ALBERTA INNOVATES

ALBERTA BIO FUTURE PROGRAM

ANNUAL REPORT 2018-19

June 2019

PREPARED BY

ALBERTA INNOVATES – BIO SECTOR

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June 2019

This document is available online at albertainnovates.ca by searching for “Alberta Bio Future Program Annual Report 2018-19”

ALBERTA INNOVATES

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1. Executive Summary

This document, "Alberta Bio Future Annual Report 2018-19," summarizes progress of the fifth year of the Alberta Innovates' Alberta Bio Future (ABF) program.

The program is co-funded between Alberta Economic Development Trade and Tourism (EDTT) and Alberta Innovates (AI). Since its launch in 2014-15, EDTT has contributed $12.5 million in cash and AI has contributed more than $21.2 million in cash and in-kind to the program, for a total of $33.7 in funding from ABF.

The Alberta Bio Future program is the province's flagship initiative to advance the bioeconomy. It aims to identify new practical opportunities for adding value to our agricultural and forest biomass through funding, connections and a strong industry focus. Its focus is new products and technologies in advanced biomaterials, biochemicals and bioenergy that will be competitive, sustainable and profitable.

Delivery of the Alberta Bio Future program is accomplished through a series of subprograms, administered by the Bioindustrial Innovation Team in the Bio Sector of Alberta Innovates. The ABF team makes strategic bioindustrial investments in areas of focus that offer immense value-add opportunities for Alberta's agricultural and forest industries, including in areas relating to cellulose nanocrystals (CNC), lignin and green building products.

In 2018-19, the team ended the Equipment Utilization subprogram, and ended the Invited Proposal subprogram and replaced it with the Opportunities subprogram. The team initiated the Biomaterials Pursuit and the CNC Challenge 3.0 subprograms. Industry partner, Alberta Pacific Forest Industries, collaborated with researchers to develop biomaterials from CNC. The team launched the Lignin Challenge 1.0 subprogram in collaboration with West Fraser Mills for applied research into lignin production and product applications. The Lignin Pursuit subprogram was launched for further development of these materials into high-value bioproducts. A total of 88 ABF projects were active in 2018-19 across all subprograms.

As of March 31, 2019, after five years of program delivery, $33.7 million in ABF funding has resulted in 135 projects worth over $104 million in total project costs. This is a leveraging ratio of $1 from ABF to $2 from other sources.

The ABF program, which launched in 2014-15, concludes on December 31, 2020. The ABF team is hopeful the program will receive renewed funding from the Alberta government. In summer 2019, the ABF team is starting a strategic analysis initiative, including a market assessment. The team wants to take stock of what has been achieved in ABF and the opportunities ahead to create a roadmap for future bioindustrial investments.

2. Introduction

This document, "Alberta Bio Future Annual Report 2018-19," summarizes progress of the fifth year of the Alberta Innovates' Alberta Bio Future program. It explains the context for this program and how the focus areas were chosen. This document further describes program delivery and presents stories about selected grant recipients and their projects. The section on grant subprograms provides detailed lists of projects active in 2018-19 within each subprogram. The program team's knowledge extension activities are summarized. The appendices include a summary of performance measures, a detailed project list, a communications report and financial statements.

3. Strategic Overview

Alberta Innovates is Canada's largest provincial research and innovation corporation. It serves as Alberta's innovation hub, providing strategic and financial support to bridge the work of researchers and the needs of industries. Its mandate is to accelerate research, innovation and entrepreneurship in key market sectors to diversify Alberta's economy, improve its environmental performance and enhance the well-being of Albertans.

The Bio Sector is one of the key sectors within Alberta Innovates. It develops and manages funding programs and leads strategy and integration focused on the agriculture, food, forest and bioindustrial sectors as well as in the areas of ecosystem services and prions. The Bioindustrial Innovation Team in the Bio Sector aims to advance the bioindustrial economy in Alberta by investing in research and development in areas such as technology and product development from biomass as well as feedstock improvement and purpose-grown crops.

The Alberta Innovates' Alberta Bio Future program funds research to develop value-add products from agricultural and forest biomass such as ethanol and biodiesel from canola (shown in photo), jet fuel from waste restaurant grease and renewable natural gas from the forest industry's wood residue. In addition to bioenergy, the program also funds research for advanced biomaterials and biochemicals.
Source: 123RF

The Team leads the Alberta Bio Future program, which is the province's flagship initiative to advance the bioeconomy. It aims to identify new practical opportunities for adding value to our agricultural and forest biomass through funding, connections and a strong industry focus. Its focus is new products and technologies in advanced biomaterials, biochemicals and bioenergy that will be competitive, sustainable and profitable.

The program is co-funded between Alberta Economic Development Trade and Tourism (EDTT) and Alberta Innovates (AI). Since its launch in 2014-15, EDTT has contributed $12.5 million in cash and AI has contributed more than $21.2 million in cash and in-kind to the program, for a total of $33.7 in funding from ABF.

3.1. Focus Areas

The ABF Team makes strategic bioindustrial investments in areas of focus that offer immense value-add opportunities for Alberta's agricultural and forest industries. Many reports have recommended that Alberta pursue opportunities as high up the value chain as possible and to move away from selling the province's renewable resources as commodities i.e. high volume for low value.

A few of these high-value areas of focus for ABF investments include the development of products and technologies related to cellulose nanocrystals (CNC), lignin and green building products. These choices stemmed from many studies, intelligence gathering and foresighting, and an appreciation of challenges that agriculture and forestry have and are continuing to face. It is exciting to note that a recent publication by Lux Research Inc., a global think tank that helps companies identify tech innovation opportunities that drive growth, highlighted priorities aligned with the program. Included in Lux's top 19 technologies for 2019 are areas that ABF is already supporting: wearable electronics for health, 3D printing of materials and graphene.

3.2. Focus Areas – Setting the Context

Alberta's renewable resource industries have experienced many challenges over the past few decades. Pressure on Canada's forest industry started in the 1970s when intense environmental concerns caused forest companies to become more sustainable in their forest management practices.

Diversification efforts to expand Alberta's agriculture and forestry industries stalled during the energy boom from 2004 to 2015. The surging economic activity in the energy sector caused labour shortages in all sectors and siphoned research investments and risk capital away from Alberta.

Alberta's agriculture sector in 2006 was at a crossroad. Farm debt was rising despite much emphasis on productivity and agricultural subsidies for commodities. The federal government changed its R&D strategy in agriculture to focus on increasing the value of food and fibre products.

In 2007, the Alberta government started charging a carbon levy on large industrial emitters of greenhouse gases to encourage them to develop cleaner technologies or purchase offsets from other industries that were already implementing green processes, including forestry and agriculture.

An Alberta government report released in 2007, "Getting Value from Every Fibre: Making the Most of Alberta's Lignocellulose Resource," proposed the development of a bioindustrial network and infrastructure. It recommended that new biorefining technologies were needed to process biomass into products, including nanomaterials and lignin-based products to strengthen the pulp and paper, and wood products sectors.

The U.S. housing market collapse in 2008-09 caused a catastrophe in Canada's forest industry. A retrospective of this era was summarized in a 2014 Globe and Mail article "Paper Trail: The Decline of Canada's Forestry

Industry." The article estimates that more than 118,000 skilled Canadian forestry workers lost their jobs between 2004 and 2014. This was not only due to the housing crash but also from the rising popularity of the Internet as a source of news, shrinking the need to produce newsprint and other paper products.

Ceapro's 30,000 square foot commercial manufacturing plant in Edmonton, AB opened in 2016. It produces several bioactive ingredients from Alberta oats. These ingredients with therapeutic effects are used in well-known personal care products like Aveeno® and Burt's Bees®.
Source: Ceapro Inc

After the housing market collapse, the federal ministry, Natural Resources Canada (NRCan), launched the $1 billion Green Transformation Program in 2009. The funding was aimed at helping pulp and paper mills reduce costs by making production upgrades to reduce dependence on high-cost conventional energy sources. Also in 2009, Natural Resources Canada became involved in the Bio-Pathways project in collaboration with the Forest Products Association of Canada and FPInnovations. They hired a consultant to work with the forest industry and identify prospective future bio-pathways. The question was "How do you get away from stand-alone sawmills and pulp mills to diversify them and add product lines through bolt-on new technologies to existing plants?" Lignin extraction and cellulose nanocrystals were two areas of opportunity identified in the Bio-Pathways and pursued by Alberta. Alberta Innovates, companies and researchers have continued with research and development in these areas.

Natural Resources Canada also sought to garner community support to diversify industry away from commodities. A funding package became available in 2008 called the Community Development Trust (CDT) program. It had a focus to invest in diversification opportunities in agricultural and forest communities across the country, and Alberta's share was $104 million. Within a month and a half, proposals went from concept to real projects because members of the ABF Team, then called the Alberta Forestry Research Institute, already had a good working relationship with industry and a good understanding of the main issues they faced. They were successful in securing $10 million for forestry research projects. One of the projects funded in 2009 was the hemp fibre mat plant in Drayton Valley's Bio-Mile area. This CDT program supported some of the Alberta government's first work on commercialization. Subsequent to CDT, funding for pre-commercialization projects became available in 2012 under the Alberta Innovates' Advanced Material and Chemicals program (AMCP), a precursor to the ABF program, with an envelope of $5 million from the Alberta government. This allowed Alberta Innovates, then called Alberta Innovates Bio Solutions, to support innovative initiatives in the

bioindustrial sector through companies like Ceapro and Radient Technologies. These companies were involved in extraction of bioactive compounds from agricultural biomass like oats, flax and hemp. Their growth has been impressive, and they are now selling their products internationally. The CDT and AMCP program helped to shape ABF's current focus on industry involvement.

In 2011, the Alberta government and industry co-developed the report, "Alberta Forest Products Roadmap," which outlined a future for the Alberta forest industry. It stated that forest fibres grown in Alberta were well-suited to the manufacture of new products such as printable papers for electronic circuits, biocomposite products using cellulose nanocrystals, biochemicals, bioplastics and biofuels. It recommended utilizing pulping waste streams for new product opportunities.

In 2010, the federal government enacted a target for the amount of ethanol required to be present in gasoline. In 2015, the oil price crash generated renewed interest in economic diversification away from energy and gaining a social licence for Alberta to operate in the energy sector by greening its technologies. In 2016, Canada's natural gas utilities set a target for the amount of renewable natural gas to be delivered to customers. Taken as a whole, all of these "greening" initiatives have stimulated a lot of clean technology development in Alberta's energy industry. Bioindustrial and bio-based technologies from Alberta biomass have become part of the overarching clean technology solution to climate change.

> *Alberta is not just about oil and gas. We also have huge forest renewable resources as a source of the lignin in new technology – carbon quantum dots – that can help with soil remediation in our oil and gas sector.*
>
> **Dr. Weizheng Shen, Research Associate, Applied Bio/Nano Industrial Research Chair program, NAIT**
>
> ***Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"***

3.3. **Focus Area – Cellulose Nanocrystals**

The new super-strength CNC biomaterial is putting Alberta on the map. The province is one of a few places in the world that can produce CNC. It has access to 10 per cent of Canada's forests–the base material from which CNC is produced. Earlier research investigated whether CNC could be produced from agricultural biomass such as sugar beets or hemp, but forest biomass was found to be the most economical feedstock.

CNC has become known for its many unique properties including high tensile strength, emulsifier stabilization, optical properties, biodegradability and more. CNC in Alberta is becoming the centre of a new emerging industry cluster spinning out research, startup companies and new products. It is also a draw for talent.

> *Alberta is one of only a few places in the world that produces cellulose nanocrystals (CNC). I was dying to get my hands on some when I arrived at the University of Alberta in 2012. I wanted to show the advantages of using CNC in 3D-printed industrial and medical products.*
>
> **Dr. Cagri Ayranci, Associate Professor, Faculty of Engineering, Department of Mechanical Engineering, University of Alberta**
>
> ***Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"***

The business case for CNC in Alberta started in 2009 when the National Institute of Nanotechnology and the Alberta government created a roadmap to develop cellulose nanocrystals, then called nanocrystalline cellulose. The report identified business opportunities in five sectors: packaging, aerospace, automotive, coatings and consumer goods such as electronics and appliances.

The Alberta Forestry Research Institute (AFRI) started funding research on CNC at InnoTech Alberta (formerly Alberta Innovates – Technology Futures and Alberta Research Council). AFRI staff members had excellent connections with the United States Forest Products Lab, who were also interested in CNC. In 2010 and with interest building in CNC, AFRI worked to establish a Chair program at the University of Alberta in nanotechnology specific to forestry. At this same time, Natural Resources Canada through FPInnovations became interested in building CNC pilot plants in Canada. AFRI engaged in discussions with NRCan and came to agreement that eastern Canada would specialize in softwood as a source of CNC and western Canada in hardwoods. This meant Alberta would need to get one of the hardwood pulp producers on side; Alberta Pacific Industries Inc. (Al-Pac) was the most interested. As fate would have it, the notion of a pilot plant in both eastern and western Canada went by the wayside. NRCan decided to fund just one pilot plant in Quebec, and this looked like the end of CNC in Alberta.

There was still a strong drive in having a pilot plant built in Western Canada. Through the efforts of the Alberta government, funding from Western Economic Diversification Canada was secured to build a pilot CNC plant in 2013 at InnoTech Alberta. To this day, the pilot plant continues to be the foundation for much of the research on CNC, but the pilot plant wasn't the end of CNC development.

Industry partner, Al-Pac, currently has plans to build a commercial CNC production plant in the next year or two. As Al-Pac moves forward with commercialization and market development, primarily in Asia Pacific, the ABF Team will focus more on end-use applications research. The CNC research will usually be in concert with an industry partner and CNC samples from InnoTech Alberta. These samples are now in high demand from researchers around the world in ever-increasing quantities.

Over the years, the ABF Team's efforts have focussed on developing a myriad of applications for CNC and refinement of the production process, including moving from batch to continuous production at the pilot plant. Some of the medical applications developed in Alberta include using CNC to generate saliva for patients with mouth cancer, bone reconstruction scaffolding, antimicrobial paint additive for hospitals that activates by turning on the room lights, and heart stents that are inserted closed and then open with body heat. In other industries, some applications for CNC developed in Alberta include drilling mud, airplane de-icing additive to make the solution thicker and adhere to the wings longer, window coating to convert sunlight into electricity that is stored on the window like a battery. Project costs for CNC research supported by ABF funding has totalled more than $7.7 million since 2014-2015 in 59 projects.

The University of Alberta's cellulose nanofibril pilot plant is situated at InnoTech Alberta. Cellulose nanofibrils are a cousin to cellulose nanocrystals with longer fibres and significantly different properties, leading to exciting new end-use applications yet to be discovered.
Source: Marie Cusack

Many proposed applications have come forward that were astoundingly creative. Unfortunately, funding was not sufficient for all of them. The ABF Team was, nonetheless, able to leverage its excellent relationships with strategic partners including Al-Pac, Natural Resources Canada, National Research Council and FPInnovations to have them fund a large number of initiatives.

To get to this point in CNCs development, supporters around the world have had to do a lot of groundwork in standards, characterization of its properties and development of a common language. Work continues at private sector labs, U.S. Forest Products Lab and Al-Pac for the important U.S. certification "Generally Recognized as Safe."

Alberta has become a world leader in the new industry cluster of CNC research and end-use products. This is evidenced by the international conference TAPPI hosted in Edmonton, AB in 2009-its first time in Canada. TAPPI is the highly respected global non-governmental organization that advances the technical aspects, including standards, of pulp and paper production. Strategic investments and patience in CNC by the Alberta government and Alberta Innovates are starting to pay off.

Going forward, Alberta has opportunity to expand in a new and related direction, cellulose nanofibrils (CNF)–a cousin to cellulose nanocrystals. InnoTech Alberta is the host site to one of Canada's few CNF pilot plants, with equipment from the University of Alberta. CNF is produced by mechanical grinding, resulting in longer fibres than CNC crystals. CNF, therefore, has significantly different properties and researchers are exploring the exciting possibilities it offers.

3.4. **Focus Area – Lignin**

Lignin extraction was identified as another area of opportunity for Alberta. Lignin is the glue that holds a tree together. Currently, black liquor, comprising mainly of lignin, is burned as a source of energy for the pulp mill. Experts believe that lignin has a potential value that is 10 to 20 times greater as a biomaterial than as a fuel, especially in the areas of engineering plastics, polymer foams and carbon fibres.

In 2009, the national forest industry association, Forest Products Association of Canada (FPAC), started the Bio-Pathways project to examine pulp mill waste streams as sources for new high-value biochemicals and biomaterials. FPInnovations investigated how to extract lignin from the waste stream and successfully devised an extraction process–LignoForce System™.

Up to 30 tonnes per day of high-quality and pure lignin powder (shown in photo) can be consistently produced by West Fraser's commercial lignin recovery plant in Hinton, AB, which opened in 2016.
Source: Hinton Pulp, a division of West Fraser

West Fraser, Western Canada's largest forest products company, then solidified plans to build a lignin recovery plant in Hinton, AB with licensed use of the new extraction process. Alberta Innovates' Advanced Materials and Chemicals program (AMCP) was able to provide funding support to West Fraser to build the plant and, in return, West Fraser agreed to collaborate with the ABF Team to financially support research focused on value-add applications for lignin.

West Fraser envisioned a future where half of the lignin produced in the Hinton plant could be consumed in-house as a plywood resin. They continue to do business development internally and work with the ABF Team to advance product development research for lignin.

Now that the plant is in full operation, the ABF Team and West Fraser are currently very much engaged in supporting research in applications for lignin using samples from the West Fraser plant. In 2018-19, the ABF Lignin Challenge 1.0 subprogram launched with funding for 16 projects with total project costs of more than $860,000. The projects are focused on research to explore concepts for new applications of lignin. The ABF Lignin Pursuit 1.0 subprogram also launched with funding for longer-term research in four promising projects with total project costs of $1.4 million.

Researchers are using the complex chemistry of lignin, which is rich in carbon, and applying principles of engineering and nanotechnology to devise exciting new applications for lignin. Some of the ideas being researched in Alberta include using lignin for medical bioimaging to better diagnose diseases, soil remediation, sensors, electrodes, biodiesel, biojet fuel, lubricants, dispersants, batteries, panel-board and plywood adhesive resin, protective foams and coatings in products like truck beds and boats, removing toxic contaminants in wastewater, bioplastics packaging, 3D printing, flexible electronics, solar cells, sponges and other insulation materials, and removing methane greenhouse gases from tailings ponds.

ABF researchers are exploring ways to use lignin to reduce methane emissions, a greenhouse gas, from oilsands tailings ponds.
Source: Alberta Innovates

West Fraser is ready to produce commercial-level quantities of lignin at its lignin recovery plant in Hinton, AB. With support from ABF and West Fraser, multinational specialty chemicals company, Hexion Canada, could have a commercial production plant launch by the end of 2019 to produce lignin-based resin for plywood and engineered wood products manufacturers like West Fraser.

Much is already known about lignin, with research ongoing since the 1950s. However, researchers around the world and on ABF projects continue to work on developing new applications, characterizing the properties of lignin, defining extraction technologies and identifying market potential.

Similar to its reputation for CNC, Alberta is becoming the world's go-to hub for lignin research. This is evidenced by Edmonton, Alberta serving as host for the first ever Pulp and Paper Technical Association of Canada's International Lignin Conference in fall 2018. Researchers and technology developers gathered to share knowledge on lignin chemistry, its application in products and progress in market access. Following on from this success, the ABF Team hosted a workshop on lignin in February 2019 "Pursuing Added Value for Alberta Biomass" that exceeded expectations for attendance.

The time is right to make use of lignin in new green biomaterials that can diversify Alberta's economy, improve its environmental performance and provide higher value use to a previously under-utilized product.

3.5. Focus Area - Green Building Products

In the 1980s there was a push by the Alberta government to diversify the forest sector and use more of the tree species native to Alberta like aspen poplar, considered a weed at that time. InnoTech Alberta, then called the Alberta Research Council, was the go-to applied research centre in Alberta for developing and refining the manufacture of oriented strand board (OSB) panels. And it still is today.

OSB plants using strands of aspen sprang up all over Alberta. The engineered wood product produced by the plants, OSB panels, became a popular low-cost substitute for plywood panels. Old growth trees, usually from B.C., were no longer as readily available to make plywood and new growth trees had different properties not suitable for plywood.

Many OSB plants in Alberta closed as a result of the 2008-09 housing slump in the U.S. OSB markets are again on the upswing today as a result of slowly improving conditions in the new house market. OSB panels are now finding new application in more than just conventional flooring, roofing

ABF researchers are finding new ways to use oriented strand board panels such as in structural insulated panels (SIP). SIP panels use OSB to encase rigid foam from canola that is strengthened with cellulose nanocrystals to create a wall system that does not need studs.
Source: Alberta Innovates

and walls, but also furniture and structural insulated panels that eliminate the need for studs in framing. Construction companies are favouring these engineered wood products because they are exempt from the softwood tariffs on dimensional lumber.

The 2011 Alberta Forest Products Roadmap recommended reducing engineered wood products' reliance on U.S. markets, particularly in the U.S. South, and growing the range of Alberta-made engineered wood products.

Today, the mature industry cluster of engineered wood products is advocating the use of more and more new products in addition to OSB panels and plywood. Some wood products manufacturing companies like Landmark Homes no longer use dimensional lumber; they prefer to use engineered wood products because of its superior finishing qualities. Engineered wood products are precise, true and straight, with no waning.

With the current global push to reduce greenhouse gas emissions, the construction industry is looking to meet strict environmental regulations with building materials that have a lower carbon footprint than concrete and steel. Building materials from wood amply meet this need as it is a carbon-neutral biomaterial that can sequester carbon for more than 50 years. Architects and engineers are specifying the use of more and more wood. There is resurgence in post-and-beam construction and a growing preference for pre-fabricated building modules such as for house rafters, windows and doors. Many new engineered wood products are becoming available like structural composite lumber, laminated veneer lumber, cross-laminated timber, massive timber plates and composite laminated panels. Although Alberta currently only allows structures of up to six storeys, Canadian building codes come into effect in 2020 which will allow for the construction of wood structures up to 12-storeys tall. New low-cost modular construction manufacturing processes are speeding up production, delivery and installation times, and facilitating building construction in remote communities.

Much of these new innovations in building materials and construction practices are due to decades of extensive research supported by funders and industry partners across Canada. Nationally, FPInnovations has expertise in tall wood buildings, Natural Science and Engineering Research Council (NSERC) NEWBuildS Network specializes in engineered wood products and systems, and the Canada Wood Council advocates for the use of more wood.

The ABF Team is investing in projects that amplify national research efforts. It is funding green building products that test new configurations of engineered wood products and new building systems. It is also supporting development of standards based on the strength, fire retardancy and other technical properties of new products. It invests in the research of the University of Alberta's Modular and Off-Site Construction Network, NSERC Industry Research Chair in Engineered Wood & Building Systems and NSERC Strategic Network on Innovative Wood Products and Building Systems.

Project costs for green building products research supported by ABF funding has totalled more than $1 million since 2014-2015 in seven projects.

3.6. **Focus Areas - Leading-Edge Facilities**

As a result of many years of strategic bioindustrial investments, Alberta enjoys the benefit of having leading-edge facilities to develop a wide range of renewable and sustainable products. Some of these facilities are listed in the table below.

Focus Area	Facility Name
CNC	• InnoTech Alberta pilot plant in Edmonton, AB • Al-Pac commercial plant (tentatively opening in 2021)
CNF	• University of Alberta CNF pilot plant situated at InnoTech Alberta in Edmonton, AB
Lignin	• West Fraser commercial lignin recovery plant in Hinton, AB • Hexion Canada commercial production plant for lignin-based resins (tentatively opening by end of 2019) • Hexion Canada commercial R&D laboratory in Edmonton, AB
Green Building Products	• InnoTech Alberta forest products laboratory in Edmonton, AB • University of Alberta laboratory for NSERCs Industry Research Chair in Engineered Wood & Building Systems in Edmonton, AB
Other	• Bio-Resource Information Management System online (www.BRIMS.ca) • Natural Fibre Technologies' commercial hemp decortication plant in Nisku, AB • InnoTech Alberta pilot hemp decortication plant in Vegreville, AB, constructed in collaboration with Alberta Agriculture and Forestry • BioComposites Group's commercial hemp product manufacturing plant in Drayton Valley, AB

3.7. **Next Steps**

The ABF program has been very successful in advancing bioindustrial innovation in Alberta by delivering on the key areas of knowledge and linkages, technology development, innovation and financial leveraging.

As of March 31, 2019, after five years of program delivery, $33.7 million in ABF funding has resulted in 135 projects worth over $104 million. This is a leveraging ratio of $1 from ABF to $2 from other sources. See infographic “Alberta Bio Future Overview” for further summary details.

Results from these projects demonstrate that the ABF Team’s strategic bioindustrial investments are adding value to Alberta’s biomass, creating jobs and increasing company revenues through the creation of new products and technologies across many sectors.

The ABF program, which launched in 2014-15, concludes on December 31, 2020. The ABF Team is hopeful the program will receive renewed funding from the Alberta government. Over the course of this seven-year program much has changed, grown and advanced in the bioindustrial, agricultural and forestry sectors, and in the innovation ecosystem.

In summer 2019, the ABF Team is starting a strategic analysis initiative, including a market assessment. The Team wants to take stock of what has been achieved in ABF and the opportunities ahead to create a roadmap for future bioindustrial investments.

The Nisku, AB commercial hemp decortication plant, which opened in May 2019, will become the anchor to a new industry cluster in industrial hemp. The maturing hemp industry will drive increased pre-processing capacity, launch of new small companies, sale of new hemp products and more farmgate revenue for local farmers.

Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"

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Alberta Bio Future Overview

April 1, 2015 to March 31, 2019

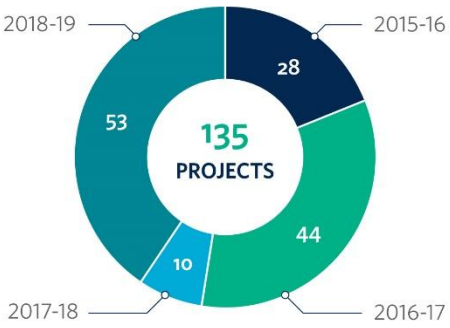
ABF FUNDING
$33.7 MILLION

TOTAL PROJECT COST
$104 MILLION

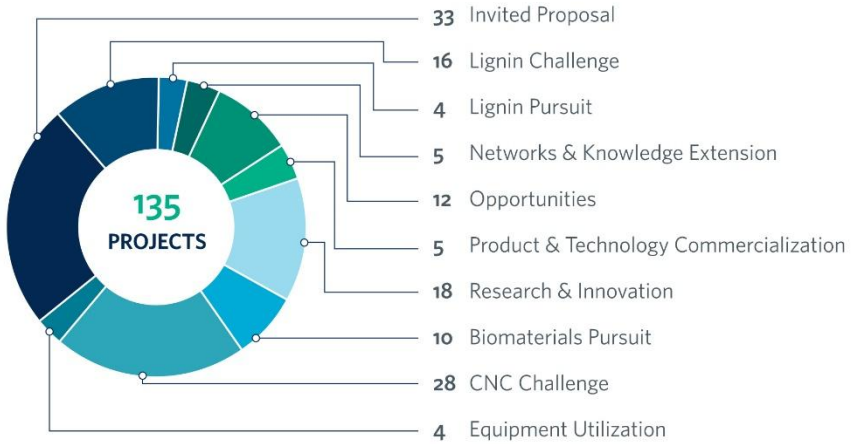
SUPPORTING
135 PROJECTS

PROJECT LEVERAGING
$1 ABF : $2 OTHERS

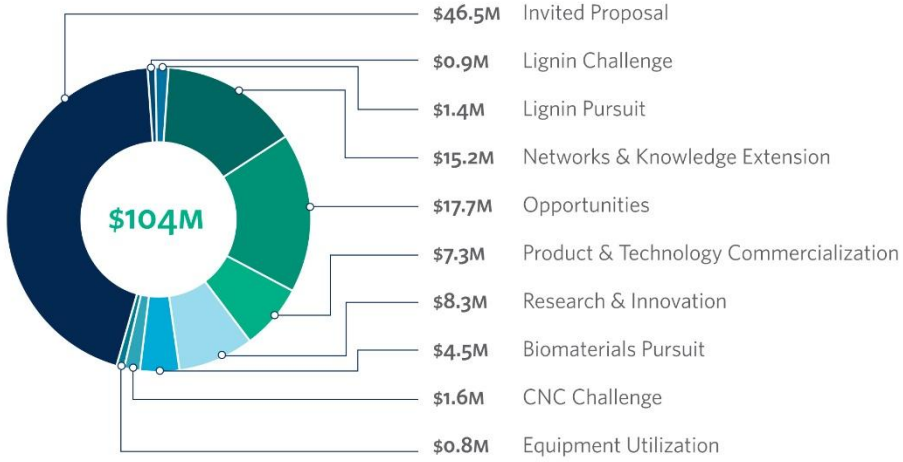
PROJECTS
(by year the project started)



PROJECTS
(by subprogram)



TOTAL PROJECT COST BY SUBPROGRAM
(for all projects from all sources in cash or in kind)



4. Program Delivery

4.1. **Alberta Bio Future Team**

Delivery of the Alberta Bio Future program is accomplished through a series of subprograms, administered by the Bioindustrial Innovation Team of the Bio Sector in Alberta Innovates.

The Alberta Innovates' Alberta Bio Future program team is a group of seven professionals with broad experience in the agriculture and forestry industries. They are knowledgeable about the research to commercialization innovation continuum leading to new bioindustrial products and technologies using biomass, advanced technologies and the integration of technologies. The Team works to facilitate and support the development of value-add products and technologies to grow the bioindustrial sector and help companies and entrepreneurs become successful.

The Team strives to stay abreast of real-world issues and opportunities in the bioindustrial sector through collaboration, relationships and networking. They engage with end-use companies to understand industry's challenges. They connect companies with researchers and technology developers who may have solutions to those challenges.

The ABF Team acts as a bridge between researchers and industry to bring together scientific expertise, industrial know-how and government support to move an idea forward. The Team has deep and varied networks with research and industry experts. They have long-standing relationships with key industry partners, universities and researchers and research organizations like InnoTech Alberta. Companies like Al-Pac, West Fraser and numerous others actively support ABF subprograms with funding, advice and samples of feedstock for many of the projects.

> *I wouldn't be doing this research without the CNC provided by InnoTech Alberta and the generous funding support from Alberta Innovates. Alberta Innovates has a great team that understands the needs of the province, industry and researchers. The team was receptive to my ideas and gave me good feedback.*
>
> **Dr. Cagri Ayranci, Associate Professor, Faculty of Engineering, Department of Mechanical Engineering, University of Alberta**
>
> ***Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"***

4.2. Subprogram Design

The ABF subprograms are designed to offer applicants a clear view of where they should engage ABF and where that path might lead as their products and technologies and products evolve along the innovation continuum.

The ABF Team has ability to advance an area of research and development because it can take on some risks in the hope of great reward – not something industry is always able to do. The Team employs an abundance of patience and a long-term view. Take CNC in Alberta for example. It took many years of strategizing and funding to secure establishment of the CNC pilot plant at InnoTech Alberta in 2013, and the strategizing is still ongoing to develop new applications and infrastructure.

Steve Price, Executive Director of the Bio Sector in Alberta Innovates, and his team work closely with industry to gain a good understanding of the issues they face. Source: Alberta Innovates

ABF supports the research, development and scale-up of a wide range of industrial bioproducts and technologies with the central tenet that they use biomass feedstock that can be economically and sustainably produced in Alberta. Agricultural biomass might include hemp, lipids and bioactive compounds. Forestry biomass might include logging and sawmill wood residue and pulping waste streams. Other biomass might include municipal solid waste and algae. ABFs portfolio of projects encompasses new products and technologies in many industry segments including: bioplastics, specialty chemicals, composite materials, bioenergy, cellulose nanocrystals, lignin, new biomass conversion processes, wood construction materials, hemp, lipids and algae.

Maximum flexibility is part of the subprogram process. As projects demonstrate progress, the ABF Team offers support to help the projects develop further. The Team works closely with grant recipients to help resolve issues, set up introductions and give advice.

Highly Qualified People (HQP) development is a requirement in all projects by encouraging support for graduate students and NSERC chairs. Student development is the key to building the workforce of tomorrow's biosector.

The Team evaluates all proposals with a view to the expertise of the people to be involved in the project, thoughtful business-focused plans, strong company leadership, meaningful outcomes and an ability to complete the proposed work. This is a prudent approach to ensure the investments made are well-spent and with the effective support needed for the project to be successful.

In 2018-19, the Team ended the Equipment Utilization subprogram, ended the Invited Proposal subprogram and replaced it with the Opportunities subprogram. The Team initiated the Biomaterials Pursuit subprogram and the CNC Challenge 3.0 subprogram to develop biomaterials from CNC. It launched Lignin Challenge 1.0, for applied

research into lignin production and product applications. It also launched the Lignin Pursuit subprogram for further development of these materials into high-value bioproducts.

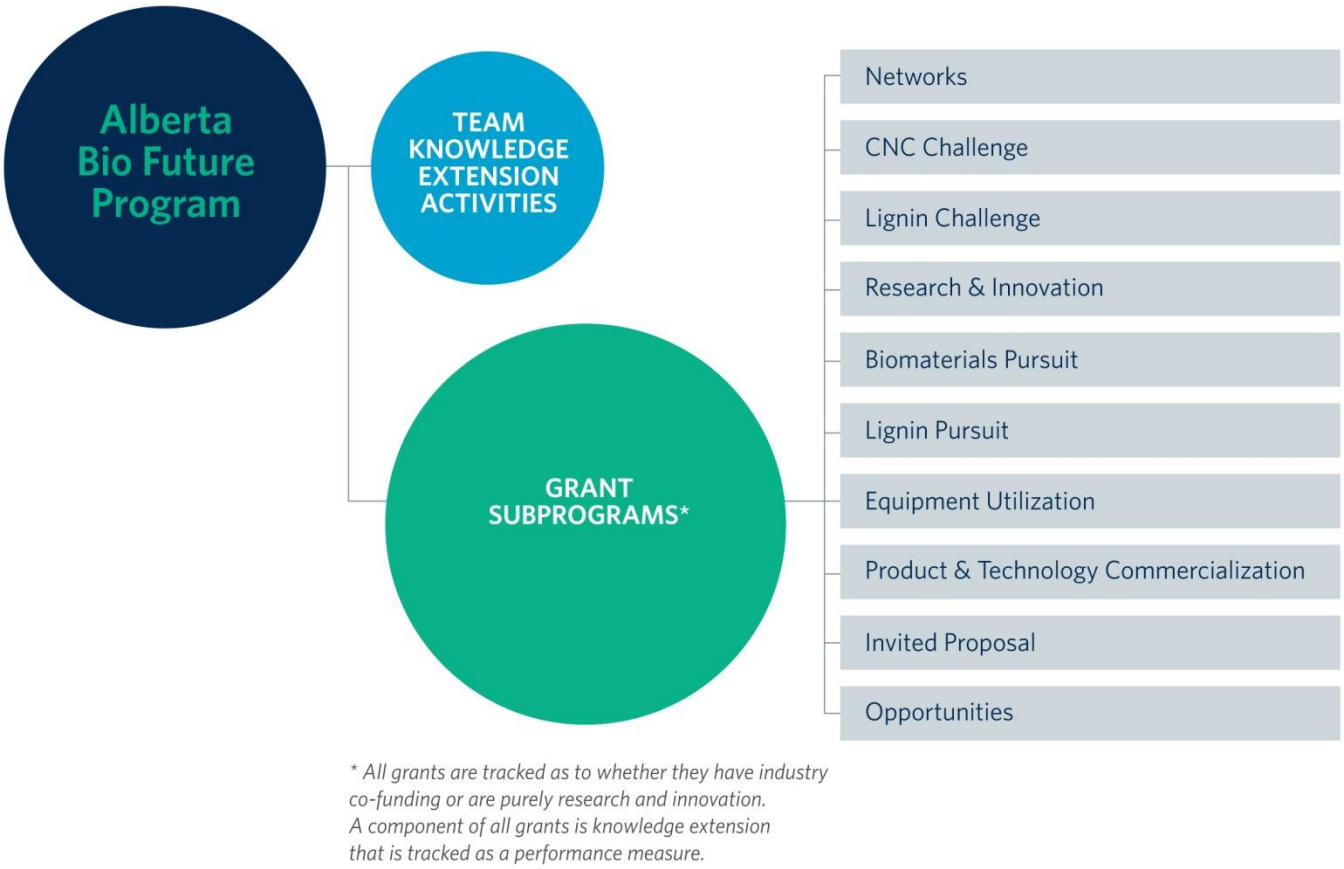
The following subprograms are designed to complement each other and move successful projects forward:

- Networks – for many researchers working together on projects under a common theme with a large budget and a long time frame.
- Challenge–CNC 1, 2, 3 – an ideas program for small one-year projects worth $25,000 to explore new ideas and encourage researchers and companies to experiment with the CNC, with technical support and CNC samples from InnoTech Alberta.

ABF team members, like Dr. Christine Murray on the right in photo, act as a bridge between researchers and industry to bring together scientific expertise, industrial know-how and government support to move an idea forward.
Source: Dr. Christophe Danumah

- Challenge–Lignin 1 – an ideas program for small one-year projects worth $25,000 to explore new ideas and encourage researchers and companies to experiment with the lignin, with technical support and lignin samples from West Fraser.
- Research and Innovation – for multi-year research projects where industry funding was optional.
- Equipment Utilization – to stimulate use of bioindustrial bricks and mortar infrastructure assets.
- Product and Technology Commercialization – for multi-year pre-commercialization projects where industry funding was mandatory.
- Biomaterials Pursuit – enhanced multi-year funding for early-stage ABF investments that showed promise.
- Lignin Pursuit – enhanced multi-year funding for early-stage ABF investments in lignin that showed promise.
- Invited Proposals – a process for high-quality proposals outside the scope and/or timelines of other ABF subprograms.
- Opportunities – designed to leverage unique and/or exceptional opportunities (from research to product commercialization) that would be missed if a project were not considered for funding in a timely fashion. Therefore, the proposal must take advantage of an exceptional, time-sensitive opportunity and partnership that justify having the project considered.

4.2.1. **Illustration of Alberta Bio Future Subprograms**



** All grants are tracked as to whether they have industry co-funding or are purely research and innovation. A component of all grants is knowledge extension that is tracked as a performance measure.*

4.3. **Subprogram Uptake**

The demand for the ABF funding program to date since 2014-15 includes:

- Eight calls for proposals, spanning the research continuum from early applied to commercialization, resulting in 322 Letters of Intent (LOI's) submitted, with requests for funds in excess of $70 million.
- About a 27 per cent success rate of LOIs advancing to full proposals to approved projects.
- Recent subprograms like the CNC Challenge, Lignin Challenge and Lignin Pursuit have included industry partnerships with Alberta-Pacific Forest Industries Inc. and West Fraser. These industry partners are deeply interested in application and technology development of Alberta-manufactured products from biomass and have contributed funding for the subprograms and biomaterial samples for the researchers.

4.4. **Resonates With Industry**

The ABF Team aims to pursue and support efforts that will ultimately resonate with industry.

They are looking for a clear line of sight to industry. In some cases, researchers leverage their own connections with industry. In other cases, the ABF Team creates opportunities for new connections and sets the environment for networking like at its workshop in February 2019 “Pursuing Added Value for Alberta Biomass.” One of the benefits of the ABF Team is that they are experts in broad areas of research and development and know a lot of people across many different disciplines. They are catalysts, making introductions and stimulating connections between academia and industry.

Projects that have an industry cash contribution are labeled in ABF as aligned under “industry co-fund.” Projects – often early applied work – without an industry cash contribution but may include industry and other in-kind contributions, are labeled in ABF as aligned under “research and innovation.”

Industry leverage strengthens a project and can provide extra resources for a more successful result. By contributing their own funds and investing in-kind resources, industry signals not only strong interest and commitment but also indication they see the real possibility of commercialization success.

> *Edmonton, Alberta has everything our wood-based renewable natural gas demonstration project needs. Here, we have an industry partner, ATCO Gas, with a vast network of distribution and transmission pipelines; abundant forest biomass close to transportation routes; many forestry communities with skilled workers and supportive government.*
>
> **Edson Ng, Principal, G4 Insights Inc.**
>
> ***Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories”***

4.5. **Strategic Partnerships**

The ABF Team supports development in areas of focus through strategic partnerships with other provincial and federal funders and their programs. This includes coordination with Emissions Reductions Alberta programs, such as the BEST Challenge, and their trusted partnership intake with Sustainable Technology Development Canada and Natural Resources Canada.

At the federal level, ABF coordinates with the Natural Resources Canada’s Clean Growth program, Natural Sciences and Engineering Research Council’s Industrial Research Chairs program and new Alliance Grant program (replaces Collaborative Research and Development Grants).

4.6. Sparking Interest

The ABF Team generates interest in its areas of focus through discussions, meetings, networking, presentations, seminars and conferences at domestic and international venues. These knowledge exchanges build relationships among Alberta Innovates, researchers and companies.

These types of discussions happen regularly. Some of these interactions have led directly to connections between specific researchers and end-use companies interested in using the researcher's knowledge, research or intellectual property for potential commercial development. In many cases, they have led to the development of non-disclosure agreements to allow the confidential exchange of information, collaborative research projects or even early-stage commercial development.

In 2018-19, the Team hosted two significant symposiums for academia and industry "*Pathways to Success for Green Fuels and Chemicals, Industry Speaks*" and *"Pursuing Added Value for Alberta Biomass."*

The ABF team regularly generates interest among researchers and companies in its areas of focus through discussions, meetings, networking, presentations, seminars and conferences at domestic and international venues.
Source: Dr. Christophe Danumah

4.7. Making Connections

The ABF program Team has extensive networks and contacts that can serve as the connecting force between researchers, manufacturers, end-use companies and even between sectors and ideas.

ABF Lignin Challenge project BFL-18-009 is a good example of how ABF can connect sectors. In this project, Dr. Shen developed carbon quantum dots from lignin for health bioimaging to better diagnose diseases. By happy coincidence, her environmental colleagues at NAIT became aware of the research. They thought her new technology would work well in remediating soil at oil and gas well sites by degrading hydrocarbon contaminants; they are now applying for funding to pursue the concept.

As projects advance and show promise, the ABF program team is able to help researchers envision the next step for their project. Through market intelligence garnered during engagements with end users, the Team can help make connections for the researchers. Conversely, with the ABF program team's knowledge of where researchers are making progress, the Team is able to initiate discussions with targeted end-use companies and present them with early-stage opportunities and ideas for applied research activities.

> *It was a chicken and egg situation. A commercial plant is a large and risky investment. Before industry invested it wanted to be sure there was a supply of hemp from farmers. On the other hand, farmers didn't want to grow hemp because they want to be certain there was confirmed demand from industry. Thankfully Alberta Innovates understood the dilemma. They stepped in to take on the risk and help fund the plant's construction, along with industry partner, Hempco Food and Fiber Inc, now owned by Aurora Cannabis Inc.*
>
> **Tamrat Tekle, President, Natural Fibre Technologies Inc.**
>
> ***Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"***

In a second example of the connection process across the innovation continuum is the cross-sector opportunity identified between agricultural-based polyurethanes with forestry-based cellulose nanocrystals. In ABF project BFR-16-027, Dr. Jonathan Curtis' team at the University of Alberta had developed formulations for bio-based polyurethanes from non-food-grade canola, for use in a variety of plastic materials. The expertise from this research led to advancements in another ABF project BFC-16-013 in the CNC Challenge 2.0 subprogram. The team has successfully developed CNC/polyurethane composites, leveraging CNC's hardness characteristics to produce a much stronger, abrasion-resistant surface coating. Through its market development efforts, the ABF Team previously had established a relationship with a large paint manufacturer. The manufacturer had significant interest in polyurethane-based paints and a desire to incorporate greener ingredients in its formulations, while maintaining strong performance. With these contacts in place, the ABF Team introduced Dr. Curtis's group to the paint manufacturer. Both are now working together to investigate whether the CNC-based composite paint formulated in Alberta can be scaled up to produce a commercially viable paint product.

A third example is the ABF Team's work with the Alberta Forest Products Innovation Consortium, a collective of like-minded forest companies interested in collaborating on issues of common interest. Dr. Paolo Mussone of NAIT proposed to develop a catalyst for the energy sector using the ash by-product from kraft pulp mills. The consortium members agreed to contribute industry co-funding to his ABF proposal submission, which was successfully funded under project BFR-16-071. Interestingly, the analysis done by Dr. Mussone to characterize the various wood-based ashes produced around Alberta was circulated by the ABF Team to some end-use companies that currently use coal-based ash. That connection has led to a number of different application development efforts, opening up previously unseen opportunities for use of a material that is typically landfilled.

A fourth example is the introduction by a member of the ABF Team of Hexion Canada to West Fraser. West Fraser built a commercial lignin recovery plant at their Hinton pulp mill. The introduction facilitated West Fraser working closely with Hexion Canada under ABF project BFP-16-025. In this project, Hexion researchers developed a lignin-based adhesive resin for plywood and other engineered wood products manufactured by wood products companies like West Fraser. In a follow-on connection, the University of Alberta's Dr. Ying-Hei Chui, NSERC Industrial Research Chair in Engineered Wood and Building Systems, supported by ABF, is now engaged with both companies, discussing how their efforts can be aligned with his research interests in cross-laminated timber and massive timber panels.

4.8. **Alberta Bio Future Industry Partners**

The ABF Team has relationships with many companies working in the bioindustrial sector, including the following:

5. Highlights

The Alberta Bio Future program has supported 135 projects over the period April 1, 2015, to March 31, 2019. The projects are at varying stages of development along the innovation continuum: basic research, applied research and pre-commercialization. What they all have in common is potential to advance Alberta's bioeconomy. The following stories highlight a few of these projects.

ALBERTA INNOVATES

ALBERTA BIO FUTURE PROGRAM HIGHLIGHTS

Algae – Problem or Valuable Asset?

When we think of algae, we often think of the unpleasant slime growing on Alberta lakes. Research done at the University of Alberta has found that this "slime" can be put to good use in the oil sands industry, both to help produce renewable energy and to reduce the industry's carbon footprint. Algae grow quickly and are not fussy about where it grows. Besides water, all it needs are sunlight, carbon dioxide and nutrients.

A team at the University of Alberta led by Dr. Amit Kumar used computer modeling to study the feasibility of using algae to produce diluents and hydrogen. Both of these products are used in large amounts in the oil sands. Diluents are used to reduce the viscosity of bitumen to allow it to flow through pipelines. Hydrogen is used in upgrading processes that convert bitumen to synthetic crude oil. Alberta Innovates supported this research through its Alberta Bio Future Invited Proposal subprogram in project ABI-14-004. Other funders included NSERC, Emissions Reduction Alberta and an industry partner.

Diluents and hydrogen from algae could offer a green solution to companies that upgrade bitumen into synthetic crude oil.

The study had two main aspects: 1) determine whether algae can be grown in central Alberta and 2) estimate the cost and environmental impacts in converting algae biomass to diluents and hydrogen. For the first aspect, the research team used satellite data and computer models to predict growth of algae through two systems: open pond raceway (a large shallow pond shaped like a raceway) and photobioreactor. Successful growth in an open pond depends largely on uncontrollable external conditions, while growth in a photobioreactor is in a closed and controllable environment. The study found that algae will indeed grow well in Alberta, though generating sufficient supply in either an open pond or a photo bioreactor would require improvements to the growing systems. For the second aspect, the research found that photobioreactors are more cost-effective than open ponds for growing algae. The team also determined that it will cost more to produce diluents and hydrogen from algae than with fossil fuels.

Soon we could use the wastewater from farms and feedlots to grow vast amounts of algae, which would not only clean the runoff water before it enters lakes and rivers, but also reduce greenhouse gas emissions and produce countless high-value green products for the energy, food and pharmaceutical industries.

The results of this study are interesting and provide a baseline that warrants further research to refine the technology. During its growing period, algae consume nearly its weight in the greenhouse gas, carbon dioxide, and are considered nearly carbon neutral over its life cycle–a benefit if algae are grown near large industrial emitters of greenhouse gases. It also means that large amounts of greenhouse gases would be absorbed during the production of diluents and hydrogen products. In addition to these products, algae can be used for other high-value products such as protein supplements, anti-oxidants, pharmaceuticals, biodiesel and jet fuel.

Commercial algae production facilities could become the anchor in Alberta for a new industry cluster in algae products. First, more research is needed to improve the technology and increase economies of scale to bring down the costs of diluents and hydrogen production from algae.

ALBERTA INNOVATES

ALBERTA BIO FUTURE PROGRAM HIGHLIGHTS

Bioimaging With Lignin-Based Carbon Quantum Dots

Health clinicians may soon have a new and effective bioimaging tool to produce in-depth personal medical reports based on a patient's genetics or to better diagnose presence of some diseases like hepatitis C and cancer.

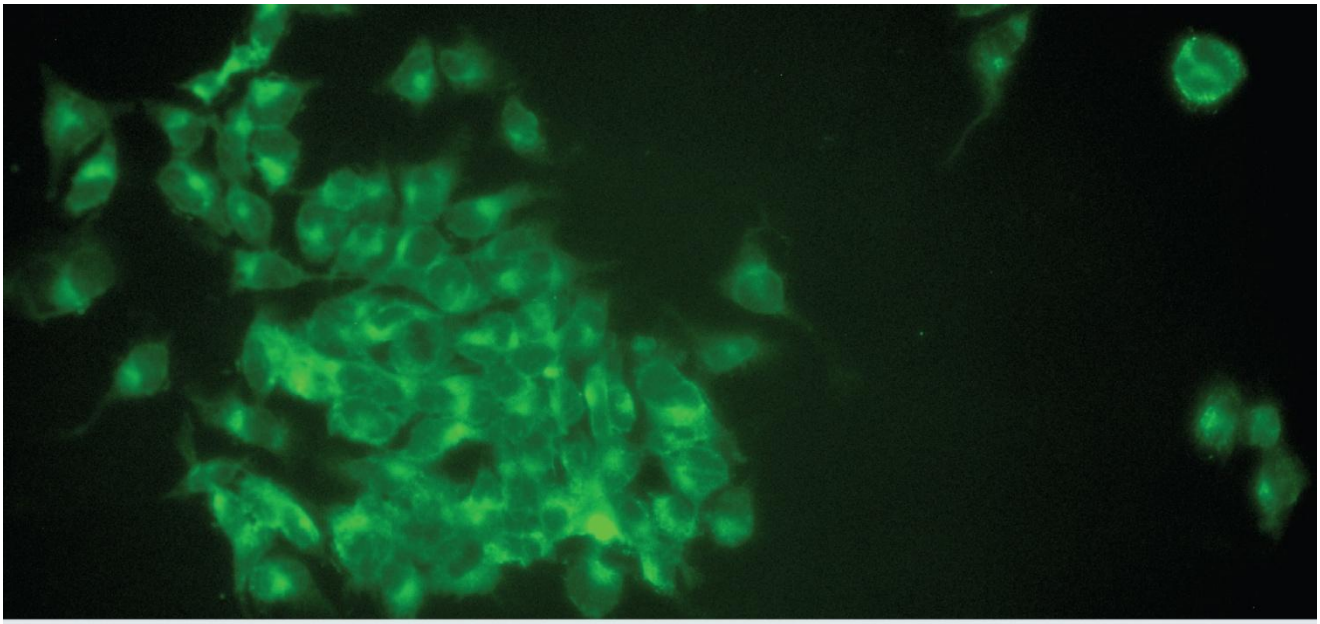
"Carbon quantum dots (C-dots) derived from lignin can 'shine the light'," said Dr. Weizheng Shen, Research Associate, Applied Bio/Nano Industrial Research Chair program in NAIT. She has proven the concept that the high-value nanomaterial C-dots are more visible under the microscope than conventional materials. C-dots are bright, non-toxic, highly soluble and low-cost as compared to the commonly used semiconductor quantum dots.

Alberta Innovates funded the research under the Alberta Bio Future Lignin Challenge subprogram in project BFL-18-009. "We appreciate the financial support from Alberta Innovates in this early stage research," said Dr. Shen. "They took a chance on this idea."

> ***We appreciate the financial support from Alberta Innovates in this early stage research. They took a chance on this idea.***
>
> **Dr. Weizheng Shen**
> Research Associate, Applied Bio/Nano Industrial Research Chair program, NAIT

The bioimaging slide is prepared and examined under a fluorescence microscope. It uses a tissue sample from a patient, then incubates it with C-dots from lignin (see photo). Lignin, a major component of trees, is plentiful in Alberta and has been underused for a very long time. The project's industry partner, West Fraser Hinton Mills, built and commissioned the first lignin recovery plant in Canada. They consistently produce high-quality and pure lignin, guaranteeing the excellent performance of the C-dots product.

Quantum dots in the past contained a very toxic chemical, cadmium, that led to serious health and environmental concerns. Research to create alternative quantum dots from carbon has been underway for a decade but no products have successfully entered the market because of difficulties scaling from the lab to commercial production. Now that Dr. Shen has a scalable process to develop C-dots from lignin, she will work with potential collaborators to move this lab product into the market. For example, the C-dots can be functionalized with DNA sequence to detect the early stages of the highly infectious disease, hepatitis C. C-dots can also be combined with DNA sequencing to generate a personal medical report. One of Dr. Shen's collaborators has a DNA sequencing facility and strong connections with international leaders in big data, genomics and personal medicine.



Carbon quantum dots from lignin, shown in photo as seen under a fluorescence microscope, hold immense potential to boost advances in personal medicine, disease diagnostics and even soil remediation.

Source: Dr. Weizheng Shen

The unique properties of C-dots, especially its high solubility, large surface area, non-toxicity and fluorescence are of interest to the soil remediation team at NAIT. Dr. Shen and the team have applied for funding to research if lignin-based C-dots can be used as a soil amendment to encourage the degradation of hydrocarbon contaminants at oil and gas sites.

While health bioimaging and soil remediation don't seem connected, the use of carbon quantum dots for these two applications is well-aligned based on the chemistry of carbon. Dr. Shen says, "Alberta is not just about oil and gas. We also have huge forest renewable resources as a source of the lignin in new technology – carbon quantum dots – that can help with soil remediation in our oil and gas sector."

> ***Alberta is not just about oil and gas. We also have huge forest renewable resources as a source of the lignin in new technology – carbon quantum dots – that can help with soil remediation in our oil and gas sector.***
>
> **Dr. Weizheng Shen**
> Research Associate, Applied Bio/Nano Industrial Research Chair program, NAIT

ALBERTA INNOVATES

ALBERTA BIO FUTURE PROGRAM HIGHLIGHTS

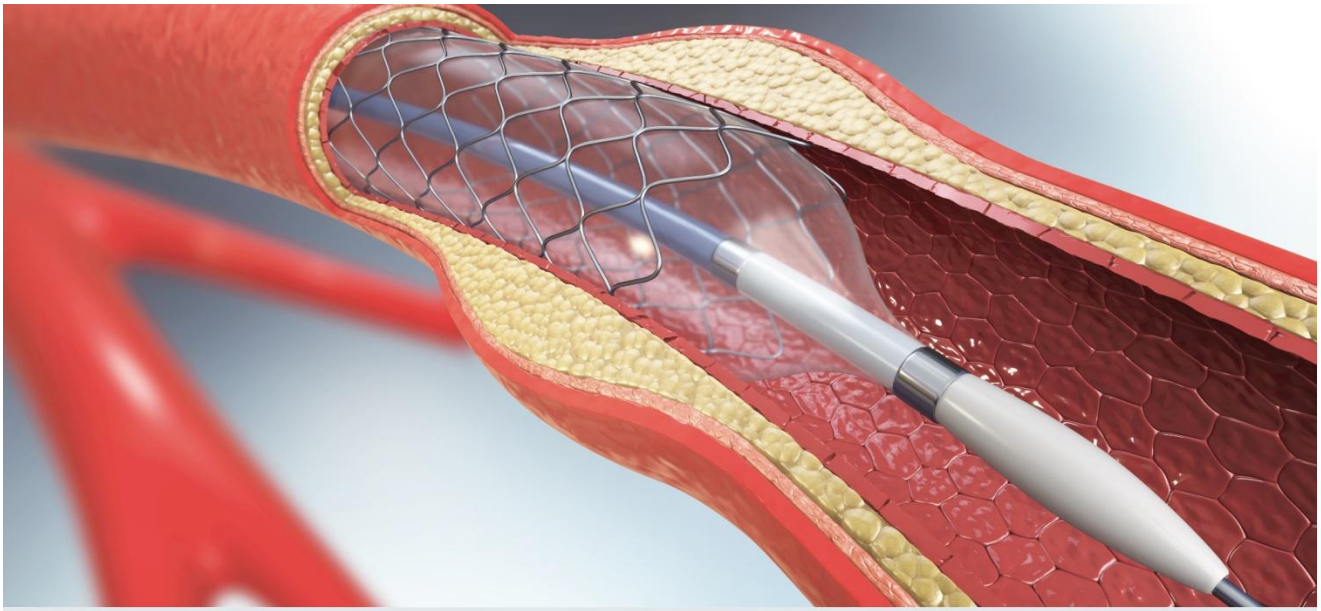
Towards Self-Expanding Heart Stents With 3D Printing

Extrusion-based additive manufacturing, also known as 3D printing, is a new and fast growing industry segment. It is used to create low-cost prototypes, intricate components and custom-tailored products that cannot be produced with conventional manufacturing techniques. The products are used in a wide range of industries including consumer products, automobiles, automation, aerospace and bioengineering.

Filaments made from fossil fuel plastics are commonly used as the base material in 3D printing, but they lack good mechanical properties. Researchers have been using nanoparticles to reinforce the base materials, but they have adverse health and environmental effects. Researchers at the University of Alberta have proven the concept that reinforcing the base material with a different nanoparticle, cellulose nanocrystals (CNC), increases strength by 50 per cent, a crucial attribute for many engineering applications. CNC comes from a renewable resource – trees and plants – and is safer to use.

Alberta Innovates funded this research under the Alberta Bio Future CNC Challenge subprogram in project BFC-16-006. The principal investigator was Dr. Cagri Ayranci, Associate Professor, Faculty of Engineering, Department of Mechanical Engineering, University of Alberta. Skilled in composite materials, he said "Alberta is one of only a few places in the world that produces CNC. I was dying to get my hands on some when I arrived at the University of Alberta in 2012. I wanted to show the advantages of using CNC in 3D-printed industrial and medical products."

> ***Alberta is one of only a few places in the world that produces CNC. I was dying to get my hands on some when I arrived at the University of Alberta in 2012. I wanted to show the advantages of using CNC in 3D-printed industrial and medical products.***
>
> **Dr. Cagri Ayranci**
> Associate Professor, Faculty of Engineering, Department of Mechanical Engineering, University of Alberta



Heart stents made with a 3D printer using a base material reinforced with CNC could be inserted in a closed position and opened fully with body heat.

Plastics manufacturing companies in Alberta are already working with 3D printing technology and have shown interest in applying these research findings to their commercial operations. This project has set the groundwork for three other CNC projects still ongoing in Dr. Ayranci's lab. In one, CNC, lignin and plastic are combined together then extruded in 3D-printed products – in effect, reconstituting trees. It could be possible to create a 3D-printed full-sized wooden chair and other wooden products, which could lead to new manufacturing processes for making furniture. In the second project, researchers are combining CNC with nylon to increase strength while decreasing weight. This could be a tremendous attribute in materials for packaging and rope for recreational activities like rock climbing. In a third project, researchers are developing 3D-printed stents. These shape memory polymer-CNC stents could be inserted in a heart valve in a closed position. The stent would open fully when warmed with body heat. They could be custom-tailored to the needs of the patient. Fan blades used in motors and HVAC systems are another industrial product that could be produced with 3D printing for a cost that is many times lower than the conventional injection moulding method.

Research projects like these are putting Alberta on the map. Dr. Ayranci's team and his close collaborators, Dr. Tian Tang, from the same department, and Dr. Mark McDermott, from the Chemistry Department, are one of the very first groups in the world to blend CNC into 3D-printed industrial products. "I wouldn't be doing this research without the CNC provided by Innotech Alberta and the generous funding support from Alberta Innovates," said Dr. Ayranci. "Alberta Innovates has a great team that understands the needs of the province, industry and researchers. The team was receptive to my ideas and gave me good feedback." Industry partner, Alberta-Pacific Forest Industries Inc., and large international plastics companies are very interested in understanding how existing plastic and polymer products could be improved by adding CNC.

ALBERTA INNOVATES

ALBERTA BIO FUTURE PROGRAM HIGHLIGHTS

Commercial Hemp Decortication Plant Starts Production

The business of cannabis is booming in Canada. The 2018 legalization of cannabis has opened new opportunities not only for marijuana, but also for its cousin, industrial hemp. And the U.S. has just become a new market for industrial hemp products with its legalization in 2018.

Commercial production of industrial hemp food and fibre products has been legal in Canada since 1998. Hemp food product manufacturing is well established in Alberta. This is not the case for hemp fibre product manufacturing. There has been much interest and research, but growth in this sector has been stymied with the lack of commercial pre-processing facilities. Before hemp fibre products can be manufactured, the fibre must be separated from the hurd in the hemp stalk, and then processed. This is called decortication. In May 2019, a commercial decortication plant started production in Nisku, Alberta – the largest commercial line in Canada.

Alberta Innovates supported the plant's construction under the Alberta Bio Future Invited Proposal subprogram project ABI-16-010. The project was based on knowledge gained from earlier projects at Alberta Innovates' pilot decortication plant in Vegreville, Alberta and Tekle Technical Services Inc. The commercial NFT plant can continuously process two tonnes per hour of hemp stalks. NFT expects it to be at almost full capacity within the next eight months and employ up to five operational staff.

> ***It was a chicken and egg situation. A commercial plant is a large and risky investment. Before industry invested it wanted to be sure there was a supply of hemp from farmers. On the other hand, farmers didn't want to grow hemp because they want to be certain there is confirmed demand from industry. Thankfully Alberta Innovates understood the dilemma. They stepped in to take on the risk and help fund the plant's construction, along with industry partner, Hempco Food and Fiber Inc, now owned by Aurora Cannabis Inc.***
>
> **Tamrat Tekle**
> President, Natural Fibre Technologies Inc. (NFT)

Natural Fibre Technologies' commercial hemp decortication plant in Nisku, AB separates hemp stalk into fibre and hurd.

Source: Natural Fibre Technologies

Hemp and marijauana are different types of the cannabis plant like lemons and oranges are different types of citrus fruit. Hemp plants comprise five valuable components: bast fibre, hurd, flower, seed and seed oil. The bast fibre is mainly used for geotextile mats and as a potential fibreglass substitute in autoparts and other industrial products; hurd for building materials such as cement, composite panels and composite plastic, and also for soil mulch and animal bedding; phytocannabinoids in the flower for nutraceuticals and cosmetics; the seed for eating raw or fractioning into animal feed, protein powder and cosmetics; and seed oil for food cooking oil or industrial products like lubricants and biodiesel. "Securing Hempco as an industry partner was pivotal to this project's success," said Tekle. "Hempco will process the hemp seed. NFT will process the hemp stalk. Together, we will utilize the whole crop and farmers now have a buyer for all parts of the hemp plant." NFT will sell the two products from the commercial plant, hurd and fibre, to other companies developing hemp products. NFT eventually plans to launch two new commercial production plants to add further value to these bulk products by producing biofibre cement and biocomposite structural panels.

The commercial decortication plant will become the anchor to a new industry cluster in industrial hemp. The maturing hemp industry will drive increased pre-processing capacity, launch of new small companies, sale of new hemp products and more farmgate revenue for local farmers.

Hemp fibre can be used in a number of different green products like geotextiles, biofibre cement and other building materials.

Source: Natural Fibre Technologies

ALBERTA INNOVATES

ALBERTA BIO FUTURE PROGRAM HIGHLIGHTS

Artificial Living Nerve Tissue for Lab Testing

Researchers in tissue engineering and regenerative medicine have long been interested in creating artificial living human tissue for drug development and disease modeling. There has been some success, but challenges have existed in culturing cells in the lab for a long enough time to be effective and then in having the tissue cells remain viable through 3D bioprinting to enable making complex tissues.

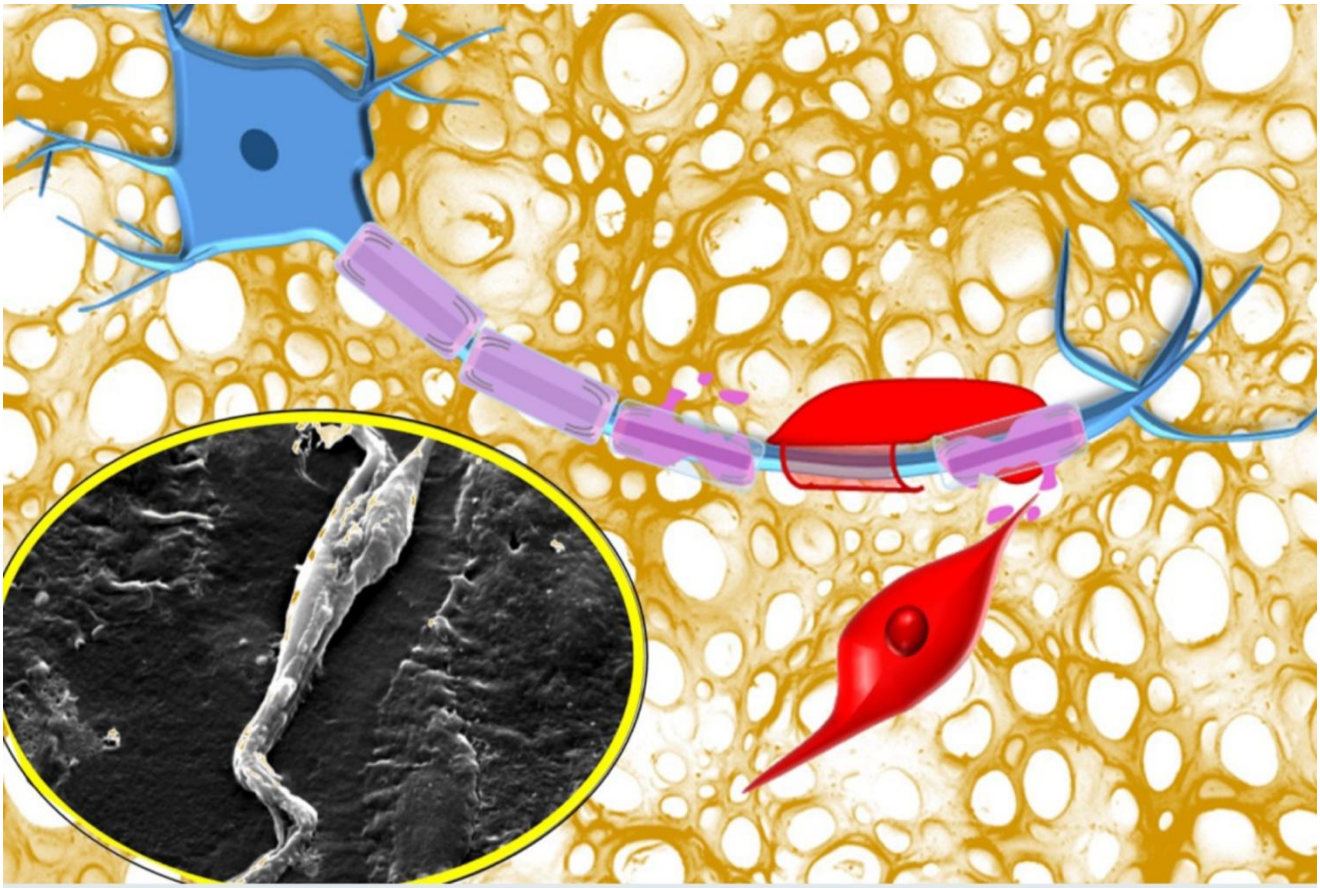
Dr. Amir Sanati-Nezhad has worked with his collaborators at the University of Calgary to solve these challenges. He is an Assistant Professor of Mechanical and Manufacturing Engineering at the University of Calgary's Schulich School of Engineering. He is also the Canada Research Chair in BioMEMS, which is short for biomedical microelectromechanical systems.

Alberta Innovates funded his research through the Alberta Bio Future CNC Challenge subprogram in project BFC-18-037. Dr. Sanati-Nezhad used nanomaterials including nanoparticles, nanofibers and nanorods to modify the hydrogel, GelMA, commonly used in culturing tissue cells in the lab. With this research, he has proven the concept that the nanomaterial additives from cellulose nanocrystals keep the cell culture viable for up to 50 days and give it the strength and resistance to tearing needed for further disease modeling, drug testing and 3D bioprinting.

From this groundwork, he went on to achieve other research breakthroughs. Through the collaboration with researchers at his institute, he has now artificially replicated living human tissue in a 3D lab model that is complemented with capillaries, immune cells and nerve growth.

This is the first time that myelination of nerve axons–nerve growth–has been successfully reported in a 3D lab model during very long-term cell culture, speeding up possible new treatments for multiple sclerosis. He was also successful in growing a mimetic cancerous tumour in a 3D lab model from culturing single cells.

Companies like Aspect Biosystems Inc. (Canada's most respected bioprinting company) are interested in using his modified hydrogels for their 3D lab models for possible sale to researchers and drug companies. Now that 3D models exist of artificial living human tissue, drug companies can use the lab models to induce a disease, and then test different experimental drugs for its treatment, instead of doing this testing on animals. This will cut costs and speed up disease modeling and drug discovery at least by half, which currently takes billions of dollars and about 10 years to approve. Big data and high throughput testing can speed up drug discovery even more. Testing on a 3D lab model would be more accurate, improving the new drug's chance of being approved by Health Canada and the U.S. Food and Drug Administration, a stage at which more than 90 percent of new drugs currently fail.



This is the first 3D tissue model of myelination of nerve axons – nerve growth – speeding up possible new treatments for multiple sclerosis.

Source: Dr. Amir Sanati-Nezhad

Some of the collaborators on this project included Hotchkiss Brain Institute, University of Calgary's Comparative Biology and Experimental Medicine Department, Biomedical Engineering Program, Center for Bioengineering Research and Education, Microsystem Hub; Nanofab; SV ChemBioTech Inc. and Zymetrix Inc. This project builds on previous research funded by Alberta Innovates, ALS-Brain Canada, NSERC and University of Calgary's BME Strategic Funds.

More research is needed to fine-tune the 3D lab model to replicate living tissue from different human organs. Some tissue types are soft as in the brain, some are elastic as in the skin and others are stronger in only one direction as in the heart. Dr. Sanati-Nezhad hopes to secure funding for a new research project that will emulate skin and heart valve tissue types in a 3D lab model. "We are still at the research stage and want to collaborate with other scientific disciplines. Bioscientists can help to model different disease conditions using these engineered tissue platforms and explore new research directions like tissue-integrated sensors. Continued funding is also crucial and we appreciate the vote of confidence in our research from all funders to date." Dr. Sanati-Nezhad noted that implantation of artificial living tissue in human patients is still decades away.

ALBERTA INNOVATES

ALBERTA BIO FUTURE PROGRAM HIGHLIGHTS

Greening Alberta's natural gas grid with wood waste

Reduction of greenhouse gas emissions is a worldwide goal. One option for reduction is decreasing the use of oil and coal by increasing usage of a lower-carbon fossil fuel – natural gas.

New technology is now available to make natural gas an even better option by converting wood waste into a much lower carbon fuel–renewable natural gas (RNG). In the summer of 2019, Burnaby-based cleantech company, G4 Insights Inc. (G4), will start field-testing the continuous injection of RNG into Alberta's natural gas grid through the Edmonton, AB distribution site for ATCO Gas.

Natural gas is used for transportation fuel in vehicles, heating in homes and electric power generation. Canada's natural gas utility companies have set a 2030 target that 10 per cent of the natural gas supplied to customers will come from renewable natural gas. Currently, the main source of RNG in Canada is from the biogas produced from landfill gas recovery, and anaerobic digesters at municipal wastewater treatment plants and agricultural facilities. RNG can be blended directly into conventional natural gas without need for additives or modification of the equipment that uses natural gas such as vehicles, appliances, generators and industrial processes.

The G4 technology is low-cost, simple, sustainable and unique in Canada. The technology can be built to any scale and in any location close to a source of biomass and a natural gas distribution pipeline.

> ***Edmonton, Alberta has everything the project needs. Here, we have an industry partner, ATCO Gas, with a vast network of distribution and transmission pipelines; abdundant forest biomass close to transportation routes; many forestry communities with skilled workers and supportive government.***
>
> **Edson Ng**
> Principal, G4 Insights Inc.

The technology currently uses wood residue from sawmills, logging and forest thinning, but it can be adapted for agricultural and construction waste. The wood waste is converted to RNG using a thermo-chemical process, which is based on a sound understanding of chemistry as a platform. One of the main benefits of RNG from G4 technology is that it emits 80 per cent fewer greenhouse gases than conventional natural gas.

Alberta Innovates supported this technology with funding from the Alberta Bio Futures Invited Proposal subprogram under project ABI-16-011. Other funders have included Natural Gas Innovation Fund, Natural Resources Canada and FPInnovations. G4 will field test the technology at several scales. Testing starts in summer 2019 and for the following six months at a small scale, consuming only 100 kilograms per day of dry biomass. Next, with support from industry and government, G4 hopes to build a pilot plant to test the processing of two dry tonnes per day of biomass. By 2022, G4 aims to build a small commercial plant that would need up to two logging trucks every day to deliver 36 dry tonnes of wood residue. This would produce enough energy to heat about 1,900 average Canadian homes and require 19 staff to run the plant.

Alberta has enough forest and agricultural biomass to support 14 large commercial plants with G4 technology that would require 2,500 full time operational staff. Utility companies in Canada, U.S., U.K., Sweden and Germany are very interested in G4s technology. RNG holds great potential to become a viable renewable energy source of the future, reduce greenhouse gas emissions, stimulate rural economic development and create skilled jobs.

The G4 Insights Inc. demonstration test unit can convert wood waste into renewable natural gas and inject it into a natural gas distribution pipeline.

Source: Edson Ng

6. Grant Subprogram Detail

6.1. **Networks Subprogram**

ABF funding for networks grows capacity in the research sector with direct line of sight from research to industrial implementation. Networks can serve to bridge the gap between academia and industry, helping industry to de-risk the challenge of developing new innovations for the marketplace. Networks signify the presence of sufficient critical mass in an area of research to warrant establishment of a co-ordinated hub of innovation. Networks are able to gather the best research, development and entrepreneurial talent, and focus on targeted and strategic areas of importance.

ABF researchers are developing technical information to enable increased use of engineered wood products such as laminated veneer lumber (shown in photo) in wall, roof and floor systems. Source: Adobe Stock

ABF has not established a separate call for proposals to networks. However, networks are welcome to apply to any ABF subprogram, including the Opportunities subprogram. If selected for funding, ABF participates as a network member. Within ABF, a separate category, Networks Subprogram, tracks funding to networks since budgets are usually much larger than for individual projects and span a longer time period.

Three networks were active in 2018-19, with total project costs of more than $9 million. These are summarized in the table below. Performance measures and financial information are available in the appendices. ABF expenditures for networks include more than project funding, they also include salaries for core network staff.

ALBERTA INNOVATES

Projects

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
ABI-17-002 *Industry Co-funded* *Networks* ---- **Amit Kumar** University of Alberta ---- **$2,100,000**	**NSERC/Cenovus/Alberta Innovates Associate Industrial Research Chair in Energy and Environmental Systems Engineering**	*Develop Canada's fundamental research capacity in the technologies of energy production, conversion and use at the systems level, along with associated environmental impacts, through development of fundamental science-based models. The program will train researchers who would contribute to Canadian workforce and contribute to Canada's effort to reduce greenhouse gas emissions. The objective is to identify pathways to low-carbon energy production and use, considering costs, environmental impacts and resource availability.*
BIO-16-010 *Industry Co-funded* *Networks* ---- **Mohamed Al-Hussein** University of Alberta ---- **$3,930,000**	**NSERC Industrial Research Chair in the Industrialization of Building Construction**	*Improve existing approaches to modular construction, manufacturing techniques, minimize construction waste and increase productivity.*
BIO-16-014 *Industry Co-funded* *Networks* ---- **Haitao Yu** Landmark Group **$3,382,849**	**Massive timber panel system behaviour study and its application in buildings**	*Develop technical information to enable increased use of engineered wood products in wall and floor systems. This is in collaboration with the NSERC Industrial Research Chair in the Industrialization of Building Construction, described above.*

** Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*

6.2. Cellulose Nanocrystal Challenge

The CNC Challenge 3.0 builds upon the success of CNC Challenges 1.0 and 2.0. The 3.0 funding call closed on February 1, 2018. The CNC Challenge series serves as a pipeline for the development of applications for cellulose nanocrystals. It supports early-stage work to demonstrate technical feasibility of CNC in high-value applications with potential for commercialization.

Successful grant recipients receive up to $25,000 in ABF funding for their CNC project research, up to one kilogram of CNC from the InnoTech Alberta pilot plant, access to InnoTech Alberta's researchers, capacity and facilities to assist in the successful delivery of their project, and must complete their projects within one year.

During 2018-19, 17 CNC Challenge projects were active, with total project costs of more than $1 million. These are summarized in the table below. Performance measures and financial information are available in the appendices.

Dr. Amir Sanati-Nezhad and his team from the University of Calgary's Schulich School of Engineering are first to replicate nerve growth in the lab with a 3D model enhanced with cellulose nanocrystals– opening up possible new treatments for multiple sclerosis.

Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"

Projects

PROJECT NUMBER *Alignment* --- **Project Investigator** Organization --- **Total Project Funding***	**Project Name**	**Project Summary**
BFC-18-003 *Research and Innovation* --- **Simon Park** University of Calgary --- **$25,000**	**Development of durable multifunctional cellulose nancrystals and copper nanocomposite inks**	*Use cellulose nanocrystals to prevent oxidation in copper composite inks, which are used in flexible electronics.*
BFC-18-005 *Research and Innovation*	**Zinc oxide – cellulose nanocrystal hybrids for**	*Use zinc oxide and cellulose nanocrystals in food packaging sensors or hand-held devices to tell when meat has spoiled.*

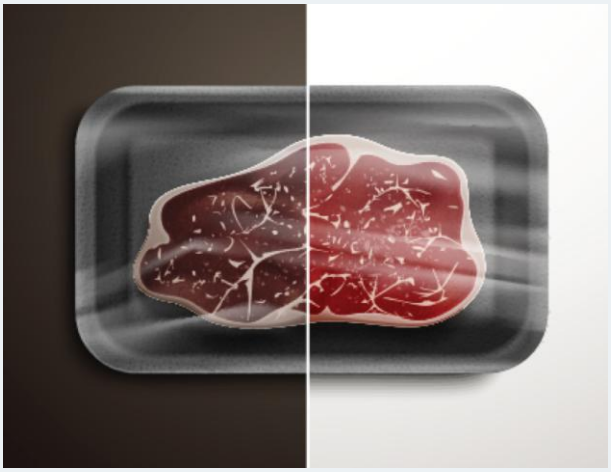
PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
---- **Kenneth Bosnick** National Research Council of Canada ---- **$50,000**	**smart food packaging**	
BFC-18-006 *Research and Innovation* ---- **Todd C. Sutherland** University of Calgary ---- **$25,000**	**Methodology to disperse CNCs into hydrophobic polymers, such as polyethylene**	*Change the surface chemistry of lightweight, high-strength cellulose nanocrystals so they can disperse evenly when added to plastics.*
BFC-18-007 *Research and Innovation* ---- **Jonathan Curtis** University of Alberta ---- **$44,250**	**Cellulose nanocrystal reinforced polyurethane rigid foams**	*Develop a simple and low-cost method of adding cellulose nanocrystals to rigid polyurethane foam to improve its strength and insulation properties when used as a construction material.*
BFC-18-008 *Research and Innovation* ---- **Yang Liu** University of Alberta ---- **$25,000**	**Nutrient recovery from municipal wastewater using cellulose nanocrystals: towards a sustainable wastewater management**	*Use cellulose nancrystals to recover ammonia and phosphorous from municipal wastewater to improve drinking water, enhance recreational activities and produce fertilizer.*
BFC-18-009 *Research and Innovation* ---- **Wei Liu** University of Alberta ---- **$55,132**	**Use CNC to improve the acid resistance of cement-based composites for sewer tunnel rehabilitation**	*Use cellulose nancrystals as an additive in the concrete liners of sanitary sewer pipes, preventing acid corrosion and leakage, reducing maintenance costs and adding strength.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFC-18-012 *Industry Co-Funded* ---- **Johnathan Veinot** Applied Quantum Materials Inc. ---- **$59,000**	**CNC-templated silicon-based nanostructures**	*Use cellulose nanocrystals combined with silica as rubber reinforcing fillers for the tire industry.*
BFC-18-014 *Research and Innovation* ---- **David Bressler** University of Alberta ---- **$73,500**	**Hockey stick reinforcement using cellulose nanocrystals**	*Use cellulose nanocrystals to produce stronger and lighter hockey sticks.*
BFC-18-018 *Research and Innovation* ---- **Vladimir Michaelis** University of Alberta ---- **$50,000**	**Drug and ion-deliverable nanomedicines directed by cellulose nanocrystalline biomaterials**	*Use cellulose nanocrystals in conventional medicinal tablets to provide filler material and act as a targeted drug delivery agent.*
BFC-18-021 *Research and Innovation* ---- **Zhi Li** University of Alberta ---- **$30,000**	**Cellulose nanocrystaline-modified filtration media for enhanced efficiency in ultrafine particulate matter removal**	*Use cellulose nanocrystals in lightweight face masks, providing ability to screen out ultrafine air pollutants without impeding airflow.*
BFC-18-022 *Research and Innovation* ---- **Tizazu Mekonnen** University of Waterloo	**Enhancing the dispersion and reinforcing effect of cellulose nanocrystal fillers in coating and**	*Use cellulose nanocrystal additives in polymer materials like plastics, increasing strength without increasing weight.*

PROJECT NUMBER *Alignment* --- **Project Investigator** Organization --- **Total Project Funding***	**Project Name**	**Project Summary**
--- **$39,000**	**nanocomposite applications**	
BFC-18-024 *Research and Innovation* --- **Hyo-Jick Choi** University of Alberta --- **$301,543**	**Development of a swine influenza vaccine using cellulose nanocrystal microneedles**	*Use cellulose nanocrystals for the strong microneedles needed for low-cost vaccination of pigs against swine influenza.*
BFC-18-026 *Research and Innovation* --- **Cagri Ayranci** University of Alberta --- **$37,000**	**Towards CNC reinforced multifunctional shape memory polymer composite biomedical stents produced by additive manufacturing**	*Use cellulose nanocrystals for low-cost 3D printing of biomedical stents used in angioplasty, making them more functional and biocompatible than stents from conventional materials.*
BFC-18-027 *Industry Co-Funded* --- **Kenneth Harris** National Research Council of Canada --- **$140,000**	**Strain-induced uniaxial alignment of CNC/polymer composites for optimized mechanical reinforcement**	*Stretch cellulose nanocrystals or use other mechanical methods to increase the strength in one direction when added to polymers like plastics.*
BFC-18-034 *Research and Innovation* --- **Darren Makeiff** National Research Council of Canada --- **$50,000**	**Cellulose nanocrystal-gel nanocomposite adsorbents for the purification of contaminated water**	*Use cellulose nanocrystals as a simple, environmentally friendly, low-cost way to remove pollutants like pesticides and heavy metals from wastewater.*
BFC-18-035	**Silver decorated CNC for**	*Create a silver-cellulose nanocrystalline material for dispersing*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
Research and Innovation ---- **Mark T. McDermott** University of Alberta ---- **$34,600**	**water analysis and purification**	*in groundwater that can help to detect presence of fungicide.*
BFC-18-037 *Research and Innovation* ---- **Amir Sanati-Nezhad** University of Calgary ---- **$25,000**	**Engineering of functionalized cellulose nanocellulose biomaterial for nerve regeneration**	*Use a cellulose nanocrystalline biomaterial to reconstruct a large nerve gap after traumatic injury with a material that mimics tissue components, reducing cell rejection and enhancing cell adherence.*

** Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*



ABF researchers are using zinc oxide and cellulose nanocrystals in food packaging sensors or hand-held devices to tell when meat has spoiled.
Source: Adobe Stock

ABF researchers are using cellulose nanocrystals for low-cost 3D printing of biomedical stents used in angioplasty, making them more functional and biocompatible than stents from conventional materials.
Source: Adobe Stock

ABF researchers are using cellulose nanocrystals for the strong microneedles needed for low-cost vaccination of pigs against swine influenza.
Source: Adobe Stock

ABF researchers are using cellulose nanocrystals to produce stronger and lighter hockey sticks.
Source: iStock

6.3. Lignin Challenge

The Lignin Challenge 1.0 sub-program supports early-stage work to demonstrate technical feasibility of lignin in high-value applications with potential for commercialization. The funding call closed on March 15, 2018.

Successful grant recipients received up to $25,000 in ABF funding for their lignin research; a quantity of lignin from the West Fraser commercial lignin recovery plant in Hinton, AB; access to InnoTech Alberta's researchers, capacity and facilities to assist in the successful delivery of their project; and must complete their projects within one year.

During 2018-19, 16 Lignin Challenge projects were active, with total project costs of more than $860,000. These are summarized in the table below. Performance measures and financial information are available in the appendices.

Projects

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFL-18-002 *Research and Innovation* ---- **Amit Kumar** University of Alberta ---- **$198,250**	**Development of renewable isocyanates from lignin**	*Use lignin in creation of biodegradable isocyanates, a vital component in the manufacture of rigid foams and protective coatings for equipment and structures like truck beds, trailers, boats, foundations and decks.*
BFL-18-003 *Research and Innovation* ---- **Suong Hoa** Concordia University ---- **$30,000**	**Odor reduction of lignin-polyolefin composites using carbon nanomaterials**	*Reduce lignin odour in consumer products using a new manufacturing process and mixing lignin with odor-controlling chemicals like activated carbon.*
BFL-18-004 *Research and Innovation* ---- **Zhi Li** University of Alberta	**Lignin-derived carbon nanomaterials with large interlayer distance for Na-ion batteries**	*Use lignin in the carbon electrodes of sodium-ion batteries to improve energy storage capacity.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
---- **$45,000**		
BFL-18-005 *Research and Innovation* ---- **Boffito Daria** Ecole Polytechnique ---- **$71,500**	**Delignification and esterification of lignin to biolubricants and biodispersants under ultrasound irradiation**	*Pre-processing of lignin using ultrasound to speed up its conversion into lubricants, dispersants and other products.*
BFL-18-006 *Research and Innovation* ---- **Daniel S. Alessi** University of Alberta ---- **$35,500**	**Electrochemical detection and reduction of hexavalent chromium using carbonized lignin electrodes**	*Use lignin in low-cost carbonized electrodes to remove hexavalent chromium and other organic pollutants from wastewater.*
BFL-18-008 *Research and Innovation* ---- **Neda Nazemifard** University of Alberta ---- **$47,500**	**Continuous flow reactor for reaction optimization and production of lignin-based phenol formaldehyde resin**	*Optimize continuous production process of lignin-based resin for use in coatings, insulation, lamination, wood bonding and plywood adhesives.*
BFL-18-009 *Research and Innovation* ---- **Weizheng Shen** Northern Alberta Institute of Technology ---- **$29,060**	**Synthesis of carbon quantum dots for bioimaging by utilizing lignin from West Fraser Mills**	*Create carbon quantum dots from lignin for use in health care bioimaging applications.*
BFL-18-010 *Industry Co-Funded* ----	**Preparation of esterified lignin for bioplastics and**	*Develop a process that converts lignin into coatings for building materials and bioplastics for packaging and 3-D printing applications.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
Scott Renneckar University of British Columbia ---- **$50,000**	**hydrophobic coatings**	
BFL-18-011 *Research and Innovation* ---- **Xihua Wang** University of Alberta ---- **$25,000**	**Laser-induced graphene formation on lignin/cellulose films**	*Use lignin to create low-cost sheets of the new supermaterial, graphene, for use in flexible electronics, solar cells, high-frequency transistors, photo-detectors, optical modulators, energy generation and storage, sensors and other bioapplications.*
BFL-18-012 *Industry Co-Funded* ---- **Scott Renneckar** University of British Columbia ---- **$50,000**	**Development of ultralight and highly flexible 99% lignin-based fibrous sponges and insulation materials**	*Use lignin for ultralight and highly elastic sponges and insulation materials.*
BFL-18-013 *Research and Innovation* ---- **Feng Jiang** University of British Columbia ---- **$76,800**	**Improving LignoForceTM lignin processability for reconstruction into hierarchical structures**	*Increase the purity and quality of lignin powder through improvements to the manufacturing process.*
BFL-18-014 *Research and Innovation* ---- **Behzad Ahvazi** InnoTech Alberta ----	**Molecular weight determination of West Fraser's lignin in black liquor**	*Standardize the molar mass of lignin to enhance market access of lignin-based products.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
$32,000		
BFL-18-015 *Research and Innovation* ---- **Yang Liu** University of Alberta ---- **$25,000**	**Production of slow release fertilizer from municipal wastewater through lignin-induced struvite precipitation**	*Use lignin to recover phosphorous from municipal wastewater to improve drinking water, enhance recreational activities and produce fertilizer.*
BFL-18-016 *Research and Innovation* ---- **Bipro Dhar** University of Alberta ---- **$30,000**	**Mitigation of methane flux from oil sands tailing ponds using lignin**	*Use lignin for GHG emission reduction from oilsands tailing ponds.*
BFL-18-020 *Research and Innovation* ---- **David Stuart** University of Alberta ---- **$50,000**	**Bioconversion of crude lignin to high value biosurfactant**	*Convert lignin into non-toxic, biodegradable surfactants for industrial use or as fine ingredients in cleaning supplies or personal care products.*
BFL-18-021 *Research and Innovation* ---- **Fanny Monteil-Rivera** National Research Council of Canada ---- **$71,700**	**Aqueous alkaline depolymerisation of lignin for application in phenolic resins**	*Modify the manufacturing process to increase the quantity of lignin used in the adhesive for engineered wood products like OSB and plywood.*

** Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*

ABF researchers are exploring ways to use lignin in the rigid foams and protective coatings of equipment and structures like truck beds, trailers, boats, foundations and decks.
Source: 123RF

ABF researchers are using lignin to create low-cost sheets of the new supermaterial, graphene, for use in flexible electronics, solar cells, high-frequency transistors, photo-detectors, optical modulators, energy generation and storage, sensors and other bioapplications.
Source: Adobe Stock

6.4. Research & Innovation Subprogram

The Research and Innovation subprogram aim is to develop, within a four-year timeframe, bioindustrial products and technologies at any stage of the innovation continuum that would add value to Alberta's biomass. Co-funding from industry was encouraged, but not mandatory.

During 2018-19, 13 Research and Innovation projects were active, with total project costs of almost $5.5 million. These are summarized in the table below. Performance measures and financial information are available in the appendices.

Projects

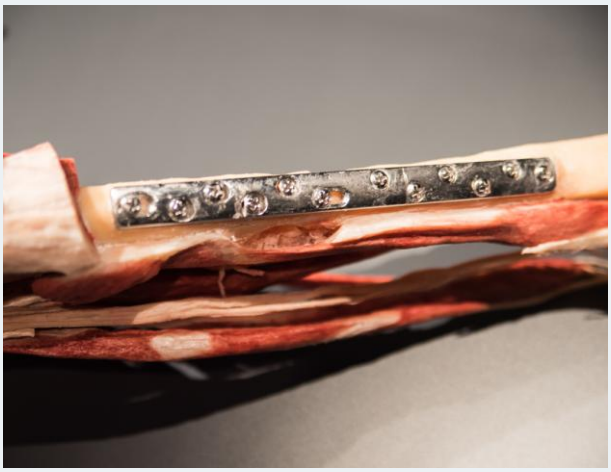
PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFR-16-005 *Research and Innovation* ---- **Rokib Hassan** BarrierTEK Inc. **$411,825**	**Development of a liquid-applied moisture vapor permeable air barrier and fire-retardant nano-composite emulsion**	*Create a nano-composite emulsion that offers moisture vapour barrier permeability and water resistance performance, easy application and strong surface adhesion for use over house barrier wraps. Testing has been completed on panel material and proponent is currently investigating next steps in evaluation and certification process.*
BFR-16-006 *Research and Innovation* ---- **Yang Lui** University of Alberta ---- **$240,000**	**Optimization of CNC hydrogel for inhibition of biofilm formation on medical devices**	*Development of a CNC-based coating which prevents the adhesion of bacteria and biofilms on the surface of medical devices. If successful, this treatment could drastically reduce the occurrence of infections, improving patient outcomes and reducing the cost and burden on the healthcare system. Patent has been granted and researchers are engaged in licensing discussions with a several companies.*
BFR-16-015 *Research and Innovation* ---- **Yaman Boluk** University of Alberta ---- **$300,000**	**Development of modified CNF for controlled atmosphere food packaging films**	*Develop intelligent food packaging to extend the life of packaged produce through the control of oxygen, carbon dioxide and moisture.*
BFR-16-017	**CNC-based**	*Develop a light sensitive CNC-dye that creates singlet oxygen.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
Research and Innovation ---- **Belinda Heyne** University of Calgary ---- **$403,750**	**antimicrobial coatings for biofilm prevention**	*This singlet oxygen becomes an extremely effective biocide to control biofilms. Technical work continues, and we are helping these researchers engage with various potential industrial end-users.*
BFR-16-027 *Research and Innovation* ---- **Jonathan Curtis** University of Alberta ---- **$676,925**	**Development of bio-based resins for industrial use in fibre mat-based composite biomaterials**	*Create a plant oil-based epoxy resin for use in the manufacture of natural fibre composite mats (e.g. automotive panels). Now working with a commercial partner to scale-up production.*
BFR-16-028 *Research and Innovation* ---- **Jeffrey Stryker** University of Alberta ---- **$712,400**	**Catalytic deoxygenative depolymerization of lignin under mild conditions - production of "petrochemicals" from waste biomass**	*Investigate the creation of biochemicals from kraft pulp mill waste materials. Continue to optimize the catalysts involved, with good progress being made.*
BFR-16-032 *Research and Innovation* ---- **Cagri Ayranci** University of Alberta ---- **$417,375**	**Engineering lignin as a precursor for carbon fiber using novel biodegradation and purification techniques**	*Investigate the use of lignin as a feedstock in the production of high value carbon fibre. Critical for its use is the removal of impurities, as those greatly impact quality. Initial electrospinning has shown good potential for success.*
BFR-16-033 *Research and Innovation* ---- **Mohammad Reza Vakili** University of Alberta ----	**Fabrication of CNC-based bionanocomposite for bone tissue repair**	*Generate biocompatible composites to mimic and assist the structure and function of natural bone healing. Work continues under this project, with progress being made in the formulation of composites and their adhesion to bone cells.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
$232,188		
BFR-16-046 *Research and Innovation* ---- **Xihua Wang** University of Alberta ---- **$249,900**	**CNC materials for novel applications in electronics and optoelectronics**	*Replace synthetic polymers with CNC-based composites to leverage their renewable, bio-based properties. Has resulted in two peer-reviewed publications and a provision patent, with another two publications at submission stage.*
BFR-16-058 *Research and Innovation* ---- **Dominic Sauvageau** University of Alberta ---- **$468,650**	**Co-conversion of C1 wastes from Alberta energy and pulp and paper sectors by methylotrophic bacteria**	*Create processing strategies, based on the behaviour of these organisms, for the recovery and production of valuable products from methane and methanol used as co-substrates.*
BFR-16-060 *Industry Co-funded* ---- **David Bressler** University of Alberta ---- **$748,400**	**Design and application of a high-pressure microwave drop-in biofuel reactor system**	*Improve upon existing biofuel production technology, with the inclusion of microwave heating. Custom-designed microwave equipment is fully operational and work is progressing.*
BFR-16-072 *Research and Innovation* ---- **Paolo Mussone** Northern Alberta Institute of Technology ---- **$172,450**	**Catalytic distillation for the production of di-methyl ether from Alberta biomass**	*Produce a low-carbon footprint, renewable fuel through a single unit operation, benefitting from significant cost reductions.*
BFR-16-078 *Research and Innovation* ----	**Engineered microbial cells for the biosynthesis of**	*Use microbial cells in the conversion of agricultural and forestry waste into compounds that could replace commonly used chemicals. The study has resulted in one peer-reviewed*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
David Stuart University of Alberta ---- **$442,794**	**industrial oleochemicals**	*publication, with a second publication being prepared and a review of patents is underway. Application for second stage funding of this work is currently being sought from AAFC AgriScience Program funds.*

** Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*



ABF researchers are using cellulose nanocrystals to reconstruct bone.
Source: Adobe Stock

ABF researchers are using cellulose nanocrystals in a coating in urinary catheters to prevent the adhesion of bacteria leading to urinary tract infection.
Source: Adobe Stock

6.5. Biomaterials Pursuit Subprogram

The Biomaterials Pursuit subprogram aims to further promising results seen through early-stage investments, such as those in the subprograms for CNC Challenge and Research and Innovation. It offers enhanced levels of funding to projects that warrant further support for scale up. Funding of up to $300,000 per project is available for periods of up 2.5 years, with the project concluding by Dec. 31, 2020. The expectation at this stage of funding is for proponents to engage with industrial partners to demonstrate the commercial potential in their work.

During 2018-19, 10 Biomaterials Pursuit projects were active, with total project costs of almost $4.5 million. These are summarized in the table below. Performance measures and financial information are available in the appendices.

Projects

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFM-18-001 *Research and Innovation* ---- **Belinda Heyne** University of Calgary ---- **$334,350**	**Light-activated cellulose nanocrystals for a clean environment**	*Use light-activated cellulose nanocrystals to eliminate antibiotic-resistant microbes. Continuation of project initially funded under CNC Challenge 2.0.*
BFM-18-002 *Research and Innovation* ---- **Cagri Ayranci** University of Alberta ---- **$376,800**	**Towards assembling nature back together: additive manufacturing of large-scale CNC-reinforced lignin components for green composites**	*Investigate the manufacturing, characterizing and modeling of cellulose nanocrystalline-lignin composites for 3D, additive manufacturing. Extension of projects supported under CNC Challenge 2.0 and the ABF Research & Innovation subprograms.*
BFM-18-003 *Industry Co-Funded* ---- **Zhi Li** University of Alberta ---- **$463,750**	**Application of cellulose nanocrystals in flexible and wearable energy storage devices**	*Use cellulose nanofibrils and cellulose nanocrystals in batteries for use in clothing and wearable accessories. Continuation of project funded under the ABF Research & Innovation subprogram.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFM-18-006 *Research and Innovation* ---- **Yang Liu** University of Alberta ---- **$430,000**	**Cellulose nanocrystal hydrogels as an effective tool for biofilm formation inhibition on medical devices: a step towards green non-adhesive catheters**	*Use cellulose nanocrystals in a coating in urinary catheters to prevent the adhesion of bacteria leading to urinary tract infection.*
BFM-18-017 *Industry Co-Funded* ---- **Aman Ullah** University of Alberta ---- **$607,770**	Development of new green bottles from carbon dioxide and waste cooking oil	*Combine cellulose nanocrystals, excessive greenhouse gas emissions and waste cooking oil to create biodegradable plastic bottles.*
BFM-18-021 *Research and Innovation* ---- **Afsaneh Lavasanifar** University of Alberta ---- **$322,000**	**Development of CNC-based muco-adhesive and muco-retentive nanogels**	*Use cellulose nanocrystals in muco-adhesives that deliver drugs to cancerous lesions in the mouth without washing off.*
BFM-18-023 *Research and Innovation* ---- **Xihua Wang** University of Alberta ---- **$77,850**	**CNC/polymer hybrid optical diffusers for LED lighting**	*Use cellulose nanocrystals in optical diffusers for LED lighting to achieve uniform backlighting, brightness enhancement, efficiency improvement and increased sensitivity in LCD, LED and other optoelectronic devices.*
BFM-18-030 *Research and Innovation* ---- **Andrew Myles** National Research Council of Canada ---- **$720,000**	CNCs as degradable elements in thermoset materials	*Use cellulose nanocrystals in epoxy adhesives for downhole tools and other thermoset materials that remove easily with very high heat.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFM-18-033 *Industry Co-Funded* ---- **Paolo Mussone** Northern Alberta Institute of Technology ---- **$280,000**	**Utilization of fly ash from Alberta pulp and paper mills for the removal of hydrogen sulfide from raw natural gas**	*Use boiler fly ash to adsorb hydrogen sulfide produced by natural gas facilities.*
BFM-18-046 *Industry Co-Funded* ---- **Cristian Scurtescu** SmileSonica Inc. ---- **$841,040**	**Development of a novel oral care product line**	*Use cellulose nanocrystals in new oral care products like gel, mouthwash and sprays to provide long-lasting relief from mouth dryness.*

* *Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*

ABF researchers are combining cellulose nanocrystals, excessive greenhouse gas emissions and waste cooking oil to create biodegradable plastic bottles.
Source: Adobe Stock

ABF researchers are using cellulose nanocrystals in new oral care products like gel, mouthwash and sprays to provide long-lasting relief from mouth dryness.
Source: Adobe Stock

6.6. Lignin Pursuit Subprogram

The Lignin Pursuit subprogram offers enhanced levels of funding to projects that warrant further support for research and scale-up in value-add utilization of lignin. Funding of up to $300,000 per project is available, along with a quantity of lignin from industry partner, West Fraser Mills. The project must conclude by January 1, 2022. The expectation at this stage of funding is for proponents to engage with industrial partners to demonstrate the commercial potential in their work.

During 2018-19, four Lignin Pursuit projects were active, with total project costs of $1.4 million. These are summarized in the table below. Performance measures and financial information are available in the appendices.

Projects

PROJECT NUMBER *Alignment* --- **Project Investigator** Organization --- **Total Project Funding***	**Project Name**	**Project Summary**
BFG-18-004 *Research and Innovation* --- **Simon Park** University of Calgary --- **$510,000**	**Development of carbon nanofibers from electrospun lignin using intensive pulsed light**	*Use lignin as quick-to-make, low-cost carbon nanofibres in fillers, sensors, electrodes and filters.*
BFG-18-019 *Research and Innovation* --- **David Bressler** University of Alberta --- **$406,416**	**Bio-processing of amallin lignin for the production of lipids for drop-in diesel and bio-jet fuels**	*Use chemicals to convert lignin into lipids for later processing into drop-in diesel and bio-jet fuels.*
BFG-18-020 *Research and Innovation* --- **Zhi Li** University of Alberta --- **$305,000**	**Lignin-derived carbon nanostructures for Na-ion batteries and capacitors: a low-cost grid energy storage solution**	*Use lignin in low-cost energy storage devices to buffer fluctuations in renewable electricity from wind and solar energy.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFG-18-028 *Industry Co-Funded* ---- **Martin Feng** FPInnovations ---- **$179,000**	**Pilot plant demonstrations of lignin modification of MDF fibre for economic, environmental and product benefits**	*Pilot plant trials to demonstrate feasibility of replacing conventional fossil-fuel-based adhesive in medium- and high-density fibreboards with greener lignin-based adhesive.*

** Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*

ABF researchers are using lignin in the carbon electrodes of sodium-ion batteries to improve energy storage capacity.
Source: Adobe Stock

ABF researchers are using lignin to recover phosphorous from municipal wastewater to improve drinking water, enhance recreational activities and produce fertilizer.
Source: InnoTech Alberta

6.7. Equipment Utilization Subprogram

The Equipment Utilization subprogram aimed to encourage increased usage of bioindustrial assets by pre-commercial and commercial proponents to facilitate development of their projects. Subscription to this program was low and it has been discontinued.

During 2018-19, one Equipment Utilization project drew to a close, with a total project cost of almost $170,000. It is summarized in the table below. Performance measures and financial information are available in the appendices.

Projects

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFE-15-003 *Industry Co-funded* ---- **Dan Madlung** BioComposites Group ---- **$168,000**	**Research and development of hemp fibre-based mat products**	*Investigate structural and non-structural hemp-based fibre mats with increased strength and stiffness, potentially replacing glass fibre mats.*

* *Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project*.

Researchers at the Vegreville, AB site of InnoTech Alberta examine hemp plants in experimental field plots that test new approaches to growing hemp in Alberta. Hemp plants comprise five valuable components: bast fibre, hurd, flower, seed and seed oil.
Source: InnoTech Alberta

6.8. Product and Technology Commercialization Subprogram

The Product and Technology Commercialization subprogram was aimed to help high-quality projects scale up to pilot stage or develop a prototype. Projects must have been ready to commercialize within three years.

During 2018-19, one Product and Technology Commercialization project was active, with a total project cost of almost $3 million. It is summarized in the table below. Performance measures and financial information are available in the appendices.

Multinational specialty chemicals company, Hexion Canada, could have a commercial production plant launch by the end of 2019 to produce lignin-based resin for plywood and engineered wood products manufacturers like West Fraser. Source: Marie Cusack

Projects

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFP-16-025 *Industry Co-funded* ---- **James Taylor** Hexion Canada ---- **$2,980,426**	**Novel steam preheating pilot unit to develop bio-based phenol formaldehyde resin technology for oriented strand board**	*Substitute or partially replace synthetic resins with naturally derived materials, with a focus on establishing pilot-scale steam preheating capacity and developing improved bio-based phenol formaldehyde resins. Mill trials beginning shortly.*

** Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*

6.9. **Invited Proposal Subprogram**

The Invited Proposal subprogram was aimed at offering support for high-quality projects that didn't align with existing funding subprograms. This subprogram was a continuous open call for proposals, and if selected, proponents were invited to submit full proposals for a thorough review. Criteria were quite broad to enable submissions from audiences not previously considered. This subprogram was discontinued in 2017-18 and replaced with the Opportunities subprogram.

During 2018-19, 11 Invited Proposal projects were active, with total project costs of almost $7.9 million. They are summarized in the table below. Performance measures and financial information are available in the appendices.

Alberta has enough forest and agricultural biomass to support 14 large commercial plants with G4's wood-based renewable natural gas technology (RNG) that would require 2,500 full time operational staff. RNG holds great potential to become a viable renewable energy source of the future, reduce greenhouse gas emissions, stimulate rural economic development and create skilled jobs.

Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"

ALBERTA INNOVATES

Projects

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
ABI-14-002 *Research and Innovation* ---- **Andriy Kovalenko** University of Alberta ---- **$1,009,800**	**Fabrication of a 4.5V supercapacitor stack prototype with electrode-grade nanoporous carbon from biochar using CNC-based inkjet printing**	*Use two locally produced biochars as a feedstock to develop nanoengineered carbon for supercapacitor (SC) applications. On physical activation and supercritical thermal treatment, carbon will be used in printable ink formulation to make SC electrodes on nanocellulose paper. Molecular theory of solvation will be used to rationally design carbon material and electrolyte composition. Using Origami assembly method, SC components will be integrated in a 0.9V cell and a 4.5V stack prototype.*
ABI-14-004 *Industry Co-funded* ---- **Amit Kumar** University of Alberta ---- **$320,000**	**Algae-based biomass for the production of fuels and chemicals**	*Evaluation of algae-based hydrogen and diluent production, including an energy and emission assessment.*
ABI-15-001 *Industry Co-funded* ---- **Bernhard Seifried** Ceapro Inc. ---- **$1,750,000**	**Implementing pressurized gas expanded technology at a commercial and demonstration scale to generate novel bio-based products with improved purity and functionality**	*Support construction of demonstration scale facility to produce highly porous and purified bionanomaterial and bioactive ingredients.*
ABI-16-002 *Industry Co-funded* ---- **Yaman Boluk** University of Alberta ---- **$240,000**	**Effects of aqueous suspension properties on the atomization and dispersibility of spray-dried cellulose nanocrystallite granules**	*Study the impact of electrolytes, surfactants and polymers in droplet formation and granule size. Leverages funding from a national funding competition, NSERC and Alberta Innovates.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
ABI-16-003 *Industry Co-funded* ---- **Karthik Shankar** University of Alberta ---- **$80,000**	**Advanced resonator- and imaging-based characterization of morphology and aggregation in cellulose nanocrystals and nanofibrils**	*Assess physical behaviour of nanocelluloses to improve understanding and facilitate application development. Leverages funding from a national funding competition, NSERC and Alberta Innovates.*
ABI-16-008 *Research and Innovation* ---- **Aman Ullah** University of Alberta ---- **$488,280**	**Scale-up trials for highly efficient and rapid plant oil conversion technology**	*Scale-up lipid conversion technology to assess commercialization applicability.*
ABI-16-009 *Research and Innovation* ---- **Jonathan Curtis** University of Alberta ---- **$491,000**	**Flame retardant polyols from oilseed crops**	*Develop phosphate / lipid-based additives to impart flame retardancy to bio-based foams and other polyurethanes.*
ABI-17-001 *Industry Co-funded* ---- **Amit Kumar** University of Alberta ---- **$2,527,000**	**Biobattery – decentralized production of fuel from forest and agricultural waste**	*Develop a decentralized, waste-to-value-added facility using technology developed by Fraunhofer. It will also demonstrate the feasibility of biobattery technology in Alberta, from wood chips and straw, with potential for small and remote communities, for the production of biofuels and biochemicals.*
ABI-17-004 *Industry Co-funded* ---- **Cagri Ayranci** University of Alberta---- **$160,000**	**Reinforcing effect of cellulose nanocrystals on polyamide-6 polymeric nano-composite films and electrospun composite**	*Investigate the addition of CNC into Nylon 6 (one of the most commonly used polymers in the world) to generate design curves for engineers to promote large scale use of CNC in Nylon 6 applications of films and fibers/yarns.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
	nano-fiber yarns	
BIO-16-005 *Industry Co-funded* ---- **Vivek Bindiganavile** University of Alberta ---- **$483,000**	**Development and characterization of nano-engineered cement-based composites for sustainable construction**	*Improve the performance of cement-based systems through the incorporation of nanocelluloses.*
BIO-16-007 *Research and Innovation* ---- **Inder Singh** SBI Bioenergy ---- **$300,000**	**Development of biofuels research contribution fund for future research investment - SBI's 10 million litre renewable fuel demonstration initiative**	*Research new feedstocks for a commercial renewable fuel production plant that may also manufacture other new products like bioplastics and renewable solvents.*

** Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project.*

Soon we could use the wastewater from farms and feedlots to grow vast amounts of algae, which would not only clean the runoff water before it enters lakes and rivers, but also reduce greenhouse gas emissions and produce countless high-value green products for the energy, food and pharmaceutical industries.

Source: Alberta Bio Future Annual Report 2018-19, section 5 "Highlight Stories"

6.10 Opportunities Subprogram

The Opportunities subprogram replaced the Invited Proposal subprogram with the aim to support proposals that did not fit into the other subprogram offerings either for reason of scope, theme or timing. This subprogram closed on March 31, 2019, and all projects must be completed by Dec. 31, 2020.

During 2018-19, 12 Opportunities projects were active, with total project costs of $17.7 million. They are summarized in the table below. Performance measures and financial information are available in the appendices.

Projects

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFI-18-001 *Industry co-funded* ---- **Geoff Clarke** Alberta Pacific Forest Industries Inc. ---- **$722,500**	**CNC refinement, drying and blending for high-value applications**	*Improve economics and quality of cellulose nanocrystal production process to open new application markets.*
BFI-18-002 *Industry co-funded* ---- **Erik Larsen** EC Labs ---- **$246,281**	**Scale-up and production of natural personal care products**	*Support interim manufacturing capacity while the company's own Health Canada registered facility is being developed. EC Labs has created 40 new and innovative natural personal care product formulations using Alberta biomass.*
BFI-18-003 *Industry co-funded* ---- **Brian Grantham** West Fraser Mills (Hinton) ----	**Process validation for anaerobic digestion of foul condensates at a kraft pulp mill**	*Investigate an approach to processing waste materials new to kraft pulp mills in North America.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
$260,000		
BFI-19-025 *Industry Co-funded* ---- **Derek Sidders** Natural Resources Canada ---- **$310,000**	**Wood biomass recovery, pre-processing and supply-chain optimization of the mature Ellerslie short-rotation woody crop (SRWC) technical development site**	*Harvest the fast-growing woody biomass from a test site in Ellerslie and demonstrate supply-chain options as a renewable energy feedstock.*
BFI-19-026 *Industry co-funded* ---- **James Lockhart** NORAM Engineering & Constructors Ltd ---- **$248,031**	**Continuous isothermal plug flow CNC reactor demonstration - phase 2 upgrade**	*Test a new reactor design for cellulose nanocrystal production that uses less acid.*
BFI-19-029 *Research and Innovation* ---- **Yaman Boluk** University of Alberta ---- **$210,000**	**Production of hydrophobic cellulose nanocrystals (CNC) by spray drying process and their use in polypropylene composites**	*Develop a low-cost spray-drying process to produce high-strength cellulose nanocrystals that can easily disperse without clumping in polymers like plastics.*
BFI-19-031 *Research and Innovation* ---- **Anastasia Elias** University of Alberta ---- **$273,000**	**Use of Alberta-based bio-products as additives in green polymers for packaging**	*Use non-food plant additives from hemp and canola in production of bioplastics for packaging materials.*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
BFI-19-032 *Industry co-funded* ---- **Ying Hei Chui** University of Alberta ---- **$360,000**	**Use of cross-laminated timber in basement construction**	*Test a new concept for constructing house basements using cross laminated timber, replacing conventional concrete which is prone to cracks and moisture seepage.*
BFI-19-033 *Industry co-funded* ---- **Rory Koska** Alberta Forest Products Association ---- **$800,000**	**Alberta Woodworks! tech transfer**	*Extend technical support and information to stimulate use of wood and engineered wood products in construction.*
BFI-19-038 *Research and Innovation* ---- **Dan Madlung** BioComposites Group Inc. ---- **$659,882**	**First to commercialize a new green insulation material produced with Alberta hemp**	*Produce at commercial-scale competitively priced construction insulation from hemp, which is biodegradable and environmentally friendly.*
BFI-19-041 *Industry co-funded* ---- **John Lavery** SYLVIS Environmental Services Inc. ---- **$10,529,710**	**BIOSALIX: mine reclamation using fabricated soils and organic residuals to augment soil quality**	*Plant fast-growing willow trees on a coal mine site using municipal biosolids as a soil amendment, creating reclaimed land and a plantation of short rotation woody biomass as feedstock for bioenergy purposes.*
BFI-19-042 *Industry Co-funded*	**Advanced CNC-reinforced PHA bioplastics**	*Use cellulose nanocrystals in biodegradable plastic films for specialized agricultural and hydroponic practices, packaging of*

PROJECT NUMBER *Alignment* ---- **Project Investigator** Organization ---- **Total Project Funding***	**Project Name**	**Project Summary**
---- **William Bardosh** Terra Verdae Bioworks Inc. ---- **$3,120,000**		*seedlings, as well as food packaging.*

* *Total project funding includes Alberta Innovates funding and all other cash and in-kind contributions to the project*.

ABF researchers are aiming to harvest fast-growing willow trees on a coal mine site using municipal biosolids as a soil amendment. This will create reclaimed land and a plantation of short rotation woody biomass as feedstock for bioenergy purposes.
Source: Alberta Innovates

7. Knowledge Extension Details

An idea does not gain entry in the marketplace through research alone. The new knowledge gained through an ABF project must be diffused through the innovation ecosystem and the bioindustrial sector to move an idea through the innovation continuum into the marketplace. Knowledge is extended to other researchers, supporting organizations, investors and industry in many ways: presentations, meetings, seminars, conferences at domestic and international venues, and more. These interactions build engagement, generate awareness and excitement, and help to spread knowledge to a broader audience. They also lead to new connections who may contribute to advancement of an idea.

Knowledge is gained by the highly qualified personnel (HQP) who work on all ABF projects. This new knowledge helps to build up Alberta's workforce and expand capacity for future projects with post-doctoral fellows, PhD candidates, master's students, undergraduate students and other experts who are trained in the latest bioindustrial advances.

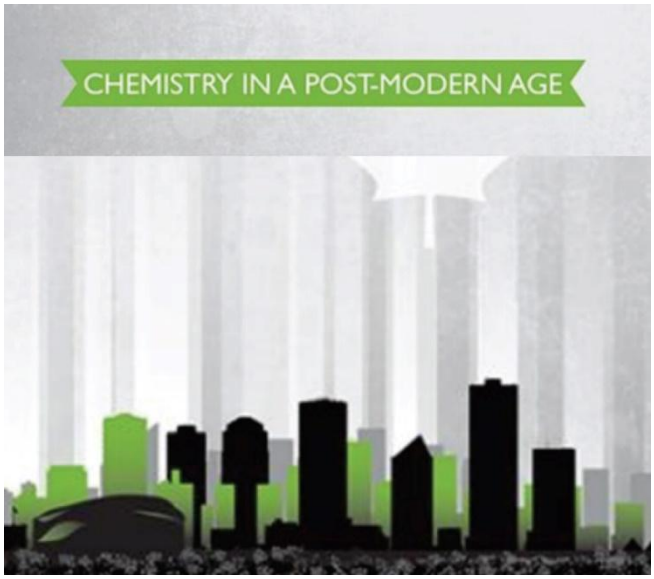
The performance measures chart and tables in Appendix A presents a summary of the outcomes of ABF projects in terms of HQP development and occurrences of knowledge management.

In addition to knowledge extension by the researchers within the ABF projects, the ABF Team themselves engage in many knowledge extension activities. The Team regularly interacts and collaborates with partners, proponents, researchers, industry, investors and other innovation support organizations. The Team members are knowledgeable about Alberta's bioindustrial sector, stimulate interest in research and innovation advances, and coordinate collaboration opportunities among researchers, entrepreneurs and investors.

This knowledge activity directly supports strategic priority three in the ABF grant agreement with Alberta Innovates: foster clusters that offer high growth potential to broaden Alberta's base.

The following section describes the ABF Team's main knowledge extension activities in 2018-19.

7.1. Pathways to Success for Green Fuels and Chemicals – Industry Speak



Alberta Innovates Bio hosted a one-day workshop on May 29, 2018, with the theme of “Pathways to Success for Green Fuels and Chemicals – Industry Speaks.” It was held as a breakout session during the 101st Canadian Chemistry Conference and Exhibition in Edmonton, AB. The event was supported by the University of Alberta, NAIT and the Alberta Innovates business line for Highly Qualified Personnel and Centre Investments. It was attended by more than 60 people from industry and academia.

Many speakers were from companies working in the bioindustrial space. This included the morning keynote by Ray Miller, Chief Business Officer, Verdezyne, Inc. who spoke on "Growing Sustainably – Lessons Learned in Developing and Launching New Bio-based Businesses in the Chemical Industry." Chris Tindal, Assistant Director, Commercial Aviation, Alternative Fuels Initiative gave the afternoon keynote. Panel speakers from LanzaTech, Enerkem and Hexion talked about Advances in Commercial Renewable Fuels, Emerging and Advanced Sustainable Materials and Emerging and Advanced Green Chemicals. Some 25 chemistry-based startups and small- to medium-sized companies gave presentations in the Company Pitch Session.

Following the workshop, a number of the speakers met with senior Alberta government officials and participated in an internal seminar at the University of Alberta.

7.2. **Alberta Innovates' Pursuing Added Value for Alberta Biomass Workshop**

Alberta Innovates Bio held a workshop on February 20-21, 2019, entitled "Pursuing Added Value for Alberta Biomass" at its Millwoods location in Edmonton, AB. The workshop was generously sponsored by Al-Pac and West Fraser, and InnoTech Alberta provided logistical support for on-site tours of the InnoTech CNC and CNF facilities.

The workshop served to meet the ABF grant requirement to host an annual industry-academic event. It was designed to foster networking among industry, students and academia, profile collaboration opportunities and promote Alberta as a hub for the development of products using cellulose nanocrystals, lignin and other value-added products. The event was very well received, exceeding the expectation that only 60 people would attend. In total, more than 135 people attended from academia (44%), industry (39%) and government (17%).

***Day 1 – CNC and CNF**:*

- Focused on CNC and CNF with an opening keynote address from Dr. Jo Anne Shatkin on the recent findings and ongoing activities around the health and safety classification of CNC and CNF.

- Presentations from some of the most important stakeholders in this field–Al-Pac, U.S. Forest Service and InnoTech Alberta. Their experts provided an overview of the current technical and commercial status and their predictions for future development and opportunities.

- Researchers presented on their projects' successes in developing applications for CNC and CNF. Most of the projects were funded by the Alberta Bio Future program.

More than 135 attendees listened to presentations on cellulose nanocrystals and lignin.
Source: Dr. Christophe Danumah

Attendees networked and viewed student posters after the workshop.
Source: Dr. Christophe Danumah

- Interested attendees toured the InnoTech Alberta CNC pilot plant and CNF production areas with InnoTech staff.

- Attendees networked at the closing reception and viewed the 38 graduate student posters on display. A panel of judges selected the top three posters and awarded each a $600 prize.

Day 2 - Lignin:

- Keynote from Dr. Michael Paleologou on the potential of lignin as a bioproduct platform.

-West Fraser and Hexion, two of the most important industry proponents of lignin in Alberta, gave presentations.

-Six researchers shared their projects' successes in developing applications for lignin.

7.3. Climate Change Innovation and Technology Framework Programs

The Climate Change Innovation and Technology Framework (CCITF) was launched in December 2017 by the Alberta government. It aims to achieve the goals of Alberta's Climate Leadership Plan through innovation and technology to reduce greenhouse gas emissions.

Two members of the ABF Team are co-leading subprograms with the broader CCITF program team to provide knowledge and expertise in the following framework areas: cleaner oil and gas, methane emissions reduction, low-carbon electricity, waste to value-added, green buildings and energy efficiency.

In 2018-19, 43 full proposals were selected for CCITF funding out of 241 applications to the following subprograms:

1. Clean Technology Development (co-lead: Dr. Christine Murray, ABF Team)
2. Clean Technology Networks
3. Clean Technology Commercialization
4. Clean Technology Business Innovation
5. Clean Technology Facility Support (co-lead: Patrick Guidera, ABF Team)

7.4. **Natural Resource Canada's Clean Growth Program**

The federal Clean Growth Program (CGP), which closed on March 5, 2018, aims to stimulate clean technology research, development and demonstration projects in Canada's energy, mining and forestry sectors. Some members of the ABF Team are collaborating with the broader CGP program team to provide knowledge and expertise about the production and use of advanced materials and bioproducts, especially in Alberta.

This program covers five areas focused on pressing environmental challenges and economic opportunities facing Canada's natural resource operations:

- Reducing greenhouse gas and air-polluting emissions.
- Minimizing landscape disturbances and improving waste management.
- Producing and using advanced materials and bioproducts.
- Producing and using energy efficiently.
- Reducing water use and impacts on aquatic ecosystems.

The program received more than 750 submissions, which are currently being evaluated for suitability of funding from CGP. Two of the submissions have received ABF funding and were active in the 2018-19 fiscal year. If they are selected for CGP funding, more details will be included in the 2019-20 ABF annual report.

7.5. **BioEconomy Alberta Team**

The BioEconomy Alberta team strives to nurture a thriving bioindustrial sector in Alberta. Led by Alberta Innovates Bio, including members of the ABF Team, It is an informal collaboration of more than 30 representatives from government, the research and innovation system, industry and academia. Team members have strong technical knowledge in biomaterials, biochemicals and bioenergy, and excellent business knowledge and relationships in the bioindustrial sector. The team meets monthly on business and marketing opportunities for the sector, maintains the website, and individually, provide advice, connections and information to entrepreneurs.

In 2018-19, the team met 10 times, including for a roundtable on Alberta's emerging cannabis industry. In fall 2018, the federal government instituted new legislation that changed the landscape for cannabis, cannabis products and industrial hemp products. Roundtable discussion covered current and future state opportunities in Alberta including: product development, investment, research and development, processing and waste management. Team members will be attending Health Canada's cannabis licencing webinar in May 2019.

Team members represented Alberta's bioindustrial sector at many local, national and international events. Events included BIO World Congress on Industrial Biotechnology; the hosting by Bioindustrial Innovation Canada, BIOTECanada, the Forest Products Association of Canada and FPInnovations of the BioDesign workshop; release of Canada's Bioeconomy Strategy: Leveraging our Strengths for a Sustainable Future in late May 2019; symposium at 101st Canadian Chemistry Conference and Exhibition 2018 called "Alberta Innovates' Pathways to Success for Green Fuels and Chemicals – Industry Speaks"; and Alberta Innovates' Inventure$ 2018. NAIT team members also attended: NAIT's 2nd Annual Industry Research Symposium, and Passmore Group Inc and advisors' Scaling Up 2018 - Competing in the Global Bioeconomy Market.

7.6. **Prairie BioEconomy Guild**

The Prairie BioEconomy Guild was established in 2013 with Alberta Innovates playing a key role. A variety of guest speakers have presented their insights into business development and research discoveries at the monthly Guild sessions in Edmonton, AB. The sessions offer the opportunity to exchange knowledge and network among business owners, researchers, developers, investors, government staff and other bioindustrial professionals. “I was very lucky to meet Patrick Guidera from Alberta Innovates at a Guild event,” said William Nkeuwa, a wood science PhD graduate from Laval University. “He introduced me to many of the professionals who attend the monthly events. As a result of these connections, I became employed by West Fraser Mills in Hinton, AB and then later by Norbord Inc. in High Level, AB.”

The Guild events aim to build relationships for a foundation of trust that will accelerate development of Alberta’s bioeconomy sector. In 2018-19, the Guild held 14 events, attended by more than 250 people from government, industry and academia. The invited expert speakers covered many bioindustrial topics ranging from ideas to promote innovation and knowledge exchange to the high-end applications of hemp and lignin.

More than 250 people have attended the monthly Guild events in the last year.
Source: Patrick Guidera

7.7. **Media Coverage**

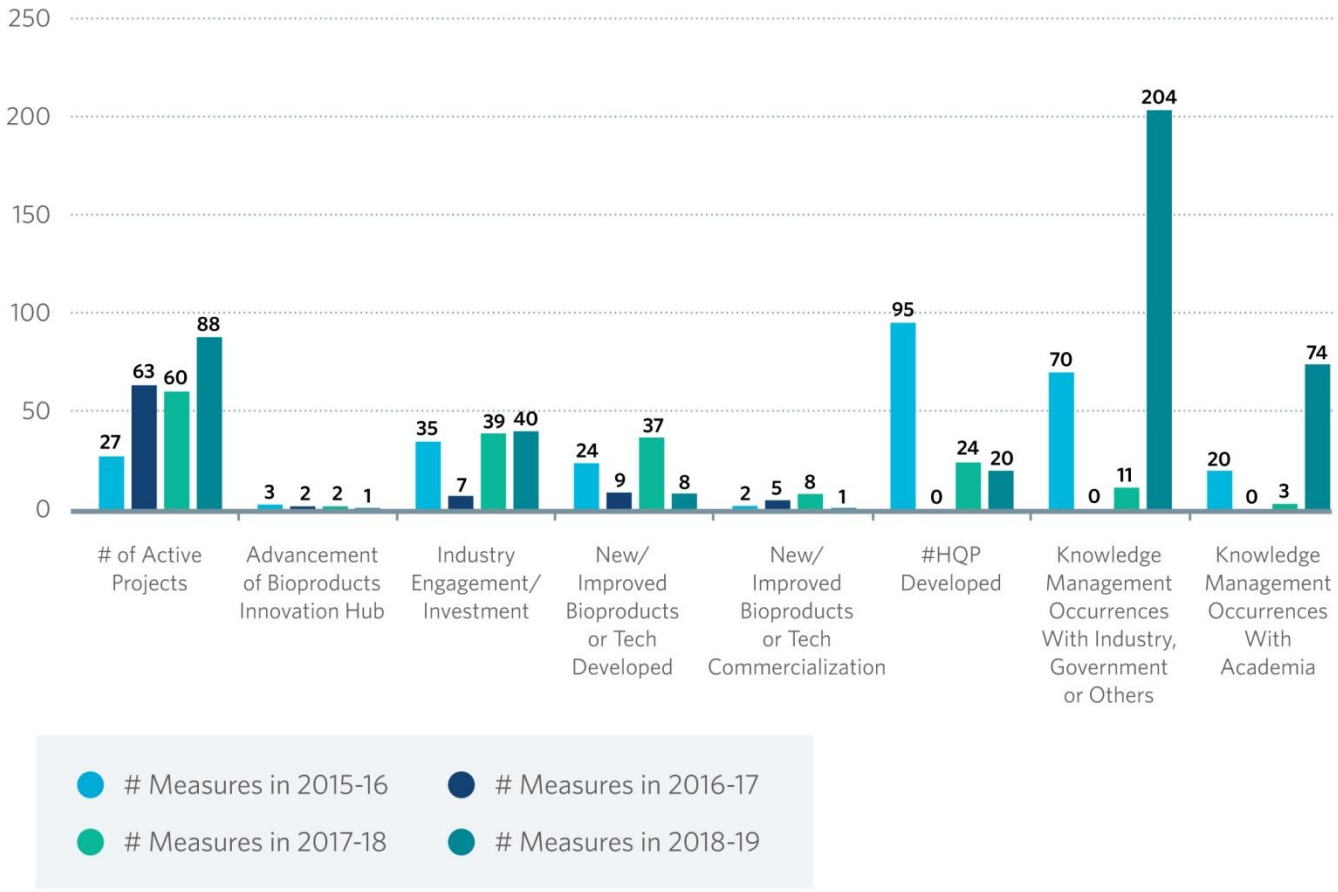
A summary of media coverage of ABF projects and events is included in Appendix C – Communications Report.

Appendix A – Performance Measures

Alberta Bio Future Program

SUMMARY OF PERFORMANCE MEASURES

As of March 31, 2019



1. Advancement of Bioproducts Innovation Hub[1] - # grand openings, # networks, other indication of growing critical mass.
2. Industry Engagement/Investment[2] - # companies involved.
3. New / Improved Bioproducts or Tech Developed[3] - # technologies developed, # patents, # licences, # successful scale-ups, # proof of concepts, # new concepts, # non-disclosure agreements. *(To avoid double-counting, for each new product/tech only one of these measures was counted in the final total regardless whether each measure was achieved.)*
4. New / Improved Bioproducts or Tech Commercialized[4]- # products experiencing first-time sales, # spin-off companies, # jobs created.
5. # HQP Developed[5]
6. Knowledge Management Occurrences with Industry, Government or Others[6] - # events hosted, # speaking opportunities, # articles, # news releases, # interviews, # trade shows with booth, # newsletter editions.
7. Knowledge Management Occurrences with Academia[7] - # events hosted, # speaking opportunities, # trade shows with booth, # papers published, # abstracts published.

ALBERTA INNOVATES

Alberta Bio Future Program - Performance Measures for Year 2 - April 1, 2015 to March 31, 2016

Subprogram	Alignment	# Active Projects	Outcomes						
			1. Advancement of Bioproducts Innovation Hub[1]	2. Industry Engagement/Investment[2]	3. New / Improved Bioproducts or Tech Developed[3]	4. New / Improved Bioproducts or Tech Commercialized[4]	5. # HQP Developed[5]	6. Knowledge Management Occurrences with Industry, Government or Others[6]	7. Knowledge Management Occurrences with Academia[7]
Networks	*Industry co-funded*	2	2	29	16	1	95	70	20
CNC Challenge	*Industry co-funded*								
CNC Challenge	*Research and Innovation*								
Research and Innovation	*Industry co-funded*								
Research and Innovation	*Research and Innovation*								
Biomaterials Pursuit	*Industry co-funded*								
Equipment Utilization	*Industry co-funded*	2							
Product and Technology Commercialization	*Industry co-funded*	4							
Invited Proposal	*Industry co-funded*	12	1	5	3	1			
Invited Proposal	*Research and Innovation*	7		1	5				
Opportunities	*Industry co-funded*								
Total		**27**	**3**	**35**	**24**	**2**	**95**	**70**	**20**

ALBERTA INNOVATES

Alberta Bio Future Program - Performance Measures for Year 3 - April 1, 2016 to March 31, 2017

Subprogram	Alignment	# Active Projects	Outcomes						
			1. Advancement of Bioproducts Innovation Hub[1]	2. Industry Engagement/ Investment[2]	3. New / Improved Bioproducts or Tech Developed[3]	4. New / Improved Bioproducts or Tech Commercialized[4]	5. # HQP Developed[5]	6. Knowledge Management Occurrences with Industry, Government or Others[6]	7. Knowledge Management Occurrences with Academia[7]
Networks	*Industry co-funded*								
CNC Challenge	*Industry co-funded*	1							
CNC Challenge	*Research and Innovation*	10							
Research and Innovation	*Industry co-funded*	2							
Research and Innovation	*Research and Innovation*	14		1					
Biomaterials Pursuit	*Industry co-funded*								
Equipment Utilization	*Industry co-funded*	4		1	1				
Product and Technology Commercialization	*Industry co-funded*	8			1				
Invited Proposal	*Industry co-funded*	13	1	4	3	5			
Invited Proposal	*Research and Innovation*	11	1	1	4				
Opportunities	*Industry co-funded*								
Total		**63**	**2**	**7**	**9**	**5**	**0**	**0**	**0**

ALBERTA INNOVATES

Alberta Bio Future Program - Performance Measures for Year 4 - April 1, 2017 to March 31, 2018

Subprogram	Alignment	# Active Projects	Outcomes						
			1. Advancement of Bioproducts Innovation Hub[1]	2. Industry Engagement/ Investment[2]	3. New / Improved Bioproducts or Tech Developed[3]	4. New / Improved Bioproducts or Tech Commercialized[4]	5. # HQP Developed[5]	6. Knowledge Management Occurrences with Industry, Government or Others[6]	7. Knowledge Management Occurrences with Academia[7]
Networks	*Industry co-funded*	4	1	3	2				2
CNC Challenge	*Industry co-funded*	1		1	1				
CNC Challenge	*Research & Innovation*	10		2	7	1			1
Research and Innovation	*Industry co-funded*	2		2	1				
Research and Innovation	*Research & Innovation*	14		5	13	0	1	5	
Biomaterials Pursuit	*Industry co-funded*	3		3					
Equipment Utilization	*Industry co-funded*	3		3	3				
Product and Technology Commercialization	*Industry co-funded*	4	1	4	2	4	10	1	
Invited Proposal	*Industry co-funded*	11		10	5	2	9	1	
Invited Proposal	*Research & Innovation*	5		3	3	1	4	4	
Opportunities	*Industry co-funded*	3		3					
Total		**60**	**2**	**39**	**37**	**8**	**24**	**11**	**3**

ALBERTA INNOVATES

Alberta Bio Future Program - Performance Measures for Year 5 - April 1, 2018 to March 31, 2019

Subprogram	Alignment	# Active Projects	Outcomes						
(* Reflects measures from project BIO-12-011, not active in 2018-19 but overlooked in 2017-18)			1. Advancement of Bioproducts Innovation Hub[1]	2. Industry Engagement / Investment[2]	3. New / Improved Bioproducts or Tech Developed[3]	4. New / Improved Bioproducts or Tech Commercialized[4]	5. # HQP Developed[5]	6. KM Occurrences with Industry, Government or Others[6]	7. Knowledge Management (KM) Occurrences with Academia[7]
Networks	*Industry co-funded*	3						82*	28*
CNC Challenge	*Industry co-funded*	2		1	2				
CNC Challenge	*Research & Innovation*	15			1		1		2
Lignin Challenge	*Industry co-funded*	2							
Lignin Challenge	*Research & Innovation*	14					5		
R & I	*Industry co-funded*	1			1		2		
R & I	*Research & Innovation*	12					4		4
Biomaterials Pursuit	*Industry co-funded*	4							
Biomaterials Pursuit	*Research & Innovation*	6					1		
Lignin Pursuit	*Industry co-funded*	1							
Lignin Pursuit	*Research & Innovation*	3						15	10
Equipment Utilization	*Industry co-funded*	1							
Product & Tech Commercialization	*Industry co-funded*	1			1	1	3	2	3
Invited Proposal	*Industry co-funded*	7					2		2
Invited Proposal	*Research & Innovation*	4	1	3	2			40	15
Opportunities	*Industry co-funded*	9		36	1		2	65	25
Opportunities	*Research & Innovation*	3							
Total		**88**	**1**	**40**	**8**	**1**	**20**	**204**	**74**

ALBERTA INNOVATES

Appendix B – Project List

TABLE LEGEND:

- **Subprograms** within ABF, conducted with an open call for proposals.
- **Alignment** with AI/EDT agreement: Industry co-funded=industry has provided cash funding; Research and Innovation=industry has not provided cash.
- **Committed Funds from ABF**=the EDT funds for ABF; **Committed Funds from AI**=AI-Bio core funds for ABF; **Committed Funds from Others**=funds from contributors including proponent (includes cash and in-kind); **Total Project Cost**=committed funding from all sources (includes cash and in-kind). All committed funds are over the life of the project.

Alberta Bio Future Program

Projects in progress or completed during period April 1, 2018 – March 31, 2019 (funding represents investments over the entire length of project)

Subprogram	Project Number	Alignment	Project Start Date	Project End Date	Project Name	Project Investigator	Organization	Committed Funds ($) From ABF	Committed Funds ($) From AI	Committed Funds ($) From Others	Total Project Cost ($)
Networks and Knowledge Extension	ABI-17-002	*Industry co-funded*	1-Sep-2017	30-Aug-2022	*NSERC/Cenovus/Alberta Innovates Associate Industrial Research Chair in Energy and Environmental Systems Engineering*	Amit Kumar	University of Alberta		$500,000	$1,600,000	$2,100,000
Networks and Knowledge Extension	BIO-16-010	*Industry co-funded*	1-Jul-2016	30-Jun-2021	*NSERC Industrial Research Chair in the Industrialization of Building Construction*	Mohamed Al-Hussein	University of Alberta		$250,000	$3,680,000	$3,930,000
Networks and Knowledge Extension	BIO-16-014	*Industry co-funded*	1-Sep-2016	31-Aug-2021	*Massive timber panel system behaviour study and its application in buildings – in collaboration with Industrial Research Chair - Dr. Chui*	Haitao Yu	Landmark Group of Companies INC		$500,000	$2,882,849	$3,382,849
CNC Challenge	BFC-18-003	*Research and Innovation*	3-Sep-2018	2-Sep-2019	*Development of durable multifunctional cellulose nancrystals and copper nanocomposite inks*	Simon Park	University of Calgary		$25,000		$25,000
CNC Challenge	BFC-18-005	*Research and Innovation*	1-Sep-2018	31-Aug-2019	*Zinc oxide – cellulose nanocrystal hybrids for smart food packaging*	Kenneth Bosnick	National Research Council of Canada		$25,000	$25,000	$50,000

CNC Challenge	BFC-18-006	*Research and Innovation*	1-May-2018	30-Apr-2019	*Methodology to disperse CNCs into hydrophobic polymers, such as polyethylene*	Todd C. Sutherland	University of Calgary		$25,000		$25,000
CNC Challenge	BFC-18-007	*Research and Innovation*	1-May-2018	30-Apr-2019	*Cellulose nanocrystal reinforced polyurethane rigid foams*	Jonathan Curtis	University of Alberta		$25,000	$19,250	$44,250
CNC Challenge	BFC-18-008	*Research and Innovation*	1-Sep-2018	31-Aug-2019	*Nutrient recovery from municipal wastewater using cellulose nanocrystals: towards a sustainable wastewater management*	Yang Liu	University of Alberta		$25,000		$25,000
CNC Challenge	BFC-18-009	*Research and Innovation*	1-May-2018	30-Apr-2019	*Using CNC to improve the acid resistance of cement-based composites for sewer tunnel rehabilitation*	Wei Liu	University of Alberta		$25,000	$30,132	$55,132
CNC Challenge	BFC-18-012	*Industry co-funded*	1-Apr-2018	31-Mar-2019	*CNC-templated silicon-based nanostructures*	Johnathan Veinot	Applied Quantum Materials Inc.		$25,000	$34,000	$59,000
CNC Challenge	BFC-18-014	*Research and Innovation*	1-Apr-2018	31-Mar-2019	*Hockey stick reinforcement using cellulose nanocrystals*	David Bressler	University of Alberta		$25,000	$48,500	$73,500
CNC Challenge	BFC-18-018	*Research and Innovation*	1-May-2018	30-Apr-2019	*Drug and ion-deliverable nanomedicines directed by cellulose nanocrystalline biomaterials*	Vladimir Michaelis	University of Alberta		$25,000	$25,000	$50,000
CNC Challenge	BFC-18-021	*Research and Innovation*	1-Apr-2018	31-Mar-2019	*Cellulose nanocrystalline-modified filtration media for enhanced efficiency in ultrafine particulate matter removal*	Zhi Li	University of Alberta		$25,000	$5,000	$30,000
CNC Challenge	BFC-18-022	*Research and Innovation*	1-Sep-2018	31-Aug-2019	*Enhancing the dispersion and reinforcing effect of cellulose nanocrystal fillers in coating and nanocomposite applications*	Tizazu Mekonnen	University of Waterloo		$25,000	$14,000	$39,000
CNC Challenge	BFC-18-024	*Research and*	1-May-2018	30-Apr-2019	*Development of a swine influenza vaccine using cellulose nanocrystal*	Hyo-Jick Choi	University of Alberta		$25,000	$276,693	$301,543

		Innovation			*microneedles*						
CNC Challenge	BFC-18-026	*Research and Innovation*	1-Apr-2018	30-Jun-2019	*Towards CNC reinforced multifunctional shape memory polymer composite biomedical stents produced by additive manufacturing*	Cagri Ayranci	University of Alberta		$25,000	$12,000	$37,000
CNC Challenge	BFC-18-027	*Industry co-funded*	3-Sep-2018	3-Sep-2019	*Strain-induced uniaxial alignment of CNC/polymer composites for optimized mechanical reinforcement*	Kenneth Harris	National Research Council of Canada		$25,000	$115,000	$140,000
CNC Challenge	BFC-18-034	*Research and Innovation*	1-Sep-2018	31-Aug-2019	*Cellulose nanocrystal-gel nanocomposite adsorbents for the purification of contaminated water*	Darren Makeiff	National Research Council of Canada		$25,000	$25,000	$50,000
CNC Challenge	BFC-18-035	*Research and Innovation*	1-May-2018	30-Apr-2019	*Silver decorated CNC for water analysis and purification*	Mark T. McDermott	University of Alberta		$25,000	$9,600	$34,600
CNC Challenge	BFC-18-037	*Research and Innovation*	1-May-2018	30-Apr-2019	*Engineering of functionalized cellulose nanocellulose biomaterial for nerve regeneration*	Amir Sanati-Nezhad	University of Calgary		$25,000		$25,000
Lignin Challenge	BFL-18-002	*Research and Innovation*	1-May-2018	30-Apr-2019	*Development of renewable isocyanates from lignin*	Amit Kumar	University of Alberta	$25,000		$173,250	$198,250
Lignin Challenge	BFL-18-003	*Research and Innovation*	1-May-2018	1-May-2019	*Odor reduction of lignin-polyolefin composites using carbon nanomaterials*	Suong Hoa	Concordia University	$25,000		$5,000	$30,000
Lignin Challenge	BFL-18-004	*Research and Innovation*	1-Jul-2018	31-May-2019	*Lignin-derived carbon nanomaterials with large interlayer distance for Na-ion batteries*	Zhi Li	University of Alberta	$25,000		$20,000	$45,000
Lignin Challenge	BFL-18-005	*Research and Innovation*	1-Oct-2018	27-Sep-2019	*Delignification and esterification of lignin to biolubricants and biodispersants under ultrasound irradiation*	Boffito Daria	Ecole Polytechnique	$25,000		$46,500	$71,500
Lignin Challenge	BFL-18-	*Research*	1-Jun-	1-Apr-	*Electrochemical detection and*	Daniel S.	University of	$25,000		$10,500	$35,500

	006	*and Innovation*	2018	2019	*reduction of hexavalent chromium using carbonized lignin electrodes*	Alessi	Alberta				
Lignin Challenge	BFL-18-008	*Research and Innovation*	1-Jun-2018	1-Jun-2019	*Continuous flow reactor for reaction optimization and production of lignin-based phenol formaldehyde resin*	Neda Nazemifard	University of Alberta	$25,000		$22,500	$47,500
Lignin Challenge	BFL-18-009	*Research and Innovation*	1-May-2018	31-Mar-2019	*Synthesis of carbon quantum dots for bioimaging by utilizing lignin from West Fraser Mills*	Weizheng Shen	Northern Alberta Institute of Technology (NAIT)	$25,000		$4,060	$29,060
Lignin Challenge	BFL-18-010	*Industry co-funded*	1-Jun-2018	31-May-2019	*Preparation of esterified lignin for bioplastics and hydrophobic coatings*	Scott Renneckar	University of British Columbia	$25,000		$25,000	$50,000
Lignin Challenge	BFL-18-011	*Research and Innovation*	1-Sep-2018	31-Aug-2019	*Laser-induced graphene formation on lignin/cellulose films*	Xihua Wang	University of Alberta	$25,000			$25,000
Lignin Challenge	BFL-18-012	*Industry co-funded*	1-Jun-2018	31-May-2019	*Development of ultralight and highly flexible 99% lignin-based fibrous sponges and insulation materials*	Scott Renneckar	University of British Columbia	$25,000		$25,000	$50,000
Lignin Challenge	BFL-18-013	*Research and Innovation*	3-Sep-2018	30-Aug-2019	*Improving LignoForceTM lignin processability for reconstruction into hierarchical structures*	Feng Jiang	University of British Columbia	$25,000		$51,800	$76,800
Lignin Challenge	BFL-18-014	*Research and Innovation*	1-Oct-2018	31-Jul-2019	*Molecular weight determination of West Fraser's lignin in black liquor*	Behzad Ahvazi	InnoTech Alberta	$25,000		$7,000	$32,000
Lignin Challenge	BFL-18-015	*Research and Innovation*	1-Oct-2018	30-Sep-2019	*Production of slow release fertilizer from municipal wastewater through lignin-induced struvite precipitation*	Yang Liu	University of Alberta	$25,000			$25,000
Lignin Challenge	BFL-18-016	*Research and Innovation*	1-Aug-2018	31-Jul-2019	*Mitigation of methane flux from oil sands tailing ponds using lignin*	Bipro Dhar	University of Alberta	$25,000		$5,000	$30,000
Lignin Challenge	BFL-18-020	*Research and*	15-Aug-2018	14-Aug-2019	*Bioconversion of crude lignin to high value biosurfactant*	David Stuart	University of Alberta	$25,000		$25,000	$50,000

		Innovation									
Lignin Challenge	BFL-18-021	*Research and Innovation*	27-Aug-2018	31-Mar-2019	*Aqueous alkaline depolymerisation of lignin for application in phenolic resins*	Fanny Monteil-Rivera	National Research Council of Canada	$25,000		$46,700	$71,700
Research and Innovation	BFR-16-005	*Research and Innovation*	1-May-2016	31-Dec-2020	*Development of a liquid-applied moisture vapor permeable air barrier and fire retardant nano-composite emulsion*	Rokib Hassan	BarrierTEK Inc.	$308,869		$102,956	$411,825
Research and Innovation	BFR-16-006	*Research and Innovation*	1-Sep-2016	31-Aug-2018	*Optimization of CNC hydrogel for inhibition of biofilm formation on medical devices*	Yang Liu	University of Alberta	$190,000		$50,000	$240,000
Research and Innovation	BFR-16-015	*Research and Innovation*	1-Jun-2016	31-May-2019	*Development of modified cellulose nanofibrils for controlled atmosphere (CA) food packaging films*	Yaman Boluk	University of Alberta	$213,750		$86,250	$300,000
Research and Innovation	BFR-16-017	*Research and Innovation*	4-Jul-2016	3-Jul-2019	*CNC-based antimicrobial coatings for biofilm prevention*	Belinda Heyne	University of Calgary	$403,750			$403,750
Research and Innovation	BFR-16-027	*Research and Innovation*	1-May-2016	30-Apr-2019	*Development of bio-based resins for industrial use in fibre-mat-based composite biomaterials*	Jonathan Curtis	University of Alberta	$392,825		$284,100	$676,925
Research and Innovation	BFR-16-028	*Research and Innovation*	1-May-2016	31-Mar-2019	*Catalytic deoxygenative depolymerization of lignin under mild conditions - production of "petrochemicals" from waste biomass*	Jeffrey Stryker	University of Alberta	$353,400		$359,000	$712,400
Research and Innovation	BFR-16-032	*Research and Innovation*	1-Aug-2016	31-Jul-2019	*Engineering lignin as a precursor for carbon fiber using novel biodegradation and purification techniques*	Cagri Ayranci	University of Alberta	$306,375		$111,000	$417,375
Research and Innovation	BFR-16-033	*Research and*	1-Sep-2016	1-Mar-2019	*Fabrication of CN- based bionanocomposite for bone tissue*	Mohammad Reza Vakili	University of Alberta	$172,188		$60,000	$232,188

		Innovation			*repair*						
Research and Innovation	BFR-16-046	*Research and Innovation*	1-May-2016	30-Apr-2018	*CNC materials for novel applications in electronics and optoelectronics*	Xihua Wang	University of Alberta	$167,200		$82,700	$249,900
Research and Innovation	BFR-16-058	*Research and Innovation*	1-May-2016	30-Apr-2020	*Co-conversion of C1 wastes from the Albertan energy and pulp and paper sectors by methylotrophic bacteria.*	Dominic Sauvageau	University of Alberta	$348,650		$120,000	$468,650
Research and Innovation	BFR-16-060	*Industry co-funded*	1-Apr-2016	31-Mar-2020	*Design and application of a high pressure microwave drop-in biofuel reactor system*	David Bressler	University of Alberta	$362,900		$385,500	$748,400
Research and Innovation	BFR-16-072	*Research and Innovation*	1-Sep-2016	31-Aug-2018	*Catalytic distillation for the production of di-methyl ether from Alberta biomass*	Paolo Mussone	NAIT	$162,450		$10,000	$172,450
Research and Innovation	BFR-16-078	*Research and Innovation*	1-Jun-2016	31-May-2019	*Engineered microbial cells for the biosynthesis of industrial oleochemicals*	David Stuart	University of Alberta	$291,573		$151,221	$442,794
Biomaterials Pursuit	BFM-18-001	*Research and Innovation*	1-Mar-2018	31-Mar-2020	*Light-activated cellulose nanocrystals for a clean environment*	Belinda Heyne	University of Calgary	$223,000		$111,350	$334,350
Biomaterials Pursuit	BFM-18-002	*Research and Innovation*	1-Mar-2018	31-Oct-2020	*Towards assembling nature back together: additive manufacturing of large-scale CNC-reinforced lignin components for green composites*	Cagri Ayranci	University of Alberta		$300,000	$76,800	$376,800
Biomaterials Pursuit	BFM-18-003	*Industry co-funded*	1-Mar-2018	30-Nov-2020	*Application of cellulose nanocrystals in flexible and wearable energy storage devices*	Zhi Li	University of Alberta	$290,000		$173,750	$463,750
Biomaterials Pursuit	BFM-18-006	*Research and Innovation*	1-Sep-2018	31-Aug-2020	*Cellulose nanocrystal hydrogels as an effective tool for biofilm formation inhibition on medical devices: a step towards green non-adhesive catheters*	Yang Liu	University of Alberta	$300,000		$130,000	$430,000

Biomaterials Pursuit	BFM-18-017	*Industry co-funded*	1-Jun-2018	30-Sep-2020	*Development of new green bottles from carbon dioxide and waste cooking oil*	Aman Ullah	University of Alberta	$243,620		$364,150	$607,770
Biomaterials Pursuit	BFM-18-021	*Research and Innovation*	1-Sep-2018	31-Dec-2020	*Development of CNC-based muco-adhesive and muco-retentive nanogels*	Afsaneh Lavasanifar	University of Alberta	$274,000		$24,000	$322,000
Biomaterials Pursuit	BFM-18-023	*Research and Innovation*	1-Jun-2018	31-May-2019	*CNC/polymer hybrid optical diffusers for LED lighting*	Xihua Wang	University of Alberta	$50,000		$27,850	$77,850
Biomaterials Pursuit	BFM-18-030	*Research and Innovation*	3-Sep-2018	3-Sep-2020	*CNCs as degradable elements in thermoset materials*	Andrew Myles	National Research Council of Canada	$300,000		$90,000	$720,000
Biomaterials Pursuit	BFM-18-033	*Industry co-funded*	1-Jul-2018	30-Jun-2020	*Utilization of fly ash from Alberta pulp and paper mills for the removal of hydrogen sulfide from raw natural gas*	Paolo Mussone	Northern Alberta Institute of Technology (NAIT)	$140,000		$140,000	$280,000
Biomaterials Pursuit	BFM-18-046	*Industry co-funded*	1-Jun-2018	30-Nov-2020	*Development of a novel oral care product line*	Cristian Scurtescu	SmileSonica Inc.	$300,000		$270,020	$841,040
Lignin Pursuit	BFG-18-004	*Research and Innovation*	1-Mar-2019	31-Aug-2021	*Development of carbon nanofibers from electrospun lignin using intensive pulsed light*	Simon Park	University of Calgary		$253,500	$256,500	$510,000
Lignin Pursuit	BFG-18-019	*Research and Innovation*	1-Mar-2019	1-Jan-2022	*Bio-processing of amallin lignin for the production of lipids for drop-in diesel and bio-jet fuels*	David Bressler	University of Alberta		$244,667	$165,749	$406,416
Lignin Pursuit	BFG-18-020	*Research and Innovation*	1-Mar-2019	30-Sep-2021	*Lignin-derived carbon nanostructures for Na-ion batteries and capacitors: a low-cost grid energy storage solution*	Zhi Li	University of Alberta		$255,000	$50,000	$305,000
Lignin Pursuit	BFG-18-028	*Industry co-funded*	1-Mar-2019	31-Dec-2019	*Pilot plant demonstrations of lignin modification of MDF fibre for economic, environmental and product benefits*	Martin Feng	FPInnovations		$125,000	$54,000	$179,000

Equipment Utilization	BFE-15-003	*Industry co-funded*	11-Feb-2016	16-Dec-2018	*Research and development of hemp fibre-based mat products*	Madlung, Dan	BioComposites Group Inc.	$100,000		$68,000	$168,000
Product and Technology Commercialization	BFP-16-025	*Industry co-funded*	1-Sep-2016	31-Jan-2019	*Novelsteam preheating pilot unit to develop bio-based phenol formaldehyde resin technology for oriented strand board manufacture*	James Taylor	Hexion Canada Inc	$500,000		$2,480,426	$2,980,426
Invited Proposal	ABI-14-002	*Research and Innovation*	9-Jun-2014	8-Apr-2019	*Fabrication of a 4.5V supercapacitor stack prototype with electrode-grade nanoporous carbon from biochar using CNC-based inkjet printing*	Andriy Kovalenko	U of A		$270,000	$739,800	$1,009,800
Invited Proposal	ABI-14-004	*Industry co-funded*	1-Jan-2015	31-Dec-2018	*Algae-based biomass for the production of fuels and chemicals*	Amit Kumar	U of A		$100,000	$220,000	$320,000
Invited Proposal	ABI-15-001	*Industry co-funded*	1-Apr-2015	16-Apr-2018	*Implementing pressurized gas expanded technology at a commercial and demonstration scale to generate novel bio-based products with improved purity and functionality. ($0.8 M total project, $0.4 K EDT, $0.4K AI Bio)*	Bernhard Seifried	Ceapro Inc.		$400,000	$1,350,000	$1,750,000
Invited Proposal	ABI-16-002	*Industry co-funded*	1-Sep-2016	31-Aug-2019	*Effects of aqueous suspension properties on the atomization and dispersibility of spray dried cellulose nanocrystal granules*	Yaman Boluk	University of Alberta		$120,000	$120,000	$240,000
Invited Proposal	ABI-16-003	*Industry co-funded*	1-Aug-2017	31-Jul-2020	*Advanced resonator- and imaging-based characterization of morphology and aggregation in CNCs and CFs*	Karthik Shankar	University of Alberta		$50,000	$30,000	$80,000
Invited Proposal	ABI-16-008	*Research and Innovation*	15-Sep-2016	14-Sep-2019	*Scale-up trials for highly efficient and rapid plant oil conversion technology*	Aman Ullah	University of Alberta		$293,580	$194,700	$488,280
Invited Proposal	ABI-16-009	*Research and Innovation*	1-Oct-2016	30-Sep-2018	*Flame retardant polyols from oilseed crops*	Jonathan Curtis	University of Alberta		$329,000	$162,000	$491,000

Invited Proposal	ABI-17-001	*Industry co-funded*	1-Feb-2017	30-Jun-2019	*Biobattery – decentralized production of fuel from forest and agricultural waste*	Amit Kumar	University of Alberta	$300,000		$2,227,000	$2,527,000
Invited Proposal	ABI-17-004	*Industry co-funded*	1-Sep-2017	31-Aug-2020	*Reinforcing effect of cellulose nanocrystals on polyamide-6 polymeric nano-composite films and electrospun composite nano-fiber yarns*	Cagri Ayranci	FPInnovations		$80,000	$80,000	$160,000
Invited Proposal	BIO-16-005	*Industry co-funded*	1-Jan-2016	31-Dec-2018	*Development and characterization of nano-engineered cement-based composites for sustainable construction*	Vivek Bindiganavile	University of Alberta		$150,000	$333,000	$483,000
Invited Proposal	BIO-16-007	*Research and Innovation*	15-May-2016	15-Oct-2018	*Development of biofuels research contribution fund for future research Investment - SBI's 10 million litre renewable fuel demonstration initiative*	Inder Singh	SBI Bioenergy Inc.		$300,000		$300,000
Opportunities	BFI-18-001	*Industry co-funded*	18-Jan-2018	31-Mar-2020	*CNC refinement, drying and blending for high value applications*	Geoff Clarke	Alberta Pacific Forest Industries Inc.		$520,000	$202,500	$722,500
Opportunities	BFI-18-002	*Industry co-funded*	1-Mar-2018	28-Feb-2020	*Scale-up and production of natural personal care products*	Erik Larsen	EC Labs		$25,201	$221,080	$246,281
Opportunities	BFI-18-003	*Industry co-funded*	28-Mar-2018	28-Feb-2019	*Process validation for anaerobic digestion of foul condensates at a kraft pulp mill*	Brian Grantham	West Fraser Mills (Hinton)		$120,000	$140,000	$260,000
Opportunities	BFI-19-025	*Industry co-funded*	1-Jan-2019	30-Sep-2020	*Wood biomass recovery, pre-processing and supply-chain optimization of the mature Ellerslie short-rotation woody crop (SRWC) technical development site*	Derek Sidders	Natural Resources Canada (NRCan)	$130,000		$180,000	$310,000
Opportunities	BFI-19-026	*Industry co-funded*	2-Jan-2019	30-Aug-2019	*Continuous isothermal plug flow CNC reactor demonstration - phase 2 upgrade*	James Lockhart	NORAM Engineering & Constructors Ltd	$142,000		$100,031	$248,031

Opportunities	BFI-19-029	*Research and Innovation*	1-Jan-2019	31-Dec-2020	*Production of hydrophobic cellulose nanocrystals (CNC) by spray drying process and their use in polypropylene composites*	Yaman Boluk	University of Alberta	$150,000		$60,000	$210,000
Opportunities	BFI-19-031	*Research and Innovation*	1-Jan-2019	31-Dec-2020	*Use of Alberta-based bio-products as additives in green polymers for packaging*	Anastasia Elias	University of Alberta	$183,000		$90,000	$273,000
Opportunities	BFI-19-032	*Industry co-funded*	1-Jan-2019	31-Dec-2020	*Use of cross-laminated timber in basement construction*	Ying Hei Chui	University of Alberta	$200,000		$160,000	$360,000
Opportunities	BFI-19-033	*Industry co-funded*	1-Jan-2019	31-Dec-2020	*Alberta Woodworks! tech transfer*	Rory Koska	Alberta Forest Products Association (AFPA)	$110,000		$690,000	$800,000
Opportunities	BFI-19-038	*Research and Innovation*	1-Jan-2019	31-May-2020	*First to commercialize a new green insulation material produced with Alberta hemp*	Dan Madlung	BioComposites Group Inc.		$200,000	$459,882	$659,882
Opportunities	BFI-19-041	*Industry co-funded*	1-Feb-2019	1-Nov-2021	*BIOSALIX: mine reclamation using fabricated soils and organic residuals to augment soil quality*	John Lavery	SYLVIS Environmental Services Inc.		$1,500,000	$9,029,710	$10,529,710
Opportunities	BFI-19-042	*Industry co-funded*	1-Feb-2019	31-Mar-2021	*Advanced CNC-reinforced PHA bioplastics*	William Bardosh	Terra Verdae Bioworks Inc.		$350,000	$2,770,000	$3,120,000

Appendix C – Communications Report

Communications activities for the Alberta Bio Future program during 2018-19 included:

- Promotion of the Pursuing Added Value for Alberta Biomass Workshop, hosted by the bioindustrial team of Alberta Innovates on Feb. 20-21, 2019, via email blasts and social media. The workshop focused on advancing research and application of cellulose nanocrystals (CNC), cellulose nanofibrils (CNF) and lignin. See section 7 for more details about this knowledge extension activity.

- AI co-ordinated regular articles in issues of Logging and Sawmilling Journal through 2018-19 to raise awareness about AI's bioindustrial-related activities of interest to the forest sector. The magazine is found online at http://forestnet.com/. The AI articles are included in a regular section of the magazine called "The Edge" (see details and links below).

- Communications support was provided to publicize ABF funding calls on the website, via email blasts to ABF's stakeholder base, via social media and each month in The Loop, the Alberta Innovates newsletter with approximately 12,000 external subscribers.

- An ABF impact story was featured in The Loop:

    - Canadian Olympic bobsleigh and luge athletes and their international competitors at the 2022 Winter Games in Beijing will be sliding on a track constructed from concrete reinforced with a unique, natural additive invented in Alberta. The concrete additive is manufactured from industrial hemp, a fibre known for its strength and durability, and developed by Calgary company Canadian Greenfield Technologies Corp. Funding from Alberta Bio Future helped the company take its idea from the lab and develop it into a commercially successful industrial bioproduct.

Media Coverage:

- An AI-written story featuring SBI BioEnergy, a company funded by ABF, appeared in an insert that ran nationally in print editions of the Financial Post on Dec. 18, 2018, as part of a sponsored campaign called Clean Innovation. The campaign was posted on websites including www.industryandbusiness.ca and Environmental and Science Engineering Magazine. It was also distributed digitally in several cleantech association newsletters and shared via social media.

Logging and Sawmilling Journal, The Edge:

- July-Aug 2018: “Alberta Innovates to co-host lignin conference as industry ramps up new resin products.” https://forestnet.com/LSJissues/2018_july_august/edge.php.
- September 2018: ‘‘Alberta supports early-stage projects to investigate new applications for lignin.” https://forestnet.com/LSJissues/2018_sept/edge.php.
- October 2018: “Mapping lignin's path forward a common theme at international conference.” https://forestnet.com/LSJissues/2018_october/edge.php
- Dec-Jan 2018-19: “Alberta Innovates aims to raise profile of tree farming, supports wood fibre recovery project in Edmonton.” https://forestnet.com/LSJissues/2019_jan_dec/edge.php.

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Writing support provided by Corporate Communications and Planning

Graphic design support provided by id8 design group