

# BITUMEN BEYOND COMBUSTION

HOW OIL SANDS CAN HELP THE WORLD  
REACH NET-ZERO EMISSIONS AND CREATE  
ECONOMIC OPPORTUNITIES FOR ALBERTA  
AND CANADA

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## About Alberta Innovates

ALBERTA INNOVATES MANAGES NEARLY 1,300 PROJECTS IN A PORTFOLIO VALUED AT \$1.33 BILLION. WE WORK WITH INNOVATORS IN ALL SECTORS OF THE ECONOMY AND ALL CORNERS OF THE PROVINCE TO DRIVE ENTREPRENEURSHIP, APPLIED RESEARCH AND INDUSTRY DEVELOPMENT. With our impact-based funding programs and services, we are transforming energy systems for a net-zero world, promoting the responsible use of land and water, leveraging provincial strengths in agriculture, and contributing to improved health and well-being by harnessing digital tech and data. We are also advancing emerging technologies and strengthening entrepreneurship for a strong and diversified economy. We operate in 11 locations with more than one million sq. ft. of industrial testing and lab facilities, and 600 acres of farmland. We employ nearly 600 highly skilled scientists, business and technical professionals. From funding to commercialization, we are Alberta's innovation engine!

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# FOREWORD

Alberta is a globally significant centre of energy production and expertise, and a growing centre of clean technology expertise.

Oil and gas will still be in demand over the near term while the world transitions to new fuels and energy sources. We must reconcile this reality with the environmental imperative to reduce if not eliminate emissions from this sector. As Alberta's most comprehensive research and innovation agency, Alberta Innovates is addressing this urgent challenge by reimagining how the province's key energy resources are developed and used.

Net-zero emissions and a viable resource industry can be possible when one approaches the problem in a different way. Alberta's natural resources, bitumen included, can contribute to the Canadian economy during the energy transition and be part of a net-zero solution over the long term.

Alberta Innovates has developed a strategy to transform bitumen from oil sands. In our 2021 Bitumen Beyond Combustion paper, we proposed utilizing the carbon in bitumen in a value chain of non-combustion products instead of releasing it through combustion of transportation fuels. These products made from bitumen can make transportation more energy efficient, infrastructure less energy intensive and more durable, and renewable generation and energy storage more economical. But global and economic conditions have changed since 2021, and so we are pleased to present this updated paper with new analyses and revised projections.

The premise remains the same. By directing bitumen toward a higher value stream, emissions from processing can be sequestered through carbon capture and storage technologies. Bitumen can be diverted away from fuel combustion emissions, and products made from bitumen can displace other high-GHG intensity products and reduce downstream GHG emissions.

We find the opportunity for bitumen beyond combustion to be compelling – based on scientific expertise, fiscal realism and our deeply shared commitment to a healthy planet and low-carbon future.

We understand that trillions of dollars' worth of investment will be required to transition to a net-zero economy. But we can create a multibillion-dollar cleantech engine in Alberta that will propel a net-zero economy. We're excited by this potential, and our promising research and results to date. But significant investment and policy courage will be required to turn the bitumen beyond combustion vision into reality.

By looking beyond convention, we can set in motion the next evolution of our resource industry.

**Laura Kilcrease**, CEO  
*Alberta Innovates*

# ACKNOWLEDGEMENT

This discussion paper has been prepared by Alberta Innovates staff. Comments were sought from more than 30 external organizations and individuals to review the ideas, assumptions, key conclusions and recommendations in our 2021 draft paper and to bring additional perspectives. All comments from external reviewers were considered but not necessarily reflected in the final version published in November 2021. Conditions have changed in the last two years, prompting us to revisit and update our 2021 analyses and projections in this revised paper issued in November 2023.

Alberta Innovates is solely responsible for the content of this discussion paper. Reviewers' willingness to provide comments does not represent their consent and/or endorsement of ideas, assumptions, conclusions and recommendations in this paper. Still, Alberta Innovates once again sincerely acknowledges and thanks the following organizations and individuals for providing valuable comments and suggestions in 2021:

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We acknowledge the contributions of the late Clem Bowman, founding chairman of the Alberta Oil Sands Technology Research Authority (AOSTRA) and president of the Alberta Research Council, who left a long-lasting impact on Alberta's oil sands industry.

## EXECUTIVE SUMMARY

The past three years have seen the greatest upheaval in energy markets in 50 years since the oil embargo of 1973. The COVID pandemic brought record low prices, with crude briefly trading at negative value. Then the Russian invasion of Ukraine brought on a global energy crisis with a rapid increase in energy prices and spiraling inflation rates in much of the world. These events have led to increased fossil fuel consumption and higher greenhouse gas (GHG) emissions. Some oil-producing companies have scaled back their plans to reduce the amount of oil and gas they produce. Others have argued that global oil demand will continue to increase through 2045 and 2050 (OPEC, 2023; ExxonMobil, 2023).

In spite of this energy crisis, policies, strategies and plans to achieve net-zero emissions (NZE) continue to be developed around the world, and energy transitions in electric power generation are taking place rapidly. The Government of Alberta released its Emissions Reduction and Energy Development (ERED) Plan, announcing its goal to reach net-zero carbon neutrality by 2050. The Government of Canada remains committed to its goal of NZE by 2050. The United States has greatly accelerated efforts to lower its economy-wide GHG emissions through the Inflation Reduction Act adopted in 2022 (EPA, 2023). The pathway to NZE by 2050 remains open, but it has narrowed since 2021 (International Energy Agency [IEA], 2023).

Alberta Innovates has developed a vision for Bitumen Beyond Combustion (BBC). We believe that the Alberta oil sands could contribute to achieving NZE goals if this resource was used to create valued products and not just combustible fuels. The BBC strategy calls for a greater portion of bitumen production to be diverted away from fuel production and dedicated to the manufacture of high-value materials. In doing so, the carbon from the bitumen would remain trapped within the products and not released into the atmosphere. Through BBC, the carbon in oil sands would become an asset. BBC products could make transportation more energy efficient, infrastructure less energy intensive and longer-lasting, and renewable electricity generation and energy storage more economical. Instead of contributing to the emissions problem, bitumen could contribute to energy efficiency solutions.

This document updates the BBC strategy from 2021 in light of the complex changes in energy markets of the last three years. We examine the roles that BBC may play and impacts it can have in a changed world. We are convinced more than ever that BBC can help the world reach net-zero emissions and create economic opportunities for Alberta and Canada.



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## Bitumen for high-value products

Bitumen is a sticky, viscous form of petroleum trapped in sand found in northern Alberta. It is processed to produce transportation fuels and other petroleum products. Bitumen has a lower value than conventional crudes when used as a source for transportation fuels.

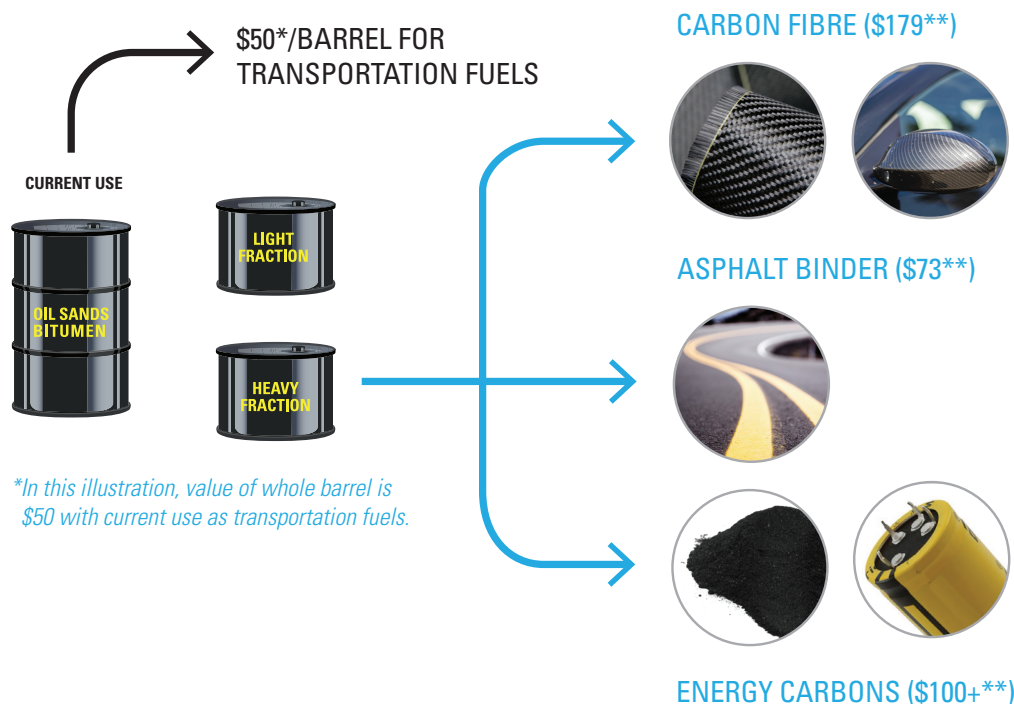
The central concept behind the BBC strategy is that the heavy fraction in bitumen would be diverted from fuels production and instead be used to generate products with growing demand around the world. Since conception of the BBC program in 2016, Alberta Innovates has been working to assess market opportunities and develop new products and technologies (see Section 2 for details). Some key BBC products (products that can be made from bitumen) include carbon fibre, asphalt binder and energy carbons (activated carbon and hard carbon) for electrical storage in supercapacitors and sodium-ion batteries. Market demand for these products has been growing and will continue to grow in a net-zero emissions future. For example, the Chinese carbon fibre market has been growing at a CAGR of more than 19 per cent.

As shown in Figure 1 below, if the heavy fraction is used to make carbon fibre, it could add an estimated \$179 to that barrel of bitumen. At the same time, the light fraction would become more valuable since it can be shipped and refined more easily. Using \$50 as the price for a barrel of bitumen (five-year average using bitumen valuation methodology), the total value of the bitumen barrel would increase from \$50 to \$233. Further value addition can be realized when carbon fibre made from bitumen is used to manufacture goods such as automobile parts.

Asphalt binder made from bitumen is superior to other sources. If the heavy fraction of the barrel was used to make asphalt binder, the added value would be \$73. For energy carbons, the added value could be more than \$100 per barrel.

Figure 1

### Benefits of using BBC for high-value products



*\*In this illustration, value of whole barrel is \$50 with current use as transportation fuels.*

*\*\*Value of BBC products that can be extracted from one barrel bitumen.*

Exporting one million barrels per day of bitumen will generate \$18 billion per year in gross revenue based on \$50 per barrel. As shown in Table 1 below, if the same volume of bitumen was used to generate BBC products in Alberta, the potential revenue would rise to \$42 billion per year: \$28 billion from BBC products and \$14 billion from sales of light fraction of the bitumen. The markets for BBC products are large and growing and have the potential to use Alberta’s future bitumen production. The actual amount of bitumen converted to BBC products in the future will depend on successfully developing new production technologies and demonstrating the value of BBC products. Significant additional economic benefit and thousands of new jobs could be realized as a result.

**Table 1**

**Revenue projection with and without BBC products for one million barrels per day bitumen production (\$50/bbl based on five-year bitumen valuation)**

	Bitumen (bbl/d)	Sales Price (CAD)	Total Revenue (Annual, CAD)
Bitumen sold as crude for fuels	1,000,000	\$50/bbl	\$18B
Bitumen used for BBC products	1,000,000		\$42B
Heavy fraction for BBC	480,000	\$163/bbl	\$28B
Light fraction for fuels	520,000	\$72/bbl	\$14B

## BBC for GHG emissions reduction

BBC products offer compelling options for GHG emissions reduction as well. Emissions reduction can be achieved in three ways: diverting bitumen away from combustion, replacing higher-intensity products and reducing downstream GHG emissions when BBC products are in use.

- BBC products can replace existing products with high-emission intensities. For example, life-cycle analysis indicates that the GHG intensity of bitumen-derived carbon fibre may be 52 per cent lower than that of existing commercial polyacrylonitrile (PAN) carbon fibre (Kumar et al., 2021). Similarly, improved technology could reduce GHG intensity for asphalt production by up to 30 per cent on a per barrel basis.
- Carbon fibre composites in lightweight vehicles increase fuel efficiency and reduce GHG emissions by 22 to 36 per cent on a life-cycle basis as compared to a conventional vehicle (Kumar et al., 2021). Similar benefits can be found when carbon fibre is used for rail cars, shipping containers and airplanes. Carbon fibre in composite wind turbine blades enables the generation of ultra-low GHG emissions electricity. The use of carbon fibre in concrete infrastructure adds durability, longevity and reduces cracking compared to existing construction methods. Activated carbon for rapid electrical storage in supercapacitors enables more efficient use of renewable energy by complementing battery technologies, while hard carbon is essential for the emerging sodium ion battery market. Using premium asphalt binder derived from Alberta bitumen increases the longevity of road surfaces, requiring less reconstruction and the associated emissions.
- For every million barrels of bitumen used for BBC, 480,000 barrels could be diverted for non-combustion products. Combustion of this oil as liquid fuels would generate 70 million tonnes per year of GHG emissions. When the final BBC products are used, combustion emissions would be avoided and emissions would be further reduced by making vehicles lighter, by enhancing electrical energy storage, and by enabling longer life of road surfaces

and infrastructure. Since bitumen is exported for fuels to be used in other countries, both the combustion-related emissions of fuels, and the end-use emission reductions from BBC products would follow the consumer. As a result, not all the emission reductions would occur in Canada.

## BBC in various emissions scenarios

We have analyzed BBC’s role and impact in representative scenarios including the following:

- *IEA’s Stated Policies Scenario (STEPS)* based on current climate change policies around the world. ExxonMobil’s global outlook is very similar to STEPS in terms of global oil demand.
- Net-zero emissions scenarios represented by the *IEA Net-Zero Emissions (NZE) by 2050 Scenario* (IEA 2021, 2023); and by the *Canada Energy Regulator [CER], 2023*.

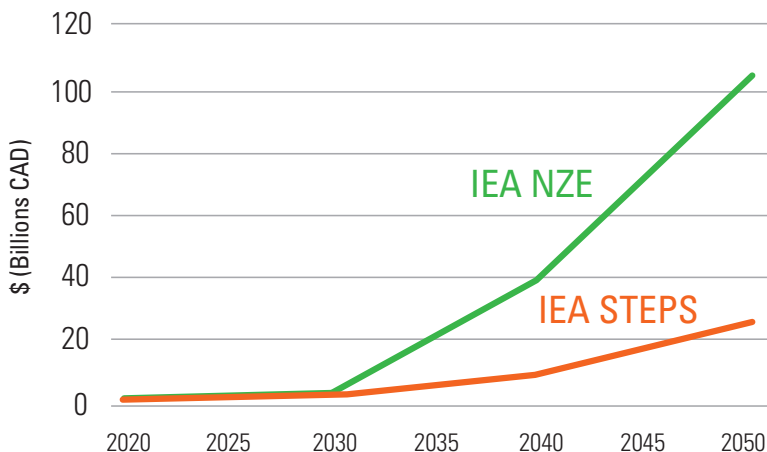
In the ExxonMobil global outlook, global oil demand will continue to increase but the demand for oil in **North America** will drop by 32 per cent between 2021 to 2050 (ExxonMobil, 2023). In the *IEA’s NZE by 2050 Scenario*, global oil demand will decrease by 75 per cent (IEA, 2021, 2023), and Canadian production will decrease significantly as well (CER, 2023). Without BBC, demand for Alberta bitumen for conventional uses will be negatively impacted in these scenarios.

Our analysis shows that BBC creates more economic value and reduces GHG emissions in all scenarios, but provides the greatest value in various NZE scenarios by 2050 (see **Figure 3 below**). In STEPS, BBC can divert a modest amount of bitumen from combustion and still create a multibillion-dollar new economic opportunity for Alberta and Canada. In NZE scenarios, the revenue from BBC after 2030 provides the incentive to significantly expand BBC capacity over time. Total annual revenue from BBC can exceed \$100 billion by 2050. The successful expansion of BBC production will support sustained demand for bitumen. As demand for fuels is increasingly challenged after 2030, the availability of cheap light fractions of bitumen as byproducts of BBC will encourage innovation and investment in their conversion to non-combustion products.

BBC CREATES MORE ECONOMIC VALUE AND REDUCES GHG EMISSIONS IN ALL SCENARIOS.

**Figure 2**

### Comparative BBC revenue projections





Alberta oil sands producers committed to achieving net-zero emissions from their operations by 2050 in the *Oil Sands Pathways to Net Zero*. However, approximately 80 per cent of total emissions occur downstream of production at the point of combustion (Scope 3 emissions). In a net-zero world, the greatest challenge is Scope 3 GHG reduction. **A recent study has shown that oil sands production would drop by as much as 90 per cent for Alberta to achieve net-zero emissions by 2050 in the absence of a BBC strategy. However, if BBC was implemented, bitumen production could be maintained or even increased in net-zero scenarios by 2050 (Navius Research, 2023).**

## **A call for leadership and investment in the future**

Bitumen Beyond Combustion is a disruptive initiative. It won't happen on its own, and inaction could result in losing significant components of the value chain to jurisdictions with heavy oil (e.g., Venezuela) or manufacturing expertise (e.g., United States and China).

The development of steam-assisted gravity drainage (SAGD) in the 1980s and 1990s provides a great lesson (Hastings-Simon, 2019). The creation of the Alberta Oil Sands Technology Research Authority (AOSTRA) in the 1970s and subsequent development of SAGD were not supported by the conventional oil industry at the time. However, former premier Peter Lougheed had the foresight at the time to prioritize the development of an innovative in situ recovery method. Lougheed's tenacity and faith in the disruption/breakthrough approach led to successful testing of the SAGD technology and the eventual creation of thousands of jobs and today's multibillion-dollar in-situ oil sands industry.

BBC is a unique opportunity to unite economic benefits with climate benefits for the common good. Our mission is to turn this vision into a reality. We call on the Government of Alberta to seize the transformational opportunity that Bitumen Beyond Combustion presents. **Significant investment will be required to achieve these benefits, and the most critical phase is between now (2023) and 2030.** With success of BBC product development and commercialization, private investment will drive much of technology and market development and commercialization post-2030.

It is estimated that \$300 million total government investment will be required over 10 years to realize the full potential of BBC. In light of the tens of billions of dollars of economic impact and climate benefits that BBC can generate out to 2050 and beyond, this could be the best investment the Government of Alberta makes.

# 1. INTRODUCTION

Alberta Innovates first publicized its Bitumen Beyond Combustion (BBC) white paper in 2021 (Alberta Innovates, 2021a). We provided a vision for oil sands to thrive in a net-zero economy and a pathway to get there. The BBC strategy called for a greater portion of bitumen production to be diverted away from fuel production and dedicated to the manufacture of high-value products. In doing so, the carbon from the bitumen would remain sequestered within the products and not released. Through BBC, the carbon in oil sands would become an asset. BBC products could make transportation more energy efficient, infrastructure less energy intensive but longer-lasting, and renewable electricity generation and energy storage more economical. Instead of contributing to the emissions problem, bitumen could contribute to energy efficiency solutions.

Much has happened since the BBC white paper was released in 2021: the Russian invasion of Ukraine, the ensuing global energy crisis, and spiraling inflation rates in much of the world. These events have led to increased fossil fuel consumption and higher GHG emissions. Some oil-producing companies have scaled back their plans to reduce the amount of oil and gas they produce. Others have argued that global oil demand will continue to increase through 2045 and 2050 (OPEC, 2023; ExxonMobil, 2023). These projections are based on the current climate change policies around the world. It should be noted that ExxonMobil's global oil demand projections to 2030, 2040 and 2050 are very close to those in the *Stated Policy Scenario (STEPS)* of the International Energy Agency (IEA, 2021; IEA, 2023).

Net-zero emission policies, strategies and plans continue to be developed around the world and energy transitions are taking place. The Government of Alberta has released its *Emissions Reduction and Energy Development (ERED) Plan*. The ERED plan declared for the first time the Alberta government's goal to reach net-zero carbon neutrality by 2050. The Government of Canada remains committed to its goal of net zero by 2050. The United States has provided unprecedented funding to support deployment and reduce costs for a range of low-emissions technologies through the *Inflation Reduction Act* adopted in 2022. This act has greatly accelerated efforts to lower economy-wide CO<sub>2</sub> emissions in the U.S. (EPA, 2023). The IEA projects the momentum behind clean energy transitions is now sufficient for global demand for coal, oil and natural gas to all reach a high point before 2030 in its *Stated Policies Scenario* (IEA STEPS, 2023). The pathway to NZE by 2050 remains open, although it has narrowed since 2021 (IEA, 2023).

In this updated white paper, we examine the roles that BBC may play in both STEPS and various NZE scenarios. We are convinced more than ever that BBC can help the world reach net-zero emissions and create economic opportunities for Alberta and Canada. In the last two years, great strides have been made in

advancing BBC technologies and more opportunities have emerged for new BBC products. Our analysis indicates that BBC can create economic value and reduce global emissions in both STEPS and various NZE scenarios. Among these, BBC would make the most impact in emissions reduction under NZE scenarios and create the greatest economic opportunities for Alberta and Canada.

All published NZE scenarios suggest a dramatic reduction in global demand for oil. IEA's NZE scenario suggests oil demand will decrease by 75 per cent (IEA, 2021; IEA, 2023). In the Canada Energy Regulator's *Global Net-zero Scenario* (CER, 2023), fossil fuel use in Canada drops by 65 per cent from 2021 to 2050, and Canadian crude oil production falls to 1.2 million barrels per day (MMb/d) by 2050 – 76 per cent lower than in 2022. In the energy regulator's *Canada Net-zero Scenario*, oil production falls to 3.9 MMb/d by 2050, 22 per cent lower than in 2022. Although ExxonMobil's global outlook predicts global oil demand will increase through 2050, the demand for oil in North America is expected to drop by 32 per cent by 2050. Demands for oil sands bitumen will be negatively impacted in these scenarios.

The Canadian oil sands are an innovation success story. This industry has been an economic engine for Alberta and Canada for decades. Oil sands development is expected to contribute more than \$1 trillion to the Canadian economy between 2019 and 2029 (Millington, 2019). However, the oil sands industry is the largest GHG emitter in Canada.

Alberta oil sands producers have committed to achieving net-zero emissions from their operations by 2050. Their *Oil Sands Pathways to Net Zero* initiative (<https://pathwaysalliance.ca>) aims to position Canada as the supplier of choice for responsibly produced oil to meet increasing energy demand. By reducing direct (Scope 1) and indirect (Scope 2) GHG emissions in oil sands operations, the *Oil Sands Pathways to Net Zero* will materially reduce GHG emissions within Canada and help to meet its climate goals.

However, approximately 80 per cent of total emissions occurs at the point of combustion (Scope 3) when oil sands are used as transportation fuels. In a net-zero world, the greatest challenge is Scope 3 GHG reduction. If North America were to achieve NZE by 2050, then the demand for Alberta's oil sands production for liquid transportation fuels could drop by 90 per cent. But if BBC was fully implemented, bitumen production would be positioned to provide feedstock for valuable products that are not burned and therefore do not create carbon dioxide emissions. With BBC in place, oil sands production could be maintained or even increased in NZE scenarios to 2050 (Navius Research, 2023).

This updated white paper advances a comprehensive vision for BBC and calls for leadership and action. Section 2 describes the vision for BBC, the nature of BBC products, their climate and economic impacts for Alberta and Canada, and how BBC products can reduce downstream GHG emissions when deployed. Section 3 outlines how BBC can provide climate and economic benefits in any energy transition scenario, including STEPS and NZE by 2050. Section 4 is a call for leadership and investment in BBC. Like many transformational technologies such as the Internet, GPS, artificial intelligence and Alberta's own steam-assisted gravity drainage for in-situ bitumen production, BBC will require government leadership and investment to turn the vision and early research into a commercial reality.

## 2. BITUMEN BEYOND COMBUSTION (BBC)

Bitumen is the heaviest grade of crude oil, present in the Alberta oil sands as a mixture with sand, clay and water (Canadian Encyclopedia, 2015). Once separated, bitumen is treated for delivery to refineries where conversion to fuels and non-combustion products occurs. The bulk of the bitumen is converted to transportation fuels while the remaining fraction is used to produce asphalt binder and other non-combustion products. Bitumen is made of light and heavy fractions and is rich in the latter compared to conventional crude oils. The heavy fraction that can be used for non-combustion products ranges from 15 to 50 per cent of a barrel of bitumen, depending on end use. The heavy fraction of bitumen requires more processing and energy than conventional crude oils to refine into gasoline and other petroleum products.

Alberta Innovates conceived the Bitumen Beyond Combustion (BBC) concept in 2016 and launched a program to support BBC products development. The BBC program encourages the development of process technologies, knowledge, and policies that will lead to the heavy fraction of bitumen being diverted away from fuel production in greater quantities and dedicated to the manufacture of high-value products. In doing so, the carbon from the bitumen remains trapped or sequestered within the products and not released.

BBC is intended to accomplish the following:

- Diversify the uses of Alberta's oil sands bitumen, resulting in high-value, large-scale, non-combustion products that can be marketed globally, thereby creating a new value-add industry.
- Reduce greenhouse gas emissions associated with utilization of bitumen.
- Contribute to global greenhouse gas emission reduction by creating lower GHG intensity manufacturing, and creating lightweight products that will displace more GHG-intensive metal and glass products used in various industrial sectors including transportation and infrastructure.

The program targets large-volume, non-combustion products and their associated production technologies which:

- Are technically and commercially feasible.
- Are competitive with, or superior to, existing products and production technologies on a technical and economic basis.

- Have lower GHG intensities in production/manufacture compared with existing products and production technologies.
- Will collectively require use of at least 100,000 barrels of bitumen per day (bpd) by 2030.
- Contribute to a diversified economy in an environmentally responsible and sustainable manner.

Alberta Innovates commissioned white papers in 2017 (Meisen, 2017) and 2018 (Stantec Consulting, 2018) that broadly defined the technical and economic opportunities related to BBC. BBC products worth pursuing and identified by the white papers are all carbon-rich materials, especially carbon fibre and asphalt binder.

Energy carbons (carbons that have application in energy applications – such as activated carbon and hard carbons) have since been identified as a new product group with strong market potential. All these products sequester carbon from bitumen, as opposed to being converted to fuels, combusted and emitted.

## Bitumen is ideally suited as a feedstock for non-combustion products

The heavy fraction of bitumen is highly viscous (does not flow easily) and contains metals and sulfur which drive down the value. However, the heavy fraction possesses chemical and physical properties suited to the manufacture of products such as carbon fibre, asphalt binder and energy carbons:

- The dominant carbon fibre manufacturing process requires multiple steps and chemical conversions (and associated energy/GHG) to produce propylene, ammonia, acrylonitrile and finally polyacrylonitrile – the starting material for 90 per cent of today’s global carbon fibre manufacturing. Polyacrylonitrile is heat-treated at temperatures greater than 1,200°C to form carbon fibre (Zoltek, n.d.). Using the heavy fraction of bitumen as a starting input feed would require less chemical conversion and energy/GHG to generate the necessary starting material for carbon fibre, while subsequent heating steps would require similar or less energy input. The heavy fraction of bitumen also has significant potential advantages for improving yield and scaling via melt-spinning. **Overall, carbon fibre derived from bitumen should have a lower embedded GHG intensity than other carbon fibre currently being made.** There is also a very significant cost advantage, as the feedstock now being used costs \$5 to 10/kg, while the heavy fraction of bitumen costs less than \$1/kg. Studies have shown that cutting the total cost of carbon fibre in half will lead to a potential tenfold market growth (Warren, 2011) from the current 100,000 tonnes/year. As an indication, the Chinese carbon fibre market has been growing at a CAGR of 19.3 per cent and its projected market by 2025 will be 150,000 tonnes (greater than the total global carbon fibre market today). Such a shift in the carbon fibre market would result in China producing 55 per cent of global carbon fibre supply (CICC 中金公司,2021).
- The heavy fraction of bitumen has a naturally lower wax content than other global crude oils. Because of this, **asphalt binder (the “glue” that holds the different components of asphalt pavement together) derived from bitumen has high durability and resistance to cracking, placing its properties among the best in the world when compared to other asphalt binders from global crudes.** (Hesp, 2021).

- The heavy fraction of bitumen has a chemical makeup offering significant potential for making hard carbon for energy storage batteries, and also for electrical energy storage in supercapacitors which are used for ultra-fast charging and release of power. Graphite anodes are a critical component in the current generation of lithium-ion batteries. But concerns about future lithium supplies are growing. Meanwhile, sodium-ion batteries are nearing commercial production. Instead of graphite, these batteries use “hard carbon” which could be manufactured from bitumen. (Hard carbon, a type of energy carbon, is a solid form of carbon that cannot be converted to graphite by heat treatment.)

## Progress in BBC program to date

Alberta Innovates realized the opportunity that the natural properties of bitumen offered for generating non-combustion products and began supporting research to exploit them. Since 2016, 53 BBC research and development projects focused on converting the heavy fraction of bitumen to carbon fibre, asphalt binder, and energy carbons have been funded and completed. Key research areas and learnings are presented below in Table 2.

**Table 2**

### Progress in BBC

BBC Product	Carbon Fibre	Asphalt Binder	Energy Carbons
<b>Development Targets</b>	<ul style="list-style-type: none"> <li>• Develop low-cost, low-emission bitumen-carbon fibre (B-CF) technology and manufacturing process</li> <li>• Life-cycle analysis of GHG emissions pathway for B-CF</li> <li>• Market development for B-CF</li> </ul>	<ul style="list-style-type: none"> <li>• Benchmark new bitumen-derived asphalt binders (B-AB) against commercial asphalt binders</li> <li>• Develop higher performing and durable B-AB for road base layers</li> <li>• New methods for shipping and transporting B-AB at ambient temperatures</li> </ul>	<ul style="list-style-type: none"> <li>• Convert the heavy fraction of bitumen to energy carbons including activated carbon and hard carbon</li> <li>• Life-cycle analysis of GHG emissions pathway for energy carbon products</li> <li>• Market development for energy carbon products</li> </ul>
<b>Progress to Date</b>	<ul style="list-style-type: none"> <li>• A global carbon fibre manufacturer has been engaged and has been providing advice</li> <li>• Collaborations have been developed with two leading carbon fibre labs in the world</li> <li>• Carbon Fibre Grand Challenge (CFGC) Phases I and II completed successfully</li> <li>• Multiple pre-treatment technologies for B-CF have been developed</li> <li>• Multiple B-CF technologies are being advanced in CFGC Phase III</li> <li>• Initial life-cycle analysis confirmed B-CF's GHG benefits</li> <li>• Market development is ongoing</li> </ul>	<ul style="list-style-type: none"> <li>• A market study performed and confirmed market potential for B-AB in North America and Asia</li> <li>• Lab study confirmed B-AB's performance superiority over commercial asphalts from around the world</li> <li>• A 500 b/d B-AB system is ready for commercial deployment</li> <li>• A FEED study is complete for a new 6,600 b/d B-AB facility</li> <li>• Studies are ongoing to compare asphalt binder used for roadways in different U.S. states and Canadian provinces to binder from Alberta bitumen</li> </ul>	<ul style="list-style-type: none"> <li>• A market study was completed for bitumen-derived activated carbon for supercapacitor use</li> <li>• A market study is being planned for hard carbon use in supercapacitor and sodium-ion batteries</li> <li>• Demonstration plant that manufactures activated carbon manufactured using the heavy fraction of bitumen is nearly operational</li> <li>• Lab studies have been initiated on bitumen-derived hard carbon</li> <li>• Six researchers have been engaged to develop hard carbon as anode materials for sodium-ion batteries</li> </ul>
<b>Remaining Challenges</b>	<ul style="list-style-type: none"> <li>• B-CF technology development is now focusing on reproducibility in manufacture and consistency of fibre properties</li> <li>• Scaleup has not yet started but is a focus area for CFGC Phase III</li> <li>• More detailed economic and life-cycle analysis to be performed as process technologies improve and become more consistent, with repeatable end-use prototype development and product testing</li> <li>• More market development required</li> </ul>	<ul style="list-style-type: none"> <li>• Methods for transporting B-AB at ambient temperatures to be demonstrated</li> <li>• Field-scale testing of B-AB products to be carried out in jurisdictions around North America</li> <li>• Economic analysis to be modelled for higher oil price situations</li> <li>• Better life-cycle analysis on GHG emissions required</li> <li>• Market development required</li> </ul>	<ul style="list-style-type: none"> <li>• Continue market analysis for energy carbons</li> <li>• Help the leading BBC activated carbon developer to commercialization but also bring in more developers</li> <li>• Develop BBC hard carbon products</li> <li>• Economic analyses to be modelled for various energy carbon products</li> <li>• Refined LCA analysis on GHG emissions as processes technology improves</li> <li>• End-use prototype development and product testing</li> <li>• Market development required</li> </ul>

Encouraging progress has been made in advancing carbon fibre manufacturing technology, demonstrating asphalt binder production and performance, and the manufacture of activated carbon.

Overall, technology development remains at an early stage for energy carbons materials, with hard carbon development only started in late summer/early fall of 2023. Carbon fibre development is only now advancing towards scaleup, with demonstration of consistency and reproducibility as the critical next step. Alberta Innovates continues to fund BBC projects, building on the learnings to date. This includes support for Phase III of the Carbon Fibre Grand Challenge, a demonstration facility for producing activated carbon (300 tonnes/year), and a pilot facility to produce asphalt binder (500 bbl/day) that can be transported at ambient temperatures. Alberta Innovates will continue to seek and support BBC projects of the highest quality.

## Adding value through BBC

Most of the bitumen or bitumen-derived fuels produced today in Alberta are exported. Economics for building new fuel refineries in Alberta are a challenge. The following illustration assumes the status quo is the shipment of bitumen (either processed or not) out of Alberta. The market price assumed for the purchase of bitumen or processed feed is \$50/bbl (average from Alberta bitumen valuation methodology for 2019–2023).

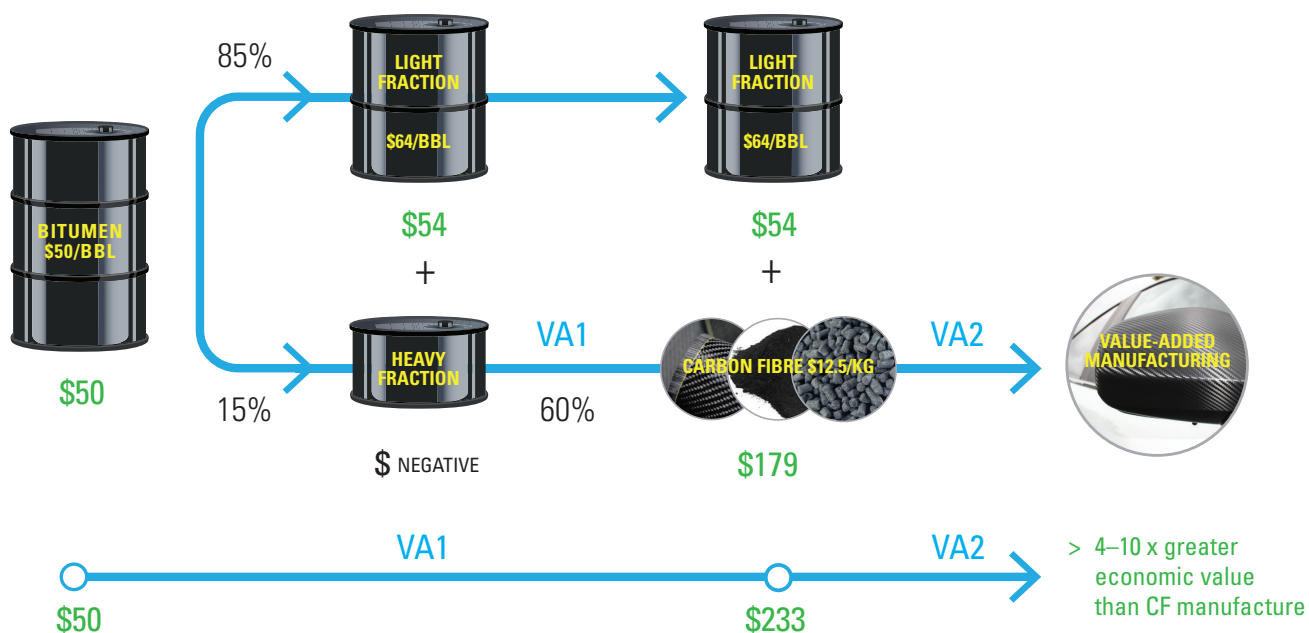
BBC products generated in the following illustration (Figure 3) are assumed to have their entire value chain of manufacture in Alberta, and that all economic benefits arising from manufacturing remain in Alberta. While it is unrealistic to assume that every unit of BBC product will be manufactured in Alberta, given manufacturing capabilities elsewhere, it is reasonable to believe that Alberta companies can capture a market share for manufacturing BBC products.

Gross revenues are used in the following illustration to demonstrate the economic opportunity because process technologies are still under development, and it is too early to characterize the manufacturing costs and associated profit margins. While this prevents calculations of net present value and return on investment, it provides a scale of economic potential. We will use information gathered from sponsored research projects over the coming years to update economic models. This illustration assumes that the manufacture of carbon fibre and energy carbons from the heavy fraction of bitumen is economical.

A breakdown of the revenue generated from a barrel of bitumen when it is transformed into carbon fibre and associated composite products is illustrated in Figure 3. Carbon fibre generation begins from a barrel of bitumen sold at a market price of C\$50/bbl. The heavy fraction must be separated from the rest of the bitumen barrel. Roughly 15 per cent of the original barrel is the heavy fraction that can be used to make carbon fibre. The remaining 85 per cent is now a light fraction that would sell for a market price of \$64/bbl. As more and more of the heavy fraction is used for BBC, the value of the remaining light fraction is higher, rising to an average of \$72/bbl when asphalt binder is also produced (shown in Table 3, p. 17). Additional processing of the light fraction of bitumen would occur outside Alberta, as is the status quo.

**Figure 3**

*Illustrative revenue increase on a per barrel basis for bitumen used for carbon fibre and associated composites (All values in Canadian dollars)*



Carbon fibre can be added to polymers, wood fibres and other materials to create composite manufactured products that end users need. Based on current market values, this step is estimated to be worth multiples of the value of carbon fibre manufacture (VA2). With strong manufacturing hubs in Ontario and Quebec, a composite manufacturing industry in Manitoba, and emerging manufacturing in Alberta and other provinces, the opportunity is here for Canada to increase the manufacture of products that incorporate carbon fibre. Carbon fibre production and the associated manufacturing is truly a pan-Canadian economic opportunity and one that could create jobs and provide economic benefits for decades to come.

Alberta companies can diversify their customer base for bitumen, unlock new value chains, and increase revenue streams by pursuing BBC pathways. By using bitumen for manufacture of carbon products instead of fuel, Albertans and Canadians can increase the revenue generated from this natural resource.

### Economic potential of BBC for Alberta and Canada

Using the same assumptions as in the previous section, increasing the amount of non-combustion products derived from bitumen offers an increase in economic potential regardless of the scenario. Table 3 illustrates the revenue increase by diverting one million barrels a day to manufacturing BBC products instead of selling the bitumen to refineries at market price. BBC products would be sold as export products with revenues retained in Alberta. If one million barrels per day of bitumen are exported from Alberta and sold to refineries at \$50/bbl (after diluent removal), the revenue is \$18 billion. In comparison, if the same volume of bitumen is used to generate BBC products in Alberta, the potential revenue rises to \$42 billion: \$28 billion from BBC products and \$14 billion from sales of the light fraction of bitumen.



The light fraction of bitumen in the IEA NZE scenario would compete strongly against low-cost competitors in an over-supplied oil market and could be viewed as a lower-emission intensity supply, since approximately half the barrel would be converted to non-combustion products. These scenarios assume the complete value chain for manufacturing non-combustion products occurs inside Alberta and Canada and is not outsourced to foreign jurisdictions. This is done for illustrative purposes to highlight the scale of the opportunity, and it is reasonable to assume that manufacturing of BBC products will also occur outside of Canada. The actual amount of bitumen that is converted to BBC products in the future will depend on successfully developing new production technologies and demonstrating the value of BBC products. Therefore, significant new economic benefit and thousands of new jobs can be realized as compared to current practice.

**Table 3**

**Revenue projection with and without BBC products for one million barrels per day bitumen production (\$50/bbl based on five-year bitumen valuation)**

	Bitumen (bbl/d)	Sales Price (CAD)	Total Revenue (Annual, CAD)
<b>Bitumen sold as crude for fuels</b>	<b>1,000,000</b>	<b>\$50/bbl</b>	<b>\$18B</b>
<b>Bitumen processed to BBC</b>	<b>1,000,000</b>		<b>\$42B</b>
Heavy fraction to BBC	480,000	\$163/bbl	\$28B
Light fraction to fuels	520,000	\$72/bbl	\$14B

Market demand for each BBC product is very different. Approximately 140 million tonnes/year of asphalt binder is consumed globally, compared to 125,000 tonnes/year of carbon fibre. In contrast, new products for energy storage are in very early stages of commercialization with production below 3,000 tonnes/year. Energy carbon markets are expected to grow rapidly.

The proportion of BBC products with revenue potential can be estimated based on market projections for each product. The amount of suitable heavy fraction of bitumen able to be converted to BBC products is based on the properties of the heavy fraction, and corresponding processes to manufacture each BBC product depends on the chemistry of the product and the conversion process. Less than 20 per cent of bitumen is suitable for making carbon fibre and energy carbons, while more than 50 per cent of bitumen can be converted to asphalt binder. Asphalt binder will be the largest BBC product by mass and has the greatest revenue potential. Realizing this potential requires the development of new technologies for transporting asphalt as solid pellets, rather than a molten liquid. Carbon fibre and energy carbons are much higher in unit price than asphalt binder, but their markets are smaller. Still, carbon fibre and energy carbons will have market potential in billions of dollars.

Table 3 does not capture the potential economic benefit from any downstream manufacturing in Canada of value-added consumer goods that use the BBC products as inputs. **The manufacturing value chain of BBC-related products can employ Albertans and Canadians of all skill levels. It represents a significant job opportunity for Albertans and Canadians with oil and gas sector experience, as well as those in chemical, manufacturing and construction industries.**

**CARBON FIBRE PRODUCTION AND THE ASSOCIATED MANUFACTURING IS TRULY A PAN-CANADIAN ECONOMIC OPPORTUNITY AND ONE THAT COULD CREATE JOBS AND PROVIDE ECONOMIC BENEFITS FOR DECADES TO COME.**

## Potential of BBC to reduce GHGs

BBC can reduce GHG emissions in three ways: diverting bitumen away from combustion, displacing high-intensity products, and reducing downstream GHG emissions when BBC products are in use.

### *Diverting bitumen away from combustion*

By diverting some bitumen away from combustion, BBC provides a pathway to reduce Scope 3 emissions (emissions from combustion as transportation fuel).

- For every million barrels of bitumen used for BBC in the IEA NZE scenario, 480,000 barrels would be for non-combustion products. Used as fuel, this oil would generate 70 million tonnes per year of emissions. (480,000 bbl/d x 365 d/yr x 0.4 tonne/bbl). But if the carbon was processed into BBC products, these emissions would be reduced in end use.
- In the IEA STEPS scenario this decreases to 14 million tonnes (100,000 bbl/d x 365 d/yr x 0.4 tonne/bbl).

It should be noted that Scope 3 emissions occur on the consumption side and that not all the GHG emission reduction will occur in Canada. Some may even argue that a barrel of bitumen taken out of combustion will be replaced by another barrel of oil from another jurisdiction as long as demand is there. However, in a net-zero scenario, when consumption of combustion fuels become highly restricted, BBC can still enable bitumen production and consumption as non-combustion products.

In addition, the economic potential in BBC will provide an extra incentive for the oil sands industry to accelerate the decarbonization of oil sands production. Reduction of Scope 1 and 2 emissions then becomes an investment for the future. In turn, the technologies (e.g., CCUS) developed in reducing Scopes 1 and 2 emissions will also help decarbonize BBC manufacturing processes.

### *BBC products displace higher GHG intensity products*

BBC products can be manufactured in a way that takes advantage of the natural properties of the heavy fraction of bitumen, resulting in similar or reduced GHG intensity compared to current products. Table 4 describes how the three major BBC products compare on an intensity basis with their incumbent counterparts.

**Table 4**

#### *Comparison of GHG emission intensities of BBC products with current products*

Product	GHG Emission Intensity Comparison
<b>Carbon Fibre</b>	A recent study indicates that the life-cycle GHG intensity of bitumen-derived carbon fibre may be 52 per cent lower than that of PAN-derived carbon fibre (Kumar, 2021).
<b>Energy Carbon</b>	GHG intensities of BBC energy carbons need to be more fully characterized. Asphaltenes from bitumen would have a higher product yield than their biomass counterparts in energy carbon production. One BBC developer indicates a 65 per cent GHG emission reduction for a bitumen-derived energy carbon.
<b>Asphalt Binder</b>	Asphalt binder production is an established process within existing refineries. New refinery builds, or modification of existing refineries to incorporate improved technology, would have an equal or reduced GHG intensity for asphalt production. Reductions could potentially reach 30 per cent on a per barrel basis.

BBC products produced with lower manufacturing energy and emissions should interest consumers conscious about low-GHG products. Furthermore, GHG emissions generated in the manufacture of BBC products can be sequestered via carbon capture and storage technologies, resulting in an ultra-low GHG emissions manufacturing process.

### Reducing downstream GHG emissions with BBC products

Carbon fibre, energy carbon and asphalt binder sequester carbon from bitumen, as opposed to bitumen being converted and then combusted as fuel. These products help enable reductions in downstream emissions by end users with examples found in Table 5.

**Table 5**

#### Downstream applications of BBC products and associated emissions reduction method

Application (BBC Product)	Rationale for Downstream Emissions Reduction
<b>Renewable Energy Production From Wind</b> <i>(Carbon Fibre)</i>	Carbon fibre is blended with polymers to make composite wind turbine blades. Carbon fibre composites make wind turbine blades lightweight or more durable, and effective at generating ultra-low GHG emissions electricity.
<b>Energy Storage in Supercapacitors and Batteries</b> <i>(Energy Carbon)</i>	Energy carbons are an important ingredient in supercapacitors and sodium-ion batteries, enabling more efficient, low-cost manufacture and operation of these energy storage devices. These are critical components in emerging smart grids and renewable energy systems that reduce consumer electricity emissions.
<b>Transportation – auto, rail, marine, aerospace</b> <i>(Carbon Fibre)</i>	Carbon fibre composites in lightweight vehicles increase fuel efficiency per kilometre. On a life-cycle basis, a carbon fibre vehicle emits 22 to 36 per cent fewer GHG emissions than a conventional vehicle (Kumar, 2021). For the rail industry, carbon fibre can be used to replace steel in bogies and other equipment, reducing the overall weight of rail cars and pressure applied to tracks, thereby increasing their longevity. Carbon fibre in marine applications is valued for creating more lightweight shipping containers but also for its anti-corrosion properties, increasing longevity of marine equipment. Carbon fibre in aircraft reduces weight and corresponding fuel usage, and also enables more comfortable humidity levels in the cabin, such as the Boeing 787 Dreamliner.
<b>Sustainable Transportation Infrastructure – concrete, structural materials, roads</b> <i>(Asphalt Binder, Carbon Fibre)</i>	<p>Asphalt binder from Alberta ranks among the best binders in the world for durability (Hesp, 2021). Using asphalt binder derived from Alberta bitumen increases the longevity of road surfaces, requiring less reconstruction and the associated emissions. Electric vehicles are much heavier than current internal combustion vehicles and that extra weight will put additional stress on asphalt pavements. Therefore, a highly durable, long-lasting asphalt binder is required for roads in the future.</p> <p>The use of carbon fibre in concrete infrastructure adds durability, longevity and reduces cracking compared to existing construction methods. The use of carbon fibre instead of steel rebar would add corrosion resistance to concrete structures, significantly extending their life and eliminating the risk of failure from corrosion. Companies have expressed interest in using carbon fibre as an additive to their concrete products, but costs are still prohibitive.</p>
<b>Built Environment</b> <i>(Carbon Fibre)</i>	The use of carbon fibre increases the strength, rigidity and durability of wood panels, concrete and composite materials used in the built environment. Corrosion risk in concrete is reduced. Extending the life of the built environment will necessitate fewer repairs and reconstruction in the future, saving on emissions associated with manufacturing replacement building materials and the building process itself.

## Summary – BBC value proposition

BBC represents a significant economic diversification opportunity to create new end uses and industries from valuable local feedstocks. It is for all these reasons that Alberta Innovates has invested significant time and energy into the BBC program and will continue to do so in the future.

BBC products can meet the global need for material goods manufactured in a sustainable manner, materials that are long-lasting and bring benefits to end users. These are products that the growing global population needs today and for decades to come. BBC can increase market competitiveness and create future markets for bitumen. Furthermore, these products maximize revenue derived from bitumen.

BBC pathways offer more economic and carbon reduction value from the heavier fraction of bitumen.

Over the past seven years, Alberta Innovates has built a strong foundation for BBC. White papers provided early direction and guidance around the opportunity, and subsequent projects demonstrated the conceptual feasibility of manufacturing non-combustion products from bitumen. Our program has generated national and international attention. We are collaborating with partners from around the world on our Carbon Fibre Grand Challenge. Concurrently, Alberta Innovates is building strong capacity for research on BBC product development in Alberta at the University of Calgary, University of Alberta, InnoTech Alberta, multiple small-medium enterprises and large industry. Together, these organizations are equipping highly qualified personnel for BBC outcomes and positioning Alberta for long-term success. Alberta Innovates' BBC program has support from the oil sands industry in the form of heavy fractions of bitumen for testing. Bitumen producers, manufacturers and end users have been engaged and are participating in the program.

Despite the success thus far, much more work needs to be done to make the BBC vision a reality. Developing carbon fibre from bitumen is at the early stage of development; scaleup to manufacturing has yet to begin. It is very important to raise awareness in the United States about the superior quality of asphalt binder from Alberta and demonstrate this through field trials. Long-distance transport of asphalt binder at room temperature must be unlocked. Technical work still needs to be performed around manufacturing pathways for energy carbons.

Most of this work remains too early and risky for private capital to invest, but over the next few years will reach a technology level suitable for private investment. Alberta Innovates has informed private investors of BBC advancements since the inception of the program and will continue to do so going forward. Investment in Alberta companies and new technologies across emerging sectors have shown significant growth over the last five years, and BBC is well positioned to take advantage of this growth in financing opportunities. End-user engagement through the technology development process will be very important to ensure that BBC products have commercial receptors once they are ready for manufacture. Governments will need to ensure policies are developed and implemented that enable BBC products to be manufactured in Alberta and Canada.

### 3. BITUMEN BEYOND COMBUSTION IN THREE IEA SCENARIOS FOR 2050

The transition of the world's energy supplies from a heavy reliance on fossil fuels to global GHG neutrality requires the rapid replacement of a large fraction of our energy and transportation, and industrial infrastructure. In heavy industry and agriculture, new technologies need to be developed and implemented at an unprecedented pace for peacetime and with global scope.

The International Energy Agency (IEA) provides three scenarios for energy use to 2050 (IEA, 2023) (<https://www.iea.org/reports/global-energy-and-climate-model/understanding-gec-model-scenarios>). In every one of these scenarios, an investment in BBC creates wealth for Canada and contributes to achieving national and international climate-change targets.

#### BBC in Stated Policies Scenario (STEPS)

The IEA *Stated Policies Scenario (STEPS)* only include specific policies that are in place or have been announced by governments. Due to the gap between announced targets and implemented policies to drive the energy transition, global GHG emissions are projected to peak in the mid-2020s then decline by 15 per cent from 2030 to 2050. In this scenario, the use of renewables increases to almost 70 per cent of global electricity generation in 2050 (up from 30 per cent in 2022), but clean energy transitions lag in other sectors. Declines in transportation fuel use in OECD countries is offset by demand in developing countries and for petrochemical products, resulting in no net change in global crude oil consumption from 2022 to 2050. It should be noted that STEPS is similar to ExxonMobil's global view to 2050 (ExxonMobil, 2023) (<https://corporate.exxonmobil.com/what-we-do/energy-supply/global-outlook>) in terms of oil demand projection.

In Canada, refining bitumen into liquid transport fuels would be the dominant production pathway. Using the assumptions of STEPS, the production of BBC products expands the market for oil sands bitumen and adds value to the bottom of the barrel (heavy fraction), which is least valued for liquid fuels production. Only three per cent of Alberta's total bitumen production would be processed to recover the heavy fraction to make BBC products in 2030, rising to as much as 20 per cent in 2050.

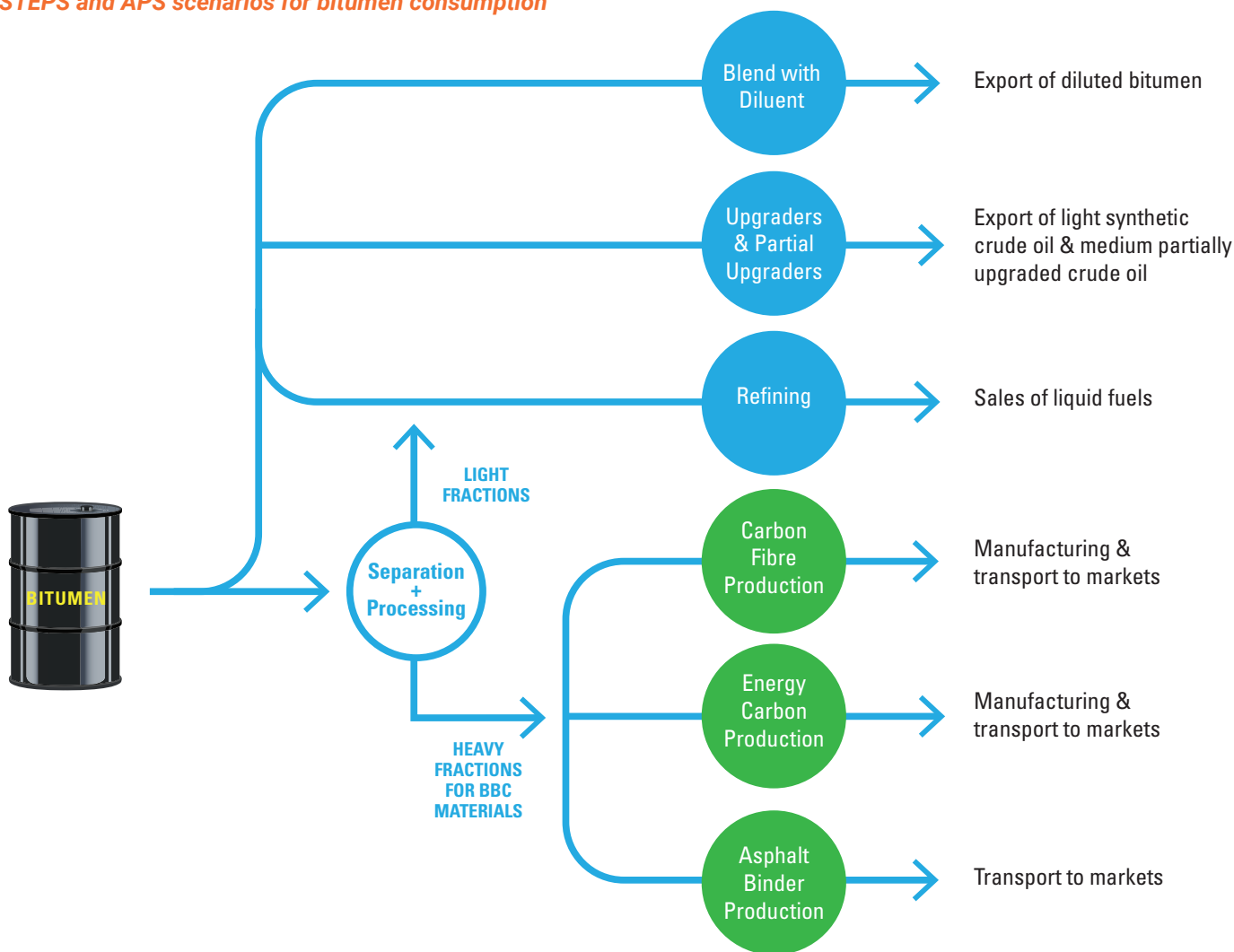
#### BBC in Announced Pledges Scenario (APS)

In the IEA *Announced Pledges Scenario (APS)*, all announced national net-zero pledges are achieved in full and on time. Significant global reductions in GHG emissions are achieved by 2050, but additional measures are required between 2050 and 2100 to keep global temperature rise under 2°C. By 2050, electrical generation capacity is almost doubled, with almost 80 per cent coming from renewables. Consumption of crude oil remains significant at about 53 million barrels per day in 2050, mainly for fuel in non-OECD countries and for non-combustion products in the OECD.

Using the assumptions of APS, bitumen production continues but oil sands producers would eliminate, capture or offset GHG emissions associated with the production and processing of crude oil and bitumen to contribute to meeting Canada’s targets. Exports of crude oil and refined crude oils and refined liquid transportation fuels would continue, but the Canadian market would be transformed by electrification and the use of renewable feedstocks. BBC products would offer strong returns on investment for processing of bitumen for both non-combustion products and light fraction crude oil for export. This combined market for bitumen is illustrated in Figure 4 below. The percentage of bitumen converted to BBC products would increase from three per cent in 2030 to 30 per cent in 2050. This scenario is an intermediate between STEPS and net zero, therefore, the following sections will focus on these bounding cases.

**Figure 4**

*STEPS and APS scenarios for bitumen consumption*



**BBC in net-zero emissions scenario by 2050**

In the IEA *Net-Zero Emissions Scenario (NZE) by 2050*, 70 per cent of total energy supply in 2050 comes from wind, solar, bioenergy, geothermal and hydro energy. Solar becomes the largest source, accounting for one-quarter of energy supplies. Fossil fuel use falls drastically, and no new oil and natural gas fields are required beyond those that have already been approved for development.

Achieving the goal of net-zero emissions results in a dramatic reduction in the combustion of liquid fuels derived from fossil sources, reducing the global demand for crude oil for manufacturing gasoline and diesel fuels. Refinery runs fall by 85 per cent between 2020 and 2050. Refiners are used to adapting to changing demand patterns, but the scale of the changes in the net-zero scenario are unprecedented and would inevitably lead to refinery closures. Crude oil would continue to be used as a raw material for manufacturing a wide range of non-combustion products, either because it is very difficult to replace, or because of favourable cost, performance and life-cycle emissions in comparison to feedstocks from renewable sources.

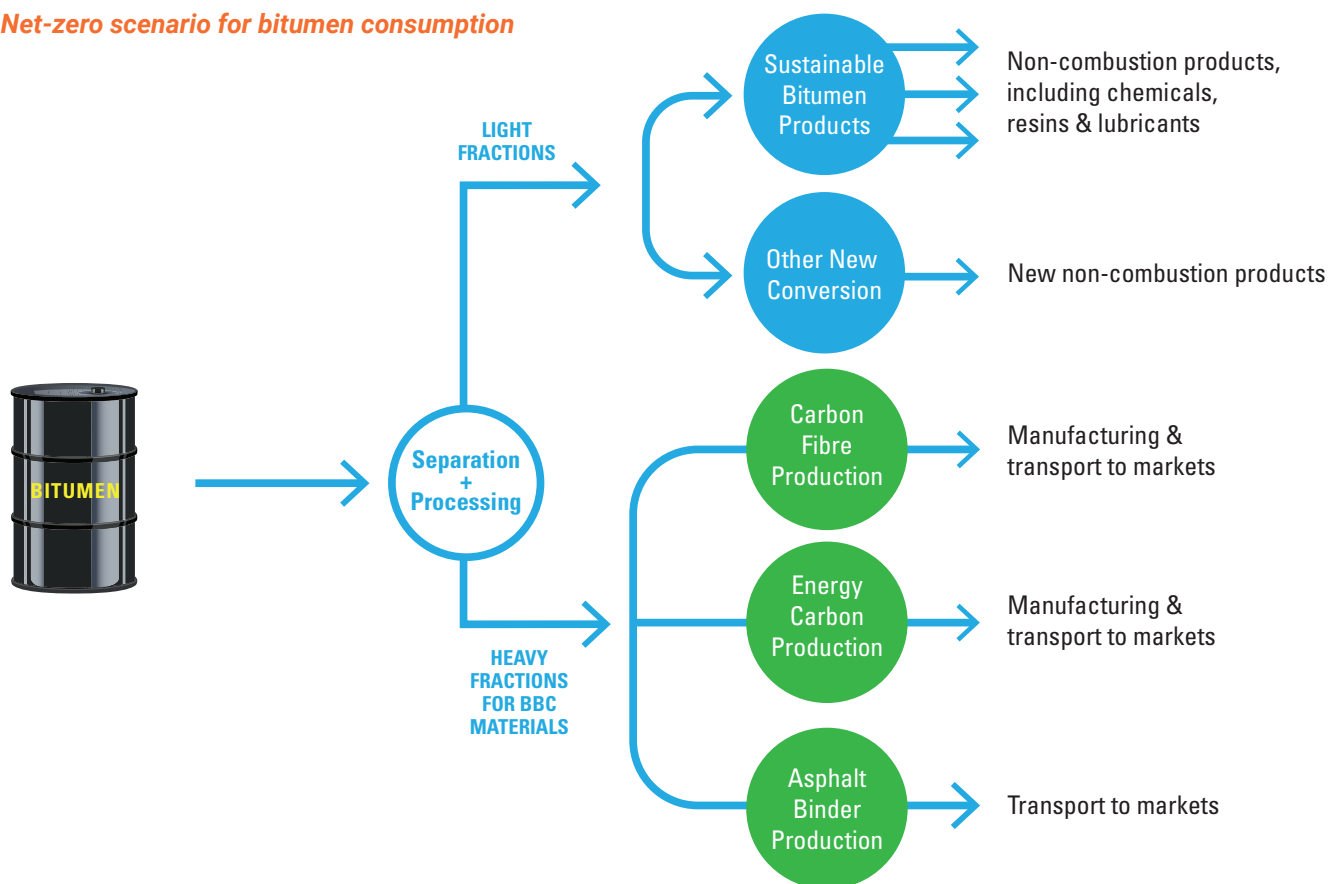
In our analysis, the dramatic reduction in demand for gasoline and diesel coupled with large-scale refinery closures would create tremendous opportunities and demand for BBC products.

- Energy efficiency would be an essential part of net-zero scenarios. BBC products would be fundamental to energy efficiency, from carbon fibre for lighter vehicles to fibre-reinforced concrete.
- Solar PV capacity would increase 20-fold between now and 2050, and wind power tenfold. This would create a tremendous market for carbon fibre for wind turbines and energy carbons for energy storage.
- With refinery runs reduced by 85 per cent, asphalt production would be less than 20 million tonnes per year. The global demand for asphalt is anticipated to be over 200 million tonnes per year between 2030 and 2050. Processing light crude oils to meet the needs of petrochemical production would struggle to satisfy that demand even with extensive recycling of pavement. As 50 per cent of bitumen can be converted to asphalt, BBC can help meet asphalt demand in a net-zero scenario. Asphalt binder from oil sands bitumen lasts two to three times longer than asphalt from light crudes, meaning less cost and emissions to repave (BCSE, 2021). A net-zero scenario would create an opportunity to establish Alberta asphalts as globally recognized premium products. New technologies for low-cost transportation of asphalt products as solids for road-paving applications are required to make this premium product available globally.

Continued investment in production and processing of bitumen in the net-zero scenario is contingent on BBC products which take advantage of the chemical and physical properties of the components of bitumen. Sustained production also requires implementing technologies to capture or eliminate GHG emissions from field production and refining. As illustrated in Figure 5 on the next page, in 2050 the heavy fractions will be the prime economic drivers for bitumen use. The light fraction of a barrel of bitumen, currently the most valuable, will no longer be in demand as feedstocks for liquid transportation fuels. New technologies are needed for non-combustion and emission-free uses of these light fractions, which comprise 50 to 85 per cent of the barrel.

Figure 5

Net-zero scenario for bitumen consumption



The technologies being developed by the Alberta Innovates BBC program have the potential to convert up to 50 per cent of the barrel of bitumen to products of higher value than conventional crude oil. Improved efficiency of oil sands production and expansion of the infrastructure for carbon capture and sequestration would also be required so that the production and processing of bitumen also meets net-zero targets for GHG emissions (Scope 1 and Scope 2 emissions). The combination of net-zero production of bitumen with net-zero conversion to BBC and other non-combustion products would result in valuable products with negligible GHG impact.

### Potential economic, environmental contributions from BBC

The potential contribution of BBC products to consumption of bitumen over time in the STEPS and NZE scenarios is illustrated in Figure 6. Regardless of the scenario, the production of carbon fibres, asphalt and energy carbons could contribute \$3 billion revenue in 2030 by converting only three per cent of bitumen production.

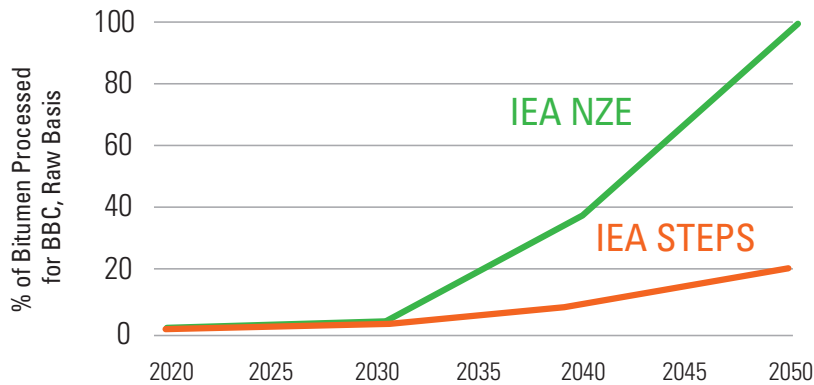
In the STEPS scenario, the percentage of total bitumen production that would be used for BBC products beyond 2030 would remain relatively small. Even at reduced levels of conversion, these BBC products could add over \$26 billion annually to Alberta’s and Canada’s economy by 2050. In the NZE scenario, the conversion of bitumen to BBC products would become more and more attractive as the demand for gasoline and diesel from crude oil sources diminishes and demand for BBC products increases. BBC products could generate over \$100 billion annually to the Alberta and Canadian economies by 2050.

THE TECHNOLOGIES BEING DEVELOPED BY THE ALBERTA INNOVATES BBC PROGRAM HAVE THE POTENTIAL TO CONVERT UP TO 50 PER CENT OF THE BARREL OF BITUMEN TO PRODUCTS OF HIGHER VALUE THAN CONVENTIONAL CRUDE OIL.



**Figure 6**

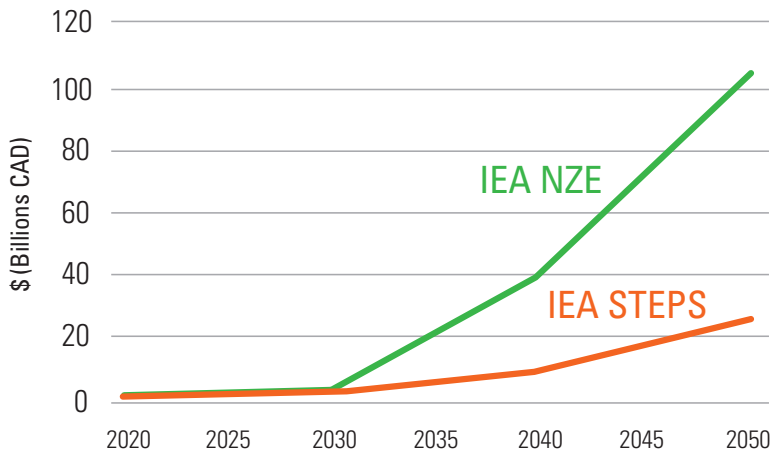
**BBC in IEA Scenarios: Percentage of bitumen barrels processed for BBC based on three BBC products supported by Alberta Innovates**



In both of the above scenarios, BBC would create more economic value and reduce climate impacts from the bottom of the barrel. In the net-zero emissions scenario, the revenue from BBC after 2030 would provide the incentive to significantly expand BBC capacity over time. As demand for fuels is more and more challenged after 2030, the availability of cheap light fractions of bitumen as byproducts of BBC would encourage innovation and investment in their conversion to non-combustion products. The revenue potential from BBC products is illustrated in Figure 7 for the limiting scenarios of STEPS and NZE.

**Figure 7**

**BBC revenue projection in STEPS and NZE Scenarios in Canada**



AS THE WORLD MOVES TOWARD NET-ZERO EMISSIONS AT DIFFERENT RATES IN EACH OF THE SCENARIOS, THE VALUE DERIVED FROM CONVERSION OF THE BOTTOM OF THE BARREL TO VALUE-ADDED PRODUCTS BECOMES MORE AND MORE IMPORTANT THAN TRADITIONAL GASOLINE AND DIESEL FUELS.

- In the NZE scenario, the development of BBC products provides an opportunity to maintain the value of the oil sands for Alberta, while contributing low-GHG footprint materials. Each of these materials generates emission reductions when they are used.
- In the STEPS scenario, the development of BBC products is expected to be slower, but the value is still substantial.

As the world moves toward net-zero emissions at different rates in each of the scenarios described above, the value derived from conversion of the bottom of the barrel to value-added products becomes more and more important than traditional gasoline and diesel fuels.

## 4: A CALL FOR LEADERSHIP AND INVESTING IN ALBERTA'S FUTURE

Achieving net-zero emissions globally by 2050 is an ambition unprecedented in human history. The timeline may be in question but the drive toward net zero is strong. Net-zero emissions implies a significant reduction in the use of fossil fuels. In the IEA and CER net-zero scenarios (IEA, 2021, 2023; CER, 2023), crude oil demand will decline by almost 75 per cent between 2022 and 2050.

Even in IEA's STEPS and the ExxonMobil's global outlook, the oil demand in North America will drop by 32 per cent from 2021 to 2050 (ExxonMobil, 2023). Demand for oil sands bitumen will be negatively impacted in these scenarios. The climate threat is real and cannot be ignored, and the economic risks to Alberta and Canada from a potential decline of its oil and gas sector also should not be ignored.

Climate policies announced or being developed by the governments of Canada and Alberta focus on reductions in GHG emissions and assume that bitumen can only provide energy as a fossil fuel. For the oil sands sector, government policies focus on emission reductions from bitumen production and refining. They do not offer a long-term vision or strategy for the oil sands industry to adapt to a net-zero world by positioning bitumen as a resource for valuable products rather than energy supply. Without such a strategy to offer multiple end products derived from bitumen as alternatives to liquid transportation fuels, the demand for oil sands bitumen will naturally decline as the world moves towards net zero, even in the current policy environment.

However, this does not need to be the future of the oil sands industry. In fact, oil sands can be part of the climate solution. In the previous two sections, we have demonstrated that in both STEPS and NZE scenarios, bitumen can play a critical role in making products that contribute to renewable energy production, energy storage, sustainable infrastructure, built environment and energy efficiency. If the industry, through its *Oil Sands Pathways to Net Zero* initiative, can achieve net-zero emissions in bitumen production, BBC can build on this foundation and create a net-zero manufacturing industry and significant economic development for Alberta and Canada.

It should be noted that great progress has been made in BBC development:

- BBC asphalt binder technologies are being commercialized.
- The first commercial BBC production facility is being commissioned for energy-storage carbon for supercapacitors, and hard carbon from bitumen has been identified as a new BBC product that may help commercialize the emerging technology for sodium-ion batteries.
- Multiple BBC carbon fibre technologies are being advanced to the point that they have attracted private investment, as well as interest from global automotive and aerospace manufacturers.

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WITHOUT SUCH A STRATEGY TO OFFER MULTIPLE END PRODUCTS DERIVED FROM BITUMEN AS ALTERNATIVES TO LIQUID TRANSPORTATION FUELS, THE DEMAND FOR OIL SANDS BITUMEN WILL NATURALLY DECLINE AS THE WORLD MOVES TOWARDS NET ZERO.

BBC can create economic value and reduce global emissions in the current policy environment already. However, it is in the IEA's NZE scenario that BBC would have the most impact on emissions reduction and create the greatest economic opportunities for Alberta and Canada.

BBC is a disruptive initiative. It will not happen on its own, and inaction could result in losing significant components of the value chain to other jurisdictions with heavy oil (e.g., Venezuela) or manufacturing expertise (e.g., United States and China).

Government leadership, policy direction and investment are needed to make BBC an economic engine and a climate solution for Alberta and Canada. The development of SAGD in the 1980s and 1990s provides a great lesson (Hastings-Simon, 2019). The creation of the Alberta Oil Sands Technology Research Authority (AOSTRA) in the 1970s and subsequent development of SAGD were not supported by the conventional oil industry at the time. However, former premier Peter Lougheed had the foresight at the time to prioritize the development of an innovative in situ recovery method. Lougheed's tenacity and faith in the disruption/breakthrough approach led to successful testing of the SAGD technology and the eventual creation of today's multibillion-dollar in-situ oil sands industry.

The lessons learned nearly half a century ago can still stand Alberta in good stead even though the challenges for the oil sands and the province look nothing like they did in the 1970s (Hastings-Simon, 2019). As Lougheed clearly understood, public investment is most impactful for innovative and disruptive technologies where private industry cannot or will not invest. Significant investment of public money in innovation is vital to unlock future economic growth in Alberta and Canada.

We call on the governments of Alberta and Canada to take advantage of the transformational opportunity that Bitumen Beyond Combustion presents. BBC is a unique opportunity to unite economic interests with climate benefits for the common good. Through Alberta Innovates, the Government of Alberta has taken a leadership in BBC development. The Government of Canada has made modest investments in BBC. However, the current investment level is insufficient to advance BBC at the speed required to realize its full potential.

Significant investment will be required to achieve the milestone targets described in this white paper. The most critical investment is between 2023 and 2030. The early investment should be made by governments. With success of BBC product development and commercialization, private investment will drive much of technology and market development and commercialization post-2030. We estimate that \$300 million total government investment will be required over 10 years.

Several policy mechanisms should be considered to accelerate commercial deployment. The first is intellectual property (IP) ownership and management. The Government of Alberta owns the IP for SAGD through AOSTRA. A small, non-exclusive licence fee is a critical success factor for wide deployment of the SAGD technology. For BBC, the challenge is even greater, and a cohesive IP policy will need to be developed.

Other policy requirements relate to investment attraction. In BBC, value addition to heavy fraction bitumen may occur anywhere in the world if it makes business sense. The governments of Alberta and Canada need to develop policies that will ensure Alberta and Canada maximize the benefits of the BBC value chain.



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The Government of Alberta's leadership in SAGD development in the 1980s led to a multibillion-dollar industry and created thousands of jobs across the country. BBC could be another transformational opportunity for Alberta and Canada. If successful, BBC can create an unprecedented economic opportunity for Alberta and help Canada to reach its net-zero emissions ambition. Furthermore, BBC could contribute to the global quest for a net-zero world.

Our mission is to turn the BBC vision into a reality.

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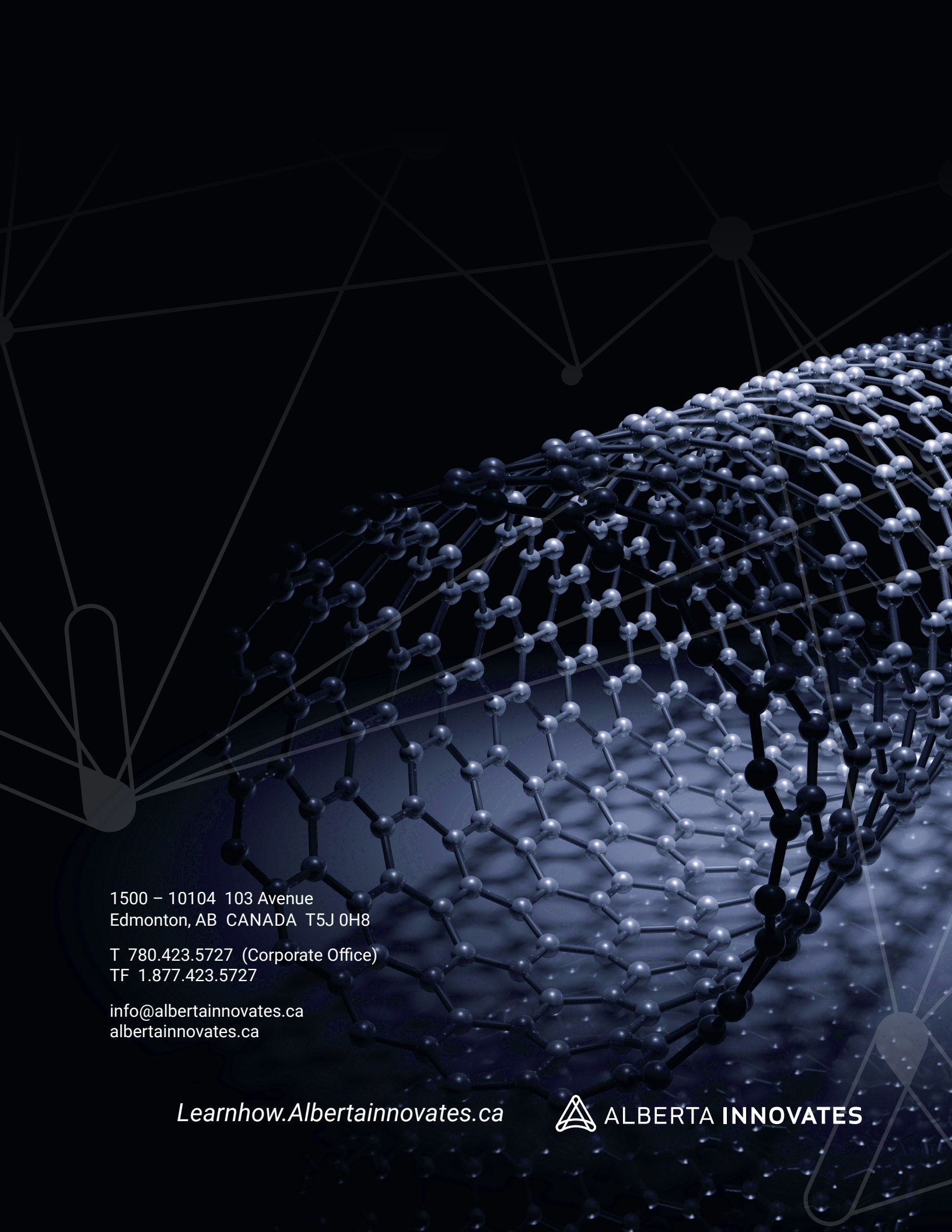
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