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CREATING VALUE THROUGH TECHNOLOGY AND INNOVATION

CASE STUDIES

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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” 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 guidance provided throughout 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 but not limited to the Horizon Oil Sands (“Horizon”) operations and future expansions, the Athabasca Oil Sands Project (“AOSP”), Primrose thermal projects, the Pelican Lake water and polymer flood project, the Kirby Thermal Oil Sands Project, the cost and timing of construction and future operations of 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 or synthetic crude oil (“SCO”) that the Company may be reliant upon to transport its products to market, development and deployment of technology and technological innovations and the assumption of operations at processing facilities also constitute forward-looking statements. This forward-looking information is based on annual budgets and multi-year forecasts, and is 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 natural gas liquids (“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 reserve 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 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 which will, among other things, impact demand for and market prices of the Company’s products; volatility of and assumptions regarding crude oil and natural gas prices; fluctuations in currency and interest rates; assumptions on which the Company’s current guidance is 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 resumption of 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 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; timing and success of integrating the business and operations of acquired companies and assets; production levels; imprecision of reserve estimates and estimates of recoverable quantities of crude oil, natural gas and NGLs not currently classified as proved; actions by governmental authorities; 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 adequacy of the Company’s provision 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 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 the Company’s MD&A could also have material 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, 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

Canadian Natural allocates significant investment towards research and development (R&D) to reduce our environmental footprint, unlock reserves and become more effective and efficient.

To leverage our R&D investments and accelerate performance improvement, we collaborate with entrepreneurs, industry, academia and government to find innovative solutions to our environmental challenges. Strong collaborative efforts such as through the Clean Resource Innovation Network (CRIN), Canada's Oil Sands Innovation Alliance (COSIA) and the Petroleum Technology Alliance of Canada (PTAC), are essential to moving everyone up the technology curve faster.

The case studies highlighted in this booklet showcase the range of new technologies and continuous improvement opportunities being evaluated, piloted and/or implemented at Canadian Natural and within the industry.

The State of Technologies refers to the current readiness stage of the technology in the development cycle, as opposed to the level of implementation within Canadian Natural's operations which varies from project to project.

List of Case Studies
by order of State of Technologies

Technologies deployed (D4)

- Advancing carbon capture and reclamation — *Tailings management technologies*
- Carbon capture and sequestration/storage (CCS) — *Leading in many CCS initiatives*
- Collaborative approach to quantifying emissions — *Area fugitive emissions measurement*
- Eliminating tailing ponds and reducing emissions — *In-Pit Extraction Process*
- Recovering valuable commodities and reducing emissions — *Titanium's 'Creating Value from Waste' technology*
- Treating process water during reclamation activities — *Pit lakes and engineered wetlands*
- Enhancing thermal production processes — *Overview of GHG reduction projects in our thermal operations*
- Improved steam quality enhances performance — *Novel steam quality measurement and control*
- Increasing water efficiencies — *Rifle tubes*
- Achieving methane emissions reductions — *Overview of projects in our operations*

Technologies under development (D3)

- Capturing carbon dioxide (CO₂) for electricity generation — *Molten Carbonate Fuel Cells*
- Improving bitumen quality — *Partial upgrading*
- Converting natural gas into a hydrogen rich fuel — *Natural gas decarbonization*
- Industry working together to reduce fresh water use — *Water Technology Development Centre*
- Converting greenhouse gases into liquid fuels — *The CEFCO process*
- Re-imagining CO₂ — *NRG COSIA Carbon XPRIZE*
- Using algae to convert CO₂ into valuable products — *Algal carbon conversion*

Technologies at the discover stage (D1)

- Uncovering new high value uses for bitumen — *Bitumen beyond combustion*

Updated November 2018

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State of Technologies

D4	Deploy
D3	Develop
D2	Design
D1	Discover

EFFECTIVE
AND EFFICIENT
OPERATIONS

CARBON
CAPTURE AND
UTILIZATION

D4
Deploy

Advancing carbon capture and reclamation in tailings

Tailings management

When we begin a project, we always have a vision and a proactive plan for the landscape after our work is complete. Our comprehensive land-use planning considers the end of mine life and includes progressive reclamation activities so that we can effectively manage environmental closure programs and obligations. Canadian Natural has invested more than \$3.5 billion to date in extensive tailings research, technologies and project construction.

Tailings are a mixture of water, sand and clay found naturally in oil sands, that remain following the mining extraction process. The majority of the tailings solids settle to the bottom of the pond, and the remaining fluid (water and clay) is called Fluid Tailings (FT). Many of our processes and the advancement of new generation technologies focus on preventing FT formation from the outset, with the addition of carbon dioxide (CO₂), and in the extraction process. For example, our In-Pit Extraction Process pilot produces dry, stackable tailings, avoiding the generation of FT.

At Horizon, a Non-Segregating Tailings (NST) process dewateres the tailings by using cyclones to separate the coarse sand, and thickeners to capture and remove water from the fines in the tailings stream prior to being sent to the tailings pond. CO₂ from Horizon's capture plant is injected and sequestered in the tailings. The addition of CO₂ to NST further enhances fines capture and accelerates dewatering. The warm water recovered is then re-used in production.

At the Athabasca Oil Sands Project (AOSP) mines, we combine the use of thickeners and centrifugation technologies, as well as Atmospheric Fines Drying (AFD) technology to help separate and remove the water from the FT.

Tailings research centre

With ongoing research being a critical piece of industry's

tailings management efforts, Canadian Natural built the **Applied Process Innovation Centre (APIC)** at Horizon. The APIC was designed and equipped to perform a variety of tests and programs, providing a dedicated workspace to investigate and accelerate the application of promising tailings technologies to commercial scale. It also facilitates direct collaboration with industry peers that can complete tailings research with samples from their own operations, as well as academia and government.

Environmental benefits

Multiple wins for the environment in air, land and water:

- Reduced GHG emissions through CO₂ sequestration and less natural gas consumption (warm process water recycled during the NST process does not need to be re-heated);
- Increased fines capture and decreased FT production reduces tailings pond size, releasing more water for recycling and reducing water intake from the Athabasca River.
- Accelerated reclamation to create landforms that support wetlands and boreal forest habitat.

Business benefits

- Minimized tailings footprint and less natural gas use translates into operating costs savings.
- Shared industry knowledge and information, tailings processes and treatments lead to more efficient operations.
- Facilitating collaboration between Canadian Natural's APIC test facility and other oil sands operators.

Collaboration

These tailings management projects are led by Canadian Natural and shared through Canada's Oil Sands Innovation Alliance (COSIA).



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy

Related projects

- D3 In-Pit Extraction Process
- D4 NRG COSIA Carbon XPRIZE
- D4 Carbon Capture and Sequestration/Storage (CCS)

TRANSFORMATIONAL
TECHNOLOGY

NEW
PRODUCT
UTILIZATION

D1
Discover

Beyond bitumen combustion — 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, especially fuels such as gasoline, diesel and heating oil. There is some work mainly with natural gases (methane, ethane, propane, butane, etc.) that link to the petrochemical industry. However, there is very limited work on the use of bitumen outside of conventional fuels and chemical feedstock.

The main objective of this project is the identification and assessment of the technological and economic potential of taking components within Alberta's oil sands and making products that are not fuels (non-combustion products). The aggregate of all product categories should utilize, by the year 2030, at least 500,000 barrels per day of bitumen. The study is to be completed in phases with specific objectives:

- **Phase 1** (completed in March 2017) focused on:
 - » Identifying, characterizing and evaluating the major oil sands components and their potential for alternate uses;
 - » Providing high-level information on the technologies (costs, energy requirements, and environmental impacts) for making the products, including any long-term disposal requirements.
- **Phase 2** (completed in March 2018): an open Request for Proposals was issued to identify alternate products, and assess their market potential. The resulting study provides insights into high-value products, on four promising areas: carbon fibers (including graphene), asphalt and asphalt transportability, vanadium flow batteries for electricity storage and polymers.

Related projects

- D3 Recovering valuable commodities and reducing emissions



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy

Uncovering new, high value uses for bitumen

- **Phase 3** (in progress): research call, with \$2 million in funding available from Alberta Innovates, to support work on producing and characterizing technologies, validating market solutions and assessing businesses, marketing, energy, environmental and greenhouse gas (GHG) issues related to alternate products.

This project brings together oil sands companies, material science companies and academic researchers to uncover new uses and methods of utilizing bitumen.

Environmental benefits

- We anticipate the production of new oil sands derived products will reduce GHG emissions intensity.

Business benefits

- Diversification in the uses of oil sands components resulting in high-value products that can be made by or in partnership with Alberta's oil sands industry.
- Accommodating increased oil sands production in Alberta by creating new and/or expanded markets for oil sands components and their derived products.
- Potential to extend long-term value of reserves.
- Potential to find new revenue streams that can be realized based on the existing process of mining or in situ extraction of bitumen.

Collaboration

The project is led by Alberta Innovates, as the province recognizes that the long-term future and strength of Alberta's hydrocarbon industry requires some amount of diversification. Other partners include: BASF Canada, Bowman Centre for Sustainable Energy, Canmet ENERGY Devon Lab of Natural Resources Canada, oil sands producers and others, including academics from the University of Alberta.



NEW TECHNOLOGY

CARBON CONVERSION

D3 Develop

Reducing GHG emissions while creating value added products

Canadian Natural is participating in the Algal Carbon Conversion Project (more commonly known as *The Algae Project*) — an innovative project that is testing the ability to turn algae and carbon dioxide (CO₂) into bio-oil and bio-materials.

In 2013, an economic and engineering assessment was initiated by Canadian Natural with the National Research Council of Canada (NRC) and Pond Technologies. Building off the learnings, the NRC, Pond Technologies and St. Marys Cement Canada began testing this technology in 2016 in a pilot-scale bio-refinery at St Marys Cement plant in Ontario.

The pilot project captures CO₂ from the cement plant operations and places it in large tanks with algae to promote photosynthesis with LED lights. Algae are then pressed to release bio-oil. The process sees algae multiply at much faster rates than normal, while at the same time consuming large quantities of greenhouse gases.

When applied to oil sands operations, the algae process could produce bio-materials, such as nutraceuticals, fertilizers and animal feed, reducing greenhouse gas (GHG) emissions and creating a revenue stream.

Using algae to convert CO₂ into valuable products

Environmental benefits

- If successfully applied on commercial scale, there is potential for this technology to significantly reduce GHG emissions at Canadian Natural's oil sands operations.

Business benefits

- This technology holds potential for a reduction in operational costs and an increase in plant efficiencies.
- Potential revenues from sale of bio-materials

Collaboration

This project began as a collaboration between Canadian Natural, the National Research Council of Canada (NRC) and Pond Technologies (a Canadian algae technology company). St. Mary's Cement Canada is participating in the current phase by providing the location for the pilot-scale bio-refinery, inside its St. Mary's Cement Plant.

Canadian Natural is participating in the first stage deployment of the biorefinery as an observer and will share in the results from the activities at the cement plant, and will evaluate the results for a later stage two deployment, potentially at an oil sands operation.

Related projects

D3 NRG COSIA Carbon XPRIZE



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy



EFFECTIVE AND EFFICIENT OPERATIONS

CARBON CAPTURE AND UTILIZATION

D4 Deploy

Leading in many CCS initiatives

As the world transitions to a lower carbon economy, there will be better, lower carbon emissions ways of producing and consuming oil and natural gas. As global demand for energy continues to grow, oil and natural gas remains an important part of the global energy mix for the foreseeable future.

Currently, the greenhouse gas (GHG) emissions intensity of Canadian Natural's oil sands operations are only approximately 5% higher than the average emissions intensity for all global crude oils, with a pathway to be below the global average with further advancements in technologies and ongoing investment in carbon capture initiatives. Canadian Natural's long-term aspiration is a journey to net zero emissions.

Canadian Natural is leading the oil and natural gas industry in Carbon Capture and Sequestration or Storage (CCS) initiatives. Our projects (listed below) make Canadian Natural the third largest industry owner of CCS capacity in the world, and the largest in Canada, based on data from the Global Carbon Capture and Storage Institute.

As part of our comprehensive GHG emissions reduction strategy, our CCS projects include carbon dioxide (CO₂) injection into tailings, CO₂ injection into geological formations and use in enhanced oil recovery techniques.

CO₂ sequestration in tailings

- At our Horizon Oil Sands operation, we have been adding CO₂ to tailings since 2009 to enhance tailings performance, reduce our footprint and sequester CO₂ in the process. Over 179,000 tonnes of CO₂ have been injected from 2009 to 2017.

Related projects

D4 Advancing carbon capture and reclamation in tailings
D3 Capturing carbon dioxide for electricity generation
D3 Recovering valuable commodities and reducing emissions



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy

Carbon capture and sequestration or storage

- A CO₂ recovery plant captures 50 tonnes/hour of CO₂ from the hydrogen plant, where it is then injected into the tailings. The plant has a capture capacity of 438,000 tonnes of CO₂ annually.

Quest CCS project

- The Quest Carbon Capture and Storage facility is located at the Scotford Upgrader and is part of the Athabasca Oil Sands Project (AOSP), of which Canadian Natural has 70% ownership interest.
- In its first two years of operations, Quest's capture technology and storage capability has exceeded its target of capturing one million tonnes of CO₂ per year.

Enhanced Oil Recovery (EOR)

- At our Hays Gas Plant in Taber, Alberta, we capture 12,000 tonnes of CO₂ per year for re-use/sequestration in our nearby Enchant EOR operations.
- Canadian Natural is a 50% partner in the North West Redwater (NWR) Sturgeon Refinery, expected to capture 1.2 million tonnes of CO₂ annually for EOR when fully online.

Environmental benefits

- Canadian Natural's CCS projects at major facilities target to capture 2.7 million tonnes/year of CO₂ — *equivalent to removing 570,000 passenger vehicles off the road annually.*

Operational benefits

- Research and development, and applied technology and innovation, lead to continuous improvement in operational efficiencies.

NEW TECHNOLOGY

EMISSIONS MEASUREMENT

D4 Deploy

Area fugitive emissions measurement

Canadian Natural is working to enhance the accuracy of greenhouse gas (GHG) emissions measurements from large industrial area sources, including open pit mines and tailings ponds, typical of the oil sands region of Alberta. This research helps address some challenges faced by industry in quantifying the rates of methane and carbon dioxide (CO₂) emissions, and allow the enactment of more effective strategies for emissions reductions.

Multiple organizations are collaborating and deploying different approaches at Horizon for measuring emissions, as looking at one technology only provides one piece of the puzzle. Incorporating multiple layers of research from the ground up provides a clearer picture of how emissions are generated and influenced by the atmosphere.

Work is well underway at Horizon and several emissions profiles are being evaluated through a range of methods:

- Probes installed in the tailings pond to determine how changes in water temperature affect the emissions generated from the pond;
- Thermal imaging to determine ground temperatures, how they affect wind flows and their impact on emissions;
- Methane and CO₂ ground sensors to measure emissions around area sources at the ground level;
- Drones to measure emissions from the ground level to a height of 500 feet;
- Aircraft to measure emissions from 500 to 3,000 feet;
- Satellite technology to measure emissions from space.

Bringing this data together allows for cross-validation between multiple technologies, creating a truly holistic system of advanced sensors, laser and fiber optic technology,

as well as computer models and meteorological data to measure emissions with accuracy. The next step is to measure emissions during various seasonal periods to show emissions fluctuations.

Environmental benefits

- Accurate quantification of methane and CO₂ emissions through all seasons will allow for quicker identification and implementation of mitigation strategies. In turn, this will lead to development of technologies that more effectively reduce emissions from area fugitive sources.
- The technology solutions will be transferable to other industrial sectors, amplifying the opportunity to reduce overall emissions in Canada and globally.

Business benefits

- Improved quantification of GHG emissions will result in the development and deployment of cost-effective solutions to reduce emissions.
- Learnings from this project are potentially applicable to conventional and thermal in situ operations.

Collaboration

- Industry partners in this project include innovators (vendors) and academic institutions: the Petroleum Technology Alliance Canada, Luxmox Technology Corporation, Agar Corporation, Boreal Laser, University of Guelph, University of Alberta, University of British Columbia, RWDI Air, SAIT and the NASA Jet Propulsion Laboratory.
- This project is funded by Emissions Reduction Alberta and through Canada's Oil Sands Innovation Alliance (COSIA) with other industry partners.
- Satellite based monitoring by [GHGSat](#) and Environment and Climate Change Canada's fixed wing aircraft measurements are coordinated to coincide with field measurements.

Related projects

D4 GHGSat – Satellite based global emissions monitoring

This COSIA project is investigating the use of satellite technology to measure GHG emissions in the oil sands.



Current state of technology
D1 Discover
D2 Design
D3 Develop
D4 Deploy

TRANSFORMATIONAL TECHNOLOGY

CARBON CAPTURE AND UTILIZATION

D3 Develop

NRG COSIA Carbon PRIZE

As part of a range of technology projects and innovative practices to reduce greenhouse gas (GHG) emissions, Canadian Natural is searching for transformational, creative solutions through our support of the NRG COSIA Carbon XPRIZE.

The US\$20 million NRG COSIA Carbon XPRIZE is a global competition challenging the brightest minds and innovators across the world to re-imagine what we can do with carbon dioxide (CO₂) emissions by advancing technology development. In April 2018, XPRIZE announced ten finalists, ranging from entrepreneurs to start-ups to academic institutions and companies that have been tackling the CO₂ emissions challenge for more than a decade.

These teams represent a diversity of approaches to turn CO₂ emissions into valuable and usable products, such as enhanced concrete, plastics, liquid fuels and carbon fiber. They are pushing the boundaries of CO₂ utilization to create breakthrough solutions.

The competition is structured with two tracks – one focused on testing technologies at a natural gas power facility, the other on testing technologies at a coal power plant. A prize of US\$10 million is available for each track. This final round involves a demonstration-scale competition.

World leading technology centre

The governments of Canada and Alberta, together with industry partners, InnoTech Alberta and the Shepard Energy Centre in Calgary (a joint venture of ENMAX and Capital Power), have invested \$20 million in the Alberta Carbon Conversion Technology Centre (ACCTC), which opened its doors in 2018.

Related projects

D4 Carbon Capture and Sequestration/Storage (CCS)

D3 Fuel cells for carbon capture and electricity generation



Current state of technology
D1 Discover
D2 Design
D3 Develop
D4 Deploy

Re-imagining CO₂

The first tenants of the ACCTC are the XPRIZE finalist teams in the natural gas track, who will test and advance their carbon conversion technologies at a larger, commercial scale. The facility provides innovators with the ability to test and refine their technologies using flue gas emissions from a natural gas-fired power plant. Following completion of the competition in early 2020, the ACCTC will continue as a test centre for new technology development and is expected to become a global hub for innovators.

Environmental benefits

- Developing technologies to convert CO₂ emissions from oil sands operations into valuable, useful products.
- Accelerating CO₂ reuse technology development by attracting more resources (intellectual and financial) to address excess CO₂ emissions.

Business benefits

- Helping tackle CO₂ emissions challenges in the energy sector on the path to a lower carbon energy future.
- Acting as a catalyst that attracts new and fresh ideas from around the world, to accelerate technology innovation in CO₂ conversion.
- Accelerating CO₂ re-use technology development from low-technology readiness to commercial-ready.

Collaboration

The NRG COSIA Carbon XPRIZE has 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 seven oil sands companies as part of a joint industry project led by ConocoPhillips Canada. Participants include Canadian Natural, Cenovus, Devon Canada, Imperial, Nexen and Suncor.

NEW TECHNOLOGY

CARBON CAPTURE AND UTILIZATION

D3 Develop

The promising potential of CEFCO

Innovating to find better and different ways to do things includes the investigation of emerging technologies used in other industrial settings and determining how well they can work for the oil and natural gas industry.

Texas company, CEFCO Global Clean Energy, created the 'CEFCO process' to capture and convert flue-gas emissions. It's suitable for a wide range of applications including at petro-chemical plants, coal-fired power plants, steel mills, incineration facilities, cement and limestone plants and pulp and paper mills.

Supersonic chemical reactions convert GHGs

The CEFCO process is a patented, industrial gas scrubbing technology using supersonic shockwaves that cause collision-impact force, mixing chemicals to capture and convert emissions and pollutants, turning them into valuable co-products.

The 'shockwave' part of the process strips flue gas of its four major pollutants — (SO_x, NO_x, CO₂ as well as metals and fine particulates). The supersonic collision causes an instant energy transfer of heat, pressure and mass that trigger molecular surface chemical reactions. Chemical processes, with selective re-agents, are used to separate the pollutants into neutralized forms of pure metals, CO₂ and other compounds.

CEFCO Global Clean Energy is testing the technology in a bench scale rig. Canadian Natural will evaluate the results and

Converting greenhouse gases into liquid fuels



A still image taken from a short video showing a close-up of the shockwave process.

study how it could be successfully applied and adapted to our operations, as an effective means of reducing greenhouse gas (GHG) emissions.

Environmental benefits

- Successful integration of this process would allow for significant reduction of GHG emissions.

Business benefits

- The CEFCO process is scientifically complex but it's also efficient and cost-effective. It requires only a small plant footprint, small equipment and little net energy consumption.
- The process can provide operations with co-products (i.e. liquid fuels) for sale.

Related projects

- D1** Converting natural gas into a hydrogen rich fuel



Current state of technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy

TRANSFORMATIONAL TECHNOLOGY

ALTERNATIVE EXTRACTION

D4 Deploy

In-Pit Extraction Process

As part of our continuous investments in research and technology, Canadian Natural focuses on improving our performance by enhancing our processes while reducing our environmental impact. In our Oil Sands Mining and Upgrading operations, reducing the need for tailings ponds and greenhouse gas (GHG) emissions are two of our main environmental goals. At Horizon, we are testing a new technology that could help us tackle both ongoing challenges at the same time, by radically changing the way we approach oil sands production.

We have completed a test of the In-Pit Extraction Process (IPEP). The IPEP technology involves a small, relocatable, modular extraction plant that can be operated in the mine pit. Ore processing and bitumen separation occurs adjacent to mining operations, significantly reducing material transportation, including the number of haul trucks, pipeline length and the energy that is required to pump material. Further development and commercialization would significantly reduce GHG emissions.

Additionally, IPEP can produce dry, stackable tailings, greatly reducing the volume of fluid tailings and, therefore, eliminating the need for tailings ponds. This will ultimately accelerate reclamation of oil sands mines, while improving cost-efficiency.

Eliminating tailing ponds and reducing emissions

We continue to invest in the IPEP project, with a commercial scale pilot operating in 2018, that includes testing the effectiveness of IPEP through the winter.

Environmental benefits

- GHG emissions could be reduced by up to 40% in bitumen production compared to conventional oil sands mining processing plants, by minimizing transportation.
- It would enable expansion of mining operations without constructing new central ore processing facilities.
- Production of "dry" stackable tailings would support immediate reclamation work.

Business benefits

- It is estimated that the technology can reduce production costs by approximately \$2/barrel, while substantially reducing tailings management costs and liabilities.

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 also one of nine projects selected for government funding through the Oil Sands Innovation Challenge, which supports economic growth in the oil sands sector and is funded by Emissions Reduction Alberta.

Related projects

- D4** Advancing carbon capture and reclamation in tailings



Current state of technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy



TRANSFORMATIONAL TECHNOLOGY

VALUE FROM WASTE

Recovering valuable commodities and reducing emissions

D4 Deploy

Creating value from waste

Canadian Natural and Titanium Corporation are working together to develop a design for the first commercial scale plant for Titanium's patented CVW™ (Creating Value from Waste) technology.

CVW™ is a suite of froth treatment tailings remediation technologies designed to reduce the environmental footprint of tailings ponds by recovering valuable bitumen, solvents and minerals, resulting in a cleaner tailings stream.

Bitumen is separated from surface-mined oil sands ore in a warm water extraction process that produces bitumen froth typically containing bitumen, water and mineral solids. After eliminating contaminants from the froth to produce clean bitumen, water and mineral solids are discharged as froth treatment tailings.

The project design for the plant entails building a new facility next to existing bitumen froth treatment plants, and applying a secondary stage of treatment before the waste from froth treatment enters the tailings pond.

The project is currently in front-end engineering design (FEED), which is the first engineering phase of such large complex projects. The FEED study is estimated to cost \$10.2 million and is being partially funded by Emissions Reduction Alberta (up to the lesser of \$5 million or 50% of the cost of an engineering design), Titanium (\$1.5 million) and Canadian Natural (up to \$3.7 million).

Environmental benefits

- Recover process water and provide cleaner/drier tailings, ultimately accelerating the reclamation process.
- Recover valuable commodities from froth treatment tailings (bitumen, solvent, zircon, titanium).
- Reduce and avoid future fugitive emissions from tailings ponds.

Business benefits

- Potentially create a new minerals industry for Alberta and Canada that will translate into economic growth, jobs, diversification and potential exports.
- Taking a waste process and creating economic value by increasing bitumen and solvent recovery, as well as revenues through sales of minerals.

Collaboration

- Titanium Corporation CVW™ technology has been developed with broad stakeholder support, including the Governments of Canada and Alberta, and collaboration from oil sands operators, such as Canadian Natural, that provided tailings, technical input and project review, over the last five years. The FEED study is being funded by Emissions Reduction Alberta.
- Other collaborators involved in the technology include Canada's Oil Sands Innovation Alliance (COSIA), Alberta Energy, Sustainable Development Technology Canada, National Research Council (NRC)/Industrial Research Assistance Program (IRAP) and Canadian investors.

Related projects

- D4** Carbon Capture and Sequestration/Storage (CCS)
- D1** Uncovering new high value uses for bitumen



Current
state of
technology

- D1** Discover
- D2** Design
- D3** Develop
- D4** Deploy



NEW TECHNOLOGY

WATER EFFICIENCY

Industry working together to reduce fresh water use

D3 Develop

The Water Technology Development Centre

About 80% of Alberta's oil sands reserves can only 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. As the warm bitumen is moved to the surface, the steam cools turning back into water, which is brought to the surface along with the bitumen. The water is separated from the bitumen and channeled through complex water treatment facilities to remove impurities. The treated water is recycled and re-used in the process and used to produce steam many times over.

In situ operators are looking to establish a world-class water technology development centre on a live oil sands facility to conduct collaborative research that reduces the high cost of water treatment, improves the reliability of recycling technology and reduces water footprint.

The Water Technology Development Centre (WTDC), a dedicated test facility, will advance new water treatment and recycling technologies for in situ oil sands development, allowing researchers to test new technologies on 'live' process fluids in real world conditions. This new facility will allow operators to share risks and costs, so that they can drive more technologies than each could on their own. This could speed the development and implementation of new water treatment technologies, shortening the current eight-year timeframe required to field test technologies and move them

to commercial application, leading to an accelerated return on investment.

Environmental benefits

- Improving water quality increases the amount of recycled water, which reduces the amount of water required in thermal in situ operations and improves overall energy efficiency.
- This project will also focus on improved technologies and practices for managing the waste products from water treatment.

Business benefits

- The WTDC will accelerate the development and commercialization of new water treatment technologies while shortening the time required to field test.
- Participating companies will be able to test more technologies than each could on their own, while collaboratively managing the risks and costs of technology development.

Collaboration

- The \$165-million Water Technology Development Centre is one of the joint industry projects being developed by Canada's Oil Sands Innovation Alliance's (COSIA) Water Environmental Priority Area (EPA).
- The WTDC will be attached to Suncor Energy's Firebag facility. Suncor is leading the WTDC initiative, which includes the following members: Canadian Natural, Devon, Husky and Nexen Energy.

Related projects

- D4** Enhancing thermal production processes
- D4** Improved steam quality enhances performance



Current
state of
technology

- D1** Discover
- D2** Design
- D3** Develop
- D4** Deploy



NEW TECHNOLOGY

CARBON CAPTURE AND UTILIZATION

D3 Develop

Converting natural gas into a hydrogen rich fuel

Natural Gas Decarbonization

Canadian Natural is committed to an industry leading level of investment in research and development. Greenhouse gas (GHG) emissions reduction comprises one of the most important areas of study, and one of the environmental priority areas for Canada's Oil Sands Innovation Alliance (COSIA).

There are a range of approaches being investigated and one of them is decreasing emissions resulting from the operation of steam-assisted gravity drainage (SAGD), which requires large quantities of natural gas to produce steam. In particular, we are working to better understand the landscape of natural gas (methane) decarbonization pathways and technologies.

The Canadian Natural led study *Natural Gas Decarbonization Global Technology Scan and Evaluation*, looked at technologies and solutions around the world to convert natural gas into a hydrogen rich fuel and a valuable co-product – ultimately, reducing its carbon content before it is burned in the steam boilers. This hydrogen rich fuel, when burned in the boiler, would produce less carbon dioxide (CO₂) emissions and yield co-products that could then be repurposed (to offset costs) for use in the oil sands extraction and production processes, such as diluent or solvent.

By understanding the current state of knowledge on the different classes of technologies, we can more effectively build upon previous work completed to date. A literature scan

and high level analysis of the potential advancements and their costs was used to evaluate the merits of a wide range of technologies globally against various environmental and economic criteria.

The research results provided valuable information to support the next phase of the project, the [ARCTIC Sprint](#) that identified decarbonization technology providers for two selected technologies for further work.

Environmental benefits

- Using methane to make hydrogen for fuel and other saleable products is transformational because it converts the carbon in methane that would otherwise be released as CO₂.
- Reducing net emissions of CO₂ from operating facilities.

Business benefits

- New technology/methods for decarbonization of natural gas holds significant cost saving potential for oil producers, by creating valuable co-products for sale.
- Annual cost savings have potential to reach \$150 million/year, based on the sale of co-products.

Collaboration

- Research related to this project was conducted through COSIA, led by Canadian Natural with participation by Suncor and Imperial, in partnership with the Gas Technology Institute (GTI) and Alberta Innovates.

Related projects

D4 NRG COSIA Carbon XPRIZE



Current state of technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy



NEW TECHNOLOGY

WATER EFFICIENCY

D4 Deploy

Treating process water during reclamation activities

Water used in the oil sands production process contains compounds that require treatment prior to release. Through Canada's Oil Sands Innovation Alliance (COSIA), industry is investigating new and better methods for treating process-affected water as part of reclamation plans. Here are some of the approaches being studied:

Demonstration Pit Lakes

When oil sands mines reach their end of life, closure landscape plans include water-capped tailings, also called pit lakes. Industry is researching ways to better manage water-capped tailings to build scientific knowledge and develop ecologically sustainable landscapes.

Canadian Natural is among the partners involved with Syncrude's Base Mine Lake (BML) — the first commercial scale demonstration pit lake. The lake holds fluid tailings (FT) at the bottom, with process-affected water above and freshwater at the top. The FT will de-water and densify at the bottom over time, while overall water quality is predicted to improve so that the lake will be a functioning aquatic ecosystem in the final reclaimed landscape.

Other ongoing research includes small scale experimental field trials (or mesocosms) that replicate natural ecosystems, and allow for controlled laboratory conditions in a field setting. The first study was initiated in 2017, with 30 in-ground walled aquatic test sites, filled with process-affected water and treated FT, to assess the biological process of tailings water in natural conditions.

Environmental benefits

- Data collected will provide operators with information to use for designing pit lakes and to determine what to measure to assess performance.

Related projects

D4 Advancing carbon capture and reclamation in tailings

Business benefits

- As a common practice in the resource mining industry globally, pit lakes are an effective approach to tailings processing and treatment, resulting in overall operational cost savings.

Engineered Wetlands

Canadian Natural is participating in the Process Water Wetlands Treatment Study, which uses engineered wetlands to clean tailings water. Researchers are: identifying the chemical composition of the water, determining environmentally acceptable levels of non-carbon based (inorganic) materials, and engineering a constructed wetland treatment system that uses plants and soil to trap, transfer and transform these inorganic elements in the water.

The project takes advantage of the natural biological processes that occur within wetlands to break down contaminants. For example, wetlands sequester carbon dioxide through the growth of plants and algae, which eventually sinks to the bottom and accumulates through time without being released back into the atmosphere. This study will provide an understanding of how reclamation wetlands respond to environmental stresses and can be used to improve water quality.

Environmental benefits

- Developing water treatment processes with low energy requirements and the potential to reduce GHG emissions.
- Wetlands serve to treat process water, becoming a key piece of the final reclamation landscape and supporting biodiversity.

Business benefits

- Dual benefit of an operational management tool and a final reclamation and closure outcome.



Current state of technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy

EFFECTIVE
AND EFFICIENT
OPERATIONS

ENERGY
EFFICIENCY

D4
Deploy

Enhancing thermal production processes

At Canadian Natural's Kirby South and Primrose/Wolf Lake (PAW) thermal in situ oil sands operations, optimization activities are a continual focus. With over 20 years of thermal operating experience, we are achieving top tier operating costs by effectively leveraging the expertise of our teams, as well as new and emerging technologies. Our applied technologies, together with day-to-day operational efficiencies, are reducing the amount of natural gas used for steam generation, which in turn reduces greenhouse gas (GHG) emissions intensity, while enhancing resource recovery. Here are some of the technologies we are testing:

Solvent Enhanced Steam-Assisted Gravity Drainage

The objective of this project is to demonstrate that the existing steam-assisted gravity drainage (SAGD) process can be improved at Kirby by co-injecting solvent with steam. As a result, we could further reduce Steam to Oil Ratio (SOR) and GHG emissions intensity.

This process is an enhancement to the existing commercial SAGD process, where only steam is used as injection fluid. Simulation studies and competitor pilot analysis have demonstrated a reduction of 50% SOR. Learnings from this pilot will be used for implementing solvent enhanced steam flood at PAW.

Vacuum Insulated Tubing

We are also testing vacuum insulated tubing (VIT), which consists of two concentric, tubing strings that reduce the amount of heat loss in wells above the bitumen-bearing zone. The air between the tubulars is removed, creating a vacuum layer that is difficult for heat to move across.

By reducing steam loss, more energy is available to heat

the bitumen, allowing us to maintain production volumes and enhance well performance. As less steam is needed to create the same production volumes (lower SOR), we can significantly reduce energy costs and GHG emissions per barrel of bitumen. Additionally, as less steam is needed to reduce bitumen viscosity, water use is also reduced.

This technology was used at Kirby South, achieving 30% reduction in steam and GHG emissions intensity during the first 90 days of operation. Our Kirby North operations will incorporate the use of VITs, and we also plan to test VIT effectiveness at PAW's steam floods.

Non-Condensable Gas Injection

Co-injecting trace amounts of non-condensable gas (NCG), like methane, with steam into an oil sands reservoir, helps keep the pressure with less steam injection. The use of NCG frees up steam capacity to be redeployed into lower SOR wells, increasing production in a cost-efficient way.

By reinjecting produced gas into the formation to increase recovery and compensate for pressure loss, we can partially offset steam demand and reduce sulphur dioxide and carbon dioxide emissions from steam generation.

The process has been tested at one pad at Kirby South and initial results show a decrease in SOR. The learnings will be incorporated for potential NCG injection in other pads at Kirby South, and other fields, such as North Tangleflags.

Environmental benefits

- Increased efficiencies result in reduced steam, which translates into reduced GHG emission intensity.

Business benefits

- Environmental and operational efficiencies are improving resource recovery and reducing SOR in a cost-effective way.

Related projects

D4 Improved steam quality enhances performance



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy

NEW TECHNOLOGY

ENERGY
EFFICIENCY

D3
Develop

Improving bitumen quality through partial upgrading

With pipelines at capacity in Canada and Canadian crude oil being sold at a significant discount to global prices, industry and government are working on a number of partial upgrading technologies currently at various levels of development within the pre-commercial phase.

The goal of partial upgrading technologies is reducing diluent use and improving bitumen quality for sale to markets. Partial upgrading also focuses on creating a higher quality medium crude oil that will be attractive to a wider range of refineries as feedstock. By creating additional market value for oil sands production, partial upgrading would both increase the value of bitumen and increase pipeline capacity by removing or reducing the need for diluent for transportation.

By improving bitumen product quality, the number of refineries capable of processing it can expand, resulting in an increased selling price. Partially upgraded crude oil is a more valuable refinery feedstock than bitumen because it requires less processing to produce gasoline and diesel, and it can be also sold at a better price.

Canadian Natural is a member of the steering committee, along with industry and provincial governments, within the National Partial Upgrading Program (NPUP) established by Alberta Innovates in 2015. NPUP's mission is to accelerate innovation and technology development targeting partial upgrading of bitumen and heavy crude oil.

Canadian Natural also has an internal Partial Upgrading Team that is evaluating options to cost-effectively implement partial upgrading technologies that would improve product quality and overall resource value, while reducing environmental impacts and eliminating the use of diluent in transportation. Government funding is available for development of partial upgrading technologies.

Environmental benefits

- Reducing use of diluent, which is shipped with the bitumen and then back, would also translate into significant energy and cost savings, potentially generating lower carbon emissions on a lifecycle basis.

Business benefits

- Partial upgrading could enhance the competitiveness of the oil sands sector by reducing costs, increasing pipeline capacity and reducing diluent purchase.
- Partial upgrading requires little to no additional diluent, which is a significant cost for bitumen producers, and could increase pipeline capacity by as much as 30%.



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy



NEW TECHNOLOGY

CARBON CAPTURE AND UTILIZATION

Capturing carbon dioxide for electricity generation

D3 Develop

Capturing and purifying carbon dioxide with fuel cells

As part of Canada's Oil Sands Innovation Alliance's (COSIA), members are identifying ways to reduce greenhouse gas (GHG) emissions intensity by exploring a number of different technologies. Some of these projects involve undertaking unconventional projects with the potential to create breakthrough technologies. One of them is the development of Molten Carbonate Fuel Cells (MCFCs) to capture carbon dioxide (CO₂) from natural gas-fired processing units while generating low-GHG electricity.

A fuel cell converts chemical energy from a fuel into electricity. MCFCs are one type of fuel cell that operates at high temperatures to produce electricity, heat and water. MCFCs have been used in commercial power generation since the 1990s, and can be adapted to capture CO₂.

A feasibility study funded by industry members and Alberta Innovates-Energy Environment Solutions indicated that using MCFCs would potentially be far less energy-intensive and more cost effective than conventional post-combustion carbon capture methods. Building on that study, a COSIA joint industry project (JIP) carried out a preliminary front-end engineering design (pre-FEED) associated with installing and operating a 200-kilowatt pilot project.

With increased interest from other partners and government, another JIP conducted a larger scale pre-FEED that evaluated the cost of piloting a 1.4 megawatt power generation project at an oil sands facility. The Athabasca Oil Sands Project (AOSP) upgrader has been identified as a potential pilot site.

Combining MCFC technology with carbon capture is transformative, bringing the cost of carbon capture down to make it a more economically viable solution.

Environmental benefits

- GHG reduction through CO₂ capture combined with electricity generation, which could be applied to other industries.
- Potential zero emissions source for electricity generation.
- Captured CO₂ can be stored or used for enhanced oil recovery (EOR) applications.
- Water from combustion can be captured and used at oil sands facilities, displacing other make-up water sources.

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 CO₂ can be used at EOR operations to increase resource recovery.
- CO₂ capture may also generate carbon credits, further enhancing economic viability of this technology.

Collaboration

This project was initially undertaken by a collaboration of COSIA members and Alberta Innovates. Canadian Natural (majority owner of the AOSP), and Shell Canada, are currently working with industry to obtain additional participants for the 1.4MW unit to pilot. The project will also be partially funded by Emissions Reduction Alberta.

Related projects

- D4** Carbon Capture and Sequestration/Storage (CCS)
- D4** Advancing carbon capture and reclamation in tailings



Current
state of
technology

- D1** Discover
- D2** Design
- D3** Develop
- D4** Deploy



CONTINUOUS IMPROVEMENT

WATER EFFICIENCY

Improved steam quality enhances performance

D4 Deploy

At most in situ oil sands operations, bitumen is extracted by injecting steam into the reservoir. Typically, the steam is produced using boilers called once-through steam generators (OTSG).

Currently, most OTSGs operate at about 75-80% steam quality, meaning this percentage of the water is converted into steam. The rest is "blowdown," a mixture of water, salt and other solids. It is very important to optimize steam quality because the more water that is converted into steam, the more scaling that builds up in the boiler tubes, increasing the risk of fouling and reducing the efficiency of the OTSGs.

Novel thermodynamic steam quality measurement and control model

Canadian Natural has developed a mathematical model that predicts the steam quality from an OTSG using only the discharge steam pressure and temperature measurements. This was made possible by simulating the characteristics of the vaporization process specific to the boiler feed water in our Primrose and Wolf Lake (PAW) thermal operations. This method is inherently more accurate than commonly used pressure drop measurements, which rely on instruments that deteriorate over time and also require frequent recalibration. The predictive model is used to aid the OTSG control resulting in more stable operations. Additional algorithms were developed to improve the model robustness and accuracy, and to recalibrate for changing OTSG performance over time. The model was successfully implemented and tested for eight OTSGs at the Primrose North plant, with the new steam quality control producing about 1.5% additional steam. As a result, plans are in place to implement this model for steam quality monitoring/control of the remaining 23 steam generators at PAW by 2019.

As a subset of this project, Canadian Natural is also investigating the long-term trend of control parameters to help predict OTSG tube fouling and scaling. The objective is to decrease downtime by optimizing the OTSG tube mechanical cleaning schedule and considering advanced analytical opportunities.

Environmental benefits

- For a typical steam-assisted gravity drainage (SAGD) facility, a steam quality improvement of 2% would result in an 8% decrease in boiler blowdown and up to a 1% reduction in greenhouse gas (GHG) emissions.

Business benefits

- The technology implemented at PAW is expected to boost efficiencies and increase oil production by 1-2%.
- Potential to predict tube fouling and scaling, which can reduce maintenance frequency and costs, reducing downtime.
- The technology is cost effective and can be quickly implemented. Production and efficiency improvements payout within a couple of months.

Collaboration

- This project, which started with the development of soft sensors by other members of Canada's Oil Sands Innovation Alliance (COSIA), led to Canadian Natural's own technology development for our operations.
- Canadian Natural contributed this technology to COSIA, and is collaborating with members for implementation in other facilities.
- This project is a good example of how the COSIA model allows members to leverage the work of other companies to improve its own environmental and operational performance.

Related projects

- D4** Enhancing thermal production processes



Current
state of
technology

- D1** Discover
- D2** Design
- D3** Develop
- D4** Deploy



EFFECTIVE AND EFFICIENT OPERATIONS

WATER EFFICIENCY

D4 Deploy

Increasing water efficiencies with rifle tubes

Achieving higher steam quality

At most in situ oil sands operations, bitumen is extracted by injecting steam into the reservoir. Typically, the steam is produced using boilers called once-through steam generators (OTSG). When the bitumen is produced to the surface, condensed steam (that has turned back into water) also comes out. This recovered water is then treated and recycled through the boiler to create more steam, and re-injected.

Most OTSGs operate at about 75 to 80% steam quality. Industry has been looking at ways to increase steam quality and energy efficiency. This has been a challenge, since as water is converted into steam, scaling builds up in the boiler tubes, increasing the risk of failure, requiring the boilers to be taken off-line for cleaning.

Industry is exploring boiler designs that could convert more water into steam while also reducing greenhouse gas (GHG) emissions intensity. One of those technologies is rifle tubes, which involves using a “rifled” or “ribbed” tube instead of smooth tubes currently used in boilers. The internal ribbing of rifle tubes introduce centrifugal force in the tubes, facilitating water distribution, and helping turn water into steam uniformly and more efficiently.

Pilot tests of boilers retrofitted with rifle tubes, have shown that this technology has the potential to enable OTSGs to transform up to 90% of water into steam using less water, and it is now considered to be commercial.

Efforts are currently focused on fully de-risking the technology by running the boiler at 90% steam quality for a few months and observe for scaling. Once this is complete,

rifle tubes will be evaluated for wider use both in new and existing operations.

Implementation of rifle tube technology is most effective and efficient when aligned with planned maintenance schedules. To that end, Canadian Natural will incorporate potential rifle tube deployment in our operations as part of future turnaround planning.

Environmental benefits

- Pilots resulted in higher steam quality (production) from 78 to 90%, while reducing water use by up to 15% and wastewater (or boiler blowdown) by 50%.
- Combined with the thermodynamic steam quality control model, could reduce GHG emissions between 2 and 7%, as less water is required for steam generation.

Business benefits

- Increased energy efficiency and reduced frequency of boilers needing to be taken off-line and cleaned, which impacts costs and production.

Collaboration

- Devon completed a successful 10-month commercial-scale demonstration pilot with a rifle tube unit running at 90% steam. In 2013, Suncor also completed a separate rifle tube project. The results were contributed to Canada’s Oil Sands Innovation Alliance (COSIA).
- This is another great example of COSIA-contributed technology with strong applicability to Canadian Natural’s operations.

Related projects

- D4** Improved steam quality enhances performance
- D4** Treating process water during reclamation activities



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy



EFFECTIVE AND EFFICIENT OPERATIONS

ENERGY EFFICIENCY

D4 Deploy

Achieving methane emissions reductions

Canadian Natural is focused on operational practices and innovative technologies to reduce methane emissions. Methane is a greenhouse gas (GHG) that is the main constituent of natural gas.

Upstream oil and natural gas industry sources of methane emissions are primarily venting (controlled release of gases) and pneumatic devices (that control natural gas pressure/flow). Canadian Natural’s methane emissions reduction plan focuses on these sources.

As part of our strong commitment to reducing methane emissions, our Methane Steering Committee consisting of senior leaders and technical experts, ensures the implementation of GHG reduction strategies and projects.

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 in Alberta. Our projects include:

- Efficient management of more than 1,000 compressor units used for gas conservation.
- Proactive tie-in of wells and multi-well pads where solution gas is conserved.
- Continuous improvement in facility design to reduce vented gas.

We are also using vapour combustor technology to convert methane to carbon dioxide (CO₂) at our heavy oil operations, when methane cannot be conserved, resulting in less CO₂ emissions equivalent. Vapor combustors burn excess methane gas in an enclosed unit, while keeping the equipment temperature cool. The lower temperature allows combustors to be installed near the wellhead, reducing surface disturbance.

Reducing emissions from pneumatic devices

Pneumatic devices use pressurized natural gas to operate valves and small pumps, which release small amounts of natural gas as part of their normal operation. Canadian Natural is retrofitting pneumatic pumps to solar powered pumps and converting high-emitting pneumatic controllers to non- or low-emitting ones. New projects typically use non- or low-emitting pneumatic models.

Measuring fugitive emissions

By enhancing understanding of fugitive methane emission sources, we can improve operational efficiencies, reduce emissions and support the development of best practices.

Canadian Natural is working with industry, the Petroleum Technology Alliance Canada (PTAC) and other partners to develop more accurate systems and technologies for quantifying fugitive emissions in conventional and oil sands operations, accelerating leak detection and repair, and reducing venting. Emissions Reduction Alberta is partially funding the oil sands research.

Environmental benefits

- 17.9 million tonnes of CO₂ equivalent has been conserved in Canadian Natural’s heavy oil operations between 2013 and 2017 — *same as removing 3.8 million passenger vehicles from the road over five years.*
- Venting volumes have decreased by 71% at our natural gas conservation projects between 2013 and 2017, significantly reducing methane emissions.

Business benefits

- One of the most cost-effective ways to decrease GHG emissions is to reduce methane emissions. CO₂ emissions have a smaller environmental impact than an equivalent amount of methane emissions.

Related projects

- D4** A collaborative approach to quantifying emissions



Current
state of
technology

D1 Discover
D2 Design
D3 Develop
D4 Deploy