for the fibre production at a few pulp mills as a raw material in specific sawdust digesters, but to be profitable this requires sufficiently high volumes of the feed. The most typical use is, however, in the energy production. Different harvesting residues are in a few cases used for the production of pyrolysis bio-oil to be used as a fuel, or more often, combusted in heat and power plants. The other uses like essential oil production from eucalyptus leaves or softwood twigs (with needles) are also known from many countries. In Latin America, the main producers of the eucalyptus oil are Brazil and Chile.

As already pointed out, this type of opportunity pathway can apparently be successful only if the actors from forest industry, other industrial sectors, agriculture, and research organisations and universities join forces in Uruguay. The participation of the industrial sectors such as mining and ore, ceramics, metals, glass, chemicals, oil and energy, and agriculture would be most beneficial to ensure that the relevant symbioses, value chains and starting materials & desired end-products or applications will be covered. The active role of the government in the initiation and motivation of such networking is also necessary. It is also important that innovative SMEs will be encouraged to participate in the co-innovation activities, as there are globally lots of examples on their ability to invent new solutions. As just one example, the production of new types of geofoams from inorganic residues by an SME can be mentioned[249].

Key enabling actions:

- Convincing the private (CI-06)
- Take advantage of the existence of large cellulose plants to develop local cases of technological applications to create value-added by-products (CI-08)
- Generate knowledge in new technologies and products (CI-09)
- Master's degree or specialization in biorefinery (PI-01)
- Associativity between industry, research centres, academia and competent authority (PI-01)

Key reactions from stakeholders and experts:

According to the stakeholder contributions, this opportunity path has a potential from local perspective but have a need of more detailed market analysis/research prior decision-making. Specific products should be selected based on an assessment of

[248] Pásztory, Z., Mohácsiné, I. R., Gorbacheva, G., & Börcsök, Z. (2016). The utilization of tree bark. *BioResources*, *11*(3), 7859–7888.
[249] https://betolar.com.

technological opportunities and market projections before introducing any piloting or incentives. The assessment should also include estimation of increase in value added of using residues vis-a-vis other possible uses for the residues or disposal.

Innovation/business needs:

A comprehensive mapping of available residues and wastes from the forest industry and other relevant sectors is essential in order to pinpoint areas with resources available for new inorganic materials, biomaterials and mixed-type materials and products from wider range of waste streams in Uruguay. Related to this LATU is currently working on finding uses for the residues and connecting biomass producers with investments.

The efficient use of wastes and residues in value added production will require integration of actors and processes from different value chains which may not have been directly connected nor interacting before. Transformation can be supported by developing clusters and industrial parks – for example around existing industry facilities such as sawmills – and by promoting matchmaking and networking across value-chains. Actors which already operate cross-sector (e.g. forest and or agriculture and processing of residues to products) can act as catalysts in process. Government can give an additional thrust for development of new innovations from waste by providing funding for ambitious R&D and innovation projects.

Research needs:

In order to strengthen domestic knowledge base, the industry-university linkages and collaboration in research should be supported. Companies could also be encouraged to use local expertise existing in university and research organisations to the extent possible. Government can promote founding of technological consortia including academia, government and companies to support development of technologically and economically viable solutions to use of waste and residues. Also allocation of research funds for usage of local biomass should be considered.

Education needs:

Joining forces in utilisation of biomass waste and residues expands and strengthens the knowledge and competence base. Collaboration makes it possible for involved parties to have access to wider pool of expertise and professionals than what would be case if working separately. Still there are need to develop domestic competence base for instance in biotechnology, synthetic biology, and chemistry. Training programmes organised jointly by industry and university can be used to disseminate information and knowledge about the potential of processing residues and side-streams to new products.

Institutional needs:

use of bio-based residues and wastes in production of value-added bio materials and products requires focusing of national efforts. There is need to identify market and product areas with high opportunities and assess which niche(s) Uruguay could and should occupy in biorefining and using of bio-based residues and side-streams. The decision about niche area(s) should take into account characteristics of wastes and sidestreams available in Uruguay as well as its competitive advantages in comparison to other biomass providers internationally.

Increased use different wastes and residues as a resource for new materials and products benefits from collaboration and networking between actors representing not only forest sector industries but also other sectors, research and academia as well as government. Therefore, supporting networking across production and value chains should be an embedded aim in national industry and R&D policies. Biorefining and use of residue flows in production of new products calls for expertise in chemical process technologies and product markets. Therefore, it is important to involve companies from chemical industry from early on.

Furthermore, Government can create an attractive institutional operation environment for joint development by ensuring that legislation on waste and waste management is supportive for recycling and re-use of valuable materials included in wastes and residues. Environment should also be supportive for early stage business development, thus encouraging commercialisation of solutions and applications based on circulation and re-using available bio-wastes.

5.6 Forest-based bioeconomy opportunity pathways of medium focus

5.6.1 Maximising the value from existing forest resource base (FBA1_OP2)

Recommendation: To implement and maximize the output value of the present forest resource, which is currently underutilized plantations (e.g. pine) and ascertaining the quality of logistics infrastructure (harvesting, roads and bridges, wood terminals).

Background:

This opportunity pathway is linked with management of present forest resources in way that enables their optimal use and maximises the value from tree plantations in Uruguay. In consultation with the Uruguayan stakeholders two issues were considered critical from perspective of economically sustainable use of forest resources and value generation; 1) underutilisation of wood feedstock from tree plantations (concerns especially use of pine), and 2) forestry related logistics infrastructure. Since revision of the Forestry Act in 1987 Uruguay has undergone a rapid change in land use. As a result of policy promoting forest plantations, the forest area has increased markedly in 30 years as pastures have been afforested mainly with fast growing exotic species, eucalyptus and pine plantations. Development of forest-based bioeconomy relies on environmentally and economically sustainable forest management which ensures availability of wood raw material for existing and potential new industrial forest sector activities both in short, medium and long term.

Key enabling actions:

- ncreasing wood production (i.e. size of forest plantations) of different species (especially pine) to meet the future needs of Uruguay's FBA agenda. (CI-01)
- Supporting the combination of eucalyptus plantations with other sectors' value chains (e.g. food and livestock policies) (PI-05)

Key reactions from stakeholders and experts:

The gaps and needs recognised are strongly geared towards improvement of logistics infrastructure (incl. railways and roads) and knowledge base (engineering, materials and road safety) supporting development of infrastructure. Public demand via public procurement were seen as an incentive to increase and find new uses for currently under-utilised pine stock in Uruguay – especially in production of engineered wood products (EWP).

While in short and medium run focus should be on efficient use of existing forest resources, longer term plans regarding advancement of forest sector activities and using timber for construction and engineered forest products call for ensuring availability of timber raw material with required properties in future. From sustainability and social acceptability perspective it is important to support emergence of activities, which form complementary relationship between forest plantations and other sectors' value creating activities, cf. silvopastoralism.

Experts see challenging that industry structures for processing pine are missing in Uruguay that hinders the optimal use of available resources. First, the replacement of species takes place in the area of pulp mills, companies buy heritage with young pines and make themselves the replacement. It results to the situation that the surface remains but does not grow. Second challenge is that the owners of pine lack of industry connection, given that they are investment funds without an "industrial leg". It is important to seek alternative domestic use for pine instead of exporting, as some studies indicate[250] that with the export of two years of pine, one could have advanced 1/3 of domestic housing needs.

Innovation/business needs:

Clear-cuts would be a straightforward solution to present under-utilisation of wood resources of (pine) plantations provided that there are no prospects about industry

[250] Based on expert's opinion in October 2018 stakeholder workshop in Uruguay.

using the raw material. If, however, there are foreseen increased use of softwood (pine) for industrial purposes in future, one needs to solve question of sustainable continuous cultivation of pine/pine plantation rotation. Optimality of clear-cuts compared to continuous cover forestry in Uruguayan context could be simultaneously assessed. Managed plantation forests with mono-age trees may not, however, provide economically attractive transition period for continuous cover forestry while there could be other societally relevant reasons such as water balance favouring continuous cover forestry. Regarding efficient land use management, agroforestry and silvopastoralism provide opportunity to foster integration and complementarity between forestry and agriculture and/or livestock. Besides, the silvopastoral management is highlighted as a good practice for CC mitigation; therefore also combination of afforestation and livestock is of an example of good economy. Combining agricultural crops such as rapeseed or Brassica carinata with afforestation is an option to consider in agroforestry. In addition, support for SMEs to develop innovative production chains for wood processing and utilization of side streams is needed from government and industry. Side streams of solid wood industry should be looked beyond bioenergy to exploit all possible forest sector activities and spills, such as forest fencing by small service providers. Overall, business sector should also take active role in awareness raising of the role of forests in climate change mitigation.

Research needs:

Cultivating commonly used species, such as eucalyptus or pine, in forest plantations does not necessarily require particular research efforts as information is internationally available. Instead, research can support finding and defining product and value chains, which are economically viable and socially acceptable. Exploring properties and adaptability of different tree species for cultivation in Uruguay should be carried out against prospects for need and usage of wood material with qualities not met with existing forest stock. Related to forest resource base, complementarities between beekeeping and afforestation are still another identified area for research. For the sustainable use of wood as raw material, systematic forest resource assessments are needed. To exploit this information, it is essential to make forest inventory data openly available for all stakeholders. Open exchange of information with industry and other stakeholders is essential to increase collaboration and innovation in the sector.

Education needs:

Beekeeping, as an area of silvopastoralism can benefit from entry to plantation forests maintained by forest sector companies. Training and education helps beekeepers to improve efficiency of their activities and ecosystems services they provide, including e.g. benefits pollination of plants and crops by bees have for yields and producing honey. Increasing use of softwood (pine) in manufacturing of engineered wood products and construction of buildings, bridges and other structural elements from softwood (pine) causes requirements for competences (e.g. load duration, load combinations, fire resistance to name a few). To implement and maximize the output value of present forest resources, providing professional training to forest sector employees (from blue to white collar workers) is needed.

Institutional needs:

Some redrafting of forest policy is required in terms of good practices in sustainable forest management. For example, rules for producer-investors, and aligned institutions should be revised. Pricing of timber and incentives for land owners to grow timber (logs) are needed for mechanical wood industry and construction sector to take off. Equally important is place emphasis on institutional strengthening agroforestry entrepreneurship. In turn, promoting demonstrations and pilot projects are seen good means for awareness raising. Impactful examples in this area to consider are, for instance construction of a public wood buildings or development of housing policies that allow wood constructions, e.g. the recent approval by MEVIR of wood construction. Government should also, in collaboration with research and industry, to systematically collect data on forest resources and conduct open access code for publishing this information. Inter-institutional coordination is needed to guarantee continuity of forest inventory. Well-functioning and efficient logistics infrastructure is a cornerstone for modern forest sector's operations from maintenance of plantations to cutting and harvesting of trees down to transportation of intermediate and final products to domestic and international customers. Among the experts, need of public infrastructure investments and modernisation of major roads emerged as areas requiring action.

5.6.2 Using native forests as source of new value added services/products (FBA1_OP1)

Recommendation: To develop environmental research/education programmes, policies, regulations and cross-sectoral investment strategies aimed to promote the use of native forests for new (non-wood-based) ecosystem services, pharmaceutical and food products.

Background:

The use of native forests in Uruguay is sensitive issue due to private ownership. It is however seen that use of native forest to wood and non-wood-based products (e.g. pharmaceutical, food products) has potential to develop in Uruguay. It is however strongly felt that natural forests have been somewhat neglected as national discussion has concentrated mostly on eucalyptus plantations. Protecting native forest is essential but current situation requires developing policies. Before setting regulations, one should first comprehensively understand the potential of native forests. In many wood-based ingredients for food research is still needed to validate the technical performance in real products and assess safety, therefore TRL is considered to be in levels of 2–3 and market entry expected in 5–10 years[251].

Uruguay has some industry potential to develop additional forest- and wood-based products in areas that require medical chemistry. Some local 85 companies and 60 laboratories are identified in pharmaceutical chemistry[252]. In addition, Uruguay has some small companies in cosmetics sectors which could be potential utilisers of different wood-based and forest-based ingredients. Potential products relate to natural and organic cosmetics.

Uruguayan government has already taken a step in improving the role of native forests in national forest development. They have launched a four year research project with German government that aims to increase the yield and use of native forest, and develop the wood and forest related ecosystem for pharmaceutical and chemical sectors. In addition, the SNAP (National System of Protected Areas) has mapped natural forest which could help to identify the areas where native forest could be prioritized; smaller zones where recreation could have an added value, e.g. for birdwatching activities.

Key enabling actions:

- Increasing research and technology development efforts in genetics of eucalyptus, pine and other species (e.g. acacia, angico, oak) (CI-07)
- Supporting the combination of eucalyptus plantations with other sectors' value chains (e.g. food and livestock policies) (PI-05)

Key reactions from stakeholders and experts:

It is important to recognise the potential of other species than eucalyptus and pine, to develop forest and wood-based ecosystem. Beekeeping and cattle raising are seen as the main ecosystem services that can be integrated into forestry. Uruguay has adopted these kinds of integrated services but for example production of organic honey could be further elaborated. The potential food products can be for instance game, berries (fresh and dried), mushrooms, or sap. Additional ecosystem services could arise for recreational purpose, e.g. for making jogging paths, barbeque facilities, camping. Several countries, like Finland and Australia, have good practices for maintaining national parks for recreation. Nevertheless, in developing additional ecosystem services and products of native forests, it is important not to disturb natural forest cover which lowers for example flooding risk. Wood-based ecosystem, and new services and products, should however be developed from forest management perspective, not to neglect sustainability of forests.

---

251 The Making of bioeconomy transformation, 2017. Kristiina Kruus & Terhi Hakala (eds). VTT.

252 Source: U.S. Department of Commerce, International Trade Administration, 2017. U.S. Country Commercial Guides: Uruguay. https://uy.usembassy.gov/wp-content/uploads/sites/113/Uruguay-CCG-2017-508-PDF.pdf

Innovation/business needs:

Innovation efforts are needed in non-traditional products basing on e.g. oak, angico and acacia. For example, the potential of oak is acknowledged. Acacia's different parts are well exploitable and traditional knowledge of the use is available in Africa. Increasing of understanding of silvopastoralism/agroforestry is needed to create more business opportunities. It would also be beneficial to examine opportunities for combining agricultural crops (rapeseed, brassica) with afforestation. In general, setting-up of cooperatives could be a way to boost forestry-related entrepreneurship.

Research needs:

One of the main needs for both industry and research is to perform a feasibility and profitability study of local ecosystem services' business in selected wood- and forest-related areas. One of the specific areas is beekeeping, its possibilities, viability, productive and quality factors. These additional aspects to use of forest should however be tightly integrated in afforestation, not to analyse separate. To perform a feasibility study is important to comprehend potential and possibilities of forest (both natural forest and plantations).

Equally important is to maintain sufficient level of basic research in agronomy, such as species diversification and genetics (e.g. genome of the relevant species of the forestry sector). Genetic research in exotic and native species is urgent to regain. Also research in biotechnology and chemistry are needed. To maintain basic and applied research requires financing resources. It has been identified that further research is needed in using Latin-American plants in pharmaceutics, nutraceuticals and cosmetics. Some university research is currently performed at local universities. For example, Brazil (southern Brazil) is a leading country in research for use of native Latin-American plants for medicine purposes. One potential area of research are wood-based ingredients in toners which is in early stages. Potential new products in these areas are foreseen in some 20 years which means it requires long-term national research investments.

Moreover, basic and applied research on the potential of alternative species of angico and acacia in pharmaceutical and cosmetics industry are needed. For example, angico has astringent, expectorant, anti-diarrheal, antiseptic and haemorrhage-arresting properties. The bark of angico has a high tannin content of 15.0% and is used in folk medicine as a bitter-tasting tonic. Acacia is known as 'super tree' given its versatile use: root, bark and fruits are valuable, and it is used for making healthy tea, cattle feed and red toner for textiles too.

An additional area of investigation is distraction of adhesive from native termites (used in ancient times to build floors) that could be developed as strengthening material in wood-based residues. This example shows how ancient local traditions could help to develop forest- and wood-based new products and ecosystem.

Education needs:

To improve the research and industry needs, the increase of training in native forests in agronomics is needed. Curricula has be developed to accommodate the potential needs. Also education in bioinformatics is seen important. Given the potential of integrating beekeeping in forestry, training and education of beekeeping skills and business opportunities to professionalise the activity are needed.

Institutional needs:

Due to local (negative) attitudes towards native forest, institutional actions are critical in changing the atmosphere. It is essential to develop awareness raising in usage and management of native forests as well as building of forest- and wood-based ecosystem. In this regard, increasing interest in recreational use of forest is important. Equal investments are needed to demonstrate the mutual benefit for companies, both cattle and agriculture producers, of the native forest conservation and a wider than mere recreational use. It would be important to value these activities as the preservation of the resource. As a good practice in silviculture, Uruguay should take active part in international climate negotiations, and participate in initiatives similar to REDD+[253] by the UNFCCC. Areas of interest include among others forest registry, the exchange of carbon and cartography development.

Impulse and institutional strengthening for the development and dissemination of agroforestry entrepreneurship is to be implemented. Protecting native forest is seen essential but current situation requires institutional actions, such as developing better policies and incentives, for example benefit schemes to land owners or subsidies to promote investment in degraded native forest and management (following a Chilean example). Developing markets and audit systems for production of sustainable ecological services are seen lucrative incentives to consider.

Lastly, building of long-term research and education competences require institutional strengthening (in HR / financing) in academia. Research skills are not sufficient alone for the development of research programs.

5.6.3 Creating internationally attractive operational environment for EWP (FBA2_OP1)

Recommendation:

Supporting and ascertaining an attractive investment environment for large international companies in sawmill, plywood mill and thereafter to engineered and modified wood products manufacturing, this should support also local SME activity in mechanical wood processing.

[253] REDD+ includes the following components: (a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forests; (e) Enhancement of forest carbon stocks. Source: https://theredddesk.org/what-redd

Background:

Existing domestic forest resources enable development of engineered wood product industry in Uruguay. According to the Uruguayan Statistics (2017), the area on plantation forests exceeded the area of natural forests in Uruguay already in the beginning of 2010s. Eucalypti (*E. grandis*, *E. globulus*, *E. dunnii*) and pine plantations that were initially intended for pulpwood production also provide the wood product industries with constantly growing raw material supply. Recently, *E. dunnii* has turned out to be the most popular species in new plantations, accounting for 58% of the new plantation area in 2016. Most of the industrial roundwood is still coming from older plantations of E. globulus and grandis that cover almost 60% of the entire area of plantations forests, but the share of E. dunnii is about to increase in the coming years. According to the literature, there are no dramatic differences between the wood properties of eucalyptus species currently growing in Uruguay. *Therefore, there is no reason to expect either sudden opportunities or threats from the wood product manufacturing point of view caused by the shift of harvests from E. globulus and grandis to E. dunnii gradually taking place during the next decades*. Eucalyptus can make all or part of raw material in production of engineered wood products. *E*ucalyptus species have been used in veneer based products for decades. Plywood (veneer layers glued crosswise) and laminated veneer lumber LVL (veneer layers glued mostly parallel) are well known and globally commercialized products. LVL is most often made of softwoods (e.g., Norway spruce, Douglas fir), but some hardwood species are applied, too. Product properties can be adjusted according to the customer needs by selecting the wood species and grading the veneers based on their knottiness and density. Some less known veneer based products, such as parallel strand lumber PSL (Parallam®), currently produced using Douglas fir in North America, could be worth consideration in case of eucalyptus species.

Only 703 hectares of pine (*Pinus radiata*, *Pinus taeda*) plantations were established in 2016, while the total planted area was 70,314 hectares (Uruguayan Statistics 2017). However, during the past decades, planting pine was much more popular and, therefore, the total area of pine plantations is as high as 258,000 hectares, accounting for 26% of the total plantation forest area in Uruguay. The annual volume of harvested pine wood from these plantations has varied between 0.5 and 1.0 million m3 during the last ten years. Thus, pine plantations make up an industrial scale raw material source now and in the near future. Pine plantations, though not being high up in the current forestry strategy, bring certain species balance and risk management ability to the Uruguayan forestry. It is of special importance to come up with feasible industrial solutions in pine timber manufacturing, and to find both domestic and international markets for pine based wood products. Pine could be utilised in production of cross-laminated timber CLT, which is the most rapidly growing engineered wood product globally. CLT enables fast element or module based construction of medium-high buildings using pre-fabricated wooden elements or furnished box modules. Hardwoods are not widely used in CLT production due to their high density and poorer strength-weight ratio in comparison to softwoods. In its initial phase, CLT production should be considered to be established on pine reserves in Uruguay. Production of mixed species CLT, where eucalyptus would provide the pine based elements with extra compression strength or better visual appearance, would be an interesting topic for research and development activities.

Strengthening of domestic demand for wood products can induce the mechanical processing industry development in Uruguay, for example increasing use of wood in construction is seen as urgent development. It would positively affect to demand of sawn wood, plywood and different types of engineered and physically or chemically modified solid wood and wood panel products. use of wood as a renewable raw material in construction and production of building materials and furniture would have an additional environmental benefit because of their capacity as a carbon storage. However, to give a thrust for mechanical processing industry requires focusing on export markets that would benefit of large companies acting as locomotives. Having prospective domestic and international demand opportunities would prepare ground for SMEs active in the sector.

Global manufactured wood materials[254] market shows growth, CAGR is estimated to be 10.80% in 2021 (increase from $294.2 billion in 2017 to $443.7 billion in 2021). Growth is mainly fuelled by rising demand for durable wooden flooring and roofs, and expected technological advances such as CLT and MDF recycling. Additional trends driving the demand for construction wood products market are emerging market growth, increasing investments, rapid urbanization and rising population[255]. In 2017, Latin American market value of was 16.46$ billion, which was 5.60% of global market[256]. The top three countries with highest demand expectations in 2021 are: China (CAGR of 13.4% during 2017-2021), Russia (10.80%) and Brazil (10.70%). The top five competitors in the market made up 9.2% of the total market in 2017 which paints a picture of relatively fragmented market. Global market is dominated by the North American players (Georgia-Pacific Corporation with 5.8% of the market; Weyerhaeuser with 1.5%; Norbord Inc. with 0.6%; RLC Industries Co. with 0.4%.), while also Chilean Celulosa Arauco y Constitución has good foothold in the market with 0.8% share of global market. One the EWP areas, CLT market, is dominated by Europe, as it constituted approximately 90% of the global CLT production in 2015 (a volume of 0.6 Million cubic meters)[257].

South America's unfinished wood/lumber manufacturing market was the fourth largest in the world in 2017 (with 9.6% share of market, worth $21.3 billion)[258]; although it was the smallest region in the construction wood manufacturing market in

[254] Includes: Hardwood Veneer and Plywood Manufacturing, Softwood Veneer and Plywood Manufacturing, and Engineered Wood Member Manufacturing.

[255] BCC Research, 2018. Construction Wood Manufacturing: Global Markets to 2022. Report Code: MFG057A.

[256] The Business Research Company, 2018. Manufactured Wood Materials Global Market Briefing 2018.

[257] Frost & Sullivan, 2016. North American and European Engineered Wood (EW) Market, Forecast to 2022.

[258] BCC Research, 2018. Unfinished Wood/Lumber Manufacturing: Global Markets to 2022. MFG059A.

2017. Market is expected to grow from $21.3 billion in 2017 to $28.6 billion in 2022 at a compound annual growth rate (CAGR) of 6.0%. Hardwood growth estimates are more positive (CAGR of 6.8% during 2017-2022) than soft wood which is expected to grow at a CAGR of 2.2% during 2017-2022. Out of South American countries in unfinished wood/lumber manufacturing, Brazil is the prominent.

Key enabling actions:

- Developing clusters and industrial parks (for example around sawmills) in the forest-based value chains (CI-03)
- Allowing new actors in the bioeconomy to efficiently adopt state-of-the-art technologies and practices (CI-05)

Key reactions from stakeholders and experts:

It is seen important that price ratio between pulpwood and logs is favourable for promoting mechanical wood industry. Wood supply is a critical precondition for EWP sector to develop. As such, eucalypti and pine plantations initially intended for pulpwood production can also supply the wood product industries with constantly growing raw material supply in Uruguay. In addition, experts see multiple transversal actions to be taken in Uruguay to promote EWP industry and attract investments. First, development of mechanical wood industry would require prioritising forestry sector in national research and innovation agenda (support needed from ANII). Second, standardization and structural certification of wood should be strengthened, and third, wood construction policies should be revised. Current investment rule, and business environment in general, in forest sector are attractive to foreign investors, they are granted the same incentives as local investors and there is no tax discrimination or restrictions for transferring profits abroad[259].

Innovation/business needs:

Strengthening of university-company relationship to create demand and exchange of knowledge and expertise is essential. Also, promoting the university-company relationships which are led by academy, not companies only. Interests of academia and industry should be better aligned. To increase level of innovation, generation of industrial parks that constitute synergies of innovation and business cooperation should be promoted. In particular, novel business models are to be developed. Integration of products from other production chains is important but also generating an information platform (network of providers) for knowledge dissemination is seen essential.

There is also need to identify local niches of specialisation to attract international companies to set up production in Uruguay. To promote local wood products, local industry should invest in promotional material, e.g. creating a website catalogues.

[259] Investment Opportunities: Forestry Sector, 2017. Uruguay XXI.

Research needs:

More research resources should be placed on examining eucalyptus-based production as eucalyptus is understudied material in EWP sector. It is also essential to develop technologies to treat eucalyptus, and assess availability of raw material according to its structural aptitude. Shift from *E. globulus* and *E. grandis* to *E. dunnii* in new plantations calls for attention considering characteristics of *E. dunnii*. According to literature, growth stresses are probably the most difficult problems in case of E. dunnii affecting negatively its utilization in wood product industries.[260] If saw or veneer logs with reasonable quality are wanted from plantation forests, site conditions and silvicultural practices that have an effect on stem taper must be taken into account in management of *E. dunnii* plantations. Furthermore, since most of the problems caused by growth stresses take place during drying of wood products, it is of a great interest to evaluate techniques capable of reducing these problems, especially in case of problematic species, such as eucalypti. The conventional techniques are based on manual applying of a heavy load on the drying stack but another highly interesting approach is wood modification. Both established thermal modification technology (see: www.thermowood.fi) and the emerging thermo-mechanical modification (see: www.finestwood.fi) could be feasible solutions to produce high added value products from eucalyptus sawn timber.[261]

Establishment of (autonomous) forest research centre would signal importance of forest industry in Uruguay, and help to perform required research. Uptake of research in engineered wood products (and related areas like wood construction) needs developing of scholarships for masters and doctorates.

Education needs:

Integrating architecture and engineering careers in academia would increase supply of local experts. Management training should not be neglected, either entrepreneurial training in forest engineering studies. Emphasis on forest bioeconomy should be included in forest area curricula through the education sector. Another area to concentrate in education is training of forest professionals. Particular needs are identified in educating industry in management and internationalisation to support export

[260] Growth stresses cause uncontrolled splitting of logs, as well as cupping, warping, and checking of sawn timber during drying. Matos et al. (2003) estimated that one third of sawn timber originating from planted *E. dunnii*, are degraded because of growth stresses. Murphy et al. (2005) noticed that even though *E. dunnii* growth stresses are heritable, they appear to be more severe in taller and thinner trees compared with short and thick trees. Murphy, T.N., Henson, M., Vanclay, J.K. 2005. Growth stress in Eucalyptus dunnii. Australian Forestry. 68:144–149.

[261] In addition to thermal and thermo-mechanical treatments, in wood modification is used chemical treatments, treatments based on biological processes, and physical treatment with the use of electromagnetic irradiation or plasma. Sandberg et al. (2017) discuss more in detail about chemical treatments and thermal and thermos-mechanical treatments. (Sandberg, D., Kutnar, A, Mantanis, G. 2017. Wood modification technologies - a review. iForest - Biogeosciences and Forestry. 10. 895–908.)

and trade of EWP sector. In addition, knowledge of properties of structural wood should be more widely disseminated in the industry.

Institutional needs:

Creating conditions for domestic demand of EWPs is essential, and for instance awareness raising actions are required to change consumer perception (not only in Uruguay but wider in Latin American region) of CLT structures being easily flammable and unable to withstand seismic loads. Construction of wooden houses should also be promoted. In addition, it is critical to make domestic investment environment attractive for foreign investors, which could be improved by highlighting sustainability of Uruguayan timber. Perceptions of wood as construction material and its environmental friendly properties are important, not only business conditions. Increasing use of wood in structures and construction calls for development of standards. For instance, use of lumber in load bearing structures requires strength grading of boards. This is rather well managed by acoustic velocity based strength grading machines in case of softwoods nowadays. Hardwoods are, however, more challenging due to their vast property variability, especially with regards to tensile strength.[262]

It is essential that both government institutions and industry actors are both engaged in promoting forest sector investments, both domestic and foreign investments. Invigoration of stakeholder dialogue is essential in order to align sectors' needs and actions. Generating a certification system for structural wood products is an essential short-term task.

5.6.4 Supporting domestic actors to develop new products from eucalyptus pulp (FBA3_OP3)

Recommendation:

Supporting local SMEs (including university spin-offs) to develop novel cellulose-based products and materials from the currently produced eucalyptus pulps.

[262] Some work has been carried out with *E. grandis* lumber grading (e.g., Piter, J. C., Zerbino, R. L., and Blaß, H. J. 2004. Machine strength grading of Argentinean Eucalyptus grandis. Holz Roh Werkst. 62(1): 9-15; Nocetti, M., Pröller, M., Brunetti, M., Dowse, G.P. & Wessels, C.P. 2017. Investigating the potential of strength grading green Eucalyptus grandis lumber using multi-sensor technology. Bioresources 12(4):9273–9286). However no information is publicly available on strength grading of *E. dunnii*. Based on the results of literature review by Thomas et al. (Thomas, D., Henson, M., Joe, B., Boyton, S. & Dickson, R. 2009. Review of growth and wood quality of plantation-grown Eucalyptus dunnii Maiden. Australian Forestry 72(1): 3–11), acoustic grading tools should be applicable to *E. dunnii* lumber, as well.

Background:

Cellulosic products have been used for more than 150 years for the manufacture of products and materials other than pulp and paper, typically in the form of different cellulose derivatives (esters and ethers) and textile fibres. Different cellulosic products can be prepared from paper grade chemical pulps, although many applications require the use of specialty celluloses. In Latin America, Bahia Specialty Cellulose (Brazil) produces 485,000 tons of specialty celluloses for the markets, for textiles and many other applications, ranging from cosmetics to car tires. As an example of the cellulose derivatisation, Quimica Amtex manufactures carboxymethylcellulose in Colombia, Argentina and Mexico. The application areas include food, cosmetics and pharmaceuticals.

As cellulose is the dominating biopolymer available in large quantities (in different forms), it holds great potential as a viable alternative to replace nonsustainable fossil-derived resources in a huge amount of applications. There is currently almost an uncountable number of R&D&I activities globally going on to fully harness the potential of cellulosic materials (from different sources) to a constantly increasing number of emerging and novel applications, aiming at "cellulose-based society"[263,264]. Chemical and biotechnical cellulose derivatisation and modification[265,266],[267] manufacture and use of nano materials[268], and reaching processable thermoplastic materials are examples of the important present research topics. Only a selection of

[263] Innventia (2016). A cellulose-based society, 71 p.

[264] A. Harlin et al. (2018). Cellulose goes digital. VTT's vision of digital cellulose-based industries. VTT Vision 14, 42 p.

[265] Jedvert, K., & Heinze, T. (2017). Cellulose modification and shaping–a review. Journal of Polymer Engineering, 37(9), 845–860.

[266] Hon, D. N. S. (2017). Chemical modification of cellulose. In Chemical Modification of Lignocellulosic Materials (pp. 97–127). Routledge.

[267] K.N. Onwukamike et al. (2019). A Critical Review on Sustainable Homogeneous Cellulose Modification: Why Renewability is not enough. ACS Sustainable Chemistry & Engineering, in press.

[268] E.F. Douglass et al. (2018). A review of cellulose and cellulose blends for preparation of bio-derived and conventional membranes, nanostructured thin films, and composites. Polymer Reviews, 58(1), 102–163.

the many existing, emerging and novel application areas can be mention as examples, including various composites[269,270,271], construction materials[272], packaging[273], (bio)medicine and healthcare[274,275], and food[276].

Other examples that can be give here include the use of cellulose in lithium batteries[277], 3D printing materials[278], multifunctional textiles[279], oil spill treatment materials[280], and energy devices[281]. The above, limited list of examples demonstrate the future potential of cellulose as a sustainable material for many industrial and other sectors, even in very demanding and challenging uses. It is essential that this type of innovation skills and competences will be developed and maintained also in Uruguay, to further demonstrate the increasing role of cellulosic materials as substitues for the fossil-based materials. In addition, the use of cellulose as the raw material will make it possible to prepare different products with specific functionalities for uses that cannot ber achieved by the fossil-based materials. As a whole, innovative SMEs and university spin-offs may have increasingly important roles in the required innovation ecosystems (in addition to the large companies), as has happened in many other countries. It is also noteworthy that in many areas, such decorative products and car parts, design-based product development may be an essential element.

It has frequently been reported that novel solvent systems, especially the use of ionic liquids (or deep eutectic solvents) may be beneficial for the dissolution and modification of cellulosic materials. Although it may take some time before they are

---

269 D. Trache et al. (2016). Microcrystalline cellulose: Isolation, characterization and bio-composites application—A review. International Journal of Biological Macromolecules, 93, 789–804.

270 Ibid.

271 S. Fujisawa et al. (2018). All-cellulose (cellulose–cellulose) green composites. Advanced Green Composites, 111–133.

272 M. Ardanuy et al. (2015). Cellulosic fiber reinforced cement-based composites: A review of recent research. Construction and building materials, 79, 115–128.

273 Vilarinho, F., Sanches Silva, A., Vaz, M. F., & Farinha, J. P. (2018). Nanocellulose in green food packaging. Critical reviews in food science and nutrition, 58(9), 1526–1537.

274 Yang, J., & Li, J. (2018). Self-assembled cellulose materials for biomedicine: A review. Carbohydr. Pol. 181, 264–274.

275 Naseri-Nosar, M., & Ziora, Z. M. (2018). Wound dressings from naturally-occurring polymers: A review on homopolysaccharide-based composites. Carbohydrate polymers 189, 379–398.

276 Osorno, D. M. S., & Castro, C. (2018). Cellulose Application in Food Industry: A Review. In Emergent Research on Polymeric and Composite Materials (pp. 38–77). IGI Global.

277 Sheng, J., Tong, S., He, Z., & Yang, R. (2017). Recent developments of cellulose materials for lithium-ion battery separators. Cellulose, 24(10), 4103–4122.

278 Wang, Q., Sun, J., Yao, Q., Ji, C., Liu, J., & Zhu, Q. (2018). 3D printing with cellulose materials. Cellulose, 1–27.

279 N.A. Ibrahim et al. (2018). Advanced Materials and Technologies for Antimicrobial Finishing of Cellulosic Textiles. Handbook of Renewable Materials for Coloration and Finishing, 301–356.

280 Doshi, B., Sillanpää, M., & Kalliola, S. (2018). A review of bio-based materials for oil spill treatment. Water research, 135, 262–277.

281 X. Du et al. (2017). Nanocellulose-based conductive materials and their emerging applications in energy devices-A review. Nano Energy, 35, 299–320.

more widely used in industrial scale, it may be important to develop competencies for their potential uses.

Key enabling actions:

- Allowing new actors in the bioeconomy to efficiently adopt state-of-the-art technologies and practices (CI-05)
- Producing reinforced fibres to meet the global demand for card/paperboards in packaging (e.g. recyclable packages in food industry). Substituting most petrochemical based products (such as plastics) with bio-based products. (CI-10)
- Building key competences in chemistry and biotechnology (so as to develop the wood-based biorefining industry) (PI-01)
- Fostering entrepreneurial SME activities in biorefining (PI-02)

Key reactions from stakeholders and experts:

In the stakeholders' assessment, this particular Opportunity Pathway is a longer term opportunity and requires time to come to fruiting. Technology is not yet mature and available as in the other pathways defined in the area of fibre-based biomaterial processing. National efforts on this area benefit from strengthening cooperation between research institutions, SMEs and large companies operating pulp mills in Uruguay as well as building consortiums with countries advanced in development of novel fibre-based solutions and materials.

Innovation/business needs:

Fostering entrepreneurship spirit and environment is crucial in getting new radical demand-driven innovations on market. For example, industry could organise cross-disciplinary hackathon's in the area of cellulose-based materials to disseminate knowledge. Industry's capabilities and willingness to participate in adoption and promotion of new forest-based material should be reviewed. Setting-up tools for industry actors, small new companies and large multinationals, to strengthen collaboration is needed to ensure intra-industry learning. Increasing of entrepreneurship and new innovative start-ups, industry needs also innovations in business models which can be attained by strengthening collaboration of business and engineering fields. Expertise in design is another competence area for which there is apparent demand in development of new cellulose-based products and materials. Designers can greatly contribute in addressing questions concerning user expectations and experience.

Research needs:

Universities and research institutes capacities in development of new cellulose based solutions and materials needs to be enhanced. To catch up global R&D, focused review of latest developments and showcases in use of cellulosic materials internationally and in Latin America (incl. Brazil, Chile, Colombia and Mexico) should be made. Likewise, focused research programmes on new cellulose- and fibre-based materials, and chemical transformation of wood should established. Effective dissemination of research and development actions to all relevant stakeholders, also beyond research community, needs to be ensured – for example through programmes supporting development of demonstration cases. Setting-up incentives for technology transfer and spin-offs in research and education institutions in order to get science-driven innovations on market is required. Investments are also needed in (cross-disciplinary) testing and piloting facilities which should be developed jointly to increase collaboration of the SMEs and universities with the large industrial pulping companies operating in Uruguay.

Research field needs more experts, which could be generated by increasing scholarships for masters and doctorates in the field of biomaterials. It is also essential that strong international collaboration partnerships within academia (for technological adaptation) are established, and dissemination of knowledge to local start-ups ensured.

Education needs:

Setting up mechanisms for entrepreneurial learning and technology transfer are essential. For instance, to boost local ecosystem, establishing a cooperative model with educational institutes and regional actors which provides entrepreneurship training and events, as well as acts as incubator for start-ups should be considered. Adding of cross-disciplinary courses (e.g. among engineers and designers) would increase needed innovativeness in education and research. In addition, entrepreneurship and innovation training programmes are needed to increase capabilities of entrepreneurs, academic entrepreneurs and large company entrepreneurs.

Institutional needs:

There is need modifying of regulation related to businesses located in free zones (in connection with pulp mills) and local SMEs, as current regulation challenges SMEs to operate large companies located in free zones. Government should also take action to reform policies and regulations for domestic adoption of fibre-based materials, and design new funding instruments to improve intra- and inter-industry, as well as industry and academia, collaboration. For instance the Plastic Bag Bill recently passed by the Government of Uruguay is a driver for introducing biodegradable substitutes (e.g. paper bags) in use.

Industry and government cooperation is needed in promoting good domestic practices in the field of bio-based materials. Higher risk-taking ability should be taken in promotion of cellulose-based products and materials for new radical innovations to be developed in Uruguay. A nationally operating business incubator focusing on supporting new businesses developing cellulose-based solutions should be established.

5.6.5 Investing in new bioproducts from side streams of pulping (FBA4_OP1)

Recommendation: To invest in the separation of lignin and hemicellulose-based by-products from the pulping operations and their further conversions to marketable (domestic, international) intermediates or end-products, such as lignin for plywood adhesives or dispersants.

Background:

Substantial amounts of lignin are globally dissolved in pulping processes, covering c. 60 million tons of kraft lignin from kraft pulping and at least 6–7 million tons of lignosulphonates from sulphite and NSSC pulping processes. Of these, lignosulphonates have traditionally been, and still are, the dominating lignin materials on the markets with a total current volume of nearly 1.5 million tons. Some kraft lignin products have been on the markets since the 1940s, but the number of the producers have always been low and in several cases the companies have recovered kraft lignin only for relatively short periods. Today, the isolation and utilization of kraft lignin is attracting a lot of new interest, as clearly shown by recent installations of new lignin plants in the USA, Canada, Finland and Brazil, which makes the total kraft lignin recovery capacity well over 100,000 tons. In addition, there are small volumes of Asian non-wood soda lignin on the markets. Furthermore, lignin is also available from the 2nd generation bioethanol plants, but its wider commercialisation as a marketable product will require further efforts.

The current industrially used methods for kraft lignin recovery are all based on precipitation via black liquor acidification with carbon dioxide and sulphuric acid, with several technology providers[282,283]. VTT in Finland has developed an alternative recovery method (based on thermal treatment of black liquor) that simultaneously activates lignin making it suitable for the phenol-formaldehyde production[284]. From large pulping installations, typically some tens of thousands of tons of lignin could be recovered without violating the energy balances of the mills. There are currently numerous commercial lignin market reports available, forecasting increasing demand for lignin in the future. According to one of them[285], the market for kraft

282 C.D. Teguia et al. (2017). Analysis of economically viable lignin-based biorefinery strategies implemented within a kraft pulp mill. Tappi Journal, 16(3), 157–169.
283 M.A. Hubbe et al. (2019). Lignin Recovery from Spent Alkaline Pulping Liquors using Acidification, Membrane Separation, and Related Processing Steps: A Review. BioResources, 14(1), 52 p.
284 H. Wikberg et al. (2017). CatLignin – reactive lignin for phenol replacement in resins. 7th Nordic Wood Biorefinery Conference, Stockholm, March 28–30, Proceedings, p. 94–97.
285 Mordor Intelligence (2018). Global lignin product market.

lignin was valued at USD59 million in 2017 and is expected to reach USD73 million by 2023, at an estimated CAGR of 3.65% during that period. The main current and planned near-future application areas for kraft lignin especially include various resins, phenol-formaldehyde resins, polyurethanes and epoxy resins, for example for wood adhesives where good market outlooks are globally foreseen[286]. As an example, UPM is actively increasing the substitution of lignin for phenol in plywood adhesives, aiming at the value from the current figure (up to 50%) close to 100% in coming years[287]. Other potential material uses of kraft lignin include carbon fibres and dispersants, for example as concrete additives where huge global markets can be seen. According to a recent innovation[288], an alkaline oxidation process can be used to convert kraft lignins to high-quality concrete plasticizers. This has been shown to work well for the eucalyptus kraft lignins, too.

In addition to lignin, relatively high amounts of hemicelluloses are dissolved into the pulping spent liquors and subsequently degraded to lower fragments and other types of compounds in the pulping process. As a consequence, the black liquors from kraft pulping contain some polysaccharides (especially xylan) and industrially important chemicals, acetic acid, hydroxy acids, and methanol as potential by-products. As will be briefly discussed below, hemicelluloses can also be isolated from wood chips prior to pulping, or from the unbleached or bleached pulps. The manufacture of dissolving pulp by prehydrolysis kraft pulping provides an additional potential source for the hemicellulose-derived sugars, as they are liberated (to some extent) in the prehydrolysis stage. Despite all these opportunities, the recovery and utilisation of hemicellulosic products from kraft pulping has so far received much less attention than lignin. The extensive current R&D efforts make it justified, however, to expect more important role for such materials in the future.

The recovery of the hemicelluloses and their degradation products from kraft pulping is currently far less mature than the recovery of kraft lignin. Although hemicelluloses (especially xylan in case of hardwood) can be recovered in varying yields from wood chips before kraft pulping[289], from black liquors and from bleached pulp[290], there are apparently not yet any industrial-scale systems in operation. In addition, there are several technical challenges to be tackled in order to maintain the required pulp qualities. It is known, however, that some xylose recovery takes place in so-called prehydrolysis stages at hardwood-based dissolving pulp mills. There are numerous established or potential applications for both of polymeric xylan and xylose sugar. As the downstream processes can use both agrobased and

---

286 Frost & Sullivan (2018). Analysis of global wood adhesives market, forecast to 2024, 221 slides.

287 https://www.upm.com/about-us/for-media/stories/articles/2018/01/bonding-breakthrough-the-new-life-of-lignin/

288 A. Kalliola et al. (2015). Alkali-O_2 oxidized lignin–A bio-based concrete plasticizer. Industrial Crops and Products, 74, 150–157.

289 J.T Lehto & R.J. Alén (2015). Chemical pretreatments of wood chips prior to alkaline pulping-A review of pretreatment alternatives, chemical aspects of the resulting liquors, and pulping outcomes. BioResources, 10(4), 8604–8656.

290 C. Laine et al. (2015). Extraction of xylan from wood pulp and brewer's spent grain. Industrial Crops and Products, 70, 231–237.

wood-based xylan[291], the joint processing of such raw materials could also be considered, for example to the manufacture of xylitol and furfural. This moment, there is some furfural production (5,000 tons) in Argentina by Silvateam. Higher furfural production capacity (35,000 tons) is provided by Central Romana Corporation in Dominican republic, based on the use of bagasse. Interestingly, there is no furfural production in Brazil[292], despite the high bagasse resources.

The black liquors form an important but overlooked source for aliphatic hydroxy acids, derived from alkaline degradation of hemicelluloses in kraft pulping[293]. These acids form a complex mixture of compounds with 2–6 carbon atoms, and they include both well-established industrially important compounds (such as glycolic and lactic acids) and more exotic, compounds unique for black liquors. The main class of the compounds is formed by so-called isosaccharinic acids that are known to be strong complexing agents, thus being of potential value to be recovered. Globally, more than 25 million tons of such acids are annually formed but combusted in the recovery boilers. In Uruguay, their "production" figure can be estimated to be nearly 400,000 tons. For the isolation of the hydroxy acids, several different methods have been tested but none of them have yet been commercialised as they would typically require the acidification of the black liquors as the first. However, a recent Finnish innovation makes it possible to separate the acids from other black liquor compounds as a mixture, in the form of sodium salts. This opens doors for more facile further separation and purification of the separate acids or their desired mixtures. Despite that, it can be foreseen that at least a few year's further R&D studies are needed before the installations can be realised. Their high total volume remains as one of the main drivers to consider their valorisation for different chemical uses.

In all kraft pulp mills, varying amounts of methanol are also formed or liberated, both from lignin and hemicelluloses. It is a common procedure at many mills to recover methanol (up to 10–15 kg per ton of pulp) as part of black liquor evaporation processes. It is typically used as a fuel, either in lime kiln or recovery boilers, as it also contains malodorous sulphur compounds that should be managed before other uses. During the past few years, some pioneering mills have adopted different methanol purification processes and are developing other uses for the purified product. These include methanol's internal use for the manufacture of chlorine dioxide bleaching chemical, or marketing to external customers.

The recovery activities for the discussed lignin and hemicellulose fractions and degradation products can obviously be initiated after securing markets or internal applications for them, and after the finalisation of the recovery process development for the emerging products (typically xylan and hydroxy acids). For lignin, it is justified

[291] D.S. Naidu et al. (2018). Bio-based products from xylan: A review. Carbohydrate polymers, 179, 28–41.

[292] G. Machado et al. (2016). Literature review on furfural production from lignocellulosic biom–ass. Natural Resources, 7(03), 115–129.

[293] J. Heinonen & T. Sainio (2019). Novel chromatographic process for the recovery and purification of hydroxy acids from alkaline spent pulping liquors. Chemical Engineering Science 197, 87–97.

to expect domestic and regional markets, for example for wood adhesives and various dispersant applications (e.g. as concrete additive). It needs to emphasised that kraft lignins can also be converted to synthetic lignosulphonates as there is currently more demand than supply for the traditional lignosulphonates (that are not produced in Latin America at all). The main lignosulphonate applications can be found in construction and agriculture, and in many other dispersant-type applications. For the hemicellulose-based products, the situation is somewhat different and will depend on the development of the future demand by chemical industry and other sectors. There are currently only limited markets for polymeric xylan, although it could be used in cosmetics, adhesives and bioplastics. Alternatively, it can be used as a source of xylose sugar for the manufacture of xylitol, furfural, and different furfural products. In the processing (hydrolysis) of hemicelluloses in the fresh raw materials or chemical wood pulps (in their upgrading to dissolving pulp), hot water catalysed treatments can be applied. The valorisation of the hydroxy acids fraction will apparently be the most demanding choice and may easily to take several years before there is fully operating recovery technology available, in addition to the existing local markets.

Key enabling actions:

- Increasing research and technology development efforts in applying wood-based (incl. bark and lignin) adhesives for EWP (CI-04)
- Building key competences in chemistry and biotechnology, so as to develop the wood-based biorefining industry (PI-01)
- Fostering entrepreneurial SME activities in biorefining (PI-02)
- Supporting biorefining as part of an industrial policy (PI-04)

Key reactions from stakeholders and experts:

Stakeholders are wary of opportunity to develop new value added bioproducts using lignin separated from wood biomass in pulping process in Uruguay. Realisation of the opportunity path is seen too dependent on large international companies' decisions. Overall, there is need for additional information about potential impacts related to realisation of this opportunity in Uruguay. Information needs can be divided into three issues. First, there is a need to ensure that biorefining as competitor for side-streams of pulping process does not negatively affect the pulp production and net earnings from wood-based economic activities in Uruguay. Second, for analytical decision making purposes there are required research regarding optimal use of wood residues and opportunity cost of alternative uses (e.g. in relative to producing energy from side streams of the pulping process and selling it to grid). Also competence base on selected bioproduct categories should be strengthened in Uruguay. Third, tariffs' impact on profitability of new bioproducts in international markets should be assessed.

Innovation/business needs:

General factors, such as market conditions, competitiveness and applicability of lignin as well as acceptability of lignin products, are significant background variables affecting on the opportunity pathway. Technological solutions to separation of lignin are available on market and large forest sector companies are developing new uses for lignin. For instance, LignoBoost separation technology – developed by Innventia and Chalmers University of Technology in Sweden and provided by Valmet – for producing kraft lignin has been in use in Domtar's pulp mill in North Carolina in the us since 2013, and in Stora Enso's Sunila mill in Finland since 2015. In recently introduced UPM's Wisa BioBond bonding technology lignin replaces to a significant degree oil-based phenol component in plywood adhesive. UPM plans gradually adopt the new bonding technology in all of its plywood production facilities. In experts' assessment, there are technological and general incentives to invest in separation and use of lignin at the pulp mills operating in Uruguay as well. Amount of investments required are moderate/fair in comparison to production capacity of the pulp mills. However, actual investment decisions depend on companies' assessment of competitiveness. Economic viability of lignin as a replacement for oil depends also on the fluctuations of oil price and the scale available at lignin production unit.

Research needs:

Lignin research and development is currently more on piloting and testing than basic research stage. There are available different methods for separating lignin from black liquor in pulping process, precipitation being the most common one in industrial use nowadays. Availability of kraft lignin has been increasing with emergence of processes enabling recover of lignin at pulp mills. International research focusing on potential uses of lignin has proceeded along two strands; finding new applications using lignin, or improving the performance of raw material by modifying the lignin structure. At the same time, researchers and companies are continuously looking for and developing new applications for lignin e.g. in adhesives and lignin dispersion. On general level, availability of competence may not be a problem for development of lignin based applications and business in Uruguay. The country could at early phase use a catch-up strategy in lignin R&D and adopt existing state-of-art technology from abroad while strengthening domestic competence level. Mobility and exchange between industry and academia would promote dissemination and cross-fertilisation of ideas and competencies. International forest sector companies operating large pulp mills in the country have also global networks and resources at their use to import know-how and competence from abroad if separation and processing of lignin in Uruguay is deemed economically feasible.

Education needs:

Proceeding along the pathway would require levelling up the knowledge base and increasing critical mass of people with skills and capabilities related to biorefining and development of lignin based applications in Uruguay. Competence development can be furthered via focused Master's programme on biorefining. There is also room for university-industry collaboration in development of chemical engineering expertise in areas of separation and purification operations. Local competence base on biorefining and lignin could be supported within a wider research programme on wood-based products and their production. For instance, use of lignin component in adhesives calls for a solution using lignin from eucalyptus – Suzano of Brazil has worked on development and offering of eucalyptus kraft lignin.

Institutional needs:

Sustainable development of new products from lignin benefits from environment which provides complementary competences and networking opportunities. Therefore, it is important to ensure that institutional framework in Uruguay encourages and supports ecosystem type of development bringing together actors from different sectors. This means creating and strengthening connections between pulp mills, mechanical wood processing firms, chemical industry representatives (incl. oil), research and education institutions and other actors including government actors. New funding instruments and incentives should be considered in order to catalyse bio-based industrial transformation and development of new solutions using residues and side-streams from pulping. In parallel, demand of bio-based raw-materials and products could be fostered for instance via incentives and adapting regulations on residues exchange and use of fossils in Uruguay (incl. special economic zones). The competence and industry base can also be strengthened by attracting from abroad firms familiar with development and production of bio-based products.

5.6.6 Turning wood-based side-streams into easy-to-storage solid biofuel (FBA5_OP2)

Recommendation: As a case-by-case alternative, white or torrefied pellet production from wood processing side streams. Pellets improve storage life of forest biomass and can be used both in Uruguay's industries and private and public buildings for energy or exported.

Background:

Comprehensive use of forest biomass provides opportunities for ramping up bioenergy production in Uruguay. Forest-based biomass used for energy production should thus be primarily wood waste that calls for an ecosystem approach in designing integrated value networks. One of the potential areas, closely integrated to sawmills and EWP manufacturing as well, is torrefied pellet production. White pellets are produced from compacted sawdust, usually softwood, are one form of solid biofuel that offer opportunity for exports as well as domestic use. Black pellets, or torrefied pellets are a product from torrefaction process, a thermal process to convert biomass into a coal-like material with better fuel characteristics in mild pyrolysis conditions 200–300 Celsius. Torrefied biomass is more brittle, making grinding easier and less energy intensive. Torrefaction modifies physical and chemical properties of biomass closer to the properties of coal. This transformation allows for example replacing large volumes of coal in existing power plants and in coal gasifiers for syngas and transportation fuel production, for example. To help logistics and handling of torrefied material, the material is usually compacted into pellets with the help of added binding agents like starch. National feed-in tariffs are boosting the co-firing of biomass to replace fossil fuels to higher shares, which are technically possible to reach with commercial white wood pellets[294].

Biomass use has been identified as one of the possibilities to mitigate fossil greenhouse gas emissions in iron and steelmaking. Biomass can be used to replace part of the fossil-based reducing agents in blast furnace without compromising the quality of the final product. The advantage of biomass compared to fossil-based fuels is that it is renewable energy source and can thus be considered carbon dioxide neutral within specified system boundaries[295].

Key enabling actions:

- Developing clusters and industrial parks (for example around sawmills) in the forest-based sawmills (CI-03)
- Allowing new actors in the bioeconomy to efficiently adopt state-of-the-art technologies and practices (CI-05)
- Supporting wood-based panel manufacturing (as part of an industrial policy) (PI-03)

Key reactions from stakeholders and experts:

Given that torrefaction technologies are emerging, adoption of pellet production in Uruguay along other countries is feasible. However, adoption requires integrated decisions like sufficient supply of wood wastes, such as sawdust but offers large opportunities as some existing power and heating plants can be transformed into bio-based with small modifications. For example, pellets are currently used to replace coal in pulverised coal (PC)-fired boilers. Canada, Finland and the us offer

294 Wilen et al. (2013) Wood torrefaction -pilot tests and utilization prospects. VTT TECHNOLOGY 122.

295 Hannu Suopajärvi, Timo Fabritius, Effects of Biomass use in Integrated Steel Plant – Gate-to-gate Life Cycle Inventory Method, ISIJ International, 2012, Volume 52, Issue 5, Pages 779–787, Released May 15, 2012, Online ISSN 1347-5460, Print ISSN 0915-1559, https://doi.org/10.2355/isijinternational.52.779,

good benchmarks as they are leaders in developing torrefaction technologies. Several pilot- and demonstration-scale plants are in operation in Europe, Canada and the us, but full commercial-scale operation is still hindered by numerous technical constraints[296]. use of torrefied biomass pellets is at testing and demonstration phase in many areas, e.g. in coal gasifiers for syngas and biomass to liquid (BTL) fuels, and synthetic natural gas (SNG) and alcohol production. Due to the properties of torrefied biomass pellets, the market potential is expected to be huge given substitution of coal in large-scale power and heat product[297]. Markets are increasing in Brazil and Japan[298].

A potential application for pine wood is carbonisation which has demand in metal industry. The greatest potential to replace fossil fuel is in the charcoal injection to the blast furnace. Life cycle emissions of steelmaking may be considerably lowered through biomass-based reducing agent use. The main constraint in facilitating the transition towards biomass-based steelmaking seems to be the high price of biomass and biomass-based reducing agents compared to fossil-based reducing agents[299]. In addition to steel production, charcoal is suitable for cement production. Regional competition exists as Brazil manufactures considerable amount of charcoal for metal industry.

One potential future area, thus far from commercialisation, is a possibility of utilising by-products to improve the overall torrefaction process efficiency[300]. For example, torrefaction gas condensate to be processed into different materials, such as biodegradable pesticides and phenols for wood protection sub-stances. These options can add to profitable business for torrefaction plant operators.

The global wood pellet market is expected to grow (CAGR of 14%) and reach a market value of $13.61 billion by 2020[301]. The drive to use of wood pellet in Europe can be attributed to government support and the need to reduce GHG emissions. Europe holds the largest share of the biomass pellet market, whereas production is largely concentrated on North America. Also global biomass pellets market is highly competitive with the presence of well-established global, mainly us owned, vendors. Due to the North American concentration, wood and wood pellets will be the fastest-growing segment in region's biomass power market by 2020. Whereas in countries or regions, such as Asia, South Africa, in which interest in biomass co-firing has only recently started torrefied biomass could provide an option to leapfrog technology given that investments in significant modifications of existing plants are not

[296] Wilen et al., 2013. Wood torrefaction -pilot tests and utilization prospects. VTT TECHNOLOGY 122.

[297] Thrän, M. et al., 2016. Moving torrefaction towards market introduction: Technical improvements and economic-environmental assessment along the overall torrefaction supply chain through the SECTOR project. Biomass and Bioenergy, 89, 184–200.

[298] Frost & Sullivan, 2016. Global Biomass Power Market Sustainable and Affordable Bioenergy Gains Momentum as a Key Renewable Energy Source. MC30-14

[299] H. Suopajärvi, A. Kemppainen, J. Haapakangas, T. Fabritius. Extensive review of the opportunities to use biomass-based fuels in iron and steel making processes J. Clean. Prod., 148 (2017), pp. 709–734, 10.1016/j.jclepro.2017.02.029

[300] Thrän, M. et al., 2016

[301] Frost & Sullivan, 2016. Global Biomass Power Market Sustainable and Affordable Bioenergy Gains Momentum as aKey Renewable Energy Source. MC30-14

needed[302]. Overall, government-supported schemes and incentives will be key drivers globally in the biomass power market where political decisions influence the potential market revenue considerably.

Innovation/business needs:

Creating domestic demand is one of the primary prerequisite for the torrefied pellet market. This to happen, energy plants' need for and interest in using pellets as fuels should be fostered. The main users can be found in the power production sector.

In order to the reap benefits of torrefied pellet production, integrated development of raw-material supply is required. This means by-product utilization at sawmills or plywood mills, but also to general wood procurement logistics at forest industry plants (e.g. panel mills or pulp mills). When processing residues can be utilized at site using integrated mills, cost savings can be achieved if the alternative option is to transport residues to an external facility. To make integrated mills feasible, new innovative business models should be fostered.

Research needs:

To adopt torrefaction technologies in Uruguay, research collaboration with advanced countries (e.g. Canada and Finland) and leading universities should be pursued. Torrefaction technologies are still largely emerging but a number of smaller pilot installations covering a wide range of different technologies are available at research institutes and universities. Research needs in torrefied pellets are more in applied research, for example in drying different raw materials, increasing calorific value and setting up demonstration plants. Research activities should also be dedicated to studying optimisation of overall value chain, standardization, trade registration and legal permissions[303]. Renewable energy as a research field requires more focus and investments in universities and other higher education institutes in order Uruguay to approach forest-based bioeconomy mentality. Besides pellets, torrefied wood is a raw material for wood-based products because of lower density than original wood chips and a significantly improved hydrophobic nature. For instance, moisture resistant particle boards (PB) and torrefied wood composites are interesting areas of application that provide research opportunities.

Education needs:

Promotion of use of biofuels and efficient stoves using biomass are needed in education (in higher education curricula) but simultaneously awareness in industry should be improved via professional trainings. Design of academic courses should include comprehensive perspective in forest-based products to learn more about

---

[302] Thrän, M. et al., 2016

[303] Thrän, M. et al., 2016.

different forest-based products and use of wood residues. Understanding of forest bioeconomy in academia should be improved.

Institutional needs:

Normalization of solid biofuels requires institutional inputs from Uruguayan government. Public awareness has to be increased and tax incentives (or other support mechanisms) to substitute current energy production should be put in place. Competitiveness of bioenergy solutions need strong policy decisions and regulation on energy production as torrefied biomass products may typically be twice as expensive as coal. Substituting coal by co-firing biomass in large pulverised coal-fired power plants needs significant green electricity incentives, or a considerably higher CO2 price in order to be feasible[304]. As for any bioenergy solutions to be implemented, feed-in tariffs are on potential option for increasing use of renewables. Furthermore, many technologies to produce solid biofuels are in developmental phase, which requires inputs in domestic research in the field. Adoption of bioenergy options in Uruguay could be supported by public procurement.

5.7 Forest-based bioeconomy opportunity pathways of lower focus

5.7.1 Supporting entrepreneurship and competences in forest management (FBA1_OP3)

Recommendation:

Creating and supporting local entrepreneurial networks or entrepreneurs and supporting the supply of competent labour in forest management and timber harvesting (education, economic incentives, stakeholder relationships).

Background:

Sustainable development of forest-based operations and business activities is based on a range of complementary resources locating in nexus of actors. Knowledge, skills and competences to manage forests resources is one of the key assets in this context. There is evident demand for competent labour force as well as expertise and services provided by specialised entrepreneurs. In general, room for entrepreneurial activity in forest management is not restricted to nurseries for seedlings, tree planting, maintenance of forest health and productivity and harvesting but extends to a variety of forest related professional services as well as logistics and transport. Today, there are over 900 companies active in forestry in Uruguay. Clear majority (92%) of the companies are micro or small ones – a characteristic

[304] Wilen et al. (2014) Wood torrefaction – market prospects and integration with the forest and energy industry. VTT TECHNOLOGY 163.

which has to be taken in account in drafting of policies and legislation for forestry.[305] Institutional practises and conditions vary between countries and influence on actual opportunities available for entrepreneurial activity in forest sector. In Uruguay, a specific aspect of the local setting relates to tendency of large forest sector companies to integrate vertically their activities along the value chain from tree breeding, forest plantations and use of raw material in industrial processes to sales and export. Widening the basis of forest-based activities highlight the need for policies and institutional environment which promote collaboration and networking among the entrepreneurs in efficient use of resources and expertise. Experiences from Europe show that from entrepreneurship perspective it would be advisable to target policy focus on building capacities of small and medium-sized enterprises (SMEs) in forest sector. Different kind of collaborative arrangements bringing together companies, research and education institutions have been found to have positive impact on capacity building especially for SMEs.[306]

Key enabling actions:

- CI-03 Developing clusters and industrial parks (for example around sawmills) in the forest-based value chains.
- PI-05 Supporting the combination of eucalyptus plantations with other sectors' value chains (e.g. food and livestock policies)

Key reactions from stakeholders and experts:

Forestry offers opportunities for different types of ecosystem services cross-cutting sector boundaries (e.g. with cattle raising, beekeeping). In this sense, also native forests could open up possibilities for sustainable businesses.

Innovation/business needs:

Forest management and innovative use of wood resources can be promoted via creation of ecosystems which link industry, land owners as well as experts and companies providing forestry related services. This kind of ecosystems are typically taking place in local settings which lowers the threshold of integrating micro and small entrepreneurs in networks and developing ecosystems. Cooperatives can serve as a seed or impetus for emergence of ecosystem type of arrangements in Uruguay. The Kuusamo forest cooperative in Northern Finland provides an example of the organisation through which private forest is jointly owned and managed to ensure sustainable and economically viable forestry locally. The cooperative with its 90,000 hectares – of which about 62,000 hectares in productive use – has a focal position in local forestry and wood supply to sawmills in the region. While timber sales is the

[305] Uruguay XXI 2017, 8.
[306] Niskanen, A., Slee, B., Ollonqvist, P., Pettenella, D., Bouriaud, L., Rametsteiner, E. (2007) Entrepreneurship in the forest sector in Europe. University of Joensuu, Faculty of Forestry, Silva Carelica 52/2007.

main source of income, the cooperative runs also a number of forest-based services (e.g. leasing land for hunting, renting cabins and land and water areas).[307] In case of Uruguay, it is particularly important to involve and integrate agriculture and cattle raising in ecosystem development in and around forestry – thus creating opportunities for combination of forest management with other sectors' value chains in efficient use of natural resources. Therefore, communication and collaboration with other sectors and the public should be strengthened which would pave the way for finding business opportunities between forestry and other sectors' value chains.

Research needs:

While competence level is developed, there is need to strengthen further forest research along the entire productive chain. Research should be targeted also on areas in intersection of sectors (e.g. forestry and cattle raising or beekeeping) to find sustainable and economically viable cross-sector niches for businesses and employment.

Education needs:

Ensuring the supply of competent labour force in forest management and forest sector sets requirements on education in Uruguay. From industry perspective it is important that companies and stakeholders involved have access to up-to-date knowledge and competence applicable in the local context. To make this happen calls for education and training programmes developed in collaboration with industry and stakeholders.[308] There is also need to coordinate especially technical schools and universities activities in provision of forest sector related education. Another identified need concerns broadening the focus of the university education towards applied sciences relevant to forest sector. International linkages in development of state-of-the-art skills and competence base are today a necessity. An option to consider in Uruguay is to set up a study abroad scheme supporting international mobility of students and professionals in forestry and forest sector in large. This type of scheme could be operated for instance by ANII – Investment, Export and Country Brand Promotion Agency. At the same time actors responsible for higher education and research should consider opportunities to attract inward mobility of talent from abroad for example through postgraduate scholarships in the area of natural resource transformation.

---

[307] Näyhä A., Pelli P. and Hetemäki L. (2015) Services in the forest-based sector - unexplored futures. Foresight, Vol. 17 (4), 378–398.

[308] As an example, Forest Education Association (https://smy.fi/en/tag/forest-education-association/) recently established in Finland aims to bring forest actors together to develop the forest sector education and increase attractiveness of the sector among young people.

Institutional needs:

Social acceptability of forest resources and image of forest sector in society has an impact how entrepreneurship in forestry and forest management will develop in any country. Realisation of business and work opportunities related to forest resources and their use depends on, at least partly, on awareness and knowledge people have about forest sector activities.

There is a need to provide education and organise training to diffuse information and facts about opportunities. Local networks could be used to reach and engage people and experienced entrepreneurs. Contractors involved in forestry is one of key groups identified by local stakeholders who could use training in development of their businesses. Providing coaching could be a practical way to support development of small and medium sized companies in forest sector in Uruguay. This could be implemented by expanding a current programme run by the CIU, Chamber of Industries, to cover also coaching of forest sector SMEs.

There is also needed channels and platforms through which different stakeholders and interested citizens have access to information and impartial knowledge on forest sector operations across the whole value chain, opportunities there are for businesses and direct and indirect impacts (economic, social and environmental).

5.7.2 Encouraging investors and firms to get involved in targeted areas (FBA2_OP2)

Recommendation:

Proof-of-concepts and incentives to wood-based panel industries and related bioenergy and biorefining areas to convince investors and companies about the opportunities of competitiveness, profitability and business volume.

Background:

Productive transformation towards a diversified higher value-added forest bioeconomy in Uruguay requires that the conditions and incentives supporting the change are systematically developed and introduced. Existing demand or at least outlook for emerging demand are crucial for a company's decision to invest in new facilities or embark on R&D. Prospect of gaining returns from market are a necessary condition for sustainable commercial investments.

In light of available market research, global demand of manufactured wood materials continues to grow in near future. Between 2013 and 2017 the global manufactured wood materials market grew from $191 billion to $294 billion at a compound annual growth rate (CAGR) of 11.5% and is forecasted continue to grow to $444 billion in 2021 (CAGR 10.8%). The foreseen increase is mainly connected with rise in demand for durable wooden flooring and roofs but also technological advancements in such areas as cross-laminated timber (CLT) and MDF. Also recycling is expected to fuel the global demand for manufactured wood. In 2017, Asia stood for the lion's share of the market (64%), whereas other regions shares were within a range of 4 (Africa) to 8,7 (North America) per cent of total. South America's share of global manufactured woods material market was 5,6% in 2017 recording second highest growth at CAGR (15%) during 2013-2017 and is expected to grow at a CAGR of 11.0% during 2017-2021.[309]

A more detailed picture on development of wood-based panel market can be get by focusing on reconstituted wood products consisting of oriented strand board (OSB), hardboard, particleboard and medium density fibreboard (MDF). These materials are made from wood fibres or particles and held together by applying adhesives, compression or both. According to BCC Research, the global reconstituted wood product manufacturing market has grown between 2013 and 2017 from $96.3 billion to $111.9 billion at a compound annual growth rate (CAGR) of 3.8%. The largest segment in the global reconstituted wood product manufacturing market consisted of MDF which stood for a 49.6% share of the market. Demand for MDF was mainly springing from manufacturing furniture products, pallets and other products used in the construction industry. Particle board was the second largest segment with a 33.2% share of the global market. Demand of particle boards was based on high usage in manufacturing cabinets, flooring and roofing. Hardboard (9.1%) and OSB (8.2%) were the third and fourth largest segments in the reconstituted wood product manufacturing market globally.[310]

The global market of reconstituted wood products is expected to grow between 2017 and 2022 at a compound annual growth rate (CAGR) of 5.6% to $147.2 billion. Foreseen growth is attributed to expected demand in China and India where reconstituted wood products are increasingly replacing plywood products. During the period, economic growth and investments in infrastructure and housing particularly in many developing countries are seen as market drivers, while forest fires due to global warming and climate change and reduction in free trade are expected to restrain the market development. The market of reconstituted wood product manufacturing is expected to grow from $6.1 billion in 2017 to $7.9 billion in 2022 at a CAGR of 5.5%. MDF segment is expected to have highest CAGR (6.8%) in Latin America during 2017–2022. particle board segment is expected to have second highest CAGR (4.1%) during the same period. (ibid.)

In order to increase share of wood-based higher value added products and solutions (e.g. engineered wood products, biorefining and bioenergy) attention should be paid to the development of domestic demand in Uruguay. Government has some instruments in its toolbox which can be used to promote development of demand for example by using regulation where appropriate and through public procurement. Development of industrial activity in bioenergy, biorefining and EWPs can also be supported by making available funds for research and technology development, and

---

309 The Business Research Company January 2018: Manufactured Wood Materials Market Global Briefing 2018. Including: Hardwood Veneer and Plywood Manufacturing, Softwood Veneer and Plywood Manufacturing, and Engineered Wood Member Manufacturing.

310 BCC Research Reference Staff July 2018. Reconstituted Wood Products Manufacturing: Global Markets to 2022. Report Code MFG056A.

proof-of-concepts and early prototypes. This would lower risks associated with development and/or adoption of new technologies and products by companies.

Key enabling actions:

- Allowing new actors in the bioeconomy to efficiently adopt state-of-the-art technologies and practices (CI-05)

Key reactions from stakeholders and experts:

Development of close to market solutions can be promoted by defining the forest sector as a priority area for research and innovation. It is also important to strengthen university-industry collaboration. Development of engineered wood products market can be advanced via standardisation and structural certification of wood as well as through policies which promote use of wood as a construction material in buildings.

Innovation/business needs:

There is need to identify products, processes and business models which provide internationally promising opportunities for Uruguayan industries to use and process wood-based raw material into finished products such as wood panels. Collect information of needs of potential customer groups. Promote and actively develop joint efforts and collaboration among industry actors as well as with research community in design and implementation of proof-of-concept and testing operations.

Research needs:

Domestic research community's capability in applied research and carrying out testing and proof-of-concepts operations needs to be ensured and strengthened. To support competence development efforts could be focused on selected areas and draw also on international expertise to give a thrust for domestic competence in these areas. In collaboration with industry could be established testing units/facilities to assess technical and economic feasibility of selected promising product groups.

There is needed an overview of feasible product portfolios based on available side streams of mechanical wood processing and forest-based biomass in Uruguay. Collaboratively arranged research is needed to develop and test productive and economic feasibility of available forest raw materials, technological solutions in production of biomass utilising products. Research is also needed to study and monitor wider impacts and sustainability of increased use of wood-based biomass and replacement of fossil-based products with bio-based ones in Uruguay.

Education needs:

Carrying out proof-of-concept studies and testing and demonstrating feasibility of ideas set requirements for professional capability and facilities. This needs to be taken into account in personnel training and further education of personnel working in research and education institutions in Uruguay.

Diffusion of knowledge on bioenergy and biorefining among stakeholders across society could be promoted by providing targeted practise-oriented training courses locally and integrating knowledge of forest bioeconomy into common education cycles.

Institutional needs:

There is needed attention and participation of public and private sectors actors in development of models (collaboration, funding etc.) which support development of proof-of-concepts and testing facilities in the selected areas of biorefining, bioenergy and engineered wood products. To catalyse the change, public funding could be channelled for instance to activities contributing to growth of wood-panel industry. Support could be allocated also to work optimising use of side streams from mechanical wood processing and low value forest biomass.

Attention should be paid also to local and domestic development of value chains and ecosystems which ensure sustainable basis for raw-material availability. To catalyse development, government needs to prepare a policy mix which encourages industry actors in EWPs and related areas of biorefining and bioenergy to get involved in development, testing and piloting of new bio-based solutions and products. Development of industrial parks should be part of the policy mix. In parallel, demand for new solutions should be promoted domestically. State administration and public sector in large could use public procurement as a leverage for example by defining minimum quotas for wood construction applied in state purchases in Uruguay. Also integration of wood construction as an objective in national housing policy and the mortgage loans for wooden houses could be used instruments boosting demand-led development.

5.7.3 Promoting production of paper and paperboard from local pulp (FBA3_OP1)

Recommendation:

Promotion of the investments by large companies for the manufacture of different paper and paperboard grades, using locally produced kraft pulps.

Background:

Integration of different types of papers and paperboard packaging production to the existing and possible new pulp mills would be a natural step in development of Uruguayan forest-based bioeconomy. To proceed this direction requires however, that raw material is available and other resources required in paper making process and in addition sufficient outlook for market demand. Paper and paperboard production would diversify fibre-based processing in Uruguay and match well with the country's strong footing in agriculture and food production by providing packaging material and packaging solutions. Besides domestic market for cardboard products, there may be demand for folding boxboard and packaging materials in Mercosur area but in depth market studies would be needed to focus on selected paper types (e.g. specialty papers instead of bulk products). Also, availability of wood with right characteristics for competitive paper production would need a thorough analysis.

Global paper and paperboard market stagnated in 2010–2013 at around 400 million tons but is forecasted to grow 482 million tons by 2030[311]. Consumer trends, such as e-commerce, eating on-the go and ageing population boost demand for paper and paperboard today. The global (B2B) e-commerce sales is predicted to reach $6.7 trillion by 2020, surpassing business-to-consumer (B2C) sales (valued at $3.20 trillion by 2020)[312]. Recyclability of paper and boards (compared to plastics) is one of the main strengths for driving demand. Other trends, like digitalisation, will place pressure on the demand of paper. While paper demand declines, containerboard (CAGR +2.3%/a), consumer boards (CAGR +2.0%/a) and tissue paper (CAGR +2.9%/a) consumptions are forecasted to experience slight growth by 2030. An average long-term demand growth for Latin America (in the above product categories) is predicted to be 2.1%/a. However, Brazil is a strong competitor for packaging and boards in Latin America due to its' most productive eucalyptus plantations in the world[313]. Growing cartonboard demand in Latin America is linked to success of food and pharmaceutical industries.

China is leading paper and paperboard production given its newer paper machines than North America and Europe. Africa and Latin America have not only old but also small machines to be competitive. Furthermore, global paper and paperboard market is fairly concentrated as 16% of global capacity in 2013 was accounted by 5 top companies (among which are UPM and Stora Enso).

[311] Pöyry, 2014. World paper markets up to 2030. Volume 1, Executive Report.

[312] Frost & Sullivan, 2017. U.S. B2B eCommerce Platform Market, Forecast to 2023 Strong Growth Forecast Resulting from the Creation of a Self-service and Intuitive Experience for B2B Customers and Organizations. K1DF-70.

[313] Farinha e Silva et al., 2015. THE PULP AND PAPER INDusTRY IN BRAZIL. Guia ABTCP FORNECEDORES & FABRICANTES. http://www.eucalyptus.com.br/artigos/2015_ABTCP_PP_Segment.pdf

Key enabling actions:

- Take advantage of the existence of large cellulose plants to develop local cases of technological applications to create value-added by-products (CI-08)
- Properties of pulp and pine wood bins (CI-08)
- Generate alliances with the pulp mills plants for the production of biorefineries (CI_09)

Key reactions from stakeholders and experts:

Investment interest in paper and paperboard from large companies is not seen very probable in Uruguay, as current trends in paperboard consumption provide mixed messages for future opportunities. For this reason, careful market and feasibility studies should precede all national efforts and incentives to be considered. Due to unpredictability, manufacture of different paper and paperboard grades is seen as a long-haul opportunity for Uruguay. Furthermore, Uruguay doesn’t have the kind of pine for producing fluff pulp, as it can substitute only 30–40% of total fibre needs.

Nevertheless, it is notable that by 2050, packaging has a much greater role in society. Packages will become lighter, more efficient and advanced. Advanced design and nanotechnology will help develop stronger, sealable and sterile containers for different contents. Even completely new products for the bioeconomy are foreseen. In addition, smart packaging in systems combined with IT solutions will produce less waste, improve logistics and reduce transport[314].

Innovation/business needs:

While existence of large cellulose plants in Uruguay provide opportunity to create value-added products, careful assessment of potential (in terms of required resources) and regional market demand in South America needs to precede decision to promote integrated production of paper and paperboard from locally produced pulp. To develop local knowledge base and expertise, it would be important to involve from start also Uruguayan research institutions in process and product development. Furthermore, a common technology centre or platform for areas of pulp, biomaterials and biorefining is to be established. Properties of renewability and recyclability of paper and paperboard will activate local businesses to develop for instance service and process innovations for circular economy. Also, feasibility studies of the most potential products and benchmark studies are needed to gain better understanding of market potential. In order to increase pine fluff pulp, new pine plantations are needed.

[314] CEPI, 2011. The Forest Fibre Industry 2050 Roadmap to a low-carbon bio-economy. http://www.cepi.org/system/files/public/documents/publications/environment/2011/roadmap_final-20111110-00019-01-E.pdf

Research needs:

Pulp and paper properties of local eucalyptus wood is well documented but properties of pulp and paper from Uruguayan pine should be researched. In addition, to support paper and paperboard production, the local research community needs to develop expertise in promising niche areas such as specialty papers with potential for global demand. Research could benefit from triple helix type of collaboration (research, industry and government) in development of new value added products from locally produced pulp. This would support transformation from a production structure heavily depended on a single product to production of variety of products such as paper, packaging and textiles. To explore different paper and paperboard grades, resources in research of wood fibres, especially of pine, should be increased.

Education needs:

It is important to ensure presence of engineering and technical competencies needed in operation of integrated mills. Planning and implementation of training experts should be done in close collaboration between industry and education institutions. Revising university programmes in cellulose and paper is essential to improve national knowledge base. Also, setting up industry training (especially in cellulose) is needed to facilitate knowledge diffusion and strengthen industry's competences.

Institutional needs:

Large scale investments in paper and paperboard production set requirements for infrastructure and other resources, which should be taken into account in policy-making. A smooth process from planning to establishment of new integrate(s) calls for engagement with different stakeholder groups early on. Simultaneously, policy-making should pay attention to domestic demand for wood-based fibre products and international trade arrangements for instance between Mercosur countries to lower unnecessary barriers for exports. Conditions of infrastructure (rail, road and port) should be improved to facilitate integration of paper and paperboard production in pulp mills.

5.7.4 Developing materials and chemical applications using bark from saw mills (FBA4_OP3)

Recommendation:

With the help of further R&D resources, finding value-added material and chemical applications for wood barks available from the saw mills.

Background:

Substantial amounts of bark are derived as left-overs in Uruguay from the logs used by forest industry. Typically, eucalyptus bark is left on soil at the plantations but the pine logs are debarked at the processing sites. In the future, bark could also be available at a pine kraft pulp mill if the ideas presented in FBA_OP2 will be realised. Finding commercially viable new uses for the bark would create additional revenue streams and increase efficiency in use of wood raw material further. Currently, (softwood) bark is often used for energy production purposes in saw mills and pulp mills or as a soil amendment.

In principle, wood barks are known to contain various substances not present in stem wood, and a lot of attention has globally been paid to their identification and potential uses for different chemical and material applications[315]. It looks, however, that the composition of eucalyptus barks have not yet been thoroughly analysed for different substances, although for example various phenolic compounds, tannins, and triterpene acids are frequently found. Although these seem to include various bioactive components potential for both food and pharmaceutical applications[316], their concentrations tend to be quite low, thus hindering commercial uses so far. In any case, it would be justified to conduct further studies on the composition of the local eucalyptus bark materials for their potential use by the local pharmaceutical companies, for example.

The pine and other softwood barks are known to contain c. 10–20% of tannins and various amounts of different bioactive low-molar mass compounds[317]. Of these substances, the tannin fractions have attracted a lot of attention as raw materials for different chemical and technical applications. In Chile, pine bark tannins were once successfully used as adhesives for particleboard and MDF production[318]. Very recently, there has been significant progress in Chile, regarding the development of the process for the extraction of pine bark tannins and. Consequently, it is now expected that in a few time some commercial pine bark tannin-producing plants are in operation in Chile[238].

Although the tannins are suitable for the manufacture of adhesives (phenol-formaldehyde resins), they find more uses in a number of other areas, such as leather, water treatment, beverage and animal feed industry. In Latin America, there is current tannin production by Silvateam in Argentina (from quebracho) and TANAC in Brazil (from acacia), with their total volume of c. 60,000 tons. Despite that, the local production and further valorisation of pine bark tannin would strengthen the local chemical industry, assuming that sufficiently high volumes of the raw material will

---

[315] S. Feng et al. (2013). Valorization of bark for chemicals and materials: A review. Renewable and Sustainable Energy Reviews, 26, 560–578.

[316] S.A. Santos et al. (2017). Secondary metabolites from Eucalyptus grandis wood cultivated in Portugal, Brazil and South Africa. Industrial crops and products, 95, 357–364.

[317] Jablonsky, M., Nosalova, J., Sladkova, A., Haz, A., Kreps, F., Valka, J., ... & Surina, I. (2017). Valorisation of softwood bark through extraction of utilizable chemicals. A review. Biotechnology advances, 35(6), 726–750.

[318] J. Valenzuela et al. (2012). Industrial production of pine tannin-bonded particleboard and MDF. European Journal of Wood and Wood Products, 70(5), 735–740.

be readily available. On a longer perspective, development of different types of bark biorefineries can be addressed, by integrating the recovery and uses of valuable bioactive low-molar mass compounds and sugar fractions for different uses. In the future, such biorefineries could either be integrated in different ways to saw mills or pulp mills, or they could operate as stand-alone installations.

Key enabling actions:

- Funds directed to research (CI-05)
- Generate knowledge in new technologies and products (CI-09)
- Associativity between industry, research centres, academia and competent authority (PI-01)
- Master's degree or specialization in biorefinery (PI-01)
- Develop local adhesives (PI-03)

Key reactions from stakeholders and experts:

The opportunity path is interesting but not hardly realisable today in Uruguay. There are a number of challenges to consider, such as the high content of silica of bark and remoteness of the locations where bark would be available (in sufficient amounts). Also, potential impacts of collecting and taking away bark on soil quality in the fields should be studied more in detail. However, in case there is increase in forest plantation activity, it may make the opportunity path topical because the increase in amount of bark residue.

Innovation/business needs:

Business potential of bark as a raw material for value added products in Uruguay should be assessed. For this purpose, available volumes of bark of different species and extent to which eucalyptus bark could be recovered from the forest plantations needs to be surveyed. Analysis of international market trends for currently known usage of barks is also needed. Collaboration between actors from different industries and sectors promotes effective search and development of new uses for barks while ensuring availability of raw material for industrial usage.

Research needs:

Immediate task would be to carry out a survey on uses of pine and eucalyptus bark in Latin America and worldwide. Resources should be channelled for R&D and piloting regarding required technologies and processes to recover compounds from bark. This type of actions would strengthen domestic R&D actors' capability to support companies interested in developing new commercial uses and applications for bark. Public support can catalyse research and technology development efforts in applying wood-based (incl. bark and lignin) adhesives for EWP.

Education needs:

Upgrade local knowledge base on current and potential uses of bark and related technological solutions. This could be implemented for instance by arranging research and training programmes which bring together industry and research communities.

Institutional needs:

Targeted programmes and funding instruments could be used to create favourable environment for take up and development of new bio-based solutions and applications for instance in in chemicals and engineered wood products industries and other relevant sectors. Networking of actors should also be promoted in order to create network additionalities and involve new actors and companies in development of novel products from barks and compounds extracted from barks.

5.7.5 Seizing opportunities for heat & energy production at industry sites (FBA5_OP1)

Recommendation:

Seizing opportunities for small-to-medium scale Combined Heat and Power (CHP) plants at new and existing mechanical wood processing sites and biorefineries.

Background:

Forest biomass can be co-fired with other fuels or alternatively used as the only fuel in CHP plants. Advanced CHP technology is currently used in Finland, Sweden and Eastern Europe. CHP plants require a market environment with demand for district or process heat. Therefore, concurrent development of process industries is essential. Forest industry can drive establishment of CHP units, which utilise side streams of forestry and low quality wood with no competing uses to produce heat and power required in pulp and paper production as well as providing renewable energy to communities locating in vicinity. Additional opportunities for CHP plant can be sought from fast pyrolysis bio-oil production when plant is combined with adequate technology.

The main driving trend in forest industry by 2050 is to cut CO_2 emissions[319]. It has been recognised that one of the central bioenergy technologies for this transition by 2050 is CHP technology. It is further seen as key intermediate technology for natural gas use, although the potential of using biogas in sufficient volumes is still to be explored. Integration of CHP technology in paper mills is highly (mainly

[319] CEPI, 2011. The Forest Fibre Industry 2050 Roadmap to a low-carbon bio-economy. http://www.cepi.org/system/files/public/documents/publications/environment/2011/roadmap_final-20111110-00019-01-E.pdf

chemical pulping, paper and board making) essential given paper production's high demand for heat. In fact, reduction of heat in production process is one of the main technological focus areas to study in future, albeit only little advancement is done in this area so far[320]. Installing biomass CHPs in sawmills, refineries and other wood processing plants would make industry sites energy self-sufficient and close to carbon neutral.

The total revenue of the global combined heat and power (CHP) is estimated to reach $7.29 billion in 2020 growing at a compound annual growth rate (CAGR) of 5.0%[321]. The market is foreseen to grow slowly but positively, where strong demand comes from developing markets due to rapid growth in distributed generation and unreliable electric grid networks.

It is calculated that in 2050, biomass will provide 35% of direct heat globally[322]. North American biomass power markets will continue growing at a steady pace by 2025 (GAGR 10.8%), with new CHP installations coming online using wood waste from the forestry and Pulp & Paper industries. Forecasted growth of installed capacity in Latin America for the period of 2017-2025 is 2.2%, in Europe 6.2% and in Asia 8.1%.

Key enabling actions:

- Developing clusters and industrial parks (for example around sawmills) in the forest-based value chains (CI-03)
- Integrating wood-based biorefining into large-scale pulp and paper mills (CI-09)
- Supporting wood-based panel manufacturing (as part of an industrial policy) (PI-03)
- Supporting biorefining (as part of an industrial policy) (PI-04)

Key reactions from stakeholders and experts:

Combined Heat and Power (CHP) plants should be considered in all new forest industry installations in Uruguay to contribute to global renewable energy targets by 2050.

In general, bioenergy field is relatively established, as most bioelectricity technologies are mature and extensively deployed commercially. There is only little scope for cost reductions, but plants with cogeneration, using low-cost fuel options such as wastes, or offering value-added services such as waste management will be more competitive than other renewable technology plants[323].

---

[320] CEPI, 2011. The Forest Fibre Industry 2050 Roadmap to a low-carbon bio-economy.

[321] Frost & Sullivan, 2015. Global Combined Heat and Power (CHP) Markets Accelerating Growth from Distributed Generation, Energy Efficiency, and the Need to Reduce Energy Consumption.

[322] DNV GL, 2018. ENERGY TRANSITION OUTLOOK 2018: A global and regional forecast to 2050.

[323] Frost & Sullivan, 2018. Global Renewable Energy Outlook. K2AC-14, Global Energy & Environment Research Team at Frost & Sullivan.

Innovation/business needs:

Given that CHP plants require integrated processes, creating domestic demand for forest-based products widely is essential for new businesses to adopt activities required in Uruguay. Understanding of heat and power value chain is critical. Increasing number of sawmills and biorefineries is needed for CHP plants to be established in country but at the same time businesses should be incentivised to design and invest in integrated mills from scratch. Industry should investigate potential of regional heat and power market to identify domestic potential of CHP plants.

Research needs:

Performing local feasibility studies with industry, as well as performing international benchmark studies of CHP projects are needed to understand the potential of CHP in Uruguayan context. Assessment of availability of forest-based biomass and side steams is important to design local projects. In addition, industry and research collaboration is needed in developing new processes related to CHP. Ecosystems investigations are needed to assess (social and economic) impact of CHP plants. Establishing technological consortia between academia, government and companies, and making it as a norm, in new emerging bioenergy areas is needed.

Education needs:

Needs in education sector concentrate largely on generating knowledge and developing sufficient level of expertise (especially in industry) to design and operate CHP processes. In addition, investments in thermal energy education in context of CHP production should be made. Education sector should put even stronger emphasis on sustainability, both in forestry and forest-based industries.

Institutional needs:

One of the central institutional areas to develop is regulations related to power and heat production. Biomass power is a policy- and regulation-driven business, where political decisions influence the potential market offtake considerably. Involvement of key stakeholders (e.g. petrol public company and other energy market players) is important to encourage development of heat and power ecosystem. Promoting of public-private partnerships is needed, especially to guarantee optimal use of resources. Public awareness raising of bioenergy’s climate benefits is needed in all levels of national innovation system and society. Different national incentives to renewables and bioenergy (such as feed-in-tariffs, pioneer status, and investment tax allowance subsidies) should be introduced to increase bioenergy use.

5.7.6 Producing second-generation biomass-based biofuels (FBA5_OP3)

Recommendation:

Improvement of solid or liquid Fischer-Tropsch synthetic fuels together with a production of hydrogen and advanced biofuels such as bio-oil, biofuel and renewable diesel.

Background:

Working towards the climate goal set by the Paris Agreement, important future enablers of bioenergy and bio-based fuels for heat, electricity and transportation reside in the availability of sustainable raw materials and industrial processes providing biomass. Feed-in tariff incentives, subsidies, and smart storage solutions have increased biomass power market attractiveness globally. Key driver for biomass opportunities are climate change policies and clean fuel agenda, but high reliance on government support in new investments restrains development globally.

Most of biofuels, as they aim to produce fuel components that are similar to those of current fossil-derived petrol and diesel fuels, can be used in existing fuel distribution systems and with standard engines. One of the largest utilisers of liquid biofuels is transportation sector (especially in aviation and shipping), which is expected to experience the highest sector growth by 2050 becoming the main alternative renewable energy option[324][325]. The sector will experience improvements in terms of the combination of fuel and transport efficiency, improved infrastructures, intermodality and use of alternative transport fuels, such as biogas, advanced biofuels, electricity or even fuel cells[326]. However, to neutralise the emissions from transport in forest industry requires securing sufficient wood residue demand – a challenge that is not easily solvable. Also GHG emissions of advanced biofuel technologies vary, but all advanced biofuels technologies produce low GHG, of which gasification technologies that use forest residues as feedstock produce the lowest emissions[327]. It is expected to achieve GHG emissions savings of more than 90% compared to fossil fuels.

In Latin America, liquid biofuels in transportation sector will compete, for instance against electrification of transport (Chile and Colombia among the leaders) by 2050. Diversification of energy sources will remain on the agenda in Latin America, as the region is expected to host some of the most dynamic wind and solar markets, building on hydropower to balance electricity systems[328]. It is further forecasted that oil

[324] DNV GL, 2018. ENERGY TRANSITION OUTLOOK 2018: A global and regional forecast to 2050.
[325] IRENA, 2016. Innovation outlook advanced liquid biofuels.
[326] CEPI, 2018. Investing in Europe for Industry Transformation CEPI. The forest fibre and paper industry in 2050.
[327] IRENA, 2016. Innovation outlook advanced liquid biofuels.
[328] DNV GL, 2018. ENERGY TRANSITION OUTLOOK 2018: A global and regional forecast to 2050.

will lose its leading position as an energy source by 2041 in the region. Latin America.

Although the production process of biomass to liquids is well known and been successfully piloted at industrial scale, integrating the various technologies for commercial production has proved challenging. Often one of the hindrances in demonstration plant investments in second-generation biofuel technologies has been sluggish regulative environment but also technical and financial obstacles[329]. Nevertheless, for example Europe and North America have several R&D&I projects in experimenting forestry residues and wood waste for biofuel production[330].

Key enabling actions:

- Increasing wood production (i.e. size of forest plantations) of different species (especially pine) to meet the future needs of Uruguay's FBA agenda. (CI-01)

Key reactions from stakeholders and experts:

Opportunity pathway was modified from original focus of balancing power grid with different bioenergy sources, to focus on solely on advanced biofuels. Biofuels as source of bioenergy are produced in biorefining processes, hence integrated to forest-based biorefining for chemicals and energy products. usually, integrated biorefinery processes into the existing pulp and papermaking processes aim at efficient uses of different side-streams or wastes, whereas the stand-alone processes typically use different thermal, thermochemical, chemical and biotechnical systems, e.g. for the manufacture of biofuels. Some of the emerging technologies for advanced biofuels are use of gasification and other thermal processes for the manufacture of biofuels and pyrolysis of different waste wood materials for bio-oil.

Overall, it is seen that the future forest industry will operate in integrated complexes, both wood-based and recycled fibre-based biorefineries that optimise raw material, energy and side-steam flows in consortia with other industries.

Innovation/business needs:

Adoption of bioenergy in large scale in Uruguay challenges industry to take proactive action simultaneously with changes in regulations steered by government. First, demand for complementing bioenergy concepts, such as forest-based biomass should be studied, and technological versatility promoted in the industry. Second, bioenergy champions who are able to promote the development of biomass use (e.g. biomass firing) should be identified in Uruguay. Third, building of bioenergy ecosystems that include agro and forestry but also end-users of heat and power

[329] EEA, 2017. Renewable energy in Europe – 2017 Update. Recent growth and knock-on effects. European Environment Agency (EEA) Report No 23/2017.

[330] http://www.etipbioenergy.eu/value-chains/feedstocks/forestry/forestry-residues (accessed 11.12.2018)

should be activated. Fourth, joint efforts with industry and research are needed in innovating solutions to renewable power supply and circular economy.

Research needs:

Resources for research field should be placed to learn from good practices abroad, e.g. flexible biomass energy storage, and explore best available technologies globally, e.g. for advanced fuels. Further research is needed to assess environmental impacts of potential bioenergy solutions, like wind and solar backed up with biomass power. Concrete research needs are identified in areas of production of synthetic hydrocarbons with hydrolysis and organic waste from afforestation. Also combining of forest biomass with other biomass sources should be further explored, and biofuels' qualities assessed.

Education needs:

Similar to all opportunities related to adoption of bioenergy in Uruguay, training and education of environmental impact of bioenergy should be upgraded. Sustainability should be extended strongly to curricula of silviculture/cultivation/harvesting. Also technical knowledge to run biomass-based bioenergy solutions is critical to increase. Emphasis should also be placed on processes of converting recycled paper into biofuels.

Institutional needs:

Public investments in power and heat infrastructure are needed for bioenergy solutions to take-off in Uruguay. Awareness of environmental benefits of bioenergy in general and biomass mobilisation in particular should also be improved. Furthermore, government should engage in a tighter stakeholder dialogue in bioenergy issues, and they should for instance urge industry to conduct feasibility studies. To increase bioenergy investments in Uruguay, policy framework should be stable and predictable, access to finance to ensure high risk investments should be secured (e.g. developing new models for sharing risk, loan guarantees and public finance instruments) and regulative costs should be kept moderate not to eat away industry's competitiveness. The above should be prepared taking into account long life cycles of forest investments, which range from 15–30 years. Furthermore, regional cooperation is encouraged to unlock benefits of bioenergy and reduce the need for fossil baseload.

5.8 Panoramic and systematic visualisation of FBA action roadmaps

This section offers a panoramic and systematic overview of the volume and nature of the 511 recommendations structured around the four implementation dimensions (context, people, process and impact) and the three implementation timeframes (2020, 2025 and 2030).

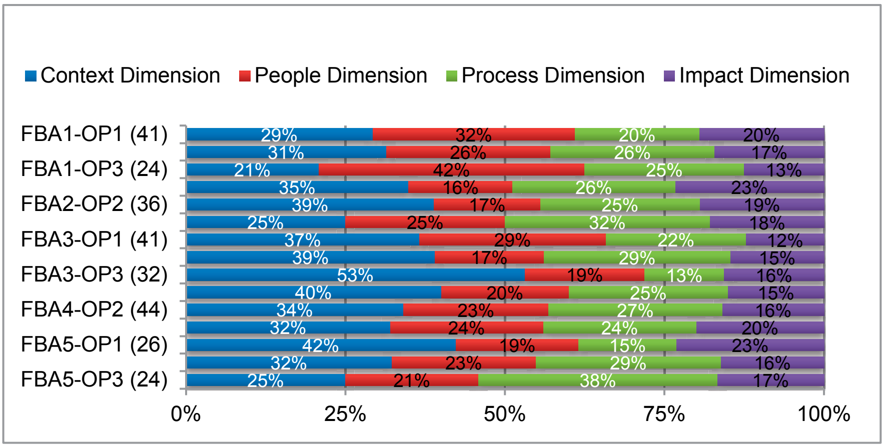


Figure 43. Share of actions by dimension.

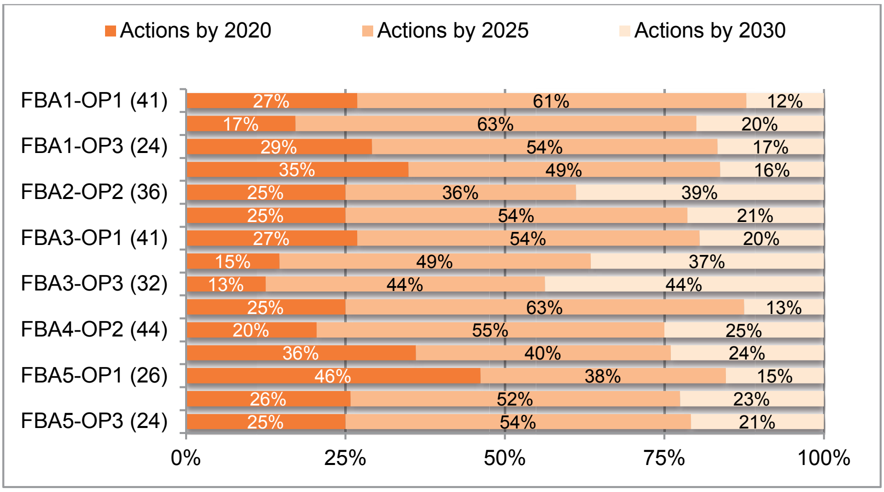


Figure 44. Share of actions by 2020, 2025 and 2030.

5.8.1 Action Roadmap for FBA1 OPs on Forest Management

FBA1	Context Dimension	People Dimension	Process Dimension	Impact Dimension	Total Actions
Actions By 2020	FBA1-OP1-KA01[1] FBA1-OP1-KA01[2] FBA1-OP1-KA02[3] FBA1-OP1-KA04[4] FBA1-OP2-KA03[5] FBA1-OP2-KA03[6] FBA1-OP3-KA02[7] FBA1-OP3-KA03[8]	FBA1-OP1-KA06[9] FBA1-OP1-KA06[10] FBA1-OP2-KA05[11] FBA1-OP3-KA05[12] FBA1-OP3-KA06[13]	FBA1-OP1-KA08[14] FBA1-OP1-KA08[15] FBA1-OP1-KA09[16] FBA1-OP2-KA07[17] FBA1-OP3-KA07[18] FBA1-OP3-KA07[19]	FBA1-OP1-KA09[20] FBA1-OP1-KA10[21] FBA1-OP2-KA10[22] FBA1-OP2-KA10[23] FBA1-OP3-KA10[24]	24 OP1 (11) OP2 (6) OP3 (7)
Actions By 2025	FBA1-OP1-KA01[25] FBA1-OP1-KA02[26] FBA1-OP1-KA02[27] FBA1-OP1-KA02[28] FBA1-OP1-KA03[29] FBA1-OP1-KA04[30] FBA1-OP1-KA04[31] FBA1-OP2-KA01[32] FBA1-OP2-KA01[33] FBA1-OP2-KA02[34] FBA1-OP2-KA03[35] FBA1-OP2-KA04[36] FBA1-OP3-KA03[37] FBA1-OP3-KA04[38]	FBA1-OP1-KA05[39] FBA1-OP1-KA05[40] FBA1-OP1-KA05[41] FBA1-OP1-KA05[42] FBA1-OP1-KA05[43] FBA1-OP1-KA05[44] FBA1-OP1-KA05[45] FBA1-OP1-KA05[46] FBA1-OP1-KA05[47] FBA1-OP1-KA09[48] FBA1-OP2-KA05[49] FBA1-OP2-KA05[50] FBA1-OP2-KA05[51] FBA1-OP2-KA05[52] FBA1-OP2-KA06[53] FBA1-OP2-KA06[54] FBA1-OP2-KA06[55] FBA1-OP3-KA05[56] FBA1-OP3-KA05[57] FBA1-OP3-KA05[58] FBA1-OP3-KA05[59] FBA1-OP3-KA05[60] FBA1-OP3-KA06[61] FBA1-OP3-KA06[62]	FBA1-OP1-KA07[63] FBA1-OP1-KA07[64] FBA1-OP1-KA07[65] FBA1-OP2-KA07[66] FBA1-OP2-KA07[67] FBA1-OP2-KA07[68] FBA1-OP2-KA07[69] FBA1-OP2-KA08[70] FBA1-OP2-KA08[71] FBA1-OP2-KA08[72] FBA1-OP3-KA07[73] FBA1-OP3-KA07[74] FBA1-OP3-KA08[75]	FBA1-OP1-KA09[76] FBA1-OP1-KA09[77] FBA1-OP1-KA09[78] FBA1-OP1-KA10[79] FBA1-OP1-KA10[80] FBA1-OP2-KA09[81] FBA1-OP2-KA10[82] FBA1-OP2-KA10[83] FBA1-OP3-KA09[84]	60 OP1 (25) OP2 (22) OP3 (13)
Actions By 2030	FBA1-OP1-KA02[85] FBA1-OP2-KA03[86] FBA1-OP2-KA03[87] FBA1-OP2-KA04[88] FBA1-OP2-KA04[89] FBA1-OP3-KA03[90]	FBA1-OP1-KA05[91] FBA1-OP2-KA05[92] FBA1-OP3-KA05[93]	FBA1-OP1-KA07[94] FBA1-OP1-KA08[95] FBA1-OP2-KA07[96] FBA1-OP3-KA07[97]	FBA1-OP1-KA10[98] FBA1-OP2-KA10[99] FBA1-OP3-KA10[100]	16 OP1 (5) OP2 (7) OP3 (4)
Total Actions	28 OP1 (12) OP2 (11) OP3 (5)	32 OP1 (13) OP2 (9) OP3 (10)	22 OP1 (7) OP2 (9) OP3 (6)	18 OP1 (9) OP2 (6) OP3 (3)	100

OP1: Developing environmental research/education programmes, policies, regulations and cross-sectoral investment strategies aimed to promote the use of native forests for new (non-wood-based) ecosystem services, pharmaceutical and food products.
OP2: Implementing and maximizing the output value of the present forest resource, which is currently underutilised plantations (e.g. pine) and ascertaining the quality of logistics infrastructure (harvesting, roads and bridges, wood terminals).
OP3: Creating and supporting local entrepreneurial networks or entrepreneurs and supporting the supply of competent labour in forest management and timber harvesting (education, economic incentives, stakeholder relationships).

5.8.2 Action Roadmap for FBA2 OPs on Mechanical wood processing

FBA2	Context Dimension	People Dimension	Process Dimension	Impact Dimension	Total Actions
Actions By 2020	FBA2-OP1-KA01[101] FBA2-OP1-KA01[102] FBA2-OP1-KA01[103] FBA2-OP1-KA02[104] FBA2-OP1-KA03[105] FBA2-OP1-KA03[106] FBA2-OP1-KA04[107] FBA2-OP2-KA01[108] FBA2-OP2-KA01[109] FBA2-OP2-KA01[110] FBA2-OP2-KA03[111] FBA2-OP2-KA03[112] FBA2-OP3-KA01[113] FBA2-OP3-KA01[114] FBA2-OP3-KA04[115]	FBA2-OP1-KA05[116] FBA2-OP1-KA05[117] FBA2-OP2-KA05[118] FBA2-OP2-KA06[119] FBA2-OP3-KA05[120] FBA2-OP3-KA05[121]	FBA2-OP1-KA07[122] FBA2-OP1-KA07[123] FBA2-OP1-KA08[124] FBA2-OP2-KA08[125] FBA2-OP3-KA07[126]	FBA2-OP1-KA09[127] FBA2-OP1-KA09[128] FBA2-OP1-KA10[129] FBA2-OP2-KA09[130] FBA2-OP3-KA19[131]	31 OP1 (15) OP2 (9) OP3 (7)
Actions By 2025	FBA2-OP1-KA01[132] FBA2-OP1-KA01[133] FBA2-OP1-KA02[134] FBA2-OP1-KA02[135] FBA2-OP1-KA02[136] FBA2-OP1-KA04[137] FBA2-OP1-KA04[138] FBA2-OP2-KA02[139] FBA2-OP2-KA02[140] FBA2-OP2-KA02[141] FBA2-OP2-KA02[142] FBA2-OP2-KA04[143] FBA2-OP3-KA02[144] FBA2-OP3-KA02[145] FBA2-OP3-KA03[146]	FBA2-OP1-KA05[147] FBA2-OP1-KA05[148] FBA2-OP1-KA05[149] FBA2-OP1-KA06[150] FBA2-OP2-KA05[151] FBA2-OP2-KA05[152] FBA2-OP3-KA05[153] FBA2-OP3-KA05[154] FBA2-OP3-KA05[155] FBA2-OP3-KA05[156]	FBA2-OP1-KA07[157] FBA2-OP1-KA07[158] FBA2-OP1-KA07[159] FBA2-OP1-KA08[160] FBA2-OP1-KA08[161] FBA2-OP2-KA07[162] FBA2-OP2-KA07[163] FBA2-OP2-KA07[164] FBA2-OP2-KA08[165] FBA2-OP3-KA07[166] FBA2-OP3-KA07[167] FBA2-OP3-KA07[168] FBA2-OP3-KA07[169] FBA2-OP3-KA07[170] FBA2-OP3-KA08[171]	FBA2-OP1-KA09[172] FBA2-OP1-KA09[173] FBA2-OP1-KA09[174] FBA2-OP1-KA10[175] FBA2-OP1-KA10[176] FBA2-OP2-KA10[177] FBA2-OP2-KA10[178] FBA2-OP3-KA09[179] FBA2-OP3-KA10[180]	49 OP1 (21) OP2 (13) OP3 (15)
Actions By 2030	FBA2-OP1-KA03[181] FBA2-OP2-KA01[182] FBA2-OP2-KA01[183] FBA2-OP2-KA03[184] FBA2-OP2-KA04[185] FBA2-OP3-KA04[186]	FBA2-OP1-KA06[187] FBA2-OP2-KA05[188] FBA2-OP2-KA06[189] FBA2-OP3-KA06[190]	FBA2-OP1-KA07[191] FBA2-OP1-KA07[192] FBA2-OP1-KA08[193] FBA2-OP2-KA07[194] FBA2-OP2-KA07[195] FBA2-OP2-KA07[196] FBA2-OP2-KA08[197] FBA2-OP3-KA07[198] FBA2-OP3-KA08[199]	FBA2-OP1-KA10[200] FBA2-OP1-KA10[201] FBA2-OP2-KA09[202] FBA2-OP2-KA10[203] FBA2-OP2-KA10[204] FBA2-OP2-KA10[205] FBA2-OP3-KA10[206] FBA2-OP3-KA10[207]	27 OP1 (7) OP2 (14) OP3 (6)
Total Actions	36 OP1 (15) OP2 (14) OP3 (7)	20 OP1 (7) OP2 (6) OP3 (7)	29 OP1 (11) OP2 (9) OP3 (9)	22 OP1 (10) OP2 (7) OP3 (5)	107

OP1: Supporting and ascertaining an attractive investment environment for large international companies in sawmill to engineered (EWP) and modified wood products manufacturing, this should support also local SME activity in mechanical wood processing.
OP2: Proof-of-concepts and incentives to selected bioenergy, biorefining and/or wood-based panel industries to convince investors and companies about the opportunities of competitiveness, profitability and business volume.
OP3: Adaptation of competitive wood-based products to international and domestic building with wood markets and distribution channels (for both pine and eucalyptus).

5.8.3 Action Roadmap for FBA3 OPs on Fibre-based biomaterial processing

FBA3	Context Dimension	People Dimension	Process Dimension	Impact Dimension	Total Actions
Actions By 2020	FBA3-OP1-KA01[208] FBA3-OP1-KA01[209] FBA3-OP1-KA01[210] FBA3-OP1-KA01[211] FBA3-OP1-KA02[212] FBA3-OP2-KA01[213] FBA3-OP2-KA02[214] FBA3-OP2-KA02[215] FBA3-OP3-KA01[216]	FBA3-OP1-KA05[217] FBA3-OP1-KA05[218] FBA3-OP1-KA05[219] FBA3-OP2-KA05[220] FBA3-OP3-KA05[221]	FBA3-OP1-KA07[222] FBA3-OP1-KA07[223] FBA3-OP2-KA08[224] FBA3-OP3-KA08[225]	FBA3-OP1-KA09[226] FBA3-OP2-KA09[227] FBA3-OP3-KA09[228]	21 OP1 (11) OP2 (6) OP3 (4)
Actions By 2025	FBA3-OP1-KA02[229] FBA3-OP1-KA02[230] FBA3-OP1-KA02[231] FBA3-OP1-KA03[232] FBA3-OP1-KA03[233] FBA3-OP1-KA03[234] FBA3-OP1-KA03[235] FBA3-OP1-KA03[236] FBA3-OP1-KA04[237] FBA3-OP2-KA01[238] FBA3-OP2-KA01[239] FBA3-OP2-KA01[240] FBA3-OP2-KA01[241] FBA3-OP2-KA02[242] FBA3-OP2-KA02[243] FBA3-OP2-KA02[244] FBA3-OP2-KA02[245] FBA3-OP2-KA04[246] FBA3-OP2-KA04[247] FBA3-OP2-KA04[248] FBA3-OP3-KA01[249] FBA3-OP3-KA01[250] FBA3-OP3-KA01[251] FBA3-OP3-KA02[252] FBA3-OP3-KA02[253] FBA3-OP3-KA04[254] FBA3-OP3-KA04[255]	FBA3-OP1-KA05[256] FBA3-OP1-KA05[257] FBA3-OP1-KA05[258] FBA3-OP1-KA05[259] FBA3-OP1-KA05[260] FBA3-OP1-KA05[261] FBA3-OP1-KA05[262] FBA3-OP1-KA06[263] FBA3-OP2-KA05[264] FBA3-OP2-KA05[265] FBA3-OP2-KA05[266] FBA3-OP2-KA06[267] FBA3-OP3-KA05[268] FBA3-OP3-KA05[269] FBA3-OP3-KA05[270] FBA3-OP3-KA06[271]	FBA3-OP1-KA07[272] FBA3-OP1-KA07[273] FBA3-OP1-KA07[274] FBA3-OP1-KA08[275] FBA3-OP2-KA07[276] FBA3-OP2-KA08[277] FBA3-OP2-KA08[278] FBA3-OP3-KA07[279] FBA3-OP3-KA08[280]	FBA3-OP1-KA09[281] FBA3-OP2-KA09[282] FBA3-OP2-KA10[283] FBA3-OP3-KA10[284]	56 OP1 (22) OP2 (20) OP3 (14)
Actions By 2030	FBA3-OP1-KA04[285] FBA3-OP2-KA02[286] FBA3-OP2-KA02[287] FBA3-OP3-KA01[288] FBA3-OP3-KA01[289] FBA3-OP3-KA01[290] FBA3-OP3-KA03[291] FBA3-OP3-KA03[292] FBA3-OP3-KA03[293] FBA3-OP3-KA03[294] FBA3-OP3-KA03[295]	FBA3-OP1-KA05[297] FBA3-OP2-KA05[298] FBA3-OP2-KA05[299] FBA3-OP3-KA06[300]	FBA3-OP1-KA07[301] FBA3-OP1-KA07[302] FBA3-OP1-KA08[303] FBA3-OP2-KA07[304] FBA3-OP2-KA07[305] FBA3-OP2-KA07[306] FBA3-OP2-KA07[307] FBA3-OP2-KA07[308] FBA3-OP2-KA07[309] FBA3-OP2-KA07[310] FBA3-OP2-KA08[311]	FBA3-OP1-KA09[313] FBA3-OP1-KA10[314] FBA3-OP1-KA10[315] FBA3-OP2-KA09[316] FBA3-OP2-KA10[317] FBA3-OP2-KA10[318] FBA3-OP3-KA09[319] FBA3-OP3-KA10[320] FBA3-OP3-KA10[321]	37 OP1 (8) OP2 (15) OP3 (14)

FBA3	Context Dimension	People Dimension	Process Dimension	Impact Dimension	Total Actions
	FBA3-OP3-KA04[296]		FBA3-OP3-KA07[312]		
Total Actions	48 OP1 (15) OP2 (16) OP3 (17)	25 OP1 (12) OP2 (7) OP3 (6)	25 OP1 (9) OP2 (12) OP3 (4)	16 OP1 (5) OP2 (6) OP3 (5)	114

OP1: Promotion of the investments by large companies for the manufacture of different paper and paper-board grades, using locally produced kraft pulps.
OP2: Encourage large companies to consider investments also in other type pulp mills, such as pine kraft pulp, dissolving pulp (medium term) and NSSC pulp mills, with recovery of lignin, tall oil or turpentine (among others)
OP3: Supporting local SMEs (including university spin-offs) to develop novel cellulose-based products and materials, (e.g. composites, bioplastics, specialty chemicals) from the currently produced eucalyptus pulps.

5.8.4 Action Roadmap for FBA4 OPs on Biorefining for chemicals and energy products

FBA4	Context Dimension	People Dimension	Process Dimension	Impact Dimension	Total Actions
Actions By 2020	FBA4-OP1-KA01[322] FBA4-OP1-KA01[323] FBA4-OP1-KA01[324] FBA4-OP1-KA04[325] FBA4-OP1-KA04[326] FBA4-OP2-KA01[327] FBA4-OP2-KA01[328] FBA4-OP2-KA04[329] FBA4-OP2-KA04[330] FBA4-OP3-KA01[331] FBA4-OP3-KA01[332] FBA4-OP3-KA01[333] FBA4-OP3-KA04[334]	FBA4-OP1-KA05[335] FBA4-OP1-KA06[336] FBA4-OP2-KA06[337] FBA4-OP2-KA06[338] FBA4-OP3-KA05[339] FBA4-OP3-KA05[340] FBA4-OP3-KA06[341]	FBA4-OP1-KA07[342] FBA4-OP2-KA08[343] FBA4-OP2-KA08[344] FBA4-OP3-KA08[345]	FBA4-OP1-KA09[346] FBA4-OP1-KA10[347] FBA4-OP2-KA09[348] FBA4-OP3-KA09[349]	28 OP1 (10) OP2 (9) OP3 (9)
Actions By 2025	FBA4-OP1-KA01[350] FBA4-OP1-KA02[351] FBA4-OP1-KA03[352] FBA4-OP1-KA03[353] FBA4-OP1-KA03[354] FBA4-OP1-KA03[355] FBA4-OP1-KA03[356] FBA4-OP1-KA03[357] FBA4-OP1-KA03[358] FBA4-OP2-KA01[359] FBA4-OP2-KA01[360] FBA4-OP2-KA01[361] FBA4-OP2-KA02[362] FBA4-OP2-KA02[363] FBA4-OP2-KA02[364] FBA4-OP2-KA03[365] FBA4-OP2-KA03[366] FBA4-OP2-KA04[367] FBA4-OP3-KA02[368] FBA4-OP3-KA02[369] FBA4-OP3-KA03[370]	FBA4-OP1-KA05[371] FBA4-OP1-KA05[372] FBA4-OP1-KA05[373] FBA4-OP1-KA06[374] FBA4-OP1-KA06[375] FBA4-OP2-KA05[376] FBA4-OP2-KA05[377] FBA4-OP2-KA05[378] FBA4-OP2-KA05[379] FBA4-OP2-KA06[380] FBA4-OP2-KA06[381] FBA4-OP3-KA05[382] FBA4-OP3-KA05[383]	FBA4-OP1-KA07[384] FBA4-OP1-KA07[385] FBA4-OP1-KA07[386] FBA4-OP1-KA07[387] FBA4-OP1-KA07[388] FBA4-OP1-KA08[389] FBA4-OP1-KA08[390] FBA4-OP1-KA08[391] FBA4-OP2-KA07[392] FBA4-OP2-KA07[393] FBA4-OP2-KA07[394] FBA4-OP2-KA08[395] FBA4-OP2-KA08[396] FBA4-OP2-KA08[397] FBA4-OP2-KA08[398] FBA4-OP3-KA07[399] FBA4-OP3-KA07[400] FBA4-OP3-KA08[401] FBA4-OP3-KA08[402]	FBA4-OP1-KA09[403] FBA4-OP1-KA09[404] FBA4-OP1-KA10[405] FBA4-OP2-KA10[406] FBA4-OP2-KA10[407] FBA3-OP3-KA09[408]	59 OP1 (25) OP2 (24) OP3 (10)
Actions By 2030	FBA4-OP1-KA02[409] FBA4-OP1-KA04[410] FBA4-OP2-KA03[411] FBA4-OP2-KA04[412] FBA4-OP3-KA04[413]	FBA4-OP1-KA05[414] FBA4-OP2-KA06[415] FBA4-OP2-KA06[416] FBA4-OP3-KA05[417]	FBA4-OP1-KA07[418] FBA4-OP2-KA07[419] FBA4-OP2-KA07[420] FBA4-OP2-KA07[421] FBA4-OP3-KA08[422]	FBA4-OP1-KA10[423] FBA4-OP2-KA09[424] FBA4-OP2-KA09[425] FBA4-OP2-KA10[426] FBA4-OP2-KA10[427] FBA4-OP3-KA10[428] FBA4-OP3-KA10[429] FBA4-OP3-KA10[430]	22 OP1 (5) OP2 (11) OP3 (6)

FBA4	Context Dimension	People Dimension	Process Dimension	Impact Dimension	Total Actions
Total Actions	39 OP1 (16) OP2 (15) OP3 (8)	24 OP1 (8) OP2 (10) OP3 (6)	28 OP1 (10) OP2 (12) OP3 (6)	18 OP1 (6) OP2 (7) OP3 (5)	109

OP1: Investments in the separation of lignin and hemicellulose-based by-products from the current pulping operations and their further conversions to marketable (domestic, international) intermediates or end-products, such as lignin for plywood adhesives or dispersants.
OP2: Encourage the creation of networks to joint utilisation of different residues and wastes from forest industry and other sectors, to produce different biochemicals, materials and biofuels.
OP3: With the help of further R&D resources, finding value-added material and chemical applications for wood barks available from the saw mills.

5.8.5 Action Roadmap for FBA5 OPs on Bioenergy

FBA5	Context Dimension	People Dimension	Process Dimension	Impact Dimension	Total Actions
Actions By 2020	FBA5-OP1-KA01[431] FBA5-OP1-KA01[432] FBA5-OP1-KA01[433] FBA5-OP1-KA02[434] FBA5-OP1-KA02[435] FBA5-OP1-KA03[436] FBA5-OP1-KA04[437] FBA5-OP2-KA01[438] FBA5-OP2-KA01[439] FBA5-OP2-KA04[440] FBA5-OP3-KA01[441] FBA5-OP3-KA04[442]	FBA5-OP1-KA05[443] FBA5-OP1-KA06[444] FBA5-OP2-KA06[445] FBA5-OP2-KA06[446] FBA5-OP3-KA05[447]	FBA5-OP1-KA08[448] FBA5-OP2-KA07[449] FBA5-OP2-KA07[450] FBA5-OP3-KA07[451] FBA5-OP3-KA08[452]	FBA5-OP1-KA09[453] FBA5-OP1-KA10[454] FBA5-OP2-KA09[455] FBA5-OP3-KA09[456]	26 OP1 (12) OP2 (8) OP3 (6)
Actions By 2025	FBA5-OP1-KA02[457] FBA5-OP1-KA03[458] FBA5-OP1-KA04[459] FBA5-OP2-KA02[460] FBA5-OP2-KA02[461] FBA5-OP2-KA03[462] FBA5-OP2-KA03[463] FBA5-OP2-KA04[464] FBA5-OP3-KA01[465] FBA5-OP3-KA02[466] FBA5-OP3-KA03[467]	FBA5-OP1-KA05[468] FBA5-OP1-KA06[469] FBA5-OP2-KA05[470] FBA5-OP2-KA06[471] FBA5-OP2-KA06[472] FBA5-OP3-KA05[473] FBA5-OP3-KA06[474] FBA5-OP3-KA06[475]	FBA5-OP1-KA07[476] FBA5-OP1-KA08[477] FBA5-OP2-KA07[478] FBA5-OP2-KA07[479] FBA5-OP2-KA08[480] FBA5-OP2-KA08[481] FBA5-OP2-KA08[482] FBA5-OP3-KA07[483] FBA5-OP3-KA07[484] FBA5-OP3-KA07[485] FBA5-OP3-KA07[486] FBA5-OP3-KA08[487]	FBA5-OP1-KA09[488] FBA5-OP1-KA10[489] FBA5-OP1-KA10[490] FBA5-OP2-KA09[491] FBA5-OP2-KA10[492] FBA5-OP2-KA10[493] FBA5-OP3-KA10[494] FBA5-OP3-KA10[495]	39 OP1 (10) OP2 (16) OP3 (13)
Actions By 2030	FBA5-OP1-KA04[496] FBA5-OP2-KA04[497] FBA5-OP2-KA04[498] FBA5-OP3-KA04[499]	FBA5-OP1-KA06[500] FBA5-OP2-KA05[501] FBA5-OP2-KA06[502] FBA5-OP3-KA05[503]	FBA5-OP1-KA07[504] FBA5-OP2-KA07[505] FBA5-OP2-KA07[506] FBA5-OP3-KA07[507] FBA5-OP3-KA08[508]	FBA5-OP1-KA09[509] FBA5-OP2-KA10[510] FBA5-OP3-KA10[511]	16 OP1 (4) OP2 (7) OP3 (5)
Total Actions	27 OP1 (11) OP2 (10) OP3 (6)	17 OP1 (5) OP2 (7) OP3 (5)	22 OP1 (4) OP2 (9) OP3 (9)	15 OP1 (6) OP2 (5) OP3 (4)	81

OP1: Seizing opportunities for small-to-medium scale Combined Heat and Power (CHP) plants at new and existing mechanical wood processing sites and biorefineries.

OP2: As a case-by-case alternative, white or torrefied pellet production from wood processing side streams. Pellets improve storage life of forest biomass and can be used both in Uruguay's industries and private and public buildings for energy or exported.

OP3: Improvement of solid or liquid FT-synthetic fuels together with a production of hydrogen and advanced biofuels such as bio-oil, biofuel and renewable diesel.

Acknowledgements

On the Uruguayan side

We would like to acknowledge all Uruguayan and Finnish experts sharing their expertise and insights of forest-based bioeconomy during project. Special acknowledgements go to Uruguayan governance team for support and engagement, namely Álvaro García, Fernando Isabella, Carolina Da Silva, Federico Rehermann, Gastón Mullin, Macarena González, Andres Coitiño, Lucia Pittaluga Fonseca from OPP-DP – Budget & Planning Office-Planning Division and Andrés Dieste, Vanessa Baño, Francisco Cassella, María Noel Cabrera; Leonardo Clavijo from University of the Republic-School of Engineering.

We would also like to thank other Uruguayan organisations involved in the project, in particular in sharing valuable insights in workshops organized in Montevideo: MGAP-OPYPA- Livestock, Agriculture and Fisheries Ministry-Planning and Livestock & Agriculture Policy Office; MGAP-DGF- Livestock, Agriculture and Fisheries Ministry-Forest Office; MVOTMA-CC -Housing, Spatial Planning and Environment Ministry-Climate Change Division; MVOTMA-DINAMA -Housing, Spatial Planning and Environment Ministry-National Environment Division; MIEM: Industry & Energy Ministry-Wood Sector Council; MEF- Ministry of Economy; Uruguay XXI: Investment and Export Promotion Institute; LATU- Industrial Technology Centre of Uruguay and INIA- National Institute for Agricultural Research-Forestry Program. For technical support, we like to acknowledge University of the Republic-School of Agronomy, Tacuarembó Centre, School of Social Sciences (Economics). In addition, various other stakeholders got engaged during the project, such as UTEC – School of Technology; UTU-Professional training school, UPM, Montes del Plata, Sociedad de Productores Forestales (SPF).

On the Finnish side

VTT's core project team is honoured to be working with distinguished experts from Luke – Natural Resources Institute Finland in selected areas of forest-based bioeconomy. Erkki Verkasalo, Research Professor in Wood Science and Technology; Henrik Heräjärvi, Senior scientist in Wood Science and Technology; Raisa Mäkipää, Research Professor in Sustainable use of natural resources; Matti Salo, Research

Scientist in Biodiversity, Saija Huuskonen, Senior Scientist in silviculture and forest cultivation and Maarit Kallio, Senior Scientist in economics of forest industry as well as Senior Customer Managers Eero Mikkola and the Director of Customer Solutions and International Relations John Kettle.

VTT's core project team likes to acknowledge colleagues whose expertise in forest-based bioeconomy has been crucial in different phases of the project, namely Henna Sundqvist-Andberg, Senior Scientist in Forest bioeconomy and foresight; Maria Barbosa Lima Toivanen, Senior Scientist in innovation systems; Juha Honkatukia, Principal Scientist in long-term development of the economy; Arho Suominen, Principal Scientist in Technology Foresight and Strategy; Antti Ahola, Research Scientist in Foresight; Jouko Myllyoja, Senior Scientist in Foresight; Ali Harlin, Research Professor in Cellulose-based materials; Kristiina Kruus, Research Professor in bioprocessing of renewable natural materials; Eija Alakangas, Principal Scientist in Bioenergy; Lauri Kujanpää, Research Scientist in Carbon Capture and Storage; and Eemeli Hytönen, Business Development Manager. In addition, we would like to thank Torsti Loikkanen, Sapar Oy, working as external expert in the project.

About the authors

VTT Technical Research Centre of Finland Ltd (Project owner)

VTT Technical Research Centre of Finland Ltd is a state owned and controlled non-profit limited liability company established by law and operating under the ownership steering of the Finnish Ministry of Employment and the Economy.

VTT is a research and technology organisation (RTO) whose activities are focused on three areas: Knowledge intensive products and services, Smart industry and energy systems, and Solutions for natural resources and environment. VTT is impact-driven and takes advantage from its wide multi-technological knowledge base to strengthen Finnish, European and global industrial competitiveness. VTT can combine different technologies, produce information, upgrade technology knowledge, and create business intelligence and value added for its stakeholders, customers and partners.

Over the years, VTT has gained vast experience from participation and coordination of numerous international projects including EU R&D Framework Programme projects and other thematic frameworks and programmes. VTT is ranked among the leading European RTOs. In December 2017, VTT has been recognized with the "HR Excellence in Research" award by the European Commission.

Core team (Authors)

Rafael Popper (PhD) is Principal Scientist in Business, Innovation and Foresight at VTT Technical Research Centre of Finland Ltd. Dr Popper is also Director of Executive Education in 'Foresight and Sustainable Futures' and Honorary Senior Lecturer at the Manchester Institute of Innovation Research (MIOIR) of the University of Manchester in the United Kingdom. He was also appointed as Professor of Foresight and Science, Technology and Innovation (STI) Governance at the National Research University Higher School of Economics (HSE) in Russia. He has over twenty years of experience working as foresight and innovation policy consultant for several international organizations including the European Commission, Economic Commission for Latin America and the Caribbean (ECLAC), United Nations Industrial Development Organization (UNIDO), United Nations Development Programme (UNDP), World Bank, United Nations Economic and Social Council, United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation Programme (UN-REDD), Andean Community of Nations (CAN), as well as for several government and business organisations in Europe, Latin America, Africa, Asia and Australia.

Nina Rilla (PhD) is Senior Scientist in Innovations, economy and policy team at VTT Ltd. Her fields of expertise are innovation policy, R&D collaboration, internationalisation, entrepreneurial and small businesses and life sciences. She has over ten years of experience in national projects related to capabilities, industry renewal and innovation (eco)systems, and innovation impact assessment. She has participated in international commissioned projects that deal with various aspects of innovation and policy such as identifying major innovations and future value chains. She has engaged in innovation capacity building in developing economies and supporting policy dialogue between Europe and Latin American countries.

Klaus Niemelä (PhD) Principal Scientist, has over 25 years of experience in wood and pulping chemistry and other forest biorefinery operations at Helsinki University of Technology, KCL (Finnish Pulp and Paper Research Institute), and VTT. His studies cover cooking, bleaching, recovery of the cooking chemicals and by-products, management of solid wastes, and various environmental issues. He has experience from several national and European projects on wood biomass/biorefinery processes. He is also one of the key persons in initiating and running an international conference series "Nordic Wood Biorefinery Conference".

Juha Oksanen, M.Soc.Sc, works as a senior scientist at VTT Technical Research Centre of Finland Ltd. He has over 20 years' experience of research and evaluation projects in the fields of innovation and R&D policies, entrepreneurship and competence development. His research interests relate to innovation processes in different settings, sector dynamics, factors driving and inhibiting change, as well impacts of innovation policies. He has followed closely innovation, technology and research policy development since the late 1990s. He has experience of comparative international studies and capacity development projects with international partners. In recent years, he has worked increasingly with projects related to ecosystems, skills and competencies, co-creation and role of public procurement in innovation.

Matthias Deschryvere works as a senior research scientist at VTT Technical Research Centre of Finland Ltd. He is specialised in innovation systems, globalisation and entrepreneurship, all important aspects of the competitiveness of businesses, industries and economies. He has a broad based experience as an economist and has contributed to several international research projects, specifically on global value chains, on major innovations in Finland and Sweden and on high growth firms. Before joining VTT he worked at economic think thanks (IFW in Kiel (DE) and ETLA in Helsinki (FI)) and in banking (BE). He was a visiting research fellow at SPRU, the Science and Technology Policy unit at the University of Sussex (UK) and at STEPI, the Science and Technology Policy Institute (South-Korea). Matthias holds a M.Sc. (Economics) from Ghent University (BE) and is a Ph.D. candidate in economics at the University of Jyväskylä (FI). In addition he gained experience as a referee for the Review of World Economics and the Journal of Industry, Competition and Trade, Research Policy and Industrial and Corporate Change.

Matti Virkkunen, has over 10 years of working experience in bioenergy sector, in forest and agro biomass supply technology and techno-economy analyses. His expertise covers biomass harvesting and transport technology, biomass fuel quality management and related business models as well as sustainability assessment of biomass fuel supply systems. Mr. Virkkunen is experienced both in national and international projects and he has wide international and national contact network. Virkkunen's previous and current projects include biomass supply availability and procurement cost analyses for heat and power in Chile, India, Canada, Central-Europe and in Scandinavia and feedstock supply analyses for biorefineries and located for example in Finland and Canada.

Sapar Ltd (Subcontractor)

Sapar Ltd founded in 2000 in Finland, delivers consulting and research services for supporting strategic decision-making of private and public clients in areas of industrial innovation and science, technology and innovation policies.

Core team (Co-Author)

Torsti Loikkanen is Senior Consultant at Sapar Oy and former Principal Scientist in VTT Technical Research of Finland Ltd. 1987–2016 and since then in Sapar Oy/Ltd, the consulting company in industrial innovation and innovation policy studies. The research and consulting expertise of Loikkanen contains industrial innovation, evaluation and impact assessment of science, technology and innovation (STI) policies, and roadmap and foresight exercises of technological and socio-economic development. His recent research topics are performance indicators and comparisons of innovation systems, challenges of globalization of STI policies, sustainable development and the rationale of STI policies. He has contributed to forward looking exercises to the European Commission and European Parliament and has been Keynote Speaker in international conferences and events. He has international consulting experience besides Europe in developed and developing economies for example in Australia, Africa, and Organization of Islamic Cooperation (OIC). He is a member of Steering Committee of the international innovation policy network Six Countries Program, VTT coordinator of the Joint Institute for Innovation Policy (JIIP) in Brussels, and invited member of The Finnish Academies of Technology (FACTE).

Luke, the Natural Resources institute Finland (Subcontractor)

The Natural Resources Institute Finland (Luke) is a public, non-profitable research and expert organisation that works to advance the bioeconomy and the sustainable use of natural resources. Luke's strategic objectives are new bio-based products and new business activities; productivity through digital solutions; revitalising regions through the circular economy; wellbeing from immaterial values; healthy and profitable food production. Luke's research is conducted in four large thematic programmes: Boreal Green Bioeconomy, Innovative Food Chain, Blue Bioeconomy, and BioSociety.

Luke was launched 1 of January 2015 as a merger of the Finnish Forest Research Institute, MTT Agrifood Research Finland, the Finnish Game and Fisheries Research Institute and the statistical services of the Information Centre of the Ministry of Agriculture and Forestry.

The Natural Resources Institute Finland is the second largest research institute in Finland and one of the biggest clusters of bioeconomy expertise in Europe. Luke employs more than 1,300 person-years, and the institute operates in 25 different locations across the country.

Core team (Contributors

In this project, Luke has been a subcontractor and has provided specific inputs to the FBA1 and FBA2 activities, especially through expert opinions, workshops participation and expert panels in Finland. The following Luke experts have been actively involved in FBA1 and FBA2 related analyses:

- **Erkki Verkasalo** (Research Professor, Wood Science and Technology)
- **Henrik Heräjärvi** (Senior scientist, Wood Science and Technology)
- **Raisa Mäkipää** (Research Professor, Sustainable use of natural resources)
- **John Kettle** (Director, Customer Solutions and International Relations)

Recommended Actions for all FBA's Opportunity Pathways (OPs)

100 recommendations of FBA1 Action Roadmap

Actions by 2020

Actions for the Context Dimension

1 FBA1-OP1-KA01: Analyse SMEs' volume and existing production of non-wood services (Responsible: Industry/consulting companies).

2 FBA1-OP1-KA01: Review utilisation of high-value non-wood forest products in Uruguay (Responsible: universities and research institutions, consulting companies).

3 FBA1-OP1-KA02: Perform a feasibility and profitability study of local ecosystem services' business in selected wood- and forest-related areas, such as beekeeping, its possibilities, viability, productive and quality factors (Responsible: universities and research institutions).

4 FBA1-OP1-KA04: Conduct surveys to understand social acceptance of the utilisation of non-wood forest products and ecosystem services (Responsible: universities and research institutions).

5 FBA1-OP2-KA03: Utilise information already available from private companies and openly online (Responsible: Industry and government actors).

6 FBA1-OP2-KA03: Support investments to logistics infrastructure (Responsible: Industry and government actors).

7 FBA1-OP3-KA03: Enhance expert capacity by providing financial support for students and professionals to study abroad (Responsible: Government agencies, such as ANII).

8 FBA1-OP3-KA03: Make forest resource information available for SMEs who could create wood-based business (Responsible: Government agencies).

Actions for the People Dimension

9 FBA1-OP1-KA06: Develop knowledge about silvicultural management of the native forest (Responsible: Agronomics School-FAGRO/ UDELAR, Government/MGAP).

10 FBA1-OP1-KA06: Promote local partnership for utilisation of non-wood ecosystem services (Responsible: Industry and government actors).

11 FBA1-OP2-KA05: Develop foresight, leadership and negotiation skills of key actors potentially dealing with underutilised (pine) plantations (Responsible: research and industry actors).

12 FBA1-OP3-KA05: Develop short professional development courses critical issues (especially opportunities) assessment and management for the more than 900 companies in forest sector in Uruguay (Responsible: Government, research, university and industry actors).

13 FBA1-OP3-KA06: Increase acceptability of the forest industry and use of forest resources by providing education, business and work opportunities for wider proportion of the population (Responsible: Government, universities, industry).

Actions for the Process Dimension

14 FBA1-OP1-KA08: Participate on international climate negotiations (and supporting task groups) and develop incentives/markets for carbon sequestration in the LULUCF sector (Responsible: government, NGOs).

15 FBA1-OP1-KA08: Further forest policy alignment with environmental, agricultural, rural development, industrial, energy and other policies (Responsible: government actors).

16 FBA1-OP1-KA09: Further integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts, in line with obligations under international agreements and targets of Sustainable Development Goal 15 on Life on Land (Responsible: government actors).

17 FBA1-OP2-KA07: Pilot the use of small 'mobile sawmills' in several pine plantations (Responsible: Industry and government actors).

18 FBA1-OP3-KA07: Initiate multi-actor cooperation and networks to certify and rate wood harvesting enterprises complying with timber harvesting regulation, taxation, labour contracts and social security norms (Responsible: Government, universities, industry).

19 FBA1-OP3-KA07: Develop clusters and industrial parks (for example around sawmills) in the forest-based value chains (Responsible: Government and industry actors).

Actions for the Impact Dimension

20 FBA1-OP1-KA09: Gather positive socio-economic and environmental stories from the widespread combination of eucalyptus plantations with other sectors' value chains (e.g. food) (Responsible: Research actors).

21 FBA1-OP1-KA10: Ensure the conservation, restoration and sustainable use of forests ecosystems and their services, in line with obligations under international agreements and targets of Sustainable Development Goal 15 on Life on Land (Responsible: government actors).

22 FBA1-OP2-KA10: Communicate the role of forests in climate change mitigation to stakeholders (Responsible: industry, government, research).

23 FBA1-OP2-KA10: Increase wood production (i.e. size of forest plantations) of different species (especially pine and other species) to meet the future needs of Uruguay's FBA agenda (Responsible: Industry and government actors).

24 FBA1-OP3-KA10: Support increasing deployment of sustainable research and technology development services in eucalyptus and pine genetics (Responsible: Research, universities and industry actors).

Actions by 2025

Actions for the Context Dimension

25 FBA1-OP1-KA01: Link identified high-value non-wood products to global megatrends of healthy food products and pharmaceuticals (Responsible: universities, industry/consulting companies).

26 FBA1-OP1-KA02: Conduct thorough market studies (local, international) related to the non-wood forest products (incl. pharmaceutical and food products) and other ecosystem services (incl. water, carbon sequestration and leisure activities) (Responsible: industry/consulting companies).

27 FBA1-OP1-KA02: Support international climate negotiations and provide sustainability (experts and infrastructure) for forest carbon inventory (Responsible: government, NGOs, universities, research institutes).

28 FBA1-OP1-KA02: Assess the opportunities that native forests offer for different types of ecosystem services cross-cutting sector boundaries (e.g. with cattle raising, beekeeping) (Responsible: NGOs, universities, research institutes).

29 FBA1-OP1-KA03: Strengthen capacity for reliable science-based carbon (and GHG) inventories for forest (and entire LULUCF) sector (Responsible: government, universities).

[30] FBA1-OP1-KA04: Promote an anthropological study about the relation between forests and society (Responsible: universities).

[31] FBA1-OP1-KA04: Encourage all companies, especially SMEs to play an active role in the development of high-value pharmaceutical and food products (Responsible: Industry actors).

[32] FBA1-OP2-KA01: Update the best practices code (Responsible: Government agencies, e.g. DGF, industry/consultancies, universities).

[33] FBA1-OP2-KA01: Commit to Paris Climate Agreement and mitigation of climate change by nationally determined contributions (NDCs), which accelerate transition from fossil to bio-based economy (Responsible: Government and industry actors).

[34] FBA1-OP2-KA02: Adopt the UN SDGs and support development of resource efficient utilisation of the renewable natural resources (Responsible: Government and industry actors).

[35] FBA1-OP2-KA03: Secure support for investments in logistics infrastructure to ensure the status of routes and roads (Responsible: Government and industry actors).

[36] FBA1-OP2-KA04: Foster societal acceptance of the use of forest resources (especially wood as a construction material) (Responsible: Government, NGO, industry actors).

[37] FBA1-OP3-KA03: Coordinate technical schools and universities that provide education for forest sector (Responsible: Government, university, industry actors).

[38] FBA1-OP3-KA04: Create a forum for coaching SMEs that work on forest sector (Responsible: Government, industry actors).

Actions for the People Dimension

[39] FBA1-OP1-KA05: Include carbon and GHG inventory for LULUCF sector capacities in the undergraduate curricula (Responsible: University actors, e.g. FAGRO, UDELAR).

[40] FBA1-OP1-KA05: Increase the training offer in native forests in agronomics with curricula developed to accommodate the potential needs, including education in bioinformatics (Responsible: Government, industry, research institutes).

[41] FBA1-OP1-KA05: Strengthen further forest research along the entire productive chain, especially on areas in intersection of sectors (e.g. forestry and cattle raising or beekeeping) to find sustainable and economically viable cross-sector niches for businesses and employment (Responsible: Government, industry, research institutes).

[42] FBA1-OP1-KA05: Train forest professionals for GHG inventories and climate smart management practices (Responsible: Government, industry, research institutes).

[43] FBA1-OP1-KA05: Promote training programmes for sustainable ecosystem management and provision of multiple ecosystem services (Responsible: University and research institutes).

[44] FBA1-OP1-KA05: Bridge a gap between agroforestry career education offer and labor market (Responsible: Government and industry actors).

[45] FBA1-OP1-KA05: Support leadership for product development in SMEs and build ecosystem of SME and large companies for high-value production chains (Responsible: Government and industry actors).

[46] FBA1-OP1-KA05: Encourage experts to share knowledge on non-wood forest products and ecosystem services to public and landowners, for example through seminars and workshops (Responsible: University and research actors).

[47] FBA1-OP1-KA05: Secure mobility of the researchers in all phases of research career (Responsible: Government, university, research institutes and industry actors).

[48] FBA1-OP1-KA06: Promote education in all levels enhancing positive attitudes towards natural forests as a resource for recreation and wellbeing (Responsible: industry, e.g. UPM, forest owners, NGOs, government and research actors).

[49] FBA1-OP2-KA05: Design a good practice guidance for forest operations (Responsible: Research institutions and government actors, e.g. MIEM).

[50] FBA1-OP2-KA05: Promote skills and competences required for safe, sustainable and efficient logistics (Responsible: Government, industry/ private transportation sector, research institutions, university/technical education actors).

[51] FBA1-OP2-KA05: Strengthen training of personnel with people in charge / middle managers, machinery operators (Responsible: Education actors, e.g. INEFOP).

[52] FBA1-OP2-KA05: Develop and experiment sustainable forest management practices (incl. regeneration of pine plantations) (Responsible: Research institutions and government actors, e.g. MIEM).

[53] FBA1-OP2-KA06: Endorse use of wood for construction to grow industry (Responsible: Government and industry actors).

[54] FBA1-OP2-KA06: Create a political consensus on good practice guidance on sustainable forest management (incl. forest regeneration) (Responsible: Government and research actors).

[55] FBA1-OP2-KA06: Encourage stakeholders and forest owners to utilize their forest resources by developing incentives that favour investments (Responsible: Government actors).

[56] FBA1-OP3-KA05: Promote the development of educational programmes at universities that emphasize forest-related professional careers as high-tech, forward-looking options (Responsible: Government, universities and industry actors).

[57] FBA1-OP3-KA05: Engage experts and entrepreneurs, who have knowledge and long experience from the whole value-chain on forestry (forest management and timber harvesting) to provide education (Responsible: Government, industry, universities and research actors).

[58] FBA1-OP3-KA05: Gather talent and promote postgraduate scholarships in the area of natural resource transformation without nationality requirement (Responsible: Government, universities and research actors).

[59] FBA1-OP3-KA05: Enhance training of professionals for sustainable good practices in the forest operations from forest management to harvesting and regeneration (Responsible: Government and industry actors).

[60] FBA1-OP3-KA05: Include training for jobs of forest sector to the current education platforms promoting permanent education (incl. academic education and training of the professionals) (Responsible: Government and university actors).

[61] FBA1-OP3-KA06: Create education and training programmes to ensure that the relevant stakeholders have access to the state-of-the-art knowledge and the competence to apply it in the local context (Responsible: Government and industry actors).

[62] FBA1-OP3-KA06: Extend current focus of the universities to education of applied sciences relevant to forest sector (Responsible: Government and university actors).

Actions for the Process Dimension

[63] FBA1-OP1-KA07: Design and set-up pilot capacity for processing of new pharmaceutical and food products (Responsible: Industry and research actors, e.g. Chemistry School at UDELAR, INIA).

[64] FBA1-OP1-KA07: Map and zone natural forests to designate those areas best suited for recreation and multiple use and those for stricter conservation with the help of existing mappings, e.g. the SNAP (Responsible: Industry actors, forest owners, consulting companies, entrepreneurs, NGOs, government, research institutes).

[65] FBA1-OP1-KA07: Create incentive mechanisms that include payment for environmental services (benchmark Chile) (Responsible: Government agencies).

[66] FBA1-OP2-KA07: Allow the amount of harvest and the cost of planting as a liability to be included in the IRAE (tax) calculation (Responsible: Government agencies).

[67] FBA1-OP2-KA07: Align requirements of different institutions to define common policies in territorial ordering (Responsible: Government agencies, e.g. MVOTMA-DINAMA, Intendencias, DGF).

[68] FBA1-OP2-KA07: Create markets and need for wooden buildings by organizing housing fair where top international and coolest local architects together with leading companies on construction industry design and build and show houses in one of the major cities in Uruguay (Responsible: Government, industry and research institutions).

[69] FBA1-OP2-KA07: Introduce incentives that reward alternative domestic use for pine (e.g. housing needs) instead of exporting (Responsible: Government and industry actors).

[70] FBA1-OP2-KA08: Support (e.g. provide fair incentives for) sustainable forest management, which will secure availability of timber also in the future (Responsible: Government actors).

[71] FBA1-OP2-KA08: Define future preconditions and needs for digitalisation to foster sustainable and efficient wood supply, procurement and logistics operations (Responsible: Industry, research institutions and government actors).

[72] FBA1-OP2-KA08: Enhance pilot projects that demonstrate benefits and challenges of the wooden buildings in Uruguayan conditions, e.g. construction of a public building, development of wood construction friendly housing policies) (Responsible: Industry and government actors).

[73] FBA1-OP3-KA07: Develop means to identify potential bottlenecks and obstacles, and discover solutions to facilitate the network creation and operationalisation. (Responsible: Research and government actors).

[74] FBA1-OP3-KA07: Develop conflict management mechanisms to attend different interest groups (Responsible: Government actors).

[75] FBA1-OP3-KA08: Expand CIU's programmes to forest SMEs' coaching (Responsible: Industry, e.g. CIU and government actors).

Actions for the Impact Dimension

[76] FBA1-OP1-KA09: Expand environmental education (Responsible: University actors).

[77] FBA1-OP1-KA09: Develop a GIS-based database of forest resources to systematically monitor and evaluate the sustainability and legality of the actions by forest owners and monitor the condition of forests (Responsible: Government, industry and research actors).

[78] FBA1-OP1-KA09: Integrate different actors, incl. large companies, to the promotion of sustainable use of multiple forest values in natural forests (incl. recreation, pharmaceutical plants and fungi, edible mushrooms, berries) (Responsible: industry, e.g. UPM, forest owners, NGOs, government and research actors).

[79] FBA1-OP1-KA10: Demonstrate the mutual benefit for companies -cattle and agriculture producers- of the native forest conservation and a wider use than recreational (Responsible: Government and society actors).

[80] FBA1-OP1-KA10: Invest in recreational infrastructure in those areas designated as priority zones for recreational use, including monitoring of impacts (Responsible: Industry, Forest owners, Consulting companies, entrepreneurs, NGOs, government and research actors).

[81] FBA1-OP2-KA09: Support extension of academic education towards applied sciences that are relevant to utilisation of forest resources as well as their sustainable management (incl. regeneration) (Responsible: Government, education and research institutions).

[82] FBA1-OP2-KA10: Develop sustainable infrastructure in forest management practices (Responsible: research institutions, government/MIEM).

[83] FBA1-OP2-KA10: Promote sustainability and social acceptability perspective by supporting activities complementing forest plantations with other sectors' value creating activities such as silvopastoralism (Responsible: government and industry actors).

[84] FBA1-OP3-KA09: Create ecosystem with SMEs for resource efficient innovative wood processing, e.g. by introducing cooperatives (Responsible: Industry actors).

Actions by 2030

Actions for the Context Dimension

[85] FBA1-OP1-KA02: Identify potential investors and alliances for the development of data-driven and digital (non-wood-based) business services (Responsible: research, industry and government actors).

[86] FBA1-OP2-KA03: Guarantee the continuity of the forest inventory (Responsible: Industry, consultancies and government actors).

[87] FBA1-OP2-KA03: Conduct periodical forest resource assessments and make forest inventory data openly available for the stakeholders (Responsible: Government and research institutes).

[88] FBA1-OP2-KA04: Support SMEs to develop innovative production chains for wood processing and utilisation of side streams (Responsible: Government agencies).

[89] FBA1-OP2-KA04: Increase general awareness at the national level (and community level) about forest resources and all their potential uses (Responsible: Government, NGOs and industry actors).

[90] FBA1-OP3-KA03: Facilitate platform and open access for relevant information (Responsible: Government and university actors).

Actions for the People Dimension

[91] FBA1-OP1-KA05: Provide incentives for research projects and capacity building in corporate social responsibility and green consumerism in the context of forest management (Responsible: research centres and universities).

[92] FBA1-OP2-KA05: Develop capacity to design new innovative products and services that are based on use of forest resources (Responsible: industry/SMEs, research centres and universities).

[93] FBA1-OP3-KA05: Creating a local information network providing real-time monitoring of needs from forest management and timber harvesting actors (e.g. learning from Finnish Ponsse's Fleet Management application services) (Responsible: industry and research actors).

Actions for the Process Dimension

[94] FBA1-OP1-KA07: Adapt the carbon quantification methods for the native forest by strengthening information gathering towards an eventual creation of carbon markets (Responsible: research, industry and government actors).

[95] FBA1-OP1-KA08: Secure intellectual property rights (patents) and support open access dissemination of the research findings (scientific paper, presentations and social media) (Responsible: university, research, industry and government actors).

[96] FBA1-OP2-KA07: Pilot crowdfunding as a way to promoting private-public-people partnerships (PPPP) and new cooperative models in logistics infrastructure (Responsible: government, industry and community actors around underutilised plantations).

[97] FBA1-OP3-KA07: Creating a network of physical and mental health centres where timber harvesting and related activities are presented as natural healing therapies to recover from stress and other conditions (Responsible: government, health and research actors).

Actions for the Impact Dimension

[98] FBA1-OP1-KA10: Create markets and audit systems for production of sustainable forest-based ecosystem services such as forest carbon sequestration, maintenance of ground water sources (Responsible: university, research, industry/consultancy and government actors).

[99] FBA1-OP2-KA10: Establish industrial parks that integrate forest-based value chains (cellulose-mechanical transformation) (Responsible: industry actors).

[100] FBA1-OP3-KA10: Develop national and local indicators or scoreboards on broader economic, social and environmental impacts of sustainable forest management and timber harvesting activities (Responsible: government, research and industry actors).

107 recommendations of FBA2 Action Roadmap

Actions by 2020

Actions for the Context Dimension

[101] FBA2-OP1-KA01: Review and further evaluate the lessons learnt so far from other Latin American countries (Chile, Brazil) on successful public and company measures for developing investment environment (Responsible: consulting, industry, governmental connections).

[102] FBA2-OP1-KA01: Assess the present status of the availability and procurement of wood raw materials and supply of side streams of mechanical wood processing (Responsible: industry, universities and research actors).

[103] FBA2-OP1-KA01: Evaluate the availability of wood and characterise it according to its structural aptitude, associated with forest management (Responsible: Government/DGF, industry/SPF, academia/FING & FAGRO, Research/ INIA & LATITUD).

[104] FBA2-OP1-KA02: Conduct market and foresight studies (domestic, international) related to sawn wood, wood panels and engineered and modified wood products and anticipated trends in a longer run (Responsible: university and research, consulting, industry).

[105] FBA2-OP1-KA03: Review and update (if needed) the local and international funding opportunities for industrial investment projects of mechanical wood processing and side stream utilisation (Responsible: government, consulting, industry).

[106] FBA2-OP1-KA03: Focus and adapt further local university expertise to conduct RTDI and foresight research to benefit large-scale and SME industry development (Responsible: university, industry, government).

[107] FBA2-OP1-KA04: Integrate public and different stakeholders to active communication network for different stages of planning and construction (Responsible: industry, NGOs, government, research).

[108] FBA2-OP2-KA01: Explore and evaluate the knowledge and experience from the recent industrial cases of bioenergy, biorefinery and wood panel manufacturing and business efforts similar to the potential of Uruguay situation (Responsible: consulting, industry, research).

[109] FBA2-OP2-KA01: Mapping and SWOT analysis on suitable products that can be produced from side streams of mechanical wood processing and/or forest biomass - species, their yield, quality and physicochemical properties (Responsible: universities and research, industry).

[110] FBA2-OP2-KA01: Seek actively references from international investment projects and machine and equipment suppliers (Responsible: consulting, industry, and government).

[111] FBA2-OP2-KA03: Design funding instrument that accepts proposals from academia and encourages industry to participate (Responsible: research/ANII).

[112] FBA2-OP2-KA03: Position the forestry sector as a priority area for research and innovation (Responsible: government, academia).

[113] FBA2-OP3-KA01: Assess and conclude present competitiveness, profitability and investment capacity and perspectives of raw material supply of Uruguay saw mill and further processing industry (Responsible: consulting, government, industry connections).

[114] FBA2-OP3-KA01: Benchmark and further evaluate the lessons learnt so far from Chile, Brazil, NZL, South Africa etc. on development of wood industry ecosystems, wood procurement and primary and side product management (Responsible: industry/consulting, government).

[115] FBA2-OP3-KA04: Increase public awareness and interest (Responsible: industry, government and civil society).

Actions for the People Dimension

[116] FBA2-OP1-KA05: Implement training for industrialists and workers on the rules of structural timber (Responsible: education actors, INEFOP).

[117] FBA2-OP1-KA05: Promote training programmes for SME owners and workers on process improvement, wood procurement and business management (Responsible: universities, research institutes).

[118] FBA2-OP2-KA05: Train university staff and modernise facilities to develop proof-of-concept activities and ideas for RTDI (Responsible: university and research, industry, government).

[119] FBA2-OP2-KA06: Identify suitable SMEs and large companies / financing bodies with sufficient motivation and management and economic perspectives to a collaborative proof-of-concept design forum for planning and executing feasibility and pilot projects – toward industrial symbiosis (Responsible: industry, research).

[120] FBA2-OP3-KA05: Develop expertise in structural and architectural design of large-scale wooden buildings for office, residential and commercial use (Responsible: research, university, industry and government actors).

[121] FBA2-OP3-KA05: Focus and adapt further local university expertise to conduct RTDI and foresight research to benefit large-scale and SME industry development (Responsible: university, industry, government).

Actions for the Process Dimension

122 FBA2-OP1-KA07: Participate in international forum of climate change, trade policy and RTDI discussions that provide new argumentation for investment attraction for international and domestic sources (Responsible: government, university & research, industry).

123 FBA2-OP1-KA07: Introduce the construction of wood within a national housing policy (Responsible: government/MVOTMA).

124 FBA2-OP1-KA08: Further promote the use of Cross-Laminated Timber (CLT) panels in architectural, residential and utility building projects (similar to the VIK hotel built in 2018 by the Enkel Group) (Responsible: government and industry actors).

125 FBA2-OP2-KA08: Promote the prototypes already tested (Responsible: industry).

126 FBA2-OP3-KA07: Establish and launch funding instrument for Wood from Uruguay Expertise Network Program for domestic development of novel products, value networks and industrial symbiosis and promotion and export alliance of bio-based products (Responsible: government, industry, consulting).

Actions for the Impact Dimension

127 FBA2-OP1-KA09: Provide well-functioning financing system and practices for renewal and expansion of wood product industries and necessary improvements in logistics and infrastructure (Responsible: industry, government).

128 FBA2-OP1-KA09: Develop well-adapting professional and university level education, training and international collaborative practices to increase the capacity of SMEs and larger companies to RTDI (Responsible: government, university and research, industry).

129 FBA2-OP1-KA10: Provide public authority actions to match national and local land use management to support both wood product industries' expansion, agriculture production and soil and water conservation (Responsible: government and industry actors).

130 FBA2-OP2-KA09: Promote the development of sustainability indicators that align the strategies of wood-based panel industries with the United Nations Sustainable Development Goal 15 targets protecting 'Life on Land' (Responsible: industry).

131 FBA2-OP3-KA09: Increase the awareness and interest of construction companies on the opportunities of urban building with wood (residential houses, office and commercial buildings) and infrastructure building through dissemination and demonstration buildings (Responsible: government, industry, research).

Actions by 2025

Actions for the Context Dimension

132 FBA2-OP1-KA01: Lift regulatory restrictions of departmental ordinances and firefighters' rules (Responsible: government/ MVOTMA, firefighters, intendancies).

133 FBA2-OP1-KA01: Promote foreign and domestic investments (Responsible: Government/MEF & Uruguay XXI & Ministry of Foreign Affairs & MIEM, Chamber of Industries).

134 FBA2-OP1-KA02: Evaluate the potential Durazno - Montevideo train impact on the competitiveness (logistics) of the sector (Responsible: government/MEF, Uruguay XXI, MIEM, universities).

135 FBA2-OP1-KA02: Assess the growth potential of domestic building with wood and prospective consumption of wood-based products (Responsible: industry, consulting, university and research).

136 FBA2-OP1-KA02: Promote the association of small industries to generate efficiency and economies of scale via industrial parks (Responsible: industry, government).

137 FBA2-OP1-KA04: Revitalise communication network (of all stakeholders) carried out by the forest council (Responsible: TU-SNCTP.Timeframe).

138 FBA2-OP1-KA04: Conduct surveys on current and potential SMEs for industrial investments in wood products sector and wood construction (Responsible: industry, university and research).

139 FBA2-OP2-KA02: Identify customers and test marketing of the selected products (domestic, international) (Responsible: industry, university and research).

[140] FBA2-OP2-KA02: Establish relevant product segments and their requirements for critical properties (Responsible: industry, university and research).

[141] FBA2-OP2-KA02: Conduct detailed surveys and/or case studies on business potential and profitability of the new product, processing and marketing concepts (Responsible: industry, university and research, consulting).

[142] FBA2-OP2-KA02: Conduct studies and surveys on potential products and processes (Responsible: international research and technology organisations).

[143] FBA2-OP2-KA04: Activate domestic decision-makers and key SMEs to gain proof-of-concepts through co-funding mechanism (Responsible: industry, university and research, government).

[144] FBA2-OP3-KA02: Assess market segments, customer groups, competitiveness and relevant product standards of Uruguay-based wood panels and engineered wood products to match wood-based construction (domestic, export) (Responsible: industry/consulting, universities, research).

[145] FBA2-OP3-KA02: Conduct foresight studies (domestic, international) related to sawn wood, engineered and modified wood products demand/supply and markets and their anticipated trends in a longer run (Responsible: university, research, consulting, industry).

[146] FBA2-OP3-KA03: Provide local and international funding opportunities for marketing and branding campaigns of Uruguay-based wood products (Responsible: government, industry/ consulting).

Actions for the <u>People</u> Dimension

[147] FBA2-OP1-KA05: Support leadership for product development and techno-economic renewal among SME and large companies and build ecosystem for high-end production chains (Responsible: government and industry).

[148] FBA2-OP1-KA05: Generate a certification of structural wood products, for example CE (Responsible: government and industry).

[149] FBA2-OP1-KA05: Explore HR training demands (Responsible: education/INEFOP).

[150] FBA2-OP1-KA06: Engage all stakeholders in the promotion and branding of wood construction (Responsible: government, industry, university, NGOs).

[151] FBA2-OP2-KA05: Establish a competent RTDI group that consists of experts called from international and domestic sources on bioenergy, small-scale biorefinery and wood panel industry (Responsible: university, research and government).

[152] FBA2-OP2-KA05: Promote local training programmes for small-scale bioenergy and biorefinery stakeholder groups (Responsible: university, research and government).

[153] FBA2-OP3-KA05: Set up a national certification body and promote standardization and structural certification of EWP (Responsible: universities, government/MIEM, firefighters, UNIT).

[154] FBA2-OP3-KA05: Promote relevant training programmes for SME owners and marketing staff on process improvement, wood procurement and business, marketing and branding management (Responsible: university, research, industry, government).

[155] FBA2-OP3-KA05: Increase professional education at all levels of wood product industries, wood construction, architecture and design (Responsible: university, professional schools, research institutes).

[156] FBA2-OP3-KA05: Evaluate the potential of atmospheric pressure plasma and vinyl monomer impregnation technologies as emerging means to improve surface functionalities (e.g. hydrophobicity, antimicrobial resistance) of local pine and eucalyptus timber (Responsible: university, research institutes and industry actors).

Actions for the <u>Process</u> Dimension

[157] FBA2-OP1-KA07: Establish requirements and potential for parallel value chain development and industrial symbiosis of mechanical and chemical wood processing (Responsible: consulting, university and research).

[158] FBA2-OP1-KA07: Support local and regional companies (especially SMEs) for testing new raw materials, products and business concepts (Responsible: government and industry).

[159] FBA2-OP1-KA07: Create a unit that articulates and coordinates private interests together with academia (Responsible: government/MIEM & DGF, research/INIA, university).

[160] FBA2-OP1-KA08: Establish and launch funding instruments for 'Wood from Uruguay Expertise Network Programme' for domestic development of novel products, value networks and industrial symbiosis and promotion and export alliance of bio-based products (Responsible: government, industry, consulting).

[161] FBA2-OP1-KA08: Foster the public authorities and banking system to support building with wood projects and export oriented wood product industry (Responsible: government, industry, consulting).

[162] FBA2-OP2-KA07: Select one or two products groups / processing technologies, and test technical and economic proof-of-concepts using new pilot plants or knowledge to be gained from on-going international projects (Responsible: consulting, universities and research, industry).

[163] FBA2-OP2-KA07: Design and set up of well-defined pilot-scale side stream upgrading and wood panel testing units in mill sites or research environment (Responsible: universities and research, industry).

[164] FBA2-OP2-KA07: Ensure public funding to support financially the growth of wood-panel industries and process and product optimization in testing activity to use side streams of mechanical wood processing and low-value forest biomass (Responsible: government, university and research).

[165] FBA2-OP2-KA08: Establish and run 'Wood from Uruguay Expertise Network Programme' for domestic development of novel products, value networks and industrial symbiosis and promotion and export alliance of bio-based products (Responsible: government, industry, consulting).

[166] FBA2-OP3-KA07: Promote and support establishment of industry parks of mechanical wood processing and side stream utilisation (Responsible: government, industry and consultancy actors).

[167] FBA2-OP3-KA07: Support product testing and national standardization of the existing and novel products (Responsible: Industry and government actors).

[168] FBA2-OP3-KA07: Establish and run 'Building with Wood Promotion and Branding Programme' – support to domestic demand and supply of wood products and implementation of climate change control, and export of products in selected countries (Responsible: Industry, consultancy and government actors).

[169] FBA2-OP3-KA07: Implement modern measurement, grading and sorting technology in saw mills and wood panel factories (Responsible: university, research, industry/consultancy actors).

[170] FBA2-OP3-KA07: Ascertain the most profitable end uses of pine and eucalypt species in Uruguay with reference to competitive species and substitute materials (Responsible: university, research and industry/consultancy actors).

[171] FBA2-OP3-KA08: Foster the public authorities and banking system to support building with wood projects and export oriented wood product industry – using the relevant argumentation (Responsible: government and industry/consultancy actors).

Actions for the Impact Dimension

[172] FBA2-OP1-KA09: Provide legislative incentives and information on economic opportunities for SMEs for further processing of sawn timber toward engineered and modified wood products (Responsible: government, industry, university and research).

[173] FBA2-OP1-KA09: Provide legislative incentives and information on economic opportunities for larger companies for further processing of sawn timber toward wood panel production (Responsible: government, university and research, industry).

[174] FBA2-OP1-KA09: Increase capacity of SMEs and larger companies in investment planning and business management via professional education (Responsible: government, university and research, industry).

[175] FBA2-OP1-KA10: Monitor and disseminate the use of forests, lands and side streams, renewable and non-renewable material usage and waste accumulation in wood construction in relation to certification criteria, energy balance and carbon storage (Responsible: government, industry, university and research, and consultancy actors).

[176] FBA2-OP1-KA10: Promote the sustainability of Uruguayan timber internationally (Responsible: government and other actors, e.g. Uruguay XXI).
[177] FBA2-OP2-KA09: Increase domestic demand for bioenergy/biorefinery by showing and implementing novel bioenergy concepts and technology and good international practices for cities and industry companies (Responsible: government and industry actors).
[178] FBA2-OP2-KA09: Develop and test further domestic raw materials, process technology, products and applications via deep collaboration between all the partners in the value chain (Responsible: university, research, industry/SMEs and spin-offs).
[179] FBA2-OP3-KA09: Establish global distribution and promotion offices and utilise the networks of global market players to open new markets for products (first for sawn timber and wood panels, and later for engineered wood products) (Responsible: government, industry and research actors).
[180] FBA2-OP3-KA10: Create Environmental Product Declarations (EPD) and Technical Product Standards (TPS) for the existing and novel products for domestic and international markets – find references from other countries in relevant market niches (Responsible: government, industry, consultancies and research actors).

Actions by 2030

Actions for the Context Dimension

[181] FBA2-OP1-KA03: Review financing opportunities (Responsible: TU-SNCTP, government/MEF).
[182] FBA2-OP2-KA01: Incorporate economic approach to complement technical analyses (Responsible: universities, UTU, TU-SNCTP).
[183] FBA2-OP2-KA01: Create pilot forest resource information networks (Responsible: university, industry chamber).
[184] FBA2-OP2-KA03: Secure financing to test prototypes (Responsible: government/ANDE, research/ANII, and universities).
[185] FBA2-OP2-KA04: Promote inter-company cooperation in the absence of collaborative action (Responsible: industry chambers and government departments).
[186] FBA2-OP3-KA04: Foster the dialogue between producers and industry (Responsible: Industry/SPF, industry chambers and government councils).

Actions for the People Dimension

[187] FBA2-OP1-KA06: Engage local (regional) governments as promoters of regional development (Responsible: municipalities, mayorships).
[188] FBA2-OP2-KA05: Promote local projects delivering practical training (Responsible: government departments, research centres and universities).
[189] FBA2-OP2-KA06: Co-integrate forestry, wood products industry and agribusiness players into small-scale bioenergy and biorefinery value chains to ascertain raw material availability, as a part of proof-of-concept (Responsible: government, research and industry actors).
[190] FBA2-OP3-KA06: Present and organize exhibitions (e.g. Wood Construction Fair) on wood in building and living for domestic consumers (B-to-C) and industrial customers (B-to-B) (Responsible: industry, government and research).

Actions for the Process Dimension

[191] FBA2-OP1-KA07: Create a forest technology centre, which is an autonomous (e.g. in managing resources), in association with academia (Responsible: government, research and university).
[192] FBA2-OP1-KA07: Ascertain and update the logistics network of raw materials and products – roads, bridges, harbours, railways and storage of side streams (Responsible: government/ OPP, town hall and MTOP, industry).
[193] FBA2-OP1-KA08: Allow mortgage loans for wooden houses (Responsible: banking industry/BCU, BHU, Government/MEF, ANV, MVOTMA).
[194] FBA2-OP2-KA07: Promote publicly wood construction through minimum quotas on state purchases (Responsible: central administration and government departments).

[195] FBA2-OP2-KA07: Develop industrial parks (Responsible: government departments and industry chambers).

[196] FBA2-OP2-KA07: Technical and financial support to renewal and transformation of existing bioenergy sector to biorefinery business, and CHP plants (local and possibly international) (Responsible: government, university and research actors).

[197] FBA2-OP2-KA08: Secure intellectual property rights (patents) and support open access dissemination of the research and piloting findings and mobility of RTDI staff (Responsible: government, university & research and industry actors).

[198] FBA2-OP3-KA07: Empower States where public buildings are made with wood (Responsible: government and intendancies).

[199] FBA2-OP3-KA08: Strengthen and focus domestic and export distribution channels and implementation of IT technology in the value chains (Responsible: industry / consultancies, hardware and software manufacturers, university and research actors).

Actions for the Impact Dimension

[200] FBA2-OP1-KA10: Assess and monitor direct and non-direct national and local effects of wood products industries and building with wood on monetary flows, job creation and development of SMEs in the value networks – economic and social sustainability, benefits of new investments (Responsible: university, research, industry/consultancy and government actors).

[201] FBA2-OP1-KA10: Ascertain secure and sustainable raw material balance and mobilisation, and sustainable side stream demand, for the basis of ecologically sound and long-term effective industrial investments in wood products and related bioenergy and biorefinery sectors (Responsible: government and industry actors).

[202] FBA2-OP2-KA09: Implement tax return policies in industries using bioenergy (Responsible: government).

[203] FBA2-OP2-KA10: Monitor and assess the proportion of oil-based products being replaced by the introduction of wood-based materials in energy sector and construction, as well as national energy and carbon balance (Responsible: university, research, government and consultancy actors).

[204] FBA2-OP2-KA10: Map and monitor the local environmental and social impacts of value chains and increasing biomass use among wood panel industries and new-types of bioenergy plants (Responsible: university, research, government and consultancy actors).

[205] FBA2-OP2-KA10: Conduct RTDI and demonstration actions on side stream utilisation and management and reduction of production wastes toward environmentally sound and economically competitive cascading uses and closed production loops (Responsible: university, research, government and consultancy actors).

[206] FBA2-OP3-KA10: Assess, benchmark and demonstrate self-organising business concepts such as co-operatives, networks of SMEs and entrepreneurs and shared marketing of wood products for local job creation and development of socially and economically sustainable business systems (Responsible: university, research, industry and consultancy actors).

[207] FBA2-OP3-KA10: Ascertain and implement the functionalities and benefits of raw material and product certification systems, such as FSC and PEFC (Responsible: research, industry and consultancy actors).

111 recommendations of FBA3 Action Roadmap

Actions by 2020

Actions for the Context Dimension

[208] FBA3-OP1-KA01: Companies assess the potential of integrated local paperboard and specialties paper manufacture in terms of logistics, availability of all raw materials & resources, and Latin American and global markets in each case (Responsible: Uruguay XXI, consultancy sector and industry actors).

[209] FBA3-OP1-KA01: Improve regulation to promote new forest project to increase forested area (Responsible: government actors).

[210] FBA3-OP1-KA01: Analyse potential to integrate production of local and imported fibres (depending on prices) (Responsible: Industry and research actors).

[211] FBA3-OP1-KA01: Analyse successful cases of other sectors to replicate (Responsible: Industry and research actors).

[212] FBA3-OP1-KA02: Conduct feasibility studies on selected products (Responsible: research and other actors, e.g. Uruguay XXI).

[213] FBA3-OP2-KA01: Promote local policies and regulations that increase the use of fibre-based products in different sectors, e.g. textiles, food packaging (Responsible: government).

[214] FBA3-OP2-KA02: Conduct feasibility studies in technology, market, product and costs (Responsible: research and other actors, e.g. Uruguay XXI).

[215] FBA3-OP2-KA02: Conduct thorough studies on the production of different types of pulps (and papers) in Latin America, also covering their import, to assess the potential production gap to be filled (Responsible: industry actors).

[216] FBA3-OP3-KA01: Promote local policies and regulations that increase the use of fibre-based products in different sectors, e.g. textiles, bioplastics, chemicals, novel materials (Responsible: government actors).

Actions for the People Dimension

[217] FBA3-OP1-KA05: Increase number of people working in research in the sector and funding to enable it. Promote academicals exchanges programmes and bilateral agreements (Responsible: government, academia).

[218] FBA3-OP1-KA05: Promote exchange programs to develop masters and doctoral degrees in Uruguay (Responsible: government, academia).

[219] FBA3-OP1-KA05: Resume masters programme in cellulose and paper (Responsible: FING-UDELAR).

[220] FBA3-OP2-KA05: Promote capabilities for training and research (Responsible: university and research actors).

[221] FBA3-OP3-KA05: Develop competences and skills on environmentally sound management of composites, bioplastics and related chemicals throughout their life cycle, in accordance with agreed international frameworks and practices aligned with the United Nations Sustainable Development Goal 12 targets for 'responsible production and consumption' (Responsible: government, industry and research actors).

Actions for the Process Dimension

[222] FBA3-OP1-KA07: Develop national bioeconomy and circular economy strategies that further promote the use and re-use of various virgin and recovered fibre and paper materials (Responsible: government, university & research, industry).

[223] FBA3-OP1-KA07: Promote alliances between the pulp mills for the joint development of more advanced biorefineries (Responsible: Industry actors).

[224] FBA3-OP2-KA08: Create actions to promote and disseminate information on pine availability and quality (Responsible: Uruguay XXI, DGF, MIEM).

[225] FBA3-OP3-KA08: Promote productive transformation of different Uruguayan sectors with a focus on increasing use of novel bio-based products (Responsible: government, industry, consulting).

Actions for the Impact Dimension

[226] FBA3-OP1-KA09: Increase local demand for sustainable, biodegradable fibre-based packaging materials, tissues and other fibre products via different policy guidelines (Responsible: government).

[227] FBA3-OP2-KA09: Increase demand for sustainable fibre-based products by promoting novel innovations-applications, for example in packaging (Responsible: government and industry actors).

[228] FBA3-OP3-KA09: Promote sustainability indicators that ensure novel cellulose-based products and materials comply with the United Nations Sustainable Development Goal

12 targets to adopt sustainable practices and sustainability information into their reporting cycle (Responsible: industry actors, especially large and transnational companies).

Actions by 2025

Actions for the Context Dimension

229 FBA3-OP1-KA02: Perform techno-economic feasibility studies with strong market research (Responsible: government).

230 FBA3-OP1-KA02: Define key products and use global standards for their production (board, pulp, pulp derivatives) (Responsible: industry actors).

231 FBA3-OP1-KA02: Conduct thorough trends and market studies (local, LA) for different types of paper products based on local kraft pulps, including fluff pulps (Responsible: industry actors).

232 FBA3-OP1-KA03: For the large investments, provide sufficient support in terms of infrastructure (train, roads, increased space in Montevideo's port), to ensure efficiently working logistics that suit selected products (Responsible: government actors).

233 FBA3-OP1-KA03: use local universities and research organisations to perform necessary lab (and pilot) studies for the process and product development and optimisation (Responsible: industry and research actors).

234 FBA3-OP1-KA03: Provide adequate infrastructure and funding in research organisations (Responsible: government actors).

235 FBA3-OP1-KA03: Create sector-specific (EWP, pulp, paper and biomaterial and biorefining) research funds, from public and private resources (Responsible: government and industry actors).

236 FBA3-OP1-KA03: Create a research fund for fibres (Responsible: ANII, industry, LATU).

237 FBA3-OP1-KA04: Integrate public and different stakeholders to active communication network at different stages of planning and construction (Responsible: industry, government, research, NGOs).

238 FBA3-OP2-KA01: Develop measures to attract and develop a national chemical industry that uses some of these inputs, i.e. by-products from pulping (Responsible: Government, Uruguay XXI).

239 FBA3-OP2-KA01: Analyse current eucalyptus pulp mill (other than kraft) operations and status in LA and elsewhere for the present state-of-the-art (Responsible: industry).

240 FBA3-OP2-KA01: Develop measures to stop the substitution of pine for eucalyptus (Responsible: government actors, DGF, MIEM).

241 FBA3-OP2-KA01: Perform investment promotion for global companies and selected opportunities (Responsible: Uruguay XXI).

242 FBA3-OP2-KA02: Assess the possibility of having NSSC production plant, not common though out Latin America (Responsible: industry).

243 FBA3-OP2-KA02: Conduct survey on the current and anticipated future needs for different pulp types and their application areas (Responsible: industry).

244 FBA3-OP2-KA03: Provide sufficient support in terms of infrastructure to ensure efficiently working logistics for very large investments (Responsible: government).

245 FBA3-OP2-KA03: Conduct necessary lab- to pilot studies for process development and optimisation with help of local university facilities and expertise (Responsible: industry, university and research actors).

246 FBA3-OP2-KA04: Integrate public and different stakeholders to active communication network at different stages of planning and construction (Responsible: industry, government, research, NGOs).

247 FBA3-OP2-KA04: Support local companies to develop industry for the utilisation of the novel national raw material, such as dissolving pulp for textiles or specialty chemicals (Responsible: government).

248 FBA3-OP2-KA04: Promote integrated industry that uses EWP residues as feedstock (Responsible: industry and government actors).

249 FBA3-OP3-KA01: Launch funding instruments that facilitate the integration of SMEs and other newcomers in the development of novel bio-based products in a variety of applications (Responsible: government actors).

[250] FBA3-OP3-KA01: Improve linkages with design sector (Responsible: industry and research actors).

[251] FBA3-OP3-KA02: Review a representative list of LA and international (in particular Brazil, Chile, Mexico, Colombia) showcases on innovative new products based on cellulosic materials (Responsible: research actors).

[252] FBA3-OP3-KA02: Conduct survey on the willingness of local industrial and other stakeholders to participate in a national programme or campaign aiming at a variety of new fibre- or cellulose-based products for specialty applications (Responsible: research, industry and government actors).

[253] FBA3-OP3-KA03: Facilitate the close integration of design experts into the development of certain new cellulose-based products and materials to increase their attractiveness (Responsible: research, design/industry and government actors).

[254] FBA3-OP3-KA04: Generate conditions that facilitate the growing number of new university spin-offs to tackle the potential of local pulps in innovative new applications (Responsible: research and government actors).

[255] FBA3-OP3-KA04: Facilitate the mobility of international cellulose experts to short- and long-term collaboration with the local university-linked start-ups (Responsible: research, industry and government actors).

Actions for the People Dimension

[256] FBA3-OP1-KA05: Strengthen companies commitment to have their personnel to finalise degrees (Responsible: industry actors).

[257] FBA3-OP1-KA05: Include training on cellulose in Tacuarembó's forestry engineering degree (Responsible: UDELAR).

[258] FBA3-OP1-KA05: Enhance research capacities on the fibre properties (Responsible: research actors and ANII).

[259] FBA3-OP1-KA05: Research the fibre properties of local wood for paperboard production and other products. Justified by the need of having public information on fibre properties of pine (Responsible: ANII, academia).

[260] FBA3-OP1-KA05: Review experience of Universidad de Misiones for attracting regional students to masters and doctoral programmes (Responsible: university actors and ANII).

[261] FBA3-OP1-KA05: Increase skills training related to lab expertise in forest-cellulose (Responsible: UDELAR, UTU, UTEC).

[262] FBA3-OP1-KA05: Build up courses on technical training in the sector (Responsible: industry, UTEC).

[263] FBA3-OP1-KA06: Review the latest achievements in paper production technologies, such as lean-water processes and alternative forming systems, to be used as pioneering pilot cases (Responsible: industry actors).

[264] FBA3-OP2-KA05: Facilitate and promote exchanges with international firms (Responsible: industry actors).

[265] FBA3-OP2-KA05: Assess the opportunities to integrate new or pioneering technologies in the new pulp mills for the demonstration purposes (Responsible: industry actors).

[266] FBA3-OP2-KA05: Evaluate the increase of pulp yield by using polysulphide pulping for pine wood, instead of normal kraft pulping (Responsible: industry actors).

[267] FBA3-OP2-KA06: Promote long-term competence development and commitment in R&D to ensure high-level local competence in the areas of new pulping processes and their further conversion to more advanced pulp mill biorefineries (Responsible: industry, research and government actors).

[268] FBA3-OP3-KA05: Promote the joint industry-university research and training programmes to increase the local capacity to take the new ideas to marketable products and services (Responsible: government, industry and research actors).

[269] FBA3-OP3-KA05: Study the potential of eucalyptus and pine kraft pulps as reinforcing materials for cement in construction (Responsible: industry, university and research actors).

[270] FBA3-OP3-KA05: Develop competences for the use of unconventional solvents (such as ionic liquids) for the dissolution and processing of wood, pulp and cellulose (Responsible: industry, university and research actors).

[271] FBA3-OP3-KA06: Create a joint innovation platform for all different pulp, paper and biomaterial and biorefining topics to ensure most efficient way to reach high innovation power for new pulping-based products and processes in Uruguay (Responsible: research, industry and government actors).

Actions for the Process Dimension

[272] FBA3-OP1-KA07: Support (e.g. by funding) the industrial players wishing to demonstrate globally pioneering processes or technology in paper manufacture in Uruguay (Responsible: government).

[273] FBA3-OP1-KA07: Create a technology centre or a joint innovation platform for all relevant pulp, paper and biomaterial and biorefining topics to ensure most efficient way to reach high innovation power for new pulping-based products and processes in Uruguay (Responsible: research, industry and government actors).

[274] FBA3-OP1-KA08: Improve conditions (e.g. funding, research capabilities, innovation programmes) for constant chain of developing and further improving the (end-)products already brought to the markets (Responsible: government, SMEs and industry actors).

[275] FBA3-OP1-KA08: Improve infrastructure conditions, specifically those relating to the projects that will be considered (each of the projects can have different infrastructure needs. like rail, roads, port improvement) (Responsible: government).

[276] FBA3-OP2-KA08: Create a joint innovation platform for all different pulp, paper and biomaterial and biorefining topics to ensure most efficient way to reach high innovation power for new pulping-based products and processes in Uruguay (Responsible: research, industry and government actors).

[277] FBA3-OP2-KA08: Strengthen policies that support the creation of new value chains in the country, based on local raw materials and intermediate products (Responsible: government).

[278] FBA3-OP2-KA08: Create conditions that assist to ensure the availability of sufficient volumes of high quality wood raw materials (Responsible: government actors).

[279] FBA3-OP3-KA07: Establish a funding instrument that also supports the development of high-risk innovations in new areas of high-tech cellulose (and other biomaterials) use, such as advanced functional materials or medical applications (Responsible: government actors).

[280] FBA3-OP3-KA08: Provide sufficient advice support for the start-ups at the early stages of business development, IPR issues, marketing and related non-technical matters (Responsible: government actors).

Actions for the Impact Dimension

[281] FBA3-OP1-KA09: Encourage companies already present in Uruguay to produce specialty products locally beside commodity products (Responsible: government actors).

[282] FBA3-OP2-KA09: Assess the opportunities to integrate new or pioneering technologies in the new pulp mills for the demonstration purposes (Responsible: industry actors).

[283] FBA3-OP2-KA10: Increase demand for sustainable fibre-based products by promoting novel innovations-applications, for example in packaging (Responsible: industry and government actors).

[284] FBA3-OP3-KA10: Harness universities and relevant engineering companies to up-scaling activities to increase production rates (Responsible: research, education and industry actors).

Actions by 2030

Actions for the Context Dimension

[285] FBA3-OP1-KA04: Ensure the integration of Mercosur to enable exports to the neighbouring countries (Responsible: industry, government, Mercosur).

[286] FBA3-OP2-KA02: Monitor development of new biochemical business in the region (Responsible: MIEM, TU-SNCTP).

[287] FBA3-OP2-KA02: Analyse possibilities of using EWP side streams for pulp production (Responsible: companies, MIEM, Uruguay XXI, TU-SNCTP).

[288] FBA3-OP3-KA01: Design programmes for supporting and generating successful cases for demonstration (Responsible: ANII).

[289] FBA3-OP3-KA01: Design a programme for integrating SMEs and industries for developing new products (Responsible: MIEM, ANII).

[290] FBA3-OP3-KA01: Increase local production of paper bags, following the approval of "Plastic Bags Law" that limits their usage in the country (Responsible: industry and government actors).

[291] FBA3-OP3-KA03: Enhance universities and research institutes' capacities (Responsible: research and university actors).

[292] FBA3-OP3-KA03: Harness local universities for piloting studies and product characterisation and tests (Responsible: research and university actors).

[293] FBA3-OP3-KA03: Promote involvement of large companies (Responsible: government and industry actors).

[294] FBA3-OP3-KA03: Seize opportunities from available capacities in design (Responsible: industry actors).

[295] FBA3-OP3-KA03: Create business incubator or modify some programmes line to suit this specific OP (Responsible: ANII, LATU).

[296] FBA3-OP3-KA04: Increase closer collaboration of the SMEs and universities with the large industrial pulp producers to better understand the links between raw materials, pulping conditions, and cellulose properties (Responsible: research and industry actors).

Actions for the People Dimension

[297] FBA3-OP1-KA05: Promote joint industry-university training programmes to develop sufficient level of engineering and technical expertise operate integrated paper and paperboard mills (Responsible: universities, industry).

[298] FBA3-OP2-KA05: Increase selection of different pulp types to satisfy potentially increasing local, LA and international demand, e.g. in textiles, packaging, tissues (Responsible: industry).

[299] FBA3-OP2-KA05: Promote radical innovation through cooperation between vested players and international frontrunners (Responsible: government and national/international industry actors).

[300] FBA3-OP3-KA06: Select successful new local cases for promising "marketed" examples on starting new bio-based business, to encourage other newcomers for the same (Responsible: industry and government).

Actions for the Process Dimension

[301] FBA3-OP1-KA07: Finalise the optimal production conditions for different products and grades in various sectors, based e.g. on pilot and demo scale runs (Responsible: industry, research).

[302] FBA3-OP1-KA08: Implementation of new technology centre with UPM in the event of a third pulpmill.(Responsible: industry, OPP, ANII).

[303] FBA3-OP1-KA08: Evaluate applicability of having an innovation platform with UPM's technology centre (Responsible: government, university and research and industry actors, UPM).

[304] FBA3-OP2-KA07: Promote productive transformation of different Uruguayan sectors further with a focus on increasing use of novel bio-based products, such as cellulosic textile fibres, specialty chemicals and fibre-based packaging materials (Responsible: government, industry).

[305] FBA3-OP2-KA07: Define through feasibility studies the necessary scale to have feasible plants (Responsible: government, university and research actors).

[306] FBA3-OP2-KA07: Seize opportunities that come from the building up of infrastructure necessary for UPM's second plant (Responsible: industry actors).

[307] FBA3-OP2-KA07: Support (e.g. by funding) the industrial players wishing to demonstrate pioneering processes or technology in pulp production in Uruguay (Responsible: government actors).

308 FBA3-OP2-KA07: Develop and integrate pulping processes with national chemical industry to produce lignin, tall oil and turpentine (Responsible: MIEM and industry actors).

309 FBA3-OP2-KA07: Develop new products obtained from cellulose (Responsible: academia, industry).

310 FBA3-OP2-KA07: Recycle fibres to benefit from existing capacities (Responsible: industry and research actors).

311 FBA3-OP2-KA08: Increase demand for sustainable fibre-based products by promoting novel innovations-applications, for example in packaging (Responsible: industry and government actors).

312 FBA3-OP3-KA07: Ensure that the lessons constantly learned on the development of new products and innovations will be known to relevant stakeholders, e.g. in the form of open workshops and seminars (Responsible: industry, research and government actors).

Actions for the Impact Dimension

313 FBA3-OP1-KA09: Increase product development and innovations in various novel specialty papers for technical applications, such as electronics, filtering paper (Responsible: university, research and industry/consultancy actors).

314 FBA3-OP1-KA10: Monitor the rate of the use of recovered paper in the raw material mix (Responsible: industry actors).

315 FBA3-OP1-KA10: Survey the impact of the new paper value chains on the number of new industrial players, locally using the paper and paperboard materials in different application areas (Responsible: university, research and government actors).

316 FBA3-OP2-KA09: Increase selection of different pulp types to satisfy potentially increasing local, LA and international demand, e.g. in textiles, packaging, tissues (Responsible: industry actors).

317 FBA3-OP2-KA10: Monitor and assess the proportion of oil-based products being replaced globally by the increased use of fibre-based materials instead of oil-based ones, e.g. for textiles, specialty chemicals and packages (Responsible: research and industry actors).

318 FBA3-OP2-KA10: Survey the impact of the new cellulosic value chains on the number of new industrial players, locally using the novel fibre materials in different application areas (Responsible: research and government.actors).

319 FBA3-OP3-KA09: Provide conditions (e.g. funding) for constant chain of developing and further improving the novel products already brought to the markets (Responsible: government actors).

320 FBA3-OP3-KA10: Monitor the impact of the SMEs and start-up companies to the markets of new bio-based products (Responsible: research and university actors).

321 FBA3-OP3-KA10: Map the impact of the new cellulose product businesses to job creation and overall increase in local innovation capacities (Responsible: research and university actors).

108 recommendations of FBA4 Action Roadmap

Actions by 2020

Actions for the Context Dimension

322 FBA4-OP1-KA01: Review and evaluate the lessons learnt so far from the similar preceding industrial separation and purification cases, taking into account scale of operations relative to local pulpmills (Responsible: industry, consulting companies, MIEM, OPP).

323 FBA4-OP1-KA01: Assess the present status of the availability of hemicelluloses and lignin from the current forest industry and revise availability of other sources (Responsible: industry and university actors).

324 FBA4-OP1-KA04: Integrate public and different stakeholders to active communication network for different stages of planning and construction (Responsible: industry, NGOs, government and research actors).

325 FBA4-OP1-KA04: Conduct surveys on potential local and regional end-users (and products) to identify relations to joint application tests and product development (Responsible: industry and university actors).

326 FBA4-OP1-KA04: Increase exchange (of knowledge and resources) with regional institutions (Responsible: INTI, INTA, LATU, INIA, universities).

327 FBA4-OP2-KA01: Exploit the results of national survey on all potentially available wastes and residues from different forest industry sectors, preferably also covering other biomass sectors (Responsible: research and industry actors).

328 FBA4-OP2-KA01: Collect and unify data from different sources (Responsible: Government actors, e.g. Ministries).

329 FBA4-OP2-KA01: Identify possible high range markets/ products (Responsible: Transforma Uruguay, OPP).

330 FBA4-OP2-KA02: Create network(s) for utilization of sawmills residues (Responsible: industry and regional governments actors).

331 FBA4-OP3-KA01: Review current and recent pine & eucalyptus bark uses in Latin America (e.g. pine tannin process in Chile), and analyse relevant examples from elsewhere (Responsible: industry and research actors).

332 FBA4-OP3-KA01: Assess potential of eucalyptus bark recovery from the plantations and the minimal value that should remain on site (Responsible: research/INIA and academia).

333 FBA4-OP3-KA01: Review availability of bark for each genus and species, and their location (Responsible: research/INIA, academia, government/DGF).

334 FBA4-OP3-KA04: Promote the role of SMEs in the development of new products and value chains (Responsible: industry and government actors).

Actions for the <u>People</u> Dimension

335 FBA4-OP1-KA05: Promote joint industry-university training programmes to develop sufficient level of chemical engineering and technical expertise to both design and run the separation and purification operations (Responsible: Universities, industry, e.g. UPM and MDP.

336 FBA4-OP1-KA06: Integrate agribusiness players into the bio-chemicals value chain to supply hemicellulose-containing agro wastes for the production of new products, such as xylitol (Responsible: Industry).

337 FBA4-OP2-KA06: Encourage clustering of biomass providers, so that investors do not have to “convince” producers to network for common objectives and opportunities (Responsible: Government/ MIEM& MGAP, regional governments).

338 FBA4-OP2-KA06: Find an actor that takes part in each part of the business/value chain (agricultural/forest producer and residues processing producer) (Responsible: industry actors).

339 FBA4-OP3-KA05: Increase closer collaboration of the bark users with the bark producers to better understand links between raw materials, debarking systems, and bark properties, such as purity (Responsible: industry).

340 FBA4-OP3-KA05: Perform detailed analyses for the composition of different national barks, including those from the exotic species (Responsible: research actors).

341 FBA4-OP3-KA06: Activate programmes that promote the increased use of bio-based chemicals and materials, e.g. in chemical and EWP industries (Responsible: government and industry actors).

Actions for the <u>Process</u> Dimension

342 FBA4-OP1-KA08: Adapt local regulation on formaldehyde and phenol concentration in adhesives (see Europe) (Responsible: industry, government/MVOTMA, MIEM).

343 FBA4-OP2-KA08: Provide sufficient advice and support for the potential start-ups at the early stages of business development: in IPR issues, marketing and related non-technical matters (Responsible: government).

344 FBA4-OP2-KA08: Promote productive transformation of different Uruguayan sectors with a focus on increasing the use of novel waste- and bio-based products (Responsible: government and industry actors).

345 FBA4-OP3-KA08: Assess bark usage as an alternative, in case bark becomes an environmental issue (Responsible: research actors).

Actions for the Impact Dimension

346 FBA4-OP1-KA09: Increase interactions between industry and academia (Responsible: industry, research and university actors).
347 FBA4-OP1-KA10: Establish stable mechanisms for residues buying agreements (Responsible: government).
348 FBA4-OP2-KA09: Incentivize the entry of chemical firms in the sector, given that they have better knowledge of markets/technologies of end-products (Responsible: government and industry actors).
349 FBA4-OP3-KA09: For the potential new uses of bark compounds in pharma, flavour and fragrance areas, ensure sufficient chemical and biotechnical education for the development of the new products and processes (Responsible: industry and research actors).

Actions by 2025

Actions for the Context Dimension

350 FBA4-OP1-KA01: Take into account the contracts between pulpmills and electric company and its deadline. Estimate the opportunity cost of producing lignin vis-a-vis selling energy to the grid (Responsible: MIEM, UTE).
351 FBA4-OP1-KA02: Conduct thorough market studies (local, international) related to the existing and potential application areas and anticipated trends for the lignin and hemicellulose products (Responsible: industry actors).
352 FBA4-OP1-KA03: Design and set up sufficient-level pilot-scale separation unit(s) at the mill sites (Responsible: industry actors).
353 FBA4-OP1-KA03: Harness local university facilities and expertise to conduct necessary lab- to pilot-scale studies for the process optimisation (Responsible: industry and university actors).
354 FBA4-OP1-KA03: Increase demand of qualified workers to encourage further training from workers (Responsible: industry actors).
355 FBA4-OP1-KA03: Ensure resources' stability and increase duration of research projects (Responsible: ANII and university actors).
356 FBA4-OP1-KA03: Increase the size of research projects (Responsible: SNI, ANII).
357 FBA4-OP1-KA03: Increase critical mass of people related to the sector to promote further development (Responsible: government and universities actors).
358 FBA4-OP1-KA03: Increase number of local stakeholders investing in firms in the sector (Responsible: government actors).
359 FBA4-OP2-KA01: Organise workshops, meetings and other networking initiatives to bring together producers and potential users of different residues and wastes, to establish new value chains (Responsible: research industry and government actors).
360 FBA4-OP2-KA01: Establish needed types of residues for each use (Responsible: industry networks and university actors).
361 FBA4-OP2-KA01: Estimate increased value added of using residues vis-a-vis other possible residues' uses (Responsible: Transforma Uruguay, OPP).
362 FBA4-OP2-KA02: Utilise the results of studies on potential markets and trends of the compounds or materials available from the national industrial and other residues and wastes (Responsible: research actors).
363 FBA4-OP2-KA02: Review which feedstock, and in which volume, could be of interest to petrochemical sector firms (Responsible: OPP, academia).
364 FBA4-OP2-KA02: Review competitive advantages of the country when compared with other biomass providers (Responsible: Uruguay XXI).
365 FBA4-OP2-KA03: Develop funding systems for the required national and regional networking to outline new value chains based on innovative use of the residues and wastes (Responsible: national and regional government).

366 FBA4-OP2-KA03: Identify potential case-specific R&D needs and national or international organisations capable for the required studies (Responsible: research and industry actors).

367 FBA4-OP2-KA04: Engage multiple stakeholders in studies to find uses for residues and connect biomass producers with investments (Responsible: LATU).

368 FBA4-OP3-KA02: Conduct analysis on market trends for the known or potential uses of different barks and their key constituents (Responsible: industry, OPP, Transforma Uruguay).

369 FBA4-OP3-KA02: Evaluate feasibility to obtain extractives from the bark; and continue towards production (Responsible: academia, INIA, industry, government/OPP).

370 FBA4-OP3-KA03: Design and set up a pilot or demo process unit for the recovery of valuable bark compounds, such as tannin or bioactive substances (Responsible: industry and research actors).

Actions for the People Dimension

371 FBA4-OP1-KA05: Increase number of trained people specifically in separation and conversion of ligning and hemicellulose (Responsible: university actors).

372 FBA4-OP1-KA05: Increase research on processes to improve lignin (Responsible: university actors).

373 FBA4-OP1-KA05: For hydrolysis of xylan to xylose, compare neutral hot water treatment (at up to 230-240 C) with normal acidic or enzymatic hydrolyse (Responsible: industry, research and university actors).

374 FBA4-OP1-KA06: Foster an innovation culture (Responsible: industry, research, government and civil society actors).

375 FBA4-OP1-KA06: Encourage all companies, especially SMEs, to play a more active role in the co-creation of a vibrant innovation ecosystem around lignin and hemicellulose-based products (Responsible: industry actors).

376 FBA4-OP2-KA05: Encourage universities to study utilisation of different residues and wastes and increase valorisation of universities' knowledge from the firms (Responsible: university and government actors).

377 FBA4-OP2-KA05: Promote the joint industry-university research and training programmes to increase the awareness of the potential value of different wastes and residues for marketable products and services (Responsible: government, industry and research actors).

378 FBA4-OP2-KA05: use local university and research organisations for the characterisation of different wastes, their processing studies and product tests (Responsible: industry and research actors).

379 FBA4-OP2-KA05: Set a research fund for usage of local biomass (Responsible: ANII).

380 FBA4-OP2-KA06: Encourage all companies, especially SMEs and start-ups to play a more active role in the co-creation of an active innovation ecosystem around the use of wastes and residues (Responsible: government and industry actors).

381 FBA4-OP2-KA06: Select successful new cases for promising "marketed" examples (from the region or other countries) on starting new waste-based business, to encourage other players for the same (Responsible: industry and government actors).

382 FBA4-OP3-KA05: Increase research on local bark (Responsible: research/INIA and university actors).

383 FBA4-OP3-KA05: Promote efforts for the value-added processing of barks without preceding fractionation, e.g. for bio-oils, biochar or pellets (Responsible: industry and government actors).

Actions for the Process Dimension

384 FBA4-OP1-KA07: Launch funding instruments similar to the bio-based industries joint undertaking (BBI-JU) in Europe supporting investments for process and product development (Responsible: Government actors).

385 FBA4-OP1-KA07: Attract firms that have experience in this area in other countries (Responsible: Uruguay XXI, MEF).

386 FBA4-OP1-KA07: Create tools to promote firms' usage of bio-based products (Responsible: ANII and industry actors).

387 FBA4-OP1-KA07: Create incentives to reutilisation of residues and side-streams considering carbon balance analysis (Responsible: government actors, e.g. tax authority).

388 FBA4-OP1-KA07: Consider other processes besides kraft for lignin extraction (Responsible: research and industry actors).

389 FBA4-OP1-KA08: Promote productive transformation of the Uruguayan construction, chemical and oil industries with a focus on increasing the use of bio-based raw materials and products (Responsible: Government, industries, tax authority).

390 FBA4-OP1-KA08: Support local and regional companies (especially SMEs) for initial tests on the new products to replace current ones in their processes/products such as lignin for plywood adhesives or dispersants (Responsible: Government and industry actors).

391 FBA4-OP1-KA08: Consider and modify, if needed, regulation on residues exchange with special economic zones, such as the ones in which pulpmills operate (Responsible: MIEM, parliament, Transforma Uruguay).

392 FBA4-OP2-KA07: Establish a funding instrument that supports the development of high-risk innovations in new areas of potential high-tech waste and residue use, such as advanced functional materials or isolation of specialty chemicals (Responsible: government actors).

393 FBA4-OP2-KA07: Accelerate investments at industrial level to use residues for further transformation (Responsible: industry actors).

394 FBA4-OP2-KA07: Implement a pellet plant investment (Responsible: industry actors).

395 FBA4-OP2-KA08: Implement national bioeconomy and circular economy strategies that favour the use of various current residues and wastes derived bio-based sources (Responsible: government actors).

396 FBA4-OP2-KA08: Include the theme of joint utilisation of different forest residues and wastes into the investment attraction portfolio of Uruguay XXI (Responsible: Uruguay XXI).

397 FBA4-OP2-KA08: Provide more information on market prices of side streams (Responsible: government/MIEM, industry networks, regional government).

398 FBA4-OP2-KA08: Design tax incentives to non-energy applications of the residues (Responsible: government/MEF, OPP).

399 FBA4-OP3-KA07: Promote the joint industry-university research and training programmes to ensure the availability of the latest bark-related knowledge to the relevant parties (Responsible: government, industry and research actors).

400 FBA4-OP3-KA07: Launch funding instruments that facilitate the integration of SMEs and other newcomers in the development of novel applications for different barks and their characteristic compounds with special properties (Responsible: industry and government actors).

401 FBA4-OP3-KA08: Promote the development of an increased valorisation of products replacing oil-based ones, because of their renewable characteristics (Responsible: industry/consumers, government, business associations).

402 FBA4-OP3-KA08: Promote productive transformation of different Uruguayan sectors with a focus on increasing use of novel bio-based sectors (Responsible: government and industry actors).

Actions for the Impact Dimension

403 FBA4-OP1-KA09: Develop and test selected products or applications via strong collaboration between all the partners in the value chain (Responsible: industry actors).

404 FBA4-OP1-KA09: Increase demand for lignin and hemicellulose products by promoting novel innovations-applications, such as the production of xylitol, for example. Increase local demand of lignin for wood-based boards (Responsible: industry/sawmills, MIEM).

405 FBA4-OP1-KA10: Estimate, and then map, the impact of new lignin and hemicellulose-based products in job creation and the number of new SMEs, start-ups in the value chain (Responsible: University actors).

406 FBA4-OP2-KA10: Measure 'ecosystemic' value of processing residues vis-a-vis disposal (Responsible: Government/MVOTMA).

[407] FBA4-OP2-KA10: Map the impact of new products on job creation and the number of new SMEs or start-ups (Responsible: research actors).

[408] FBA4-OP3-KA09: Harness universities and relevant engineering companies to up-scaling activities to increase production rates (Responsible: industry and research actors).

Actions by 2030

Actions for the Context Dimension

[409] FBA4-OP1-KA02: Establish key products and their requirements for purities and other properties (Responsible: industry actors).

[410] FBA4-OP1-KA04: Support integration between large pulp firms and SMEs (Responsible: industry, government/tax authority).

[411] FBA4-OP2-KA03: Establish a ‘Cono Sur’ funding scheme supporting Circular Economy projects aimed at producing biochemicals and biofuels from cross-border residues and wastes (Responsible: Mercosur countries, Inter-American Development Bank, government actors).

[412] FBA4-OP2-KA04: Integrate public and different stakeholders to active communication network for different stages of planning and implementation (Responsible: industry, research, NGOs and government actors).

[413] FBA4-OP3-KA04: Integrate different industrial sectors for the development of novel value chains for the most promising uses of known and identified new bark compounds (Responsible: industry actors).

Actions for the People Dimension

[414] FBA4-OP1-KA05: Assess and select suitable SMEs or large companies and research organisations for innovations for the conversion and modification (end-use) steps (Responsible: industry and research actors).

[415] FBA4-OP2-KA06: Incentivise design of residues’ collection adjacent to a medium/large plant (Responsible: regional government, MIEM).

[416] FBA4-OP2-KA06: Work with a “biomass residues” logic that does include all kinds of biomass residues not only forest-based ones (Responsible: industry actors).

[417] FBA4-OP3-KA05: Develop different incentives to encourage researchers to cover topics, which are less studied and less attractive (i.e. not very publishable currently) (Responsible: universities, ANII, research actors, e.g. INIA).

Actions for the Process Dimension

[418] FBA4-OP1-KA07: Finalise the optimal processing conditions for different planned product grades and varieties (Responsible: industry and research actors).

[419] FBA4-OP2-KA07: Design regulation on final disposition of residues that will catalyse new processes (Responsible: government actors, e.g. MVOTMA).

[420] FBA4-OP2-KA07: Finalise the optimal production conditions for different products and grades in various sectors, based e.g. on pilot and demo scale runs (Responsible: industry actors).

[421] FBA4-OP2-KA07: Develop chemical industry as a needed step for end-use of products from forest-based residues and wastes (Responsible: government and industry actors).

[422] FBA4-OP3-KA08: Support local and regional companies for initial tests on the new products to replace currently those currently used (e.g. tannins as adhesives water treatment chemicals) (Responsible: research and industry actors).

Actions for the Impact Dimension

[423] FBA4-OP1-KA10: Estimate, and then monitor and assess, the proportion of oil-based products being replaced by the introduction of lignin and hemicellulose-based products (Responsible: University actors).

[424] FBA4-OP2-KA09: Ensure conditions (e.g. funding) for constant chain of developing and further improving the novel products already brought to the markets (Responsible: government actors).

425 FBA4-OP2-KA09: Harness universities and relevant engineering companies to up-scaling activities to increase production rates (Responsible: industry, research/ Polo Pando & LATU).

426 FBA4-OP2-KA10: Monitor final total waste and residue disposal, reduction volumes & amounts of oil-based products replaced by the bio-based ones, in different sectors (Responsible: research and industry actors).

427 FBA4-OP2-KA10: Find a market niche for the end-products, since a dense industry is unfeasible (Responsible: industry actors and Uruguay XXI).

428 FBA4-OP3-KA10: Prompt a certification that guarantees that products are derived from biomass (Responsible: industry/business associations, government/MIEM, research/LATU).

429 FBA4-OP3-KA10: Monitor and assess the proportion of oil-based products being replaced by the increased use of tannin and other bark compounds, e.g. as adhesives (Responsible: research and industry actors).

430 FBA4-OP3-KA10: Survey the impact of new bark-based value chains on the number of SMEs and other newcomers, e.g. in the use of niche compounds (Responsible: research and government actors).

81 recommendations of FBA5 Action Roadmap

Actions by 2020

Actions for the Context Dimension

431 FBA5-OP1-KA01: Disseminate results of key bioenergy projects (projects to all relevant sectors (incl. forest industry) (Responsible: government and research actors).

432 FBA5-OP1-KA01: Assess the present availability side streams of wood processing industries and forest fuels from silvicultural operations and ensure all feedstock meets the forest certification requirements (Responsible: University actors).

433 FBA5-OP1-KA01: Review and evaluate the lessons learnt so far from the similar preceding for small-to-medium scale CHP projects (Responsible: University actors).

434 FBA5-OP1-KA02: Conduct thorough market analysis on local and regional heat and power markets (Responsible: university actors).

435 FBA5-OP1-KA02: Collect electricity market information from already identified places such as Tacuramebó, Rivera, north region (Responsible: UTE, MIEM-DNE, ADME).

436 FBA5-OP1-KA03: Revise the spatial availability of biomass (residues from forests and industrial side streams) (Responsible: University, DGF, MIEM-DNE, Sawmill Censuses, MIEM).

437 FBA5-OP1-KA04: Establish public-private partnerships to allow optimal use of resources. Industrial actors/assets linked to municipal operations (Responsible: Government and industry actors).

438 FBA5-OP2-KA01: Review and evaluate mechanical forest industries' side product availability and map suitable sites for white pellet/torrefied pellet manufacturing (Responsible: University actors).

439 FBA5-OP2-KA01: Review the global pellet export market (Responsible: University, Uruguay XXI, Pellet industry actors).

440 FBA5-OP2-KA04: Perform studies related to the health of the inhabitants in relation to the use of different stoves and energy (Responsible: research actors).

441 FBA5-OP3-KA01: Map potential residue and waste streams (pine) (Responsible: INIA, MIEM).

442 FBA5-OP3-KA04: Promote multi-stakeholder discussions on environmental benefits of producing biofuels (Responsible: industry, research, government, NGOs).

Actions for the People Dimension

443 FBA5-OP1-KA05: Promote and develop sufficient level of expertise to both design and run the CHP and related processes and seek spearhead companies for demonstrations (Responsible: Industry, SME, municipality).

[444] FBA5-OP1-KA06: Improve collaborative attitude among parties (Responsible: government, industry and research actors).

[445] FBA5-OP2-KA05: Develop sufficient level of technical expertise to both design and run the pelletization and torrefaction processes as well as integrated heat and power production (Responsible: Universities actors).

[446] FBA5-OP2-KA06: Integrate and motivate agro/forest business players to supply forest biomass and agro wastes for torrefaction/ pelletization through the emergence of new demand for forest industry side streams (Responsible: industry actors).

[447] FBA5-OP3-KA05: Ensure that the national waste legislation favours the use of wastes and residues for value-added applications (Responsible: government actors).

Actions for the Process Dimension

[448] FBA5-OP1-KA08: Support local and regional companies (especially SMEs) for pre-feasibility and feasibility studies on the new installation and new potential sites (Responsible: Government actors).

[449] FBA5-OP2-KA07: Develop regulation that promotes for solid biofuels (Responsible: government actors, UNIT, LATU certification).

[450] FBA5-OP2-KA07: Promote the use of district heating plants with pellets and wood residues as a source of energy (Responsible: government actors, municipalities).

[451] FBA5-OP3-KA07: Enhance process research in biorefining (Responsible: University and research actors).

[452] FBA5-OP3-KA08: Identify pioneers and forerunners from stakeholders promoting biofuels, e.g. URSEA, ANCAP (Responsible: industry, government actors).

Actions for the Impact Dimension

[453] FBA5-OP1-KA09: Increase awareness of the climate benefits of bioenergy and assure BAT technology (Responsible: Government and industry actors).

[454] FBA5-OP1-KA10: Promote sustainable forestry and sustainability within forest industry (Responsible: University actors).

[455] FBA5-OP2-KA09: Support new players' entry to export market (Responsible: Government actors).

[456] FBA5-OP3-KA09: Promote pilots to generate relevant new knowledge (Responsible: LATU, UTEC, UTU).

Actions by 2025

Actions for the Context Dimension

[457] FBA5-OP1-KA02: Establish a roadmap for identifying the most promising industrial sites and review policy frameworks that may affect the market in the near future (Responsible: industry actors).

[458] FBA5-OP1-KA03: Perform analyses on specific suitable mill sites and national/regional/site specific case analyses on biomass feedstock availability financed by the key beneficiary/regional development organizations (Responsible: University and industry actors).

[459] FBA5-OP1-KA04: Promote multi-stakeholder engagement in the systematization of information (Responsible: government actors).

[460] FBA5-OP2-KA02: Ensure sustainability of the forest industry, forestry and agriculture feedstock to safeguard sustainability and climate benefits of the production (Responsible: University actors).

[461] FBA5-OP2-KA02: Conduct thorough studies on the foreseen global market drivers, e.g. environmental impacts (future user profiles domestic/ industrial) (Responsible: University actors).

[462] FBA5-OP2-KA03: Study regional/national flows of virgin and residual biomasses suitable for pelletization/torrefaction (Responsible: University actors).

[463] FBA5-OP2-KA03: Benchmark the identified production sites to existing mills and study key financial indicators (Responsible: industry actors).

[464] FBA5-OP2-KA04: Integrate biomass producers (forest and landowners) to discussion and promote new emerging business opportunities (Responsible: University and government actors).
[465] FBA5-OP3-KA01: Seek combinations with other biomass sources (urban waste, rice husk) (Responsible: industry actors).
[466] FBA5-OP3-KA01: Develop regional circular economy in connection with biorefining (Responsible: Government actors).
[467] FBA5-OP3-KA03: Ensure existence of rails (Responsible: Government actors).

Actions for the <u>People</u> Dimension

[468] FBA5-OP1-KA05: Assess and select suitable SMEs or large companies and research organisations for case studies in their locations (Responsible: industry and research actors).
[469] FBA5-OP1-KA06: Integrate biomass suppliers into the heat and power value chain to supply high quality fuel material (Responsible: industry actors).
[470] FBA5-OP2-KA05: Investigate the viability of plants according to the scale (Responsible: industry and research actors).
[471] FBA5-OP2-KA06: Foster cultural change to residential consumption (Responsible: government, industry actors and academia).
[472] FBA5-OP2-KA06: Increase awareness of the highest calorific value of the pellet vs firewood (Responsible: industry actors and academia).
[473] FBA5-OP3-KA05: Promote the joint industry-university research and training programmes to increase the awareness of the potential value of different wastes and residues for marketable products and services (Responsible: government, industry and research actors).
[474] FBA5-OP3-KA06: Promote involvement of ANCAP (Responsible: government actors).
[475] FBA5-OP3-KA06: Encourage early entrepreneurship (Responsible: government and industry actors).

Actions for the <u>Process</u> Dimension

[476] FBA5-OP1-KA07: Encourage new companies to enter the market through promoting the existing business cases (Responsible: government actors).
[477] FBA5-OP1-KA08: Provide incentives for early adopters (Responsible: Government actors).
[478] FBA5-OP2-KA07: Seek suitable national and regional funding instruments such supporting investments for process and product development (Responsible: Government actors).
[479] FBA5-OP2-KA07: Develop quality standards and environmental certification, evaluation and control (Responsible: government and research actors).
[480] FBA5-OP2-KA08: Promote transformation of the Uruguayan biomass and wood industries with a focus on increasing the use of residual and side stream raw materials and products (Responsible: Government actors).
[481] FBA5-OP2-KA08: Seek support for local and regional companies (especially SMEs) for initial tests on the new processes to utilize local biomass feedstock (Responsible: industry actors).
[482] FBA5-OP2-KA08: Improve regulation of the use of residual pine (thrown wood, mountains of sawdust) (Responsible: government and industry actors).
[483] FBA5-OP3-KA07: Establish a funding instrument that also supports the development of high-risk innovations in new areas of potential high-tech waste and residue use, such as advanced functional materials or isolation of specialty chemicals (Responsible: government actors).
[484] FBA5-OP3-KA07: Develop control of biofuel quality (Responsible: industry actors).
[485] FBA5-OP3-KA07: Develop incentives for buying biofuels (tax differences) (Responsible: government actors).
[486] FBA5-OP3-KA07: Develop new regulations in standardization and quality certification (Responsible: MIEM-DNE, industry, e.g. ANCAP).

487 FBA5-OP3-KA08: Provide sufficient advice support for the potential start-ups at the early stages of business development, IPR issues, marketing and related non-technical matters (Responsible: government actors).

Actions for the Impact Dimension

488 FBA5-OP1-KA09: Seek industrial processes that can be integrated into a CHP in the wood biomass heat and power value chain (Responsible: industry actors).

489 FBA5-OP2-KA10: Map the impact of biomass CHP on job creation and the number of new SMEs, start-ups in the value chain (Responsible: University and government actors).

490 FBA5-OP2-KA10: Investigate the economic and environmental impact of not taking advantage of treating wood waste (Responsible: Research actors).

491 FBA5-OP2-KA09: Increase demand for thermally treated biomass products by investigating and promoting climate neutral applications and end uses (Responsible: Industry, government, academia).

492 FBA5-OP2-KA10: Highlight sustainable forestry and the climate benefits of the thermally treated wood products replacing fossil fuels (Responsible: Government actors).

493 FBA5-OP2-KA10: Investigate activated carbon and biochar (Responsible: university and research actors).

494 FBA5-OP3-KA10: Measure GHG reductions (Responsible: research actors).

495 FBA5-OP3-KA10: Measure or estimate sustainability gains by migrating from petrochemicals to biofuels (Responsible: research actors).

Actions by 2030

Actions for the Context Dimension

496 FBA5-OP1-KA04: Revitalise a national working group with the key stakeholders (raw material resources, R&D, energy market, industry and regional/community) to discuss system interfaces (Responsible: Government actors).

497 FBA5-OP2-KA04: Integrate public and different stakeholders to active communication network for different stages (Responsible: Industry, NGOs and research actors).

498 FBA5-OP2-KA04: Promote the renewable nature/climate benefits of biomass fuels (Responsible: Industry, NGOs and research actors).

499 FBA5-OP3-KA04: Evaluate scalability of local production (Responsible: industry and research actors).

Actions for the People Dimension

500 FBA5-OP1-KA06: Encourage all parties (investors, heat and power clients, regional developers) to play an active role in the innovation ecosystem around heat and power supply and related auxiliary processes (Responsible: Government actors).

501 FBA5-OP2-KA05: Assess and select suitable SMEs or large companies and research organisations for conversation and business development of innovations on pellet and torrefaction (Responsible: industry and research actors).

502 FBA5-OP2-KA06: Encourage the creation of an innovation ecosystem around heat and power, including thermal treatment of residual biomass and mechanical forest industry side streams (Responsible: industry actors).

503 FBA5-OP3-KA05: Implement systematic evaluation system on future emerging technologies, jobs and skills in the production of bio-oil, biofuels and renewable diesel (Responsible: industry and research actors).

Actions for the Process Dimension

504 FBA5-OP1-KA07: Finalise the optimal process conditions and business opportunities (Responsible: industry and research actors).

505 FBA5-OP2-KA07: Finalise the optimal processing conditions for different planned product torrefaction grades and pellet product varieties (Responsible: industry and research actors).

[506] FBA5-OP2-KA07: Reward municipalities outside the capital region that use district heating plants, where pellets and wood residues are the primary or secondary source of energy (Responsible: government actors, municipalities).

[507] FBA5-OP3-KA07: Finalise the optimal production conditions for different products and grades in various sectors, based e.g. on pilot and demo scale runs (Responsible: industry actors).

[508] FBA5-OP3-KA08: Promote productive transformation of different Uruguayan sectors with a focus on increasing the use of novel waste- and bio-based products (Responsible: industry and government actors).

Actions for the Impact Dimension

[509] FBA5-OP1-KA09: Increase awareness on the novel thermal energy utilising concepts that can be integrated into CHP (Responsible: Government and industry actors).

[510] FBA5-OP2-KA10: Map the impact of thermally treated biomass products in job creation and the number of new SMEs, start-ups in the value chain (Responsible: University actors).

[511] FBA5-OP3-KA10: Reduce expenses to buy hydrocarbons (Responsible: government actors).

How to cite this report?

Popper, R., Rilla, N., Niemelä, K., Oksanen, J. Deschryvere, M., Virkkunen, M. & Loikkanen, T. (2020). The Future of Forest-based Bioeconomy Areas: Strategic openings in Uruguay and the World by 2050. VTT Technical Research Centre of Finland. VTT Technology, No. 379 https://doi.org/10.32040/2242-122X.2020.T379

VTT

Series title and number

VTT Technology 379

Title	**The Future of Forest-based Bioeconomy Areas** Strategic openings in Uruguay and the World by 2050
Author(s)	Rafael Popper, Nina Rilla, Klaus Niemelä, Juha Oksanen, Matthias Deschryvere, Matti Virkkunen, Torsti Loikkanen
Abstract	This VTT Technology report on '*The Future of Forest-based Bioeconomy Areas: Strategic openings in Uruguay and the World by 2050*' is the result of a multi-stakeholder and multi-disciplinary foresight exercise commissioned by the Government of Uruguay in 2018 and completed in 2019. The overall goal of the project was to contribute to Uruguay's National Development Strategy 2050 through the following specific objectives: (1) To identify key global forest-based bioeconomy areas by 2050; (2) To identify needs and gaps in the prioritised FBA in Uruguay; (3) To develop a shared vision for the forest-based bioeconomy in Uruguay by 2050; and (4) To develop a strategic Action Roadmap to achieve the shared vision for the forest-based bioeconomy in Uruguay by 2050. The most important outcomes of the project include: a shared vision for key foresight-based bioeconomy areas (FBAs), as well as five consolidated Action Roadmaps with 511 concrete short-medium-to-long-term actions related to Forest management (FBA1), Mechanical wood processing (FBA2), Fibre-based biomaterial processing (FBA3), Biorefining (FBA4), and Bioenergy (FBA5). In addition, the report provides more detailed recommendations addressing a wide range of research, education, innovation and institutional needs related to the Top 3 Opportunity Pathways (OPs) of the five FBAs. The methodology of the project involved systematic critical issues analysis (drivers, barriers, threats and opportunities), a multi-stakeholder Delphi-like survey, global value network and business news analysis, visioning workshops and action roadmapping. This report is valuable for government, business, research and civil society actors interested in the state-of-the-art and the future of key forest-based bioeconomy areas in the world. Foresight researchers and practitioners will also find interesting methodological approaches, such as the consolidated action roadmaps. Finally, taking worldview perspective, while the project provided an opportunity for foresight knowledge transfer from Europe to Latin America, both the findings and methodology are equally relevant for other world regions and countries concerned with the future of the forest-based bioeconomy.
ISBN, ISSN, URN	ISBN 978-951-38-8739-1 (Soft back ed.) ISBN 978-951-38-8737-7 ISSN-L 2242-1211 ISSN 2242-1211 (Print) ISSN 2242-122X (Online) DOI: 10.32040/2242-122X.2020.T379
Date	August 2020
Language	English
Pages	268 p.
Name of the project	
Commissioned by	
Keywords	
Publisher	VTT Technical Research Centre of Finland Ltd P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111, https://www.vttresearch.com

The Future of Forest-based Bioeconomy Areas
Strategic openings in Uruguay and the World by 2050

This Technology Report is the result of a foresight study applying an action roadmapping approach to key forest-based bioeconomy areas (FBAs). The following outcomes offer a big picture overview of the nature, volume and strategic importance of the report:

- systematic analysis of five FBAs: Forest management, Mechanical wood processing, Fibre-based biomaterials processing, Biorefining, and Bioenergy;
- mapping of global FBA actors, industries and top ten future industry foci for Uruguay, as well as eight other benchmark countries: Finland, Sweden, Canada, Australia, New Zealand, South Africa, Chile and Brazil;
- identification of 300+ critical issues (barriers, drivers, opportunities and threats), followed by their assessment and prioritisation, which led to the identification of top 15 critical/policy issues and top 15 opportunity areas;
- better understanding of the state-of-the-art of the global and Finnish forest-based bioeconomy as well as the strategic goals of 200+ global value network (GVN) actors, which helped to define some 100+ research, education, innovation and regulation needs and aspirations of key FBA players;
- shared vision for key FBAs, together with 15 opportunity pathways (OP) or strategic openings for Uruguay and the World; supported by a robust advice framing process consisting of five action roadmaps by FBA with some 511 recommendations structured around their main implementation dimensions and timeframes.

ISBN 978-951-38-8739-1 (Soft back ed.)
ISBN 978-951-38-8737-7
ISSN-L 2242-1211
ISSN 2242-1211 (Print)
ISSN 2242-122X (Online)
DOI: 10.32040/2242-122X.2020.T379

VTT beyond the obvious