Forward-looking Statements

Certain statements relating to Canadian Natural Resources Limited (the "Company") in this document or documents incorporated herein by reference constitute forward-looking statements or information (collectively referred to herein as “forward-looking statements”) within the meaning of applicable securities legislation. Forward-looking statements can be identified by the words “believe”, “anticipate”, “expect”, “plan”, “estimate”, “target”, “continue”, “could”, “intend”, “may”, “potential”, “predict”, “should”, “will”, “objective”, “project”, “forecast”, “goal”, “guidance”, “outlook”, “effort”, “seeks”, “schedule”, “proposed”, “aspiration” or expressions of a similar nature suggesting future outcome or statements regarding an outlook. Disclosure related to expected future commodity pricing, forecast or anticipated production volumes, royalties, production expenses, capital expenditures, income tax expenses, and other targets provided throughout this publication and the Company’s Management’s Discussion and Analysis (“MD&A”) of the financial condition and results of operations of the Company, constitute forward-looking statements. Disclosure of plans relating to and expected results of existing and future developments, including, without limitation, those in relation to the Company’s assets at Horizon Oil Sands (“Horizon”), the Athabasca Oil Sands Project (“AOSP”), the Oil Sands Pathway to Net Zero Initiative, the Primrose thermal oil projects, the Pelican Lake water and polymer flood projects, the Kirby Thermal Oil Sands Project, the Jackfish Thermal Oil Sands Project, the North West Redwater bitumen upgrader and refinery, construction by third parties of new, or expansion of existing, pipeline capacity or other means of transportation of bitumen, crude oil, natural gas, natural gas liquids (“NGLs”) or synthetic crude oil (“SCO”) that the Company may be reliant upon to transport its products to market, the development and deployment of technology and technological innovations, and the financial capacity of the Company to complete its growth projects and responsibly and sustainably grow in the long-term also constitute forward-looking statements. These forward-looking statements are based on annual budgets and multi-year forecasts, and are reviewed and revised throughout the year as necessary in the context of targeted financial ratios, project returns, product pricing expectations and balance in project risk and time horizons. These statements are not guarantees of future performance and are subject to certain risks. The reader should not place undue reliance on these forward-looking statements as there can be no assurances that the plans, initiatives or expectations upon which they are based will occur.

In addition, statements relating to “reserves” are deemed to be forward-looking statements as they involve the implied assessment based on certain estimates and assumptions that the reserves described can be profitably produced in the future. There are numerous uncertainties inherent in estimating quantities of proved and proved plus probable crude oil, natural gas and NGLs reserves and in projecting future rates of production and the timing of development expenditures. The total amount or timing of actual future production may vary significantly from reserves and production estimates.

The forward-looking statements are based on current expectations, estimates and projections about the Company and the industry in which the Company operates, which speak only as of the earlier of the date such statements were made or as of the date of the report or document in which they are contained, and are subject to known and unknown risks and uncertainties that could cause the actual results, performance or achievements of the Company to be materially different from any future results, performance or achievements expressed or implied by such forward-looking statements. Such risks and uncertainties include, among others: general economic and business conditions (including as a result of effects of the novel coronavirus (“COVID-19”) pandemic and the actions of the Organization of the Petroleum Exporting Countries Plus (“OPEC+”)) which may impact, among other things, demand and supply for and market prices of the Company’s products, and the availability and cost of resources required by the Company’s operations; volatility of and assumptions regarding crude oil and natural gas and NGLs prices including due to actions of OPEC+ taken in response to COVID-19 or otherwise; fluctuations in currency and interest rates; assumptions on which the Company’s current targets are based; economic conditions in the countries and regions in which the Company conducts business; political uncertainty, including actions of or against terrorists, insurgent groups or other conflict including conflict between states; industry capacity; ability of the Company to implement its business strategy, including exploration and development activities; impact of competition; the Company’s defense of lawsuits; availability and cost of seismic, drilling and other equipment; ability of the Company and its subsidiaries to complete capital programs; the Company’s and its subsidiaries’ ability to secure adequate transportation for its products; unexpected disruptions or delays in the mining, extracting or upgrading of the Company’s bitumen products; potential delays or changes in plans with respect to exploration or development projects or capital expenditures; ability of the Company to attract the necessary labour required to build, maintain, and operate its thermal and oil sands mining projects; operating hazards and other difficulties inherent in the exploration for and production and sale of crude oil and natural gas and in mining, extracting or upgrading the Company’s bitumen products; availability and cost of financing; the Company’s and its subsidiaries’ success of exploration and development activities and its ability to replace and expand crude oil and natural gas reserves; the Company’s ability to meet its targeted production levels; timing and success of integrating the business and operations of acquired companies and assets; production levels; imprecision of reserves estimates and estimates of recoverable quantities of crude oil, natural gas and NGLs not currently classified as proved; actions by governmental authorities (including production curtailments mandated by the Government of Alberta); government regulations and the expenditures required to comply with them (especially safety and environmental laws and regulations and the impact of climate change initiatives on capital expenditures and production expenses); asset retirement obligations; the sufficiency of the Company’s liquidity to support its growth strategy and to sustain its operations in the short, medium, and long-term; the strength of the Company’s balance sheet; the flexibility of the Company’s capital structure; the adequacy of the Company’s provisions for taxes; and other circumstances affecting revenues and expenses.

The Company’s operations have been, and in the future may be, affected by political developments and by national, federal, provincial, state and local laws and regulations such as restrictions on production, changes in taxes, royalties and other amounts payable to governments or governmental agencies, price or gathering rate controls and environmental protection regulations. Should one or more of these risks or uncertainties materialize, or should any of the Company’s assumptions prove incorrect, actual results may vary in material respects from those projected in the forward-looking statements. The impact of any one factor on a particular forward-looking statement is not determinable with certainty as such factors are dependent upon other factors, and the Company’s course of action would depend upon its assessment of the future considering all information then available.

Readers are cautioned that the foregoing list of factors is not exhaustive. Unpredictable or unknown factors not discussed in this publication or the Company’s MD&A could also have adverse effects on forward-looking statements. Although the Company believes that the expectations conveyed by the forward-looking statements are reasonable based on information available to it on the date such forward-looking statements are made, no assurances can be given as to future results, levels of activity and achievements. All subsequent forward-looking statements, whether written or oral, attributable to the Company or persons acting on its behalf are expressly qualified in their entirety by these cautionary statements. Except as required by applicable law, the Company assumes no obligation to update forward-looking statements in this publication or the Company’s MD&A, whether as a result of new information, future events or other factors, or the foregoing factors affecting this information, should circumstances or the Company’s estimates or opinions change.
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Creating value through technology and innovation

Canada’s natural resources are safely and responsibly developed with world-leading standards, under comprehensive regulatory oversight and emissions regulations, and with significant technology investment. Canadian ingenuity and continued innovation in the oil sands strongly positions Canada to be the ESG-leading barrel of crude oil. Canada’s significant long life, no decline oil sands mining resources with manufacturing-like operations represent one of the clearest routes to net zero emissions of any global crude oil asset, providing the opportunity for investments in innovation to achieve net zero from oil sands operations.

At Canadian Natural, we know technology and innovation are keys to success in a lower carbon emissions future. We invest in a range of technology projects, such as carbon capture, utilization or storage (CCUS), molten carbonate fuel cells, solvent enhanced SAGD, and expanding on uses for bitumen. We understand that helping to address the challenge of climate change requires significant collaboration between industry and governments, including investing together in the research, development and scaling of new and emerging technologies. As we advance innovation, oil and natural gas production provides a foundation to incorporate many valuable opportunities for lower carbon emission products and to support renewable energy.

Delivering on GHG emissions reductions

Our defined pathway to drive long-term GHG emissions reduction and improve efficiencies is anchored in the development and adoption of technology. With $3.9 billion invested in research and development (R&D) between 2009-2020, and $48 million invested in GHG research and technologies in 2020, leveraging technology and innovation are key elements in our long-term plan and to achieving our targets. We are seeing meaningful results today and will continue to create long-term value on our journey to net zero through a comprehensive strategy.

Our integrated GHG emissions management strategy includes:

- Integrating emissions reduction in project planning and operations
- Leveraging technology to create value, enhance performance and reduce emissions
- Investing in research and development (R&D) and supporting collaboration
- Focusing on continuous improvement to drive long-term emissions reductions through energy and process efficiencies
- Leading in CCUS
- Engaging proactively in policy and regulation to effectively manage climate risks and opportunities, including trading capacity and offsetting emissions
- Considering and developing new business opportunities and trends

As an industry and company, we are driving actionable plans to achieve net zero emissions in our oil sands operations that will help meet Canada’s climate objectives while providing long-term economic and social benefits for Canadians. Developing and piloting technologies that can be effectively adopted across the industry, and other sectors, is an integral part of these plans.

Pamela McIntyre, Senior Vice-President, Safety, Risk Management and Innovation

↓18% Reduction

Corporate GHG emissions intensity from 2016 to 2020

↓28% Reduction

North America E&P methane emissions from 2016 to 2020

↓38% Reduction

GHG emissions intensity in oil sands mining and thermal from 2016 to 2020

12.5 million tonnes of CO₂e conserved since 2016 in primary heavy crude oil and in situ oil sands operations

Equivalent to removing 2.7 million passenger vehicles from the road over the same period
Accelerating technology development

Throughout this booklet are projects poised to deliver everything from incremental greenhouse gas (GHG) reductions to potentially game-changing results. Supporting innovation and leveraging technology are key to reducing risk and advancing projects to commercialization faster. New technology takes time to test and commercialize. By working together, coordinating efforts and collaborating, we are helping our projects move along the technology curve faster.

### Pathway to Net Zero

**Current Actions**
- Molten Carbonate Fuel Cells (MCFC) pilot
- Solvent Enhanced Oil Recovery (EOR) pilots
- In-Pit Extraction Process (IPEP) pilot
- NRG COSIA Carbon XPRIZE
- Methane Reductions
  - Enhanced detection and measurement of technologies for fugitive emissions
  - Pneumatic retrofits
  - Reducing heavy oil venting projects
- Ultra-low emissions heavy oil pad
- Cyclic CO₂ Injection pilot
- Advanced data analytics/digital operationalization
- Carbon Capture, Utilization and Storage (CCUS)
  - Horizon’s CO₂ utilization
  - Quest carbon capture and storage project
  - North West Refinery’s CO₂ utilization/Carbon Trunk Line
  - Hays Gas Plant capture for Enchant EOR operations
- Water Technology Development Centre technology testing

**Medium-Term Actions**
- MCFC commercialization
- Solvent EOR commercialization
- IPEP commercialization
- Technology separating minerals from tailings stream
- Leverage CCUS advancements and learnings into the next generation of CCUS facilities
- Advanced data analytics/digital operationalization
- High Temperature Reverse Osmosis

**Long-Term Actions**
- Expand/develop future CCUS projects
- Carbon capture and conversion (carbon fibers, asphalts, plastics) opportunities
- Advanced data analytics and digital operationalization
- Natural gas decarbonization
- Alternative fuel opportunities
- Direct air capture
- Small modular reactors

To accelerate innovation, our technology development model focuses on:

1. Understanding our business challenges and opportunities
2. Finding and assessing technology
3. Connecting employees with projects, R&D and technologies in the most efficient and cost-effective way

Every day, employees at Canadian Natural are accelerating technology development by reducing risk and taking technologies from lab concept to pilots and on to commercialization.

Canadian Natural is a strong, resilient company that uses creativity and innovation to create value for our shareholders. The case studies highlighted in this booklet showcase a sample of the new technologies and continuous improvement opportunities being evaluated, piloted and/or implemented at Canadian Natural and within the industry. Canada’s oil industry’s significant investment in leading-edge technologies puts us on a path to be a preferred supplier of responsibly produced energy the world will need in a lower carbon emissions future.
Leading in Carbon Capture, Utilization and Storage (CCUS)

Canadian Natural’s long-term aspiration is a journey to net zero emissions in our oil sands operations by advancing technologies and ongoing investment in carbon capture initiatives.

Canadian Natural is leading the oil and natural gas industry in CCUS initiatives. Our projects make us the largest owner of capture capacity in the Canadian crude oil and natural gas sector, based on data from the Global Carbon Capture and Storage Institute. In 2021, Canadian Natural, along with Canada’s largest oil sands producers, formed the Oil Sands Pathways to Net Zero initiative with the goal to work collectively with the Federal and Alberta governments to achieve net zero GHG emissions from oil sands operations by 2050 to help Canada meet its climate goals, including its Paris Agreement commitments and 2050 net zero aspirations.

**CO₂ Injection in Tailings**

At Horizon Oil Sands, we add captured carbon dioxide (CO₂) to tailings to enhance tailings performance and reduce our footprint. Our CO₂ recovery plant is designed to capture up to 50 tonnes/hour of CO₂ from the hydrogen plant, and CO₂ is then injected into the tailings. The plant has a capture capacity of 438,000 tonnes of CO₂ annually.

**Quest Carbon Capture and Storage (CCUS) Project**

The Quest CCUS facility is located at the Scotford Upgrader and is part of the Athabasca Oil Sands Project (AOSP), of which Canadian Natural has a 70% ownership interest. The Quest CCUS facility has safely captured and permanently stored 5.5 million tonnes of CO₂ at the end of 2020.

**Enhanced Oil Recovery (EOR)**

Canadian Natural is a 50% partner in the North West Redwater (NWR) Sturgeon Refinery, which supplies CO₂ to the Alberta Carbon Trunk Line (ACTL), an integrated system that can transport and store 14.6 MT CO₂/year for enhanced oil recovery (EOR). At full capacity, the ACTL is the largest carbon capture, transportation, utilization and storage system in the world using captured industrial CO₂. At our Hays Gas Plant, we also capture up to 12,000 tonnes of CO₂ per year for re-use/sequestration in our nearby Enchant EOR operations.

<table>
<thead>
<tr>
<th>Capture Capacity (Tonnes Per Year)</th>
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<tbody>
<tr>
<td>Horizon</td>
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<tr>
<td>Quest(1)</td>
</tr>
<tr>
<td>NWR(2)</td>
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<tr>
<td><strong>Total</strong></td>
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</table>

(1) Canadian Natural is a 70% working interest owner in Quest.
(2) On stream in 2020. Canadian Natural is a 50% owner in NWR.
Targeting zero emissions in heavy oil

Canadian Natural is continuously leveraging technology to develop the most efficient, environmentally sustainable methods for resource recovery while moving us further in the journey to net zero emissions.

Ultra-Low Emissions Primary Heavy Oil Pad Sites
In our primary heavy oil operations, Canadian Natural is piloting ultra-low emissions pad sites from reservoir to storage tank. These first of their kind pilots are testing how a typical heavy oil pad site would operate when most emissions are captured or reduced. In a typical heavy oil pad site, pumps powered by natural gas engines are used to transport oil from the reservoir to a storage tank. Once in the tank, the emulsion must be heated. This normally requires using the energy from burning solution gas.

At one of the ultra-low emissions sites, heat generated from burning the solution gas is replaced with electricity that has renewable potential. When heavy oil is produced, solution gas is normally consumed as fuel to power the engine and heat the tank. However, Canadian Natural’s ultra-low emissions site conserves the produced solution gas through on-site compression and a vapour recovery unit, reducing natural gas consumption potentially by 40%. The conserved solution gas is then sent to sales to be consumed elsewhere. Once in place, the test pad will allow us to operate and make improvements on cost-effective technologies that result in ultra-low emissions.

At another type of ultra-low emissions site less energy is consumed in the production process. Innovations that make this possible are tank heating to reduce wasted energy, and fit-for-purpose on-site skids that have increased efficiency over traditional models. These technologies are being field tested now and showing great promise.

Cyclic CO$_2$ Injection
Canadian Natural’s Cold Heavy Oil Production with Sand (CHOPS) assets in the Bonnyville/Lloydminster area typically have a primary recovery factor of approximately 10%. To access the up to 90% remaining oil, Canadian Natural is exploring an enhanced oil recovery (EOR) process.

Over 200 million barrels of incremental oil could be recovered from Canadian Natural-owned CHOPS areas using Cyclic CO$_2$ Injection. This process involves injecting carbon dioxide (CO$_2$) into a depleted reservoir to re-energize the oil, lower its viscosity and build pressure. During production, the dissolved gas gradually comes out of solution, creating foamy oil which enhances flow rates and helps preserve the reservoir pressure. Produced CO$_2$ is captured and re-injected on the next injection cycle. On completion of injection/production cycles, the CO$_2$ remains permanently sequestered in the reservoir.
Improving production and reducing environmental impact

Canadian Natural is continuously exploring technologies with the potential to make a significant difference in emissions reductions. Our applied technologies and day-to-day operational efficiencies are also increasing productivity and reducing greenhouse gas (GHG) emissions.

**Optimizing Multi-laterals to Enhance Productivity**

In 2017, Canadian Natural piloted a multi-lateral horizontal technique to increase reservoir contact, improve productivity and unlock reserves in conventional heavy oil areas where Cold Heavy Oil Production with Sand (CHOPS) wells were not economic. Multi-lateral horizontal wells had proven successful and effective in unlocking reserves in other areas, so we adapted the process to the unique geological parameters and production characteristics of primary heavy oil areas.

The first horizontal well in 2017 had 400 to 800 metres of reservoir contact, increasing to 2,000 to 4,000 metres of contact in 2018. In 2019, our teams scaled it up to 10,000 metres. With this new approach, Canadian Natural is seeing improved productivity and recovery. We’re also able to reduce our surface land area with pad drilling while increasing location inventory in our heavy oil assets.

**Liquids Enhancement and Gas Storage (LEGS)**

Optimizing recovery efficiency is key to maximizing the value of an asset. In 2020, the Liquids Enhancement and Gas Storage pilot at Septimus, in British Columbia, successfully used cyclic natural gas injection to re-vaporize and mobilize stranded liquids in a tight Montney reservoir, allowing them to flow readily to the well.

The pilot captured produced field gas and injected it into the wellbore during injection cycles and produced the gas back with incremental liquids volumes. Success of the LEGS pilot demonstrated the potential of the technology to add capital efficient reserves on existing and future developments, with the added potential to improve liquid sales rates by removing gas market and transportation limitations.
Capturing CO$_2$ for electricity generation

Canada’s Oil Sands Innovation Alliance’s (COSIA) members are identifying ways to reduce greenhouse gas (GHG) emissions intensity by exploring different technologies, including novel projects with the potential to create breakthrough technologies and help move Canadian Natural closer to net zero emissions.

Molten Carbonate Fuel Cells (MCFC)
A typical fuel cell converts chemical energy from a fuel into electricity. MCFCs are one type of fuel cell that operate at high temperatures to produce electricity, heat, and water that can be adapted to capture carbon dioxide (CO$_2$). This technology combines capturing CO$_2$ with generating low GHG-intensity electricity that could be used on site or sold back to the power grid.

A feasibility study funded by industry members and Alberta Innovates - Energy Environment Solutions found that MCFC technology to capture CO$_2$ was promising. This led to a preliminary front-end engineering design (pre-FEED) study to evaluate the cost of piloting a 1.4 megawatt power generation project at the Scotford Upgrader, part of the Athabasca Oil Sands Project (AOSP).

As a result of this study, Canadian Natural (majority owner of the AOSP) is leading a COSIA Joint Industry Project to pilot a 1.4 megawatt MCFC at the Scotford Upgrader. The project will be funded (40%) by Emissions Reduction Alberta and is targeted to start Front End Engineering and Design (FEED) in 2022.

Collaboration: This project is funded by the Athabasca Oil Sands Project (majority ownership by Canadian Natural 70%, Chevron Canada 20% and Shell Canada 10%), Cenovus and Suncor. It also has funding through Emissions Reduction Alberta.

Business Benefits
- Electricity for on-site use or export to the Alberta grid can provide a revenue stream to offset the costs associated with carbon capture.
- Captured CO$_2$ can be used at EOR operations to increase resource recovery.
- Potential to generate carbon credits, further enhancing economic viability of this technology.

Environmental Benefits
- Reduce GHGs by capturing CO$_2$ to generate electricity which could be applied to other industries.
- Potential zero emissions option for electricity generation.
- Water produced from the process can be captured and used at oil sands facilities, displacing other make-up water sources.

DEPLOY

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<th>BENEFITS</th>
<th>GHG</th>
<th>WATER</th>
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**DEPLOY**
- **Electricity for on-site use or export to the Alberta grid** can provide a revenue stream to offset the costs associated with carbon capture.
- **Captured CO$_2$** can be used at EOR operations to increase resource recovery.
- **Potential to generate carbon credits**, further enhancing economic viability of this technology.
Re-imagining CO₂

On the journey to net zero emissions, Canadian Natural is searching for transformational, creative solutions to reduce greenhouse gas (GHG) emissions through our support of the NRG COSIA Carbon XPRIZE.

**NRG COSIA Carbon XPRIZE**

Through Canada’s Oil Sands Innovation Alliance (COSIA) and with other partners, we are helping to transform waste CO₂ emissions into useful products like enhanced concrete to plastics, liquid fuel and carbon fiber. The US$20 million NRG COSIA Carbon XPRIZE global competition challenged entrepreneurs and innovators to develop breakthrough technologies. The two award-winning technologies, announced in 2021, converted the most CO₂ into products with the highest value, while minimizing their overall footprint in terms of emissions, land, water, and energy use.

Selected by a panel of independent judges, both winning teams advanced technologies that can address climate change by converting CO₂ emissions into products like environmentally friendly concrete. The two winning teams are recycling CO₂ emissions into concrete-related products – one of the most abundantly used materials on earth. Globally, the carbon capture and utilization sector is thought to be a $6 trillion opportunity, with the potential to spur new industries and products.

**World Leading Technology Centre**

The Alberta Carbon Conversion Technology Centre (ACCTC) is a specially designed facility that opened in May 2018 for innovators around the world to test and advance carbon conversion technologies. These technologies are aimed at fast-tracking CO₂ emission reductions through the conversion of carbon into usable products.

The ACCTC, owned and operated by InnoTech Alberta Inc., is located next to the Shepard Energy Centre, an 860 megawatt (MW) natural gas-fuelled power generation facility jointly owned by ENMAX and Capital Power. Innovators have the opportunity to evaluate new carbon capture and utilization technologies at demonstration scale using flue gas from Shepard or concentrated CO₂ from an on-site CO₂ capture unit. In addition to Canadian Natural’s support through COSIA project member companies, the ACCTC is funded by Natural Resources Canada and the Alberta Ministry of Economic Development and Trade.

**Business Benefits**

- Act as a catalyst to attract new and fresh ideas from around the world, to accelerate technology innovation in CO₂ conversion.
- Create opportunities to develop relationships and partnerships with global innovators that could lead to more technology development.

**Environmental Benefits**

- Reduce CO₂ emissions through the use of carbon conversion technologies.
- Accelerate CO₂ reuse technology development by attracting more resources (intellectual and financial) to address excess CO₂ emissions.

**Collaboration:** The NRG COSIA Carbon XPRIZE had two co-title sponsors — NRG Energy, a U.S. integrated wholesale power generation and retail electricity company, and COSIA. The COSIA sponsorship is funded by six oil sands companies as part of a joint industry project. Participants include Canadian Natural, ConocoPhillips Canada, Cenovus, Imperial, CNOOC, and Suncor.
Reducing emissions through carbon conversion

**Canadian Natural** is always looking for new research and development opportunities for reducing greenhouse gas (GHG) emissions from our operations towards our goal of net zero emissions in the oil sands.

**Natural Gas Decarbonization**

Canadian Natural is exploring how to decrease emissions resulting from in situ operations that require burning natural gas to produce steam. The Canadian Natural-led study, “Natural Gas Decarbonization Global Technology Scan and Evaluation”, looked at technologies and solutions available around the world to convert natural gas into a hydrogen rich fuel and a carbon rich co-product. The hydrogen rich fuel has a lower carbon content, emitting less CO$_2$ when burned, and the carbon rich co-product can either be used in oil sands extraction and production processes, or sold to offset costs.

As a result of the successful study, the **ARCTIC Innovation Challenge** was launched to identify potential decarbonization technologies. Of the many technologies submitted, two were selected for a techno-economic study that showed that each technology had the potential to economically produce a hydrogen rich fuel gas and a carbon byproduct.

With the support of Emissions Reduction Alberta and the **Natural Gas Innovation Fund (NGIF)**, we have partnered with other natural gas producers to invest in the testing of one of these technologies, as well as another novel natural gas decarbonization technology, to help accelerate development and commercialization.

Working with industry partners through COSIA, we are also investing in technology that separates methane molecules into a hydrogen rich fuel (for use as a replacement for diesel or natural gas) and valuable carbon nanotubes which can then be sold as separate products. In 2021, we launched a techno-economic evaluation to determine how to integrate this technology into the in situ processes and to what extent this reduces our GHG emissions.

**Collaboration:** The technology scan was conducted through COSIA, led by Canadian Natural with participation by Suncor and Imperial, in partnership with the Gas Technology Institute (GTI). The **ARCTIC Innovation Challenge** program is a partnership with British Columbia-based not-for-profit Foresight Cleantech Accelerator Centre and COSIA member companies to find and fund clean technology solutions for resource sector challenges in Western Canada.
Reducing the energy required to produce a barrel of oil

Canadian Natural is piloting using solvent for enhanced oil recovery. When used in combination with heat, solvent technology will increase oil recovery, improve steam efficiency and reduce operating expenses to achieve environmental benefits including reductions in greenhouse gas (GHG) emissions, water use, and land footprint.

**Solvent Enhanced Oil Recovery**

Solvent technologies will play a significant role in creating value across all of our thermal operations on our journey to net zero emissions.

In typical thermal oil sands operations, water is heated to create steam that mixes with bitumen and reduces its viscosity so it can be pumped to the surface. When solvent is added, the process requires less steam and operates at a lower temperature – letting heat do half of the job to improve bitumen viscosity with solvent doing the other half. As a result, the steam-to-oil ratio (SOR) and the amount of water needed overall is significantly reduced, leading to lower operating expenses for steam and water treatment. In addition to the enhanced project economics, solvent EOR can achieve important environmental performance improvements with up to 50% lower GHG emissions intensity and improved water use intensity.

Our ongoing pilot at Kirby South tested solvent effectiveness to improve oil recovery in a steam-assisted gravity drainage (SAGD) process. Results were positive, showing SOR and GHG intensity reductions of 45% through the pilot process, as well as solvent recoveries of approximately 85%, confirming the viability of this technology. As a result, Canadian Natural is progressing with engineering and design of a commercial scale SAGD pad development at Kirby North.

At Primrose, in the steam flood area, a solvent injection pilot commenced in Q4 2021. Canadian Natural’s second pilot consists of nine net wells (five producers and four injectors). Similar to the pilot at Kirby South, is targeted to operate for a two-year period with targeted SOR and GHG intensity reductions of 40 to 45% and solvent recoveries of greater than 70%.
DEPLOY

Increase the number of technologies tested, while collaboratively managing the risks, leveraging multi-company expertise, and lowering the costs of technology development.

Reduce the costs of commercial facility development.

Environmental Benefits

• Lower GHG emissions and land footprint through improved water recycling technologies.
• Improve technologies and practices for managing the waste products from water recycling.

Canadian Natural is a joint industry partner in the Water Technology Development Centre to help reduce the cost of water recycling, improve recycling technology, and reduce the environmental footprint of facilities.

The Water Technology Development Centre (WTDC)

About 80% of Alberta’s oil sands reserves can be recovered through in situ extraction technology. In situ operations use water to produce high-temperature steam that is injected into the reservoir to heat the bitumen. The water is recovered, treated and used again.

In situ operators have established a world-class water technology development centre at an operating oil sands facility to conduct collaborative research that could reduce the cost of water recycling, improve the reliability and efficiency of recycling technology, and reduce the environmental footprint of facilities.

The WTDC is a dedicated facility to test new technologies on ‘live’ process fluids in real-world conditions. Its unique design allows operators to share risks and costs so they can drive the development of more technologies than they could on their own. The test centre will speed technology development and implementation, shortening the current timeframe required to field test technologies and move them to commercial application, leading to an accelerated return on investment.
Canadian Natural is continuously looking for ways to improve operational efficiencies and reduce our greenhouse gas (GHG) emissions. Effective water management is an integral piece of lowering our GHG emission intensity across all our projects.

**High Temperature Reverse Osmosis**

As part of in situ oil sands development, steam is injected into the reservoir to recover bitumen from the reservoirs beneath the surface. Natural gas is used to heat water and produce steam. In a typical in situ oil sands facility, recycled water that is used to generate steam is cooled and heated as part of the treatment process and this requires additional equipment. If our facilities can be redesigned to keep the water hot throughout the treatment process, significant cost savings and reductions in land footprint could be realized.

Canadian Natural, in partnership with Suncor and Suez Water Technologies, is developing High Temperature Reverse Osmosis (HTRO) membranes to enable the in situ oil sands water treatment process to operate at higher temperatures, thus eliminating the need for cooling and re-heating the water. The HTRO project is breaking new ground by developing commercial reverse osmosis membranes to treat produced/recycled water and operate above 100°C. Bench-scale testing is currently underway with a larger pilot planned for 2023 at the Water Technology Development Centre.

**Conventional Reverse Osmosis to Further Reduce Fresh Water Use**

At our Primrose and Wolf Lake operations, we are also deploying conventional reverse osmosis technology for saline water treatment. The higher quality, treated water will be used as make-up boiler feed water, and will reduce impacts to surface facilities and improve well productivity. This project, which will continue to help us reduce fresh water use at the plant, is targeted to be commissioned by the end of 2022.

**Business Benefits**

- Reduce the capital cost of new Steam Assisted Gravity Drainage (SAGD) facilities.
- Reduce natural gas consumption, reducing fuel costs.
- Reduce impacts to thermal surface facilities and improve well productivity.

**Environmental Benefits**

- Reduce GHG emissions by 5%-10% by efficiently producing high quality water that enables the use of high efficiency steam generators.
- Reduce plant footprint by adopting membrane technology.
- Reduce fresh water use.

**Collaboration:** The HTRO project was convened under Canada’s Oil Sands Innovation Alliance’s (COSIA) with funding support provided by Emissions Reduction Alberta.
Canadian Natural is focused on operational practices and innovative technologies to reduce methane emissions.

Methane is a greenhouse gas (GHG) that is the main component of natural gas. In the upstream oil and natural gas industry, methane emissions are typically from venting (controlled release of gases) and pneumatic devices (that control natural gas pressure/flow). These sources are the focus of Canadian Natural’s methane emissions reduction plan and our Methane Steering Committee of senior leaders and technical experts.

Reducing Heavy Oil Venting
For almost two decades, Canadian Natural has been investing in natural gas conservation projects to reduce venting in our heavy oil operations. Our projects include:

- efficient management of more than 1,200 compressor units used for gas conservation;
- proactive tie-in of wells and multi-well pads where solution gas is conserved; and
- continuous improvement in facility design to reduce vented gas.

We also expanded our use of vapour combustor technology to convert methane to carbon dioxide (CO₂) at our heavy oil operations when methane cannot be conserved, resulting in less CO₂ equivalent emissions. In 2020, over 144,750 tCO₂e of methane was converted to CO₂ using this technology, reducing GHG emissions by more than 85% when compared to venting.

Reducing Emissions from Pneumatic Devices
Pneumatic devices use pressurized natural gas to function, some of which release low volumes of natural gas as part of their normal operation. We continue to reduce emissions through our pneumatic retrofit program. From 2018-2020, over 5,000 high-emitting pneumatic controllers were removed or converted to low-emitting ones, reducing emissions by 535,000 tonnes of CO₂e/yr.

In 2020, Canadian Natural completed 249 solution gas conservation projects in our primary heavy crude oil operations, resulting in a reduction of approximately 1.3 million tonnes/year of CO₂e.
Enhanced Management of Fugitive Emissions

Canadian Natural is exploring methods to enhance the accuracy of greenhouse gas (GHG) emissions measurements from large industrial area sources, including open pit mines and tailings ponds.

Canadian Natural’s research helps address the challenge of quantifying rates of methane and carbon dioxide (CO₂) emissions from non-point sources. Continuous improvement in the consistency and accuracy of measurement techniques will allow us to refine strategies for emission reduction.

A multi-year study was completed at the Horizon Oil Sands facility from 2017 – 2019 to provide a more complete picture of how emissions are generated and influenced by the atmospheric conditions. A series of advanced sensors, laser and fiber optic technologies, meteorological data, as well as computer modelling techniques were evaluated. Data collection and analysis was completed over four discrete field seasonal campaigns.

The studies concluded that there are several alternative techniques for quantifying GHG emissions superior to our current methods in terms of accuracy, efficiency and cost. Canadian Natural is currently working to have those methods approved by regulators for compliance monitoring at our mining operations.

**Enhanced Detection of Fugitive Methane Emissions**

We have also implemented Alternative Fugitive Emissions Management Program pilots in 2021 under the jurisdiction of the Alberta Energy Regulator (AER) in our conventional operations. With the support of Emissions Reduction Alberta (ERA), these pilots are deploying emerging technologies across 2,500 facilities in our North American Exploration and Production operations to evaluate technology performance and validate forecasted emission and cost reductions. Commercialization of technologies that offer accelerated detection and accurate characterization of methane emissions will assist industry in continuous improvement of leak detection and repair efficiencies and overall methane emission reductions.

**Collaboration:** The multi-year area fugitives study at Horizon was funded by Canadian Natural, Emissions Reduction Alberta and through Canada’s Oil Sands Innovation Alliance (COSIA) with other industry partners including Teck Resources, Imperial, Syncrude and Suncor. The Alternative Fugitive Emissions Management Program is funded by Canadian Natural and Emissions Reduction Alberta.
**Essentials for the renewables industry**

**Creating Value from Froth Treatment Tailings**
Titanium Corporation’s CVW™ is a suite of froth treatment tailings remediation technologies designed to reduce the environmental footprint of tailings ponds while recovering valuable products that would otherwise be lost in tailings ponds. These technologies recover bitumen, solvents, heavy minerals and rare earths from froth treatment tailings, preventing these commodities from entering tailings ponds and the atmosphere. Industry-wide implementation of CVW™ could impact future greenhouse gas (GHG) emissions from tailings ponds and the extraction of heavy minerals.

**DEPLOY**
- Potentially create a new minerals industry for Alberta and Canada that could translate into economic growth, jobs, diversification and potential exports.
- Recover up to 100,000 tonnes per year of valuable minerals (zircon and titanium-bearing high-grade titanium with TiO$_2$ content).
- Recover process water, residual solvent, bitumen, and provide cleaner tailings, thereby accelerating reclamation.
- Reduce and avoid future fugitive emissions from tailings ponds.
- Improve tailings water quality for recycling.
- Potentially avoid future GHG emissions by approximately 570,000 tCO$_2$e per year.
- Provide a lower GHG extraction process for heavy minerals.

**Recovering Vanadium and Nickel for Renewables**
Vanadium and nickel are essential to building longer-lasting batteries in the electrification sector. These elements appear in trace concentrations in Canadian Natural’s bitumen streams. In a separate project, we are looking at methods of capturing vanadium and nickel as part of our synthetic oil generation process.

**Collaboration:** Titanium Corporation’s CVW™ technology has been developed with broad stakeholder support, including the Governments of Canada and Alberta, and collaboration from Canadian Natural and other oil sands operators that provided tailings samples, technical input and project reviews over the last five years. The Front-End Engineering Design (FEED) study received funding from Emissions Reduction Alberta. Other collaborators include Canada’s Oil Sands Innovation Alliance (COSIA), Alberta Energy, Sustainable Development Technology Canada, National Research Council (NRC), and Industrial Research Assistance Program (IRAP).
Canadian Natural is collaborating with industry, entrepreneurs, academics, and funders to uncover new uses and methods of utilizing bitumen to reduce potential downstream greenhouse gas (GHG) emissions intensity.

Assessing the Viability of Non-Combustion Products

Most bitumen produced from Alberta’s oil sands, like other types of petroleum, is primarily used for making combustion products like fuels such as gasoline, diesel and heating oil. Canadian Natural and industry continue to look for opportunities and ways to incorporate solutions to become more effective and efficient and find new markets for our products. Some opportunities we are currently exploring include:

- **Bitumen Beyond Combustion (BBC):** Led by Alberta Innovates, the program was designed to explore alternative, non-combustion uses for bitumen. Canadian Natural recently provided industrial samples to the Carbon Fibre Grand Challenge, a $15 million competition designed to accelerate the development of carbon fibre from bitumen-derived asphaltenes.

- **Converting Bitumen into Valuable Products:** Work is ongoing with vendors to develop technology to convert bitumen, particularly the heaviest part of the bitumen, into activated carbon, graphene and graphite.

- **Converting Petroleum Coke into Activated Carbon:** Canadian Natural is exploring methods of converting petroleum coke, a byproduct from our upgrading process that is made of almost pure carbon, into activated carbon that can be input into applications like water treatment and battery manufacturing.

Potential Value-Added Products

<table>
<thead>
<tr>
<th>Carbon Fibres and Combination Products (Including Graphene)</th>
<th>Asphalts</th>
<th>Plastics or Polymers</th>
</tr>
</thead>
</table>
| Used in steel, cement and wood | • High quality asphalts for roads  
• Asphaltenes for carbon fiber feedstock | • Polymers that are compostable and biodegradable  
• Vanadium flow batteries |

Source: Canada’s Oil Sands Innovation Alliance (COSIA.ca)

Environmental Benefits

- Reduce life-cycle GHG emissions intensity by producing new products derived from oil sands that will not be combusted as fuel.
Reducing emissions through value-added opportunities

Canadian Natural’s energy requirements are diverse among our facilities. Currently, some of our projects in British Columbia use hydroelectricity from the grid, and we are exploring unique ways to meet our power needs while reducing greenhouse gas (GHG) emissions.

**Alternative Fuels**

Canadian Natural is exploring using hydrogen to offset some of the diesel fuel used in combustion engines. Hydrogen is a cleaner burning fuel, and when combined with diesel, it has been found to reduce emissions by 25%. We are working with industry peers to test this technology and improve its economics at the Southwest Research Institute (SWRI).

When used as a replacement for diesel, biodiesel can reduce a diesel engine’s overall GHG emissions up to 50%. We are evaluating the use of biodiesel in our haul trucks and other facilities and investigating methods to generate our own biodiesel, either through partnerships or generation via waste streams at our facilities.

We are also looking at the development of electrification for haul trucks in our mines and/or potentially introducing hydrogen fuel cells to help reduce their GHG emissions intensity.

**Solar, Wind and Hydroelectricity**

In 2022, Canadian Natural is planning to launch a multi-year project to convert approximately 3,000 pneumatic injection pumps in our Alberta and British Columbia conventional areas to solar configurations in an effort to reduce methane emissions and decrease safety hazards. This project will help us reduce methane emissions by up to 270,000 tCO₂e/yr.

We are also actively evaluating opportunities to add solar and wind generators to supplement the electrical needs of our existing and new facilities.

In our International operations, we are working with the Net Zero Technology Centre in the UK to explore the potential of installing a floating wind turbine generator to supply power to our offshore platforms. A 10 megawatt wind turbine could reduce GHG emissions by approximately 35,000 tonnes per year on one platform.

**Quality and Safety**

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**Collaboration:** Canadian Natural is part of a hydrogen/diesel joint industry project through Canada’s Oil Sands Innovation Alliance (COSIA) that includes Imperial and Teck Resources. In our international operations, we work with the Net Zero Technology Centre to explore joint industry projects.
Minimizing risk and improving tailings reclamation timelines

Canadian Natural invests in extensive tailings research, technologies and project construction to help minimize risk and reduce our environmental footprint.

Proactive Tailings Management
When we begin a project, we always have a vision and a proactive plan for the landscape that considers the end of mine life and tailings reclamation. The graphic below depicts a typical tailings pond.

At Horizon Oil Sands, a Non-Segregating Tailings (NST) process uses cyclones to separate the coarse sand and thickeners to capture fines and remove water in the tailings stream prior to being sent to the tailings pond. The warm water recovered is re-used in production. Carbon dioxide (CO₂) from Horizon’s capture plant is injected in the tailings, further enhancing fines capture and accelerating dewatering. Since its launch at Horizon in 2016, Canadian Natural has continuously improved the NST process to make it more effective and efficient.

At the Athabasca Oil Sands Project (AOSP) we use thickeners, centrifuges, and Atmospheric Fines Drying (AFD) to remove water from our fluid tailings (FT). Canadian Natural has also tested pressure filtration technology which uses a mechanical filter to separate water from the FT, producing solids suitable for reclamation shortly after treatment and water that can be re-used in the extraction process. This is used in hard rock mining and is a good example of how innovation in other industries can be considered and used to drive environmental performance improvements in our business.

Collaboration: These tailings management projects are led by Canadian Natural and shared through Canada’s Oil Sands Innovation Alliance (COSIA).
Canadian Natural is an industry leader for abandonment, decommissioning and reclamation activities. We are continually looking for new and improved ways to manage our tailings to reduce their footprint, decrease reclamation time, and reduce tailings pond stability risk.

Reclaiming Canadian Natural’s First Tailings Facility

The South Expansion Area (SEA) at our Muskeg River Mine, part of our Albian operations, was the first tailings facility to apply for dam decommissioning and closure under Alberta’s Dam and Canal Safety Directive (2018). The Directive requires the operator to present a plan and obtain authorization from the AER for the decommissioning and closure of the facility that ensures the stability and safety of the landform. As part of the decommissioning process, the dam consequence risk was successfully reduced to the lowest category in 2021 under this more stringent Directive.

Canadian Natural has transformed the site into a reclamation area that includes natural landscape features, like streams, wetlands and upland forest areas with hummocks to create natural wildlife habitat.

![Active Pond](image1) ![Reclaimed Area](image2)

**Active Pond**
July 2018

**Reclaimed Area**
October 2020

*In 2021, we expect to achieve final reclamation of approximately 295 hectares in this area (13 years after first disturbance).*

Canadian Natural is a leader in progressive reclamation. For our mining operations, we are reclaiming our tailings ponds and overburden waste dumps during the operating stage up to the end of life of the facilities, therefore reducing our liability and risk over time. At our external tailings facilities to date, we have reclaimed 545 ha at Horizon Mine, 153 ha at Muskeg River Mine, and 104 ha at Jackpine Mine.

**Applied Process Innovation Centre (APIC)**

The APIC was designed and equipped at Horizon to perform a variety of tests and programs to investigate and accelerate the application of promising tailings technologies to commercial scale. It also acts as a collaboration hub so industry peers can complete tailings research with samples from their own operations, working together with academia, entrepreneurs and government. In 2021, we invested in a lab-scale centrifuge to allow us to further our understanding of consolidation and speed-up settlement of tailings fines.
Reducing tailing ponds and emissions

In Canadian Natural’s Oil Sands Mining and Upgrading operations, reducing the need for tailings ponds and greenhouse gas (GHG) emissions are environmental priorities.

In-Pit Extraction Process for Tailings
As part of our continuous investments in research and technology, Canadian Natural focuses on improving performance by enhancing our processes while reducing environmental impact. At Horizon Oil Sands, a field pilot was completed on an alternative bitumen extraction method — the In-Pit Extraction Process (IPEP). This involves a relocatable, modular extraction plant that processes ore and separates bitumen right in the mine pit. IPEP reduces materials transportation by truck, pipeline length and the energy needed to pump material. This process also produces stackable dry tailings, potentially eliminating the need for future fluid tailings ponds.

Collaboration: Canadian Natural has committed to making this technology available to oil sands mining companies through Canada’s Oil Sands Innovation Alliance (COSIA) for more rapid industry-wide adoption. IPEP was developed with broad stakeholder support, including support from the Governments of Canada and Alberta.

DEPLOY

Business Benefits
- Potential to reduce production costs by approximately $1 to $2/barrel while substantially reducing tailings management costs and liabilities.

Environmental Benefits
- Reduce GHG emissions by up to 40% in bitumen production compared to conventional oil sands mining processing plants by minimizing transportation.
- Reduce footprint of mining operations by eliminating the need for constructing new central ore processing facilities.
- Accelerate reclamation, reduce and avoid fugitive emissions, and potentially eliminate the need for future fluid tailings ponds through the production of “dry” stackable tailings.
Accelerating the pace of reclamation and protecting biodiversity

Canadian Natural’s land management strategy is to reduce our impact by progressively reclaiming large contiguous areas of land more efficiently and cost effectively. We incorporate long-term biodiversity and reclamation objectives in our programs to maintain the characteristics of each ecosystem and restore wildlife habitat.

Area-Based Abandonment and Reclamation
In our conventional and thermal operations, Canadian Natural’s industry-leading closure program is accelerating the pace of well abandonment and site reclamation in innovative and cost-effective ways, while advancing environmental closure obligations. We group well and pipeline abandonments, reclamation and remediation activities to take sites out of service in a safe and environmentally sound manner removing our footprint over larger areas. These activities have reduced the average time to reclamation certification from four years to three years. Between 2016 and 2020 we have abandoned 5,570 inactive wells and submitted 4,182 reclamation certificates.

Improving Remediation Targets
Canadian Natural is working with industry and regulators through the Petroleum Technology Alliance Canada (PTAC) on outcome-based remediation targets that use site-specific parameters to reduce traditional excavation and disposal of impacted material. This approach reduces disturbance at native prairie sites, a region of high biodiversity and challenging growing conditions. The Alberta Environment and Parks protocol focuses on leaving impacted material in the ground that does not pose a risk to groundwater, vegetation or livestock at native prairie sites to avoid disturbing well-established native prairie. This protocol helps to minimize vegetation disturbance, preserve the existing native grasslands, and shorten the time to reclamation certification.

Wetland Monitoring and Reclamation
Canadian Natural continues to monitor and learn from the pilot reclamation of a borrow excavation to a constructed wetland in 2018. Working with consultants, we engaged local Indigenous community members from Conklin, Alberta to advise us on the specific qualities of the vegetative species and participate in the planting of seedlings. Today, this wetland is thriving and the Indigenous knowledge, combined with novel planting and reclamation techniques, is leading to improved wetland reclamation and potentially decreased costs.

Through 2020 and 2021 Canadian Natural realized operational cost savings and improved risk reduction by improving the efficiency and efficacy of wetland environmental monitoring programs required for our operating approvals. Through Canada’s Oil Sands Innovation Alliance (COSIA), we led the development of industry-wide guidance for monitoring protocols and worked with our suppliers to develop modified programs that deliver enhanced risk management at less than half the cost.
Improving reclamation and protecting biodiversity

Canadian Natural develops every project with a strategic vision and plan to proactively manage impact on the land. We are committed to reclaiming all our worksites once our activities are complete — whether that is boreal forest, native prairie or farmed land. Our reclamation strategies support the establishment of healthy ecosystems, biodiversity, wildlife habitat and a range of land uses.

H2nanO

Water used in the oil sands production process contains compounds that require treatment prior to release. Canadian Natural and other oil sands producers are working with water treatment company H2nanO and researchers at the University of Toronto on a sunlight-activated, reusable treatment process for process-affected water. This treatment, called Solar Pass, uses tiny particles that when mixed with water and sunlight, cause a chemical reaction to be activated that would continuously treat the process-affected water so it supports aquatic life. Our Canada's Oil Sands Innovation Alliance (COSIA) Joint Industry Project has proven the technology works and Canadian Natural is now working with H2nanO to refine the technology to add it to our water treatment options.

Compensation Lakes

Canadian Natural has three compensation lakes that we are continuing to develop and monitor. Compensation lakes are constructed to replace fish habitat disturbed from development activities. They are designed to support the habitat requirements of selected native fish species and to provide the necessary components for a natural ecosystem to evolve. Research and monitoring is conducted to measure progress, verify use of constructed fish habitat, and to advance the science of building lakes.

To ensure the success of establishing the lake ecosystem, we are using Environmental DNA (eDNA) to identify fish species in our compensation lake and amphibians in natural and reclaimed wetlands. Study samples revealed more species in the aquatic community than conventional sampling methods, demonstrating that eDNA results can profile fish communities and their progression over time. Another eDNA pilot was conducted to identify the presence of Canadian toads in new development areas. If Canadian toads are detected, they are safely relocated out of planned development areas.

Reducing Bird Interactions

To enhance our robust bird detection and deterrent systems at Horizon, we are working with Environment Canada to identify the target signal of specific bird species. We installed a long range radar unit in 2019 designed to track birds up to 20 km away from our site. This allows us to detect bird flights near incoming aircraft and through the filtering of the data, detect large bodied birds when they get close to our operations. Work is ongoing to develop real-time data displays that will be used to prevent birds from landing near our operations.

DEPLOY

• Accelerate water treatment at the end of mine life when an oil sands facility is decommissioned.
• Improve identification of species in our compensation lakes to help us meet regulatory requirements more cost-effectively and quickly.

Business Benefits

• Treat process-affected water without the use of additive chemicals or absorbents.
• Demonstrate the biodiversity of compensation lakes, reducing our environmental footprint.
• Reduce bird contact near operating facilities.

Environmental Benefits

• Improve identification of species in our compensation lakes to help us meet regulatory requirements more cost-effectively and quickly.

Canadian Natural
Leveraging digital technology for safety and environmental performance

Canadian Natural is leveraging three dimensional (3-D) digital models, virtual reality (VR) and augmented reality (AR) technologies in innovative ways to benefit the company.

Major Canadian Natural facilities have been designed for a number of years with a series of 3-D models using the Smart Plant Review (SPR) software. Teams can perform ‘virtual walkthroughs’ of the models on their computers to identify potential hazards and optimize project planning. SPR is used by close to 1,800 employees to gain efficiencies and lower operational costs through plant planning activities, particularly during turnarounds and other maintenance periods, facility design changes and orientation/training.

Virtual Reality

The VR plant is spatially identical to the actual Horizon Oil Sands facility with every single vessel, valve, pump and other components in its correct location. Using VR, employees can train on equipment, operational procedures, orientation, and emergency response in the exact plant location. This allows a level of training that would otherwise be impossible in an operating plant. Similar SPR and Laser Scanned models are being developed for Albian and opportunities are being investigated to use 3-D models in other areas to improve drilling methods and resource capture.

In 2020, we extended 3-D modelling to our UK platforms (Ninian Central, Ninian South and Tiffany). The three locations are now fully scanned and 3-D models are available to all employees and contractors for easy access to centralized data for project planning, facility design changes and risk assessments.

Artificial Intelligence

Canadian Natural is also using data analytics on Horizon’s multiyear, industry-leading data set to maximize the operation’s uptime and proactively prevent failures and ensure steady production. For example, analyzing our data set for patterns has enabled us to predict when Horizon’s carbon dioxide compressors could go offline. We are also using predictive analysis to help reduce the amount of chemical used in the hot lime softener at our Jackfish operations. If successful, this project will help to reduce chemical and water recycling costs.
Canadian Natural has teams of highly experienced individuals with technical expertise in pipeline integrity management. These teams drive a consistent approach to problem solving, align solutions with industry best practices, and continually identify new ways to detect and reduce the potential of pipeline incidents.

Canadian Natural has a proactive pipeline integrity management program that places a high level of focus on pipelines near moving water bodies and in geotechnically active areas. As a result, we have further strengthened our processes and tools to predict possible failure locations, along with the early detection of small leak rates to mitigate potential environmental impacts. Some of the new technologies deployed to help us maintain safe, reliable operations of our pipeline network are shown below.

**Real-Time Pipeline Data Comparison**
Canadian Natural adopted PipeWISE, a cost effective real-time software that uses current pipeline meter data to determine if the pressure and flow of the line has deviated from previously recorded norms. The technology is sensitive, allowing us to detect smaller leaks well in advance. We are currently working on further developments of this technology.

**Fiber Optic Sensing for New Pipelines**
In 2019, Canadian Natural installed the first commercial fiber optic sensing for leak detection in the Swan Hills, Alberta area to detect smaller, previously undetectable leaks. This technology also senses geotechnical ground movement in real time, effectively allowing us to proactively respond. Building on this success, we are working toward deploying a live data feed to detect strain and leaks, as well as track pigs (scrapers), inspection tools that we send down the inside of pipelines to look for corrosion, cracking and physical deformation.

**Better Insulation for Above-Ground Pipe**
Above-ground pipeline must be insulated to prevent stress corrosion cracking in the cold northern winters. Canadian Natural is working with InnoTech Alberta and other industry partners to review and share knowledge and enhance the thermally insulated carbon steel used in these pipelines. Together, we will develop enhanced inspection and monitoring, and mitigation practices for pipelines, piping and vessels already in-service, as well as for new construction.
Canadian Natural partners with organizations that bring companies, innovators and investors together to help leverage our investments into incremental and game-changing technologies and accelerate development timelines.

The Clean Resource Innovation Network (CRIN) is an industry-led network that leverages large-scale collaboration and aligns research and technology priorities. Canadian Natural is an active participant in the network, bringing together the oil and natural gas industry and the sectors necessary to accelerate the commercialization of new technologies (service companies, private and public innovators, think tanks, investors, policy makers and academics). CRIN’s vision is for Canada to be a global leader in producing clean hydrocarbon energy from source to end use.

Canada’s Oil Sands Innovation Alliance (COSIA) is an alliance of oil sands producers focused on accelerating the pace of improvement in environmental performance in Canada’s oil sands through collaborative action and innovation. Canadian Natural is a founding member and active participant in COSIA. Since its inception in 2012, COSIA members have collectively shared over 1,100 distinct technologies worth $1.8 billion to develop, with a focus on managing greenhouse gas (GHG) emissions reductions, tailings, water and land.

The Petroleum Technology Alliance Canada (PTAC) is a Canadian hydrocarbon industry association that serves as a neutral non-profit facilitator of collaborative research and technology development, and operates in partnership with all industry stakeholders to transform challenges into opportunities. Canadian Natural is an active participant in a number of PTAC projects. Through PTAC, nearly 500 R&D projects have been launched to date, with a realized value of almost $133 million per year.

The Natural Gas Innovation Fund™ (NGIF) was created by the Canadian Gas Association to fill a technology development gap in the sector and invests in innovation led by cleantech start-ups and small and medium-sized enterprises, enabling natural gas solutions for current and emerging challenges facing Canada’s energy system. NGIF plays an important role in the natural gas sector and aligns with Canadian Natural’s commitment to lowering GHG emissions intensity by leveraging technology and Canadian ingenuity.

The Petroleum Technology Research Centre (PTRC) is a not-for-profit corporation that facilitates research and development and demonstration projects into enhanced oil recovery and carbon storage, with the goals of improving recovery rates while reducing the environmental footprint of the oil and gas industry. Canadian Natural contributes to PTRC’s Heavy Oil Research Network (HORNET), a program that is focused primarily on enhanced oil recovery.