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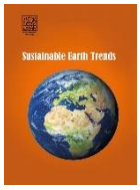

Oil sands development in Alberta, Canada: A geological, environmental, socio-economic and industrial perspective review

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ABSTRACT

The extraction and development of oil sands in Alberta, Canada, present a complex interplay between economic growth and environmental sustainability. Alberta boasts the world's largest concentration of oil sands, with approximately 1.7 trillion barrels of bitumen in place across its three major areas: Athabasca, Peace River, and Cold Lake. Alberta's oil sands, particularly in the Athabasca Basin, hold substantial reserves, necessitating specialized extraction technologies and great environmental challenges. The economic benefits including job creation and contributions to Canada's GDP are juxtaposed with the volatility of oil prices and the environmental costs. This review provides a comprehensive analysis of the geological history, technological advancements, and a brief review of the environmental and socio-economic impact of Alberta's oil sands industry. This paper is to provide a comprehensive report on how the industrial revolution took place from 1980 to the present, detailing all operators, types of industries, project statuses, and oil sand regions. The GIS maps further illustrate a visual representation of the industry's evolution. The analysis concludes with a discussion on the future trajectory of the oil sands industry, underscoring the imperative for sustainable development amid global climate change pressures.

ARTICLE INFO

Keywords:
Alberta oil sands technology
Research authority
Gross domestic product
International energy agency
Canadian association of petroleum producers

Article history:
Received: 24 Apr 2024
Accepted: 26 Jun 2024

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Citation:
Ahmed, T. et al., (2024). Oil sands development in Alberta, Canada: a geological, environmental, socio-economic and industrial perspective review, *Sustainable Earth Trends:* 4(4), (10-29).

DOI: 10.48308/set.2024.236233.1058

1. Introduction

Fossil fuels remain the primary source of energy, comprising 86 percent of global energy consumption. They are favored for their ease and cost-effectiveness in production. However, extracting, processing, and distributing fossil fuels require significant energy inputs. Moreover, conventional or lighter oils are increasingly challenging and costly to locate and extract (Aaron, 2008; Kosowski et al., 2023). Historically, bitumen served various purposes such as waterproofing boats and serving as a coating for buildings. According to the Greek historian Herodotus, hot bitumen was utilized as mortar in the construction of the walls of Babylon. Additionally, bitumen found application in early photographic techniques. Oil sands consist of naturally occurring thick blends of sand or clay, water, and an exceptionally dense material known as bitumen. Bitumen remains immobile unless subjected to heat or dilution. At ambient temperatures, it exhibits characteristics similar to cold molasses (Aaron, 2008). Canada stands as one of the globe's prominent energy producers and exporters, as highlighted in a recent study by the International Energy Agency (IEA). Notably, it emerges as the sole member nation experiencing a rise in native oil production. Nonetheless, this upward trajectory primarily stems from unconventional sources, given the ongoing decline in Canada's conventional oil output (Hester and Lawrence, 2010).

Conventional oil reserves of Canada are estimated to be around 5.2 billion barrels, with proven recoverable unconventional reserves reaching 174 billion barrels, ranking second globally only after Saudi Arabia. Additionally, potential unconventional reserves are estimated to be as high as 315 billion barrels. Despite these substantial figures, Canada's overall oil production has experienced fluctuations. While total production increased from 1.99 million barrels per day (mmb/d) in 1996 to 2.67 mmb/d in 2006, conventional production witnessed a decline, contrasting with the significant growth in bitumen (oil sands) production from 430,000 b/d to 1.22 mmb/d over the same period (Hester and Lawrence, 2010). Alberta boasts the world's largest concentration of oil sands, with approximately 1.7 trillion barrels of bitumen in place across its three major areas. Of this, proven measures suggest there are 173 billion barrels of recoverable oil within the oil sands. The ownership of oil sands resources lies with Albertans, while industries acquire mineral rights to extract the bitumen. Through the Alberta government, royalties from oil sands production are paid back to the owners. In the fiscal year 2006-2007, the province collected $2.4 billion in royalties from oil sands production (Aaron, 2008). Although the Alberta Research Council initially identified specific oil sand areas, the definitions became more refined in the early 1970s, delineating four distinct regions: Athabasca, Cold Lake, Peace River, and Wabasca (Baiton and Crombie, 2022). Each area possesses unique physical characteristics, necessitating specialized knowledge and technology for commercial development. Only about 20 percent of the total reserves are accessible through surface mining methods employing large draglines and trucks (Hester and Lawrence, 2010). The remaining reserves, located at depths greater than 75 meters, require in-situ extraction techniques. Complicating matters further is the presence of muskeg, sandstone, and shale layers covering the reserves, much of which remains frozen for more than half of the year. Geologically, the resource is relatively shallow with low formation temperatures, necessitating heating to increase its viscosity for extraction. Present recovery and upgrading technologies predominantly utilize natural gas as the primary fuel source (Hester and Lawrence, 2010; Yatimi et al., 2024).

The establishment of the Alberta Oil Sands Technology and Research Authority (AOSTRA) under Premier Peter Lougheed's visionary leadership marked a pivotal moment in the development of Alberta's oil sands industry. Recognizing the need for technological innovation and private sector involvement, AOSTRA was tasked with spearheading research and development efforts to enhance the extraction and processing of bitumen (Hester and Lawrence, 2010). AOSTRA's mandate extended beyond in situ technology to encompass the development of more sustainable and efficient methods for upgrading bitumen and extracting valuable petroleum and mineral products from oil sands. Recognizing the environmental challenges posed by traditional surface mining operations, AOSTRA directed its research towards finding alternatives that would minimize environmental impact and improve resource utilization (Baiton and Crombie, 2022).

Since the late 1990s, the Alberta Geological Survey (AGS) has continued its research efforts, focusing on updating drilling data, enhancing outcrop studies, and digitizing information related to the Athabasca deposit (Hein and Cotterill, 2006). Recent work by AGS has emphasized facies mapping on a regional scale, employing a multidisciplinary approach that includes palynological and facies analysis of outcrops and cores, well-log analysis, seismic modeling, and comparison with modern analogues. Numerous field guides have been published detailing the geology of the Fort McMurray area, with a particular emphasis on the oil sands. Notable contributions include works by (Hein et al., 2001). According to (Paulen et al., 2004) from 1997 to 2005, AGS collaborated with the EUB (Alberta Energy and Utilities Board) on issues concerning bitumen conservation in the Athabasca Wabiskaw-McMurray deposit. The EUB conducted inquiries and gas-over-bitumen hearings to address bitumen conservation, primarily driven by the necessity to curtail gas production to safeguard potentially recoverable bitumen using in-situ techniques. As part of this initiative, a regional geological study (RGS) of the Athabasca Wabiskaw-McMurray deposit was undertaken, focusing on developing a unified stratigraphic nomenclature, regional mapping, and addressing pooling concerns (Ranger and Gingras, 2002). Therefore, the purpose of this article is to examine the

geological, environmental, socio-economic, and industrial perspectives for oil sands development in Alberta, Canada.

2. Material and Methods

2.1. Study area

Canada is lodged on the Northern part of the North American tectonic plate. It is an oil-producing country standing 4th internationally in exporting oil. However, it has 10% of the world's oil accumulation, making Canada the holder of the third-largest oil reserves globally, of which 97% lies in the oil sand deposits of Northern Alberta (Dub et al., 2021). The study area for this research was Athabasca Basin, Alberta Canada. The basin comprises of McMurray Formation with its different stratigraphic succession, the formation is fluvial sediments surrounded by the clear water of the Peace River to one end and fluvial sands sheets to the other end of Cold Lake. Fig.1 shows the map of the study area with major oil sands zones.

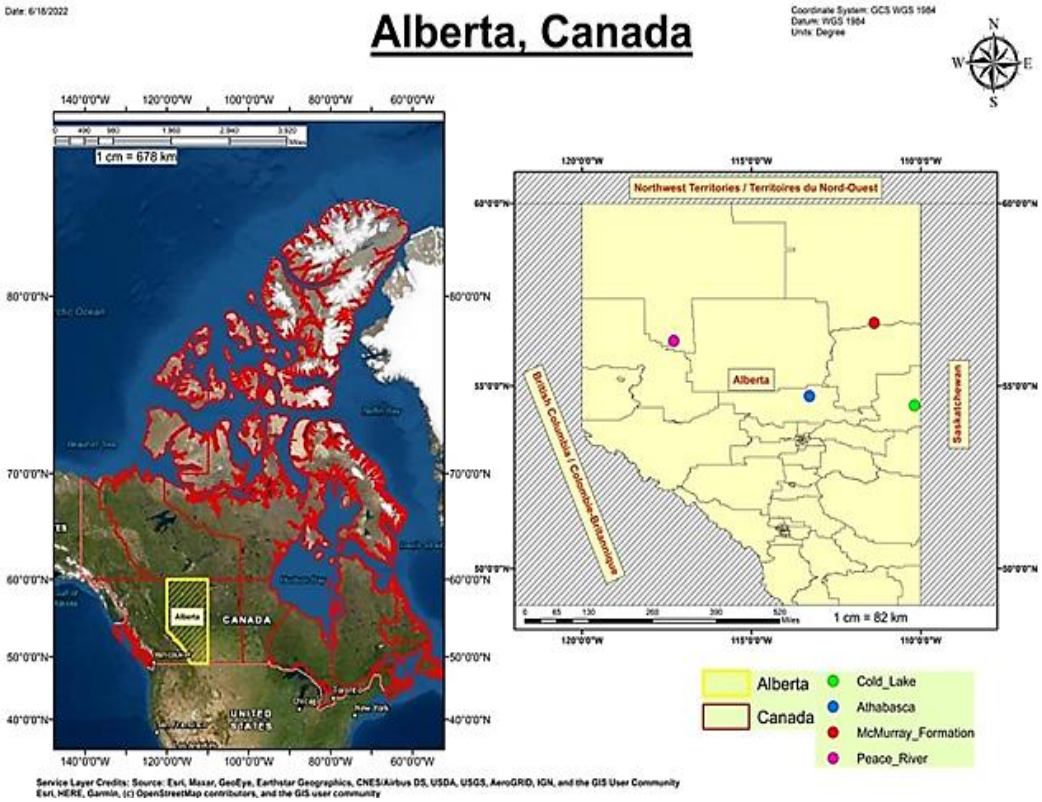

Fig. 1. Map showing major oil sands area in the study area zone

3. Results and discussion

3.1. Geological perspective

The primary oil sands areas include the Athabasca, Peace River, and Cold Lake deposits, with approximately 81% of bitumen concentrated in the lower Athabasca and Cold Lake regions. Exploration and development efforts have predominantly focused on the Lower Cretaceous McMurray Formation in the Athabasca region, where over 90% of deposits necessitate in situ recovery due to their deep burial depth (Flach and Mossop, 1985). The Lower McMurray fluvial succession is primarily preserved in depressions on the sub-Cretaceous unconformity, characterized by predominantly bottom water conditions. Recent studies, such as those by (Flach and Hein, 2001), indicate that companies operating in this zone, particularly in the lower zone of the McMurray Formation near Peace River, are focusing on extracting bitumen from Lower McMurray braided river-sand reservoirs. These reservoirs consist of sand-dominated channel-bar complexes, exhibiting high porosity and permeability, with local averages reaching 8.6 darcies and ranging from 12 to 13 darcies. Additionally, they demonstrate high interconnectivity and are devoid of internal barriers or baffles (Flach and Hein, 2001).

Sheet sands of this nature may exhibit interconnections along the bases of primary paleo valley fills, while outside the primary valley trends, basal sands tend to be more localized. These sedimentary formations were deposited during periods of low sea level during the Lower McMurray phase (Hein and Langenberg, 2003).

In contrast, the Upper McMurray succession represents a transgressive systems tract, harboring some of the most abundant bitumen reservoirs within the Athabasca deposit. These reservoirs are primarily hosted within amalgamated or stacked estuarine channel-and-point bar complexes. Notably, these formations include thick estuarine channel sands, reaching up to 58 meters in thickness, without significant lateral shale breaks (Strobl et al., 1997a). Prominent examples of such reservoirs can be observed in the lower portion of the Steepbank Mine, the Amphitheatre outcrop section near Fort MacKay (approximately 65 kilometers northwest of Fort McMurray), and both in outcrop and subsurface regions at the northern boundary of the surface mineable area (Zhang et al., 2007). In various regions, the geological formations exhibit estuarine channel configurations characterized by lateral accretion point bar sands (Hein et al., 2001). These sands are distinguished by well-defined, shallow-dipping mud inter beds, displaying inclined heterolithic stratification (IHS). These sedimentary structures gradually fine upwards into point bar tops, crevasse-splay formations, and floodplain deposits (Zhang et al., 2007).

The Upper McMurray formations consist of amalgamated estuarine meandering channel-and-point bar complexes, which exhibit slightly lower porosity, averaging about 6.5 darcies locally. Additionally, these formations display reduced permeability and interconnectivity compared to the Lower McMurray fluvial sheet sands (Flach and Hein, 2001). Before the deposition of the McMurray Formation, the land was covered by Devonian limestone of the Waterways Formation (Hein et al., 2001). The formation of the McMurray sub-basin occurred due to the removal of Middle Devonian Evaporites, resulting in a depression trending North-South marked by a sharp unconformity (Westman and Joly, 2019). During the early Cretaceous period, this region was occupied by a fluvial drainage system, with the fluvial channels forming part of the Northward flowing river system that was eventually encroached by the rising Clearwater Sea or transgressive Boreal Sea (Flach and Mossop, 1985). The deposition of sand in this region led to the preservation of fossils. Over time, chemical processes played a crucial role in converting these preserved fossils in the sands of Athabasca into bitumen, also known as oil sands (Hassanpour, 2009). Fig. 2 shows the lithostratigraphic column for the geological markings and horizons present at the McMurray Formation.

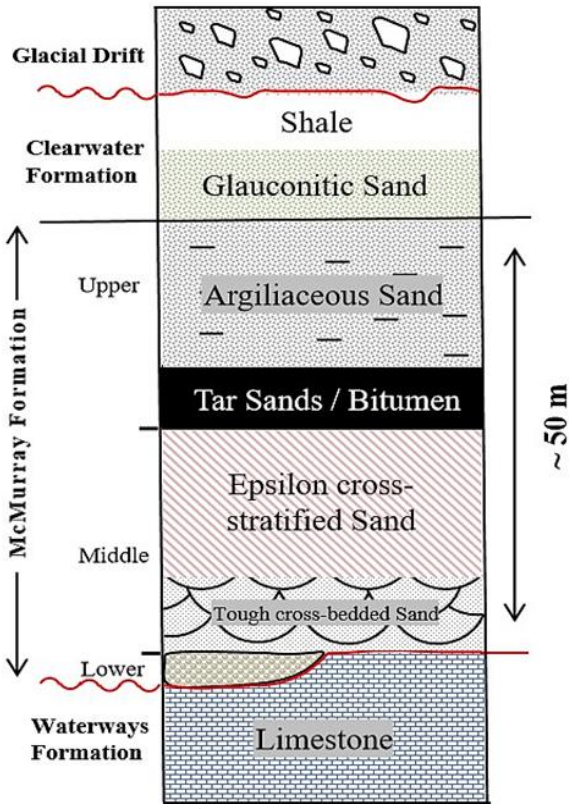

Fig. 2. Litho column for the McMurray Formations showing lower, middle, and upper members of the Formation with deposits of tar sands in the upper zone

3.2. Environmental perspective

The development of oil sands in Alberta, Canada, presents a multifaceted environmental challenge, balancing economic benefits with significant ecological impacts (Charpentier et al., 2009). The extraction and processing of bitumen from oil sands are energy-intensive, resulting in high greenhouse gas (GHG) emissions. This significantly contributes to Canada's overall carbon footprint and exacerbates global climate change (Charpentier et al., 2009). The carbon intensity of oil sands is substantially higher than conventional oil production, making it a critical area of concern for emission reduction efforts (Jordaan, 2012).

Oil sands development involves extensive land disturbance, including deforestation of boreal forests, which are vital carbon sinks and habitats for diverse wildlife (Rooney et al., 2012).

Open-pit mining, commonly used in oil sands extraction, results in the removal of vast areas of soil and vegetation, disrupting ecosystems and biodiversity (Schindler, 2010). The oil sands industry requires large amounts of water for bitumen extraction, particularly for steam-assisted gravity drainage (SAGD). This leads to significant water withdrawals from the Athabasca River, impacting aquatic ecosystems (Gosselin et al., 2010). Tailings ponds, which store wastewater and residual bitumen, pose a risk of leakage and contamination of groundwater and surface water, containing toxic substances harmful to wildlife and potentially human health (Kelly et al., 2010).

Extraction and upgrading of bitumen release pollutants such as nitrogen oxides (NOx), sulfur dioxide (SO_2), and volatile organic compounds (VOCs), contributing to air quality degradation and respiratory problems for local communities (Jaramillo et al., 2009). Many Indigenous communities in Alberta face disruptions to their traditional lands and lifestyles due to oil sands development, raising concerns about long-term health impacts and loss of culturally significant landscapes (Garvin et al., 2009). Alberta's government and federal authorities have implemented regulations to manage the environmental impacts, including emission limits, land reclamation requirements, and water management policies (Aaron, 2008).

3.3. Socio-economic perspective

The oil sands industry plays a crucial role in driving economic growth in Canada, especially in Alberta. It has drawn significant investments, resulting in the creation of numerous jobs in the area. According to the Government of Alberta, the oil sands sector directly employed approximately 140,000 people in 2019. Additionally, indirect employment in related industries such as construction, transportation, and services has further boosted job numbers (Aaron, 2008).

Canada has become a significant player in the global energy sector, particularly in the heavy crude oil market, due to its oil sands. The development of Alberta's oil sands has drawn considerable foreign investment, with billions spent on extraction technologies and infrastructure over the last two decades. This influx of capital is motivated by the strategic role of the oil sands in ensuring a stable oil supply, especially in a geopolitical landscape where energy security is crucial (Jordaan, 2012).

The industrial growth of Alberta's oil sands has led to substantial technological advancements, especially in extraction and refining methods. Techniques such as Steam-Assisted Gravity Drainage (SAGD) have been introduced to enhance extraction efficiency while reducing surface impact. Despite these technological improvements, challenges remain, particularly regarding greenhouse gas emissions, water consumption, and land reclamation. The oil sands are among the most carbon-intensive sources of crude oil, raising significant environmental concerns both in Canada and worldwide (Rooney et al., 2012).

The oil sands industry is subject to global oil price fluctuations, which can lead to economic instability in regions heavily dependent on this sector. The volatility of oil prices has led to periods of boom and bust, affecting employment rates and economic stability in Alberta. During downturns, the reduction in oil prices can lead to job losses and decreased public revenues, impacting public services and economic resilience (Plourde, 2009). The Canadian government has implemented policies and regulations aimed at balancing economic benefits with environmental and social responsibilities. This includes mandatory greenhouse gas emission reductions for large industrial facilities, carbon pricing mechanisms, and support for research into sustainable technologies (Sawyer and Stiebert, 2010).

3.4. Industrial perspective

Although the presence of oil sands in Alberta has been known for centuries, it wasn't until a significant technological breakthrough that commercial ventures became feasible. Oil drilling commenced in the late 1960s near Fort McMurray, spurred by the discovery and exploration of the area and the development of viable alternatives in the mid-1980s (Sawyer and Stiebert, 2010). Alberta's oil sands are among the largest reserves of crude oil globally, with approximately 165 billion barrels of oil that can be recovered. Industrially, the oil sands are vital to Canada's economy, providing substantial contributions to GDP and

employment. The industry directly employs over 140,000 people and indirectly supports many more jobs in fields such as construction, The types of industries shown in tables below that exist for oil sand deposits and their extraction include pilot in situ industry, this type of industry is a small-scale, experimental effort aimed at testing and refining methods for extracting bitumen from oil sands without the need for mining (Aaron, 2008). These projects are vital for developing and optimizing technologies before they are scaled up for commercial use. The other type of industry is oil sands mine, this involves extracting bitumen, a dense and sticky type of crude oil, from mixtures of sand, clay, and water found in sedimentary rocks (Kelly et al., 2010). This extraction can be performed using surface mining or in situ techniques, depending on how deep the deposits are. The third one is commercial in situ industry that describes the large-scale, fully operational stage of in situ extraction techniques employed in the oil sands industry, and the last one is the upgrader industry which commonly is a facility that converts bitumen extracted from oil sands into synthetic crude oil (Aaron, 2008).

engineering, and technology (Canadian Association of Petroleum Producers) (Aaron, 2008).

3.5. Development Phases

The tables (1-9) and Figs 3-4 provide the different development phases of oil sands development data from 1980 to the present, detailing all operators, types of industries, project statuses, and oil sands regions. Additionally, the records from 1980 to 2016 are illustrated with maps, offering a visual representation of the industry's evolution.

Table 1. Oil Sands Project in Alberta 1980 (OSIP - Data Library, 2017)

1980s				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
AOSTRA	Dover Facility	Pilot in situ	Operating	Athabasca
Suncor Energy	Millennium, Steepbank & Voyageur	Oil Sands Mine	Operating	Athabasca
Syncrude	Mildred Lake, Aurora North & South	Oil Sands Mine	Operating	Athabasca
Imperial Oil Resources	Cold Lake Operations	Commercial in situ	Operating	Cold Lake

Table 2. Oil sands project in Alberta 1990 (OSIP - Data Library, 2017)

1998				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
Canadian Natural Resources Limited	Primrose-Wolf Lake	Commercial in situ	Operating	Cold Lake
Japan Canada Oil Sands Limited	Hangingstone Pilot	Pilot in situ	Operating	Athabasca
Suncor Energy	Millennium, Steepbank & Voyageur	Oil Sands Mine	Operating	Athabasca
Imperial Oil Resources	Cold Lake Operations	Commercial in situ	Operating	Cold Lake
Syncrude	Mildred Lake, Aurora North & South	Oil Sands Mine	Operating	Athabasca
AOSTRA	Dover Facility	Pilot in situ	Operating	Athabasca

Table 3. Oil sands project in Alberta 2007 (OSIP - Data Library, 2017)

2007				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
Albian Sands	Muskeg River Mine	Oil Sands Mine	Operating	Athabasca
Birch Mountain Resources Ltd.	Muskeg Valley Quarry	Other	Operating	Athabasca
Canadian Natural Resources Limited- Horizon Mine	Horizon Mine	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Kirby Lake Pilot	Pilot In situ	Operating	Athabasca
Canadian Natural Resources Limited- Promrose	Wolf Lake	Commercial In situ	Operating	Cold Lake
Connacher oil and gas	Great Divide Pilot	Pilot In situ	Operating	Athabasca
Conoco Philips Canada Resources Limited	Surmont	Commercial In situ	Operating	Athabasca
Deer Creek Energy Ltd	Joslyn Creek Pilot	Pilot In situ	Operating	Athabasca
Devon Canada Corporation	Jackfish	Commercial In situ	Operating	Athabasca
ET-Energy	Poplar Creek	Pilot In situ	Operating	Athabasca
EnCana	Foster Creek	Commercial In situ	Operating	Athabasca
Encana	Christina Lake	Commercial In situ	Operating	Athabasca
Husky Energy	Sunrise	Commercial In situ	Operating	Athabasca
Husky Energy	Tucker Lake	Commercial In situ	Operating	Cold Lake
Imperial Oil Resources	Cold Lake Operations	Commercial In situ	Operating	Cold Lake
Imperial Oil Resources	Kearl Mine	Oil Sands Mine	Operating	Athabasca
Japan Canada Oil Stands Limited	Hangingstone Pilot	Pilot In situ	Operating	Athabasca
MEG Energy Corp.	Christina Lake Regional Project	Commercial In situ	Operating	Athabasca
OPTI Canada Inc./Nexen Canada Ltd.	Long Lake	Commercial In situ	Operating	Athabasca
Petro-Canada	Fort Hills Mine	Oil Sands Mine	Operating	Athabasca
Petro-Canada	MacKay River	Commercial In situ	Operating	Athabasca
ShellCanada Limited	Orion EOR	Commercial In situ	Operating	Cold Lake
Suncor Energy	Firebag	Commercial In situ	Operating	Athabasca
Suncor Energy	Millennium, Steepbank & Voyageur	Oil Sands Mine	Operating	Athabasca
Syncrude	Mildred Lake, Aurora North & South	Oil Sands Mine	Operating	Athabasca
Whitesands In situ Ltd.	Whitesands Fireflood	Pilot In situ	Operating	Athabasca
Shell Canada Limited	Jackpine Mine	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Lindbergh/Elk Point	Commercial In situ	Approved	Cold Lake
Canadian Natural Resources Limited	Brintnell	Pilot In situ	Approved	Athabasca
Shell Canada Limited	Peace River	Commercial In situ	Operating	Peace River2
Pengrowth Corporation	Lindbergh Pilot	Pilot In situ	Susp	Cold Lake

Table 4. Oil sands project in Alberta 2009 (OSIP - Data Library, 2017)

2009				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
Syncrude	Aurora North	Oil Sands Mine	Operating	Athabasca
Athabasca Oil Sands Corp	MacKay River	Commerical in situ	Operating	Athabasca
Statoilhydro Canada Ltd.	Kai Kos Dehseh	Pilot in situ	Operating	Athabasca
Laricina Energy Ltd	Germain	Pilot in situ	Approved	Athabasca
Suncor Energy	Meadow Creek	Commercial in situ	Approved	Athabasca
Korea National Oil Corporation	Black Gold	Commercial in situ	Approved	Athabasca
Andora Energy Corporation	Sawn Lake	Pilot in situ	Approved	Peace River #2
North Peace Energy Corp	Red Earth	Pilot in situ	Operating	Peace River #2
Shell Canada Limited	Scotford Upgrader	Upgrader	Operating	
Laricina Energy Ltd	Saleski	Pilot in situ	Operating	Athabasca
Shell Canada Energy	Muskeg River	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Horizon	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Kirby Lake Pilot	Pilot in situ	Operating	Athabasca
Canadian Natural Resources Limited	Primrose-Wolf Lake	Commercial in situ	Operating	Cold Lake
Connacher Oil and Gas	Great Divide Pilot	Pilot in situ	Operating	Athabasca
ConocoPhillips Canada Resources Limited	Surmont	Commercial in situ	Operating	Athabasca
Total E&P (formerly Deer Creek Energy Ltd.)	Joslyn Creek Pilot	Pilot in situ	Operating	Athabasca
Devon Canada Corporation	Jackfish	Commercial in situ	Operating	Athabasca
ET-Energy	Poplar Creek	Pilot in situ	Operating	Athabasca
Cenovus	Foster Creek	Commercial in situ	Operating	Athabasca
Cenovus	Christina Lake	Commercial in situ	Operating	Athabasca
Husky Energy	Sunrise	Commercial in situ	Operating	Athabasca
Husky Energy	Tucker Lake	Commercial in situ	Operating	Cold Lake
Imperial Oil Resources	Cold Lake Operations	Commercial in situ	Operating	Cold Lake
Imperial Oil Resources	Kearl Mine	Oil Sands Mine	Operating	Athabasca
Japan Canada Oil Sands Limited	Hangingstone Pilot	Pilot in situ	Operating	Athabasca
MEG Energy Corp.	Christina Lake Regional Project	Commercial in situ	Operating	Athabasca
OPTI Canada Inc./Nexen Canada Ltd	Long Lake	Commercial in situ	Operating	Athabasca
Suncor Energy	Fort Hills Mine	Oil Sands Mine	Operating	Athabasca
Suncor Energy	MacKay River	Commercial in situ	Operating	Athabasca
Shell Canada Limited	Orion EOR	Commercial in situ	Operating	Cold Lake
Suncor Energy	Firebag	Commercial in situ	Operating	Athabasca
Suncor Energy	Millennium, Steepbank & Voyageur	Oil Sands Mine	Operating	Athabasca
Petrobank	Whitesands Fireflood	Pilot in situ	Operating	Athabasca
Shell Canada Limited	Jackpine Mine	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Lindbergh/Elk Point	Commercial in situ	Approved	Cold Lake
Canadian Natural Resources Limited	Brintnell	Pilot in situ	Approved	Athabasca
Shell Canada Limited	Shell Peace River	Commercial in situ	Operating	Peace River #2
Syncrude	Aurora South	Oil Sands Mine	Approved	Athabasca
Syncrude	Mildred Lake	Oil Sands Mine	Operating	Athabasca

Table 5. Oil sands project in Alberta 2011 (OSIP - Data Library, 2017)

2011				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
Suncor Energy Inc.	Meadow Creek	Commercial in situ	Applied	Athabasca
Suncor Energy Inc.	Fort Hills Mine	Oil Sands Mine	Approved	Athabasca
Suncor Energy Inc.	Firebag	Commercial in situ	Operating	Athabasca
Suncor Energy Inc	Millennium, Steepbank & Voyageur	Oil Sands Mine	Operating	Athabasca
Suncor Energy Inc	Dover	Pilot in situ	Approved	Athabasca
Suncor Energy Inc.	Mackay River	Commercial in situ	Operating	Athabasca
Husky Oil Operations Limited	McMullen Thermal Conduction Pilot	Pilot in situ	Approved	Athabasca
Syncrude	Aurora North	Oil Sands Mine	Operating	Athabasca

Laricina Energy Ltd	Germain	Pilot in situ	Approved	Athabasca
Korea National Oil Corporation	Black Gold	Commercial in situ	Approved	Athabasca
Andora Energy Corporation	Sawn Lake	Pilot in situ	Approved	Peace River #2
North Peace Energy Corp.	Red Earth	Pilot in situ	Operating	Peace River #2
Shell Canada Limited	Scotford Upgrader	Upgrader	Operating	
Laricina Energy Ltd.	Saleski	Pilot in situ	Operating	Athabasca
Shell Canada Energy	Muskeg River Mine	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Horizon Mine	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Kirby Lake Pilot	Pilot in situ	Approved	Athabasca
Canadian Natural Resources Limited	Primrose-Wolf Lake	Commercial in situ	Operating	Cold Lake
ConocoPhillips Canada Resources Limited	Surmont	Commercial in situ	Operating	Athabasca
Total E&P Canada Ltd.	Joslyn Creek Pilot	Oil Sands Mine	Approved	Athabasca
Devon Canada Corporation	Jackfish	Commercial in situ	Operating	Athabasca
ET-Energy	Poplar Creek	Pilot in situ	Operating	Athabasca
Cenovus FCCL Ltd	Foster Creek	Commercial in situ	Operating	Athabasca
Husky Energy	Sunrise	Commercial in situ	Approved	Athabasca
Husky Energy	Tucker Lake	Commercial in situ	Operating	Cold Lake
Imperial Oil Resources	Cold Lake Operations	Commercial in situ	Operating	Cold Lake
Imperial Oil Resources	Kearl Mine	Oil Sands Mine	Approved	Athabasca
Japan Canada Oil Sands Limited	Hangingstone Pilot	Pilot in situ	Operating	Athabasca
MEG Energy Corp.	Christina Lake Regional Project	Commercial in situ	Operating	Athabasca
OPTI Canada Inc./Nexen Canada Ltd.	Long Lake	Commercial in situ	Operating	Athabasca
Shell Canada Limited	Orion EOR	Commercial in situ	Operating	Cold Lake
Petrobank	Whitesands Fireflood	Pilot in situ	Operating	Athabasca
Shell Canada Limited	Jackpine Mine	Oil Sands Mine	Operating	Athabasca
Canadian Natural Resources Limited	Lindbergh/Elk Point	Commercial in situ	Suspended	Cold Lake
Canadian Natural Resources Limited	Brintnell	Pilot in situ	Suspended	Athabasca
Syncrude	Aurora South	Oil Sands Mine	Approved	Athabasca
Syncrude	Mildred Lake	Oil Sands Mine	Operating	Athabasca
Blackpearl Resources Inc.	Blackrod	Pilot in situ	Operating	Athabasca
Cenovus Energy Inc	Pelican Lake	Pilot in situ	Approved	Athabasca
Husky Oil Operations Limited	Caribou	Pilot in situ	Approved	Cold Lake
Pengrowth Corporation	Lindbergh Pilot	Pilot in situ	Suspended	Cold Lake
Value Creation Inc.	Terre de Grace	Pilot in situ	Approved	Athabasca
Grizzly Oil Sands ULC	Algar Lake	Pilot in situ	Approved	Athabasca
Canadian Natural Resources Limited	Algar Lake	Pilot in situ	Approved	Athabasca
Petrobank Energy and Resources Ltd.	Dawson Pilot Project	Pilot in situ	Approved	Peace River #2
Shell Canada Limited	Peace River	Commercial in situ	Operating	Peace River #2

Southern Pacific Resource Corp.	STP McKay	Pilot in situ	Approved	Athabasca
Cenovus FCCL Ltd	Christina Lake	Commercial in situ	Operating	Athabasca
Penn West Petroleum Ltd.	Seal	Commercial in situ	Applied	Peace River #2
Connacher Oil and Gas Limited	Algar	Commercial in situ	Operating	Athabasca
Statoil Canada Ltd.	Leismer/Kai Kos Dehseh Pilot	Commercial in situ	Operating	Athabasca
Statoil Canada Ltd.	Corner	Commercial in situ	Applied	Athabasca
Sunshine Oilsands Ltd	Harper	Commercial in situ	Applied	Athabasca
Mackay Operating Corp	Mackay River	Commercial in situ	Approved	Athabasca
Connacher Oil and Gas Limited	Great Divide	Commercial in situ	Operating	Athabasca
Baytex Energy Ltd.	Cliffdale Pilot	Commercial in situ	Approved	Peace River #2
Shell Canada Limited	Pierre River	Oil Sands Mine	Applied	Athabasca
BA Energy Inc	Heartland Bitumen Upgrader	Upgrader	Approved	<Null>
Teck Resources Ltd	Frontier	Oil Sands Mine	Applied	Athabasca
Cenovus FCCL Ltd.	Narrows Lake	Commercial in situ	Applied	Athabasca
NorthWest Upgrading Inc	North West Bitumen Upgrader	Upgrader	Approved	<Null>

Table 6. Oil sands project in Alberta 2012 (OSIP - Data Library, 2017)

2012				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
eImperial Oil Resources	Cold Lake Operations	Commercial in situ	Operating	Cold Lake
Suncor Energy Inc	Fort Hills Oil Sands Project	Oil Sands Mine	Approved	Athabasca
Shell Canada Limited	Jackpine Mine	Oil Sands Mine	Operating	Athabasca
Connacher Oil and Gas Limited	Great Divide	Commercial in situ	Operating	Athabasca
Husky Energy	Sunrise	Commercial in situ	Approved	Athabasca
Canadian Natural Resources Limited (CNRL)	Horizon Mine	Oil Sands Mine	Operating	Athabasca
Suncor Energy Inc	Base Operations	Oil Sands Mine	Operating	Athabasca
MEG Energy Corp	Christina Lake Regional Project	Commercial in situ	Operating	Athabasca
Shell Canada Limited	Orion	Commercial in situ	Operating	Cold Lake
Cenovus FCCL Ltd	Foster Creek	Commercial in situ	Operating	Athabasca
Husky Energy	Tucker	Commercial in situ	Operating	Cold lake
Japan Canada Oil Sands Limited (JACOS)	Hangingstone	Commercial in situ	Operating	Athabasca
Imperial Oil Resources	Kearl Mine	Oil Sands Mine	Approved	Athabasca
Nexen Canada Ltd.	Long Lake	Commercial in situ	Operating	Athabasca
Suncor Energy Inc.	Mackay River	Commercial in situ	Operating	Athabasca
Suncor Energy Inc.	Firebag	Commercial in situ	Operating	Athabasca
ConocoPhillips Canada Resources Limited	Surmont	Commercial in situ	Operating	Athabasca

Syncrude	Mildred Lake	Oil Sands Mine	Operating	Athabasca
Grizzly Oil Sands ULC	Whitesands Experimental Pilot Project	Pilot in situ	Suspended	Athabasca
Canadian Natural Resources Limited (CNRL)	Primrose, Wolf and Burnt Lakes	Commercial in situ	Operating	Cold Lake
Canadian Natural Resources Limited (CNRL)	Kirby Lake Pilot	Pilot in situ	Operating	Athabasca
Shell Canada Limited	Muskeg River Mine	Oil Sands Mine	Operating	Athabasca
Cenovus FCCL Ltd.	Christina Lake	Commercial in situ	Operating	Athabasca
ET-Energy	Poplar Creek	Pilot in situ	Operating	Athabasca
Devon Canada Corporation	Jackfish	Commercial in situ	Operating	Athabasca
Suncor Energy Inc.	Meadow Creek	Commercial in situ	Withdrawn	Athabasca
Shell Canada Limited	Peace River	Commercial in situ	Operating	Peace River #2
Southern Pacific Resource Corp.	Red Earth	Commercial in situ	Suspended	Peace River #2
Andora Energy Corporation	Sawn Lake	Commercial in situ	Approved	Peace River #2
Laricina Energy Ltd.	Saleski	Pilot in situ	Operating	Athabasca
Laricina Energy Ltd.	Germain	Commercial in situ	Approved	Athabasca
Harvest Operations Corp.	BlackGold	Commercial in situ	Approved	Athabasca
Statoil Canada Ltd.	Leismer/Kai Kos Dehseh Pilot	Commercial in situ	Operating	Athabasca
Syncrude	Aurora North	Oil Sands Mine	Operating	Athabasca
Syncrude	Aurora South	Oil Sands Mine	Approved	Athabasca
Shell Canada Limited	Scotford Upgrader	Upgrader	Operating	Industrial Heartland
Total E&P Canada Ltd.	North Joslyn	Oil Sands Mine	Approved	Athabasca
Value Creation Inc. (VC)	Heartland Bitumen Upgrader	Upgrader	Suspended	Industrial Heartland
North West Upgrading Inc.	Redwater Upgrader	Upgrader	Approved	Industrial Heartland
Blackpearl Resources Inc.	Blackrod	Commercial in situ	Operating	Athabasca
Cenovus Energy Inc.	Pelican Lake Grand Rapids	Commercial in situ	Operating	Athabasca
Husky Oil Operations Limited	McMullen Thermal	Commercial in situ	Approved	Athabasca
Husky Oil Operations Limited	Caribou	Commercial in situ	Approved	Cold Lake
Pengrowth Corporation	Lindbergh Pilot	Commercial in situ	Operating	Cold Lake
Southern Pacific Resource Corp	STP McKay	Commercial in situ	Operating	Athabasca
Terre de Grace Partnership	Terre de Grace	Commercial in situ	Approved	Athabasca
Grizzly Oil Sands ULC	Algar Lake	Commercial in situ	Approved	Athabasca
Petrobank Energy and Resources Ltd.	Dawson Pilot Project	Pilot in situ	Approved	Peace River #2
Suncor Energy Inc.	Dover	Commercial in situ	Approved	Athabasca

Canadian Natural Resources Limited (CNRL)	Kirby North	Commercial in situ	Approved	Athabasca
Baytex Energy Ltd.	Cliffdale Pilot	Commercial in situ	Approved	Peace River #2
Statoil Canada Ltd.	Corner	Commercial in situ	Approved	Athabasca
Sunshine Oilsands Ltd.	Harper	Commercial in situ	Exploration	Athabasca
Mackay Operating Corp. (Brion Energy)	Mackay River	Commercial in situ	Approved	Athabasca
Penn West Petroleum Ltd.	Seal	Commercial in situ	Applied	Peace River #2
Teck Resources Ltd.	Frontier	Oil Sands Mine	Applied	Athabasca
Shell Canada Limited	Pierre River	Oil Sands Mine	Applied	Athabasca
Cenovus FCCL Ltd.	Narrows Lake	Commercial in situ	Approved	Athabasca
Shell Canada Limited	Carmon Creek	Pilot in situ	Approved	Peace River #2
Athabasca Oil Corporation	Dover West Carbonates, Sands and Clastics	Commercial in situ	Applied	Athabasca
Dover Operating Corp. (Brion Energy)	Dover North and South	Commercial in situ	Applied	Athabasca
Cenovus TL ULC	Telephone Lake	Commercial in situ	Applied	Athabasca
Ivanhoe Energy Inc.	Tamarack	Commercial in situ	Applied	Athabasca
Marathon Oil Canada Corporation	Birchwood	Pilot in situ	Applied	Athabasca
Sunshine Oilsands Ltd.	Legend Lake	Commercial in situ	Applied	Athabasca
Sunshine Oilsands Ltd.	Thickwood	Commercial in situ	Applied	Athabasca
Sunshine Oilsands Ltd.	West Ells	Commercial in situ	Approved	Athabasca
Alberta Oilsands Inc.	Clearwater West	Pilot in situ	Applied	Athabasca
Athabasca Oil Corporation	Hangingstone	Commercial in situ	Approved	Athabasca
Canadian Natural Resources Limited (CNRL)	Grouse	Commercial in situ	Applied	Athabasca
Canadian Natural Resources Limited (CNRL)	Kirby South	Commercial in situ	Approved	Athabasca
Devon NEC Corporation	Pike	Commercial in situ	Applied	Athabasca
Koch Oil Sands Operating ULC	Muskwa	Pilot in situ	Applied	Athabasca
MEG Energy Corp.	Surmont	Commercial in situ	Applied	Athabasca
Surmont (Bounty Developments Ltd)	Wildwood	Commercial in situ	Applied	Athabasca
Value Creation Inc. (VC)	Advanced TriStar	Commercial in situ	Applied	Athabasca
Devon Canada	Walleye	Pilot in situ	Applied	Cold Lake
Baytex Energy Ltd.	Gemini	Commercial in situ	Approved	Cold Lake
OSUM Oil Sands Corp.	Taiga	Commercial in situ	Approved	Cold Lake

Shell Canada Limited	Electric	Pilot in situ	Applied	Athabasca
Oak Point Energy Ltd.	Lewis Steepbank	Commercial in situ	Approved	Athabasca
Suncor Energy Inc.	Lewis	Commercial in situ	Applied	Athabasca
Shell Canada Limited	Jackpine Mine Expansion	Oil Sands Mine	Applied	Athabasca
Murphy Oil Company Ltd.	Seal	Commercial in situ	Approved	Peace River #2
Northern Alberta Oil Ltd.	Sawn Lake	Commercial in situ	Approved	Peace River #2

Table 7. Oil sands project in Alberta 2013 (OSIP - Data Library, 2017)

2013				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
Imperial Oil Resources	Cold Lake Operations	Commercial in situ	Operating	Cold Lake
Shell Canada Limited	Jackpine Mine	Oil Sands Mine	Operating	Athabasca
Connacher oil and Gas limited	Great Divide	Commercial in situ	Operating	Athabasca
Husky Energy	Sunrise	Commercial in situ	Approved	Athabasca
Canadian Natural Resources Limited (CNRL)	Horizon Mine	Oil Sands Mine	Operating	Athabasca
MEG Energy Corp.	Christina Lake Regional Project	Commercial in situ	Operating	Athabasca
Shell Canada Limited	Orion	Commercial in situ	Operating	Cold lake
Cenovus FCCL Ltd.	Foster Creek	Commercial in situ	Operating	Athabasca
Husky Energy	Tucker	Commercial in situ	Operating	Cold lake
Jappan Canada Oil Sands Limtied (JACOS)	Hangingstone	Commercial in situ	Operating	Athabasca
Imperial Oil Resources	Kearl Mine	Oil Sands Mine	Operating	Athabasca
China National Offshore Oil Corporation (CNOOC)	Long Lake	Commercial in situ	Operating	Athabasca
Suncor Energy Inc.	Mackay River	Commercial in situ	Operating	Athabasca
ConocoPhillips Canada Resources Limited	Surmont	Commercial in situ	Operating	Athabasca
Canadian Natural Resources limited (CNRL)	Primrose, Wolf and Burnt Lakes	Commercial in situ	Operating	Cold lake
Canadian Natural Resources limited (CNRL)	Kirby Lake	Pilot in situ	Approved	Cold lake
Shell Canada Limited	Muskeg River Mine	Oil Sands Mine	Operating	Cold lake
Cenvous FCCL Ltd.	Christina Lake	Commercial in situ	Operating	Cold lake
ET- Energy	Poplar Creek	Pilot in situ	Suspended	Cold lake
Devon Canada Corporation	Jackfish	Commercial in situ	Operating	Cold lake
Suncor Energy Inc.	Meadow Creek	Commercial in situ	Withdrawn	Cold lake
Southern Pacific Resource Corp.	Red Earth	Commercial in situ	Suspended	Peace River #2
Andora Energy Corporation	Sawn lake	Commercial in situ	Approved	Peace River #2
Laricina Energy Ltd.	Saleski	Pilot in situ	Operating	Athabasca
Laricina Energy Ltd.	Germain	Commercial in situ	Operating	Athabasca
Harvest Operations Corp.	Black Gold	Commercial in situ	Approved	Athabasca
Statoil Canada Ltd.	Leismer\ Kai Kos Dehsan Pilot	Commercial in situ	Operating	Athabasca
Syncrude	Aurora South	Oil Sands Mine	Approved	Athabasca
Shell Canada Limited	Scotford Upgrader	Upgrader	Operating	Industrial Heartland
Total E&P Canada Ltd.	North Joslyn	Oil Sands Mine	Approved	Athabasca
Value Creation Inc. (VC)	Heartland Bitumen Upgrader	Upgrader	Suspended	Industrial Heartland
NorthWest Upgrading Inc.	Redwater Upgrader	Upgrader	Approved	Industrial Heartland
Blackpearl Resources Inc.	Blackrod	Commercial in situ	Operating	Athabasca
Cenovus Energy Inc.	Pelican Lake Grand Rapids	Commercial in situ	Operating	Athabasca
Husky Oil Operations Limited	McMullen Thermal	Commercial in situ	Operating	Athabasca
Husky Oil Operations Limited	Caribou	Commercial in situ	Approved	Cold Lake
Pengrowth Corporation	Lindbergh	Commercial in situ	Operating	Cold Lake
Southern Pacific Resource Corp.	STP McKay	Commercial in situ	Operating	Athabasca
British Petroleum (BP)	Terre de Grace	Commercial in situ	Approved	Athabasca
Grizzly Oil Sands ULC	Algar Lake	Commercial in situ	Operating	Athabasca
Petrobank Energy and Resources Ltd.	Dawson Pilot Project	Pilot in situ	Operating	Peace River #2

Suncor Energy Inc	Dover	Commercial in situ	Approved	Athabasca
Canadian Natural Resources Limited (CNRL)	Kirby North	Commercial in situ	Approved	Athabasca
Baytex Energy Ltd.	Cliffdale Pilot	Commercial in situ	Operating	Peace River #2
Statoil Canada Ltd.	Corner	Commercial in situ	Approved	Athabasca
Sunshine Oilsands Ltd.	Harper	Commercial in situ	Operating	Athabasca
Brion Energy Corporation	Mackay River	Commercial in situ	Approved	Athabasca
Penn West Petroleum Ltd	Seal	Commercial in situ	Operating	Peace River #2
Teck Resources Ltd.	Frontier	Oil Sands Mine	Applied	Athabasca
Shell Canada Limited	Pierre River	Oil Sands Mine	Applied	Athabasca
Cenovus FCCL Ltd.	Narrows Lake	Commercial in situ	Approved	Athabasca
Athabasca Oil Corporation	Dover West Carbonates, Sands and Clastics	Commercial in situ	Approved	Athabasca
Dover Operating Corp. (Brion Energy)	Dover North and South	Commercial in situ	Approved	Athabasca
Cenovus TL ULC	Telephone Lake	Commercial in situ	Applied	Athabasca
Ivanhoe Energy Inc	Tamarack	Commercial in situ	Applied	Athabasca
Marathon Oil Canada Corporation	Birchwood	Pilot in situ	Applied	Athabasca
Sunshine Oilsanda Ltd.	Legend Lake	Commercial in situ	Applied	Athabasca
Sunshine Oilsanda Ltd.	Thickwood	Commercial in situ	Approved	Athabasca
Sunshine Oilsanda Ltd.	West Ells	Commercial in situ	Approved	Athabasca
Alberta Oilsands Inc.	Clearwater West	Pilot in situ	Cancelled	Athabasca
Athabasca Oil Corporation	Hangingstone	Commercial in situ	Approved	Athabasca
Canadian Natural Resources Limited (CNRL)	Grouse	Commercial in situ	Applied	Athabasca
Devon NEC Corporation	Pike	Commercial in situ	Applied	Athabasca
Koch Oil Sands Operating ULC	Muskwa	Pilot in situ	Applied	Athabasca
MEG Energy Corp	Surmont	Commercial in situ	Applied	Athabasca
Surmont (Bounty Developments Ltd)	Wildwood	Commercial in situ	Applied	Athabasca
Value Creation Inc. (VC)	Advanced TriStar	Commercial in situ	Applied	Athabasca
Devon Canada	Walleye	Pilot in situ	Applied	Cold lake
Baytex Energy Ltd.	Gemini	Commercial in situ	Operating	Cold lake
Baytex Energy Ltd.	Taiga	Commercial in situ	Approved	Cold lake
Shell Canada Limited	Electric	Pilot in situ	Applied	Athabasca
Oak Point Energy Ltd.	Lewis Steepbank	Commercial in situ	Approved	Athabasca
Suncor Energy Inc	Lewis	Commercial in situ	Applied	Athabasca
Shell Canada Limited	Jackpine Mine Expansion	Oil Sands Mine	Applied	Athabasca
Murphy Oil Company Ltd.	Seal	Commercial in situ	Opening	Peace River #2
Northern Alberta Oil Ltd.	Sawn lake	Commercial in situ	Approved	
Statoil Canada Ltd.	Thornbury	Commercial in situ	Applied	Athabasca
Statoil Canada Ltd.	Hangingstone	Commercial in situ	Applied	Athabasca
Husky Energy	Saleski	Pilot in situ	Applied	Athabasca
Penn West Petroleum Ltd.	Harmon Valley South	Commercial in situ	Approved	Peace River #2
Baytex Energy Ltd.	Harmon Valley	Pilot in situ	Operating	Peace River #2
Cavalier Energy Inc.	Hoole	Commercial in situ	Applied	Athabasca
OSUM Oil Sands Corp.	Sepilo Kesik	Commercial in situ	Applied	Athabasca
Birchwood Resources Inc.	Sage	Pilot in situ	Applied	Cold Lake
Grizzly Oil Sands ULC	Thickwood	Commercial in situ	Applied	Athabasca
Imperial Oil Resources	Aspen	Commercial in situ	Applied	Athabasca
SilverWillow Energy Corporation	Audet	Pilot in situ	Applied	Athabasca
Prosper Petroleum Ltd.	Rigel	Commercial in situ	Applied	Athabasca
Koch Oil Sands Operating ULC	Dunkirk	Commercial in situ	Applied	Athabasca
Syncrude	Mildred Lake	Oil Sands Mine	Operating	Athabasca
Syncrude	Aurora North	Oil Sands Mine	Operating	Athabasca
Suncor Energy Inc.	Fort Hills Oil Sands Project	Oil Sands Mine	Approved	Athabasca
Suncor Energy Inc.	Oil Sands Base Mine	Oil Sands Mine	Operating	Athabasca
Shell Canada Limited	Peace River	Commercial in situ	Operating	peace River #2
Cenovus FCCL Ltd.	Foster Creek North	Pilot in situ	Operating	Athabasca
Grizzly Oil Sands ULC	May River	Commercial in situ	Applied	Athabasca
Suncor Energy Inc	Firebag	Commercial in situ	Operating	Athabasca
Canadian Natural Resources Limited	Brintnell	Pilot in situ	Suspended	Athabasca

Table 8. Oil sands project in Alberta 2014 (OSIP - Data Library, 2017)

2014				
Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
Imperial Oil Resources	Cold Lake Operations	Commercial in situ	Operating	Cold Lake
Shell Canada Limited	Jackpine Mine	Oil Sands Mine	Operating	Athabasca
Connacher Oil and Gas Limited	Great Divide	Commercial in situ	Operating	Athabasca
Canadian Natural Resources Limited (CNRL)	Horizon Mine	Oil Sands Mine	Operating	Athabasca
MEG Energy Corp.	Christina Lake Regional Project	Commercial in situ	Operating	Athabasca
Shell Canada Limited	Orion	Commercial in situ	Operating	Cold Lake
Cenovus FCCL Ltd.	Foster Creek	Commercial in situ	Operating	Athabasca
Imperial Oil Resources	Kearl Mine	Oil Sands Mine	Operating	Athabasca
China National Offshore Oil Corporation (CNOOC)	Long Lake	Commercial in situ	Operating	Athabasca
Canadian Natural Resources Limited (CNRL)	Primrose, Wolf and Burnt Lakes	Commercial in situ	Operating	Cold Lake
Shell Canada Limited	Muskeg River Mine	Oil Sands Mine	Operating	Athabasca
Cenovus FCCL Ltd.	Christina Lake	Commercial in situ	Operating	Athabasca
Devon Canada Corporation	Jackfish	Commercial in situ	Operating	Athabasca
Suncor Energy Inc.	Meadow Creek East	Commercial in situ	Applied	Athabasca
Laricina Energy Ltd.	Saleski Experimental	Pilot In situ	Suspended	Athabasca
Laricina Energy Ltd	Germain	Commercial in situ	Suspended	Athabasca
Syncrude	Aurora South	Oil Sands Mine	Approved	Athabasca
Shell Canada Limited	Scotford Upgrader	Upgrader	Operating	Industrial Heartland
Value Creation Inc. (VCI)	Heartland Bitumen Upgrader	Upgrader	Suspended	Industrial Heartland
NorthWest Upgrading Inc	Redwater Upgrader	Upgrader	Approved	Industrial Heartland
Blackpearl Resources Inc	Blackrod	Commercial in situ	Operating	Athabasca
Cenovus Energy Inc	Pelican Lake Grand Rapids	Commercial in situ	Operating	Athabasca
Husky Oil Operations Limited	McMullen Thermal	Commercial in situ	Operating	Athabasca
Husky Oil Operations Limited	Caribou	Commercial in situ	Approved	Cold Lake
Pengrowth Corporation	Lindbergh	Commercial in situ	Operating	Cold Lake
Southern Pacific Resource Corp	STP McKay	Commercial in situ	Suspended	Athabasca
British Petroleum (BP	Terre de Grace	Commercial in situ	Suspended	Athabasca
Grizzly Oil Sands ULC	Algar Lake	Commercial in situ	Suspended	Athabasca
Baytex Energy Ltd.	Dawson	Pilot In situ	Suspended	Peace River2
Suncor Energy Inc	Dover	Commercial in situ	Approved	Athabasca
Baytex Energy Ltd.	Cliffdale	Commercial in situ	Suspended	Peace River2
Sunshine Oilsands Ltd	Harper	Commercial in situ	Suspended	Athabasca
Penn West Petroleum Ltd	Seal Main	Commercial in situ	Operating	Peace River2
Teck Resources Ltd	Frontier	Oil Sands Mine	Applied	Athabasca
Shell Canada Limited	Pierre River	Oil Sands Mine	Withdrawn	Athabasca
Cenovus FCCL Ltd	Narrows Lake	Commercial in situ	Approved	Athabasca
Ivanhoe Energy Inc	Tamarack	Commercial in situ	Closed	Athabasca
Marathon Oil Canada Corporation	Birchwood	Pilot In situ	Applied	Athabasca
Sunshine Oilsands Ltd.	Legend Lake	Commercial in situ	Applied	Athabasca
Sunshine Oilsands Ltd	West Ells	Commercial in situ	Operating	Athabasca
Alberta Oilsands Inc	Clearwater West	Pilot In situ	Cancelled	Athabasca
Canadian Natural Resources Limited (CNRL)	Grouse	Commercial in situ	Applied	Athabasca
Devon NEC Corporation	Pike	Commercial in situ	Approved	Athabasca
Koch Oil Sands Operating ULCv	Muskwa	Pilot In situ	Applied	Athabasca
MEG Energy Corp	Surmont	Commercial in situ	Applied	Athabasca
Surmont (Bounty Developments Ltd)	Wildwood	Commercial in situ	Applied	Athabasca
Value Creation Inc. (VCI)	Advanced TriStar	Commercial in situ	Closed	Athabasca
Devon Canada	Walleye	Commercial in situ	Suspended	Cold Lake

Baytex Energy Ltd	Gemini	Commercial in situ	Suspended	Cold Lake
OSUM Oil Sands Corp	Taiga	Commercial in situ	Approved	Cold Lake
Shell Canada Limited	Electric	Pilot In situ	Applied	Athabasca
Oak Point Energy Ltd	Lewis Steepbank	Commercial in situ	Approved	Athabasca
Suncor Energy Inc	Lewis	Commercial in situ	Announced	Athabasca
Shell Canada Limited	Jackpine Mine Expansion	Oil Sands Mine	Applied	Athabasca
Murphy Oil Company Ltd	Seal	Commercial in situ	Operating	Peace River2
Northern Alberta Oil Ltd.	Sawn Lake	Commercial in situ	Approved	Peace River2
PTT Exploration and Production Canada Ltd.	Mariana - Hangingstone	Commercial in situ	Prospective	Athabasca
Penn West Petroleum Ltd.	Harmon Valley South	Commercial in situ	Operating	Peace River2
Baytex Energy Ltd	Harmon Valley	Pilot In situ	Suspended	Peace River2
Cavalier Energy Inc.	Hoole	Commercial in situ	Approved	Athabasca
OSUM Oil Sands Corp	Sepiko Kesik	Commercial in situ	Applied	Athabasca
Birchwood Resources Inc	Sage	Pilot In situ	Applied	Cold Lake
Grizzly Oil Sands ULC	Thickwood	Commercial in situ	Suspended	Athabasca
Imperial Oil Resources	Aspen	Commercial in situ	Applied	Athabasca
Value Creation Inc. (VCI)	Audet	Pilot In situ	Closed	Athabasca
Prosper Petroleum Ltd	Rigel	Commercial in situ	Applied	Athabasca
Koch Oil Sands Operating ULC	Dunkirk	Commercial in situ	Withdrawn	Athabasca
Syncrude	Mildred Lake	Oil Sands Mine	Operating	Athabasca
Syncrude	Aurora North	Oil Sands Mine	Operating	Athabasca
Suncor Energy Inc	Fort Hills Oil Sands Project	Oil Sands Mine	Approved	Athabasca

Table 9. Oil sands project in Alberta 2015 (OSIP - Data Library, 2017)

2015

Operator Name	Project Name	Industry Type	Project Status	Oil sands Area
Imperial Oil Resources	Cold Lake Operations	Commercial In situ	Operating	Cold Lake
Shell Canada Limited	Jackpine Mine	Oil Sands Mine	Operating	Athabasca
Connacher Oil and Gas Limited	Great Divide	Commercial In situ	Operating	Athabasca
Canadian Natural Resources Limited (CNRL)	Horizon Mine	Oil Sands Mine	Operating	Athabasca
MEG Energy Corp	Christina Lake Regional Project	Commercial In situ	Operating	Athabasca
Shell Canada Limited	Orion	Commercial In situ	Operating	Cold Lake
Cenovus FCCL Ltd.	Foster Creek	Commercial In situ	Operating	Athabasca
Imperial Oil Resources	Kearl Mine	Oil Sands Mine	Operating	Athabasca
China National Offshore Oil Corporation (CNOOC)	Long Lake	Commercial In situ	Operating	Athabasca
Canadian Natural Resources Limited (CNRL)	Primrose, Wolf and Burnt Lakes	Commercial In situ	Operating	Cold Lake
Shell Canada Limited	Muskeg River Mine	Oil Sands Mine	Operating	Athabasca
Cenovus FCCL Ltd.	Christina Lake	Commercial In situ	Operating	Athabasca
Devon Canada Corporation	Jackfish	Commercial In situ	Operating	Athabasca
Suncor Energy Inc	Meadow Creek East	Commercial In situ	Applied	Athabasca
Laricina Energy Ltd.	Saleski Experimental	Pilot In situ	Suspended	Athabasca
Laricina Energy Ltd.	Germain	Commercial In situ	Suspended	Athabasca
Syncrude	Aurora South	Oil Sands Mine	Approved	Athabasca
Shell Canada Limited	Scotford Upgrader	Upgrader	Operating	Industrial Heartland
Value Creation Inc. (VCI)	Heartland Bitumen Upgrader	Upgrader	Suspended	Industrial Heartland
NorthWest Upgrading Inc	Redwater Upgrader	Upgrader	Approved	Industrial Heartland
Blackpearl Resources Inc.	Blackrod	Commercial In situOperating	Operating	Athabasca
Cenovus Energy Inc.	Pelican Lake Grand Rapids	Commercial In situ	Operating	Athabasca
Husky Oil Operations Limited	McMullen Thermal	Commercial In situ	Operating	Athabasca

Husky Oil Operations Limited	Caribou	Commercial In situ	Approved	Cold Lake
Pengrowth Corporation	Lindbergh	Commercial In situ	Operating	Cold Lake
Southern Pacific Resource Corp.	STP McKay	Commercial In situ	Suspended	Athabasca
British Petroleum (BP)	Terre de Grace	Commercial In situ	Suspended	Athabasca
Grizzly Oil Sands ULC	Algar Lake	Commercial In situ	Suspended	Athabasca
Baytex Energy Ltd	Dawson	Pilot In situ	Suspended	Peace River2
Suncor Energy Inc	Dover	Commercial In situ	Approved	Athabasca
Baytex Energy Ltd	Cliffdale	Commercial In situ	Suspended	Peace River2
Sunshine Oilsands Ltd	Harper	Commercial In situ	Suspended	Athabasca
Penn West Petroleum Ltd	Seal Main	Commercial In situ	Operating	Peace River2
Teck Resources Ltd	Frontier	Oil Sands Mine	Applied	Athabasca
Shell Canada Limited	Pierre River	Oil Sands Mine	Withdrawn	Athabasca
Cenovus FCCL Ltd.	Narrows Lake	Commercial In situ	Approved	Athabasca
Ivanhoe Energy Inc.	Tamarack	Commercial In situ	Closed	Athabasca
Marathon Oil Canada Corporation	Birchwood	Pilot In situ	Applied	Athabasca
Sunshine Oilsands Ltd	Legend Lake	Commercial In situ	Applied	Athabasca
Sunshine Oilsands Ltd	West Ells	Commercial In situ	Operating	Athabasca
Alberta Oilsands Inc	Clearwater West	Pilot In situ	Cancelled	Athabasca
Canadian Natural Resources Limited (CNRL)	Grouse	Commercial In situ	Applied	Athabasca
Devon NEC Corporation	Pike	Commercial In situ	Approved	Athabasca
Koch Oil Sands Operating ULC	Muskwa	Pilot In situ	Applied	Athabasca
MEG Energy Corp	Sumont	Commercial In situ	Applied	Athabasca
Surmont (Bounty Developments Ltd)	Wildwood	Commercial In situ	Applied	Athabasca
Value Creation Inc. (VCI)	Advanced tristar	Commercial In situ	Closed	Athabasca
Devon Canada	Walleye	Commercial In situ	Suspended	Cold Lake
Baytex Energy Ltd.	Gemini	Commercial In situ	Suspended	Cold Lake
OSUM Oil Sands Corp.	Taiga	Commercial In situ	Approved	Cold Lake
Shell Canada Limited	Electric	Pilot In situ	Applied	Athabasca
Oak Point Energy Ltd.	Lewis steepbank	Commercial In situ	Approved	Athabasca
Suncor Energy Inc.	Lewis	Commercial In situ	Announced	Athabasca
Shell Canada Limited	Jackpine Mine Expansion	Oil Sands Mine	Applied	Athabasca
Murphy Oil Company Ltd.	Seal	Commercial In situ	Operating	Peace River2
Northern Alberta Oil Ltd	Sawn lake	Commercial In situ	Approved	Peace River2
PTT Exploration and Production Canada Ltd.	Mariana – Hangingstone	Commercial In situ	Prospective	Athabasca
Penn West Petroleum Ltd.	Harmon Valley South	Commercial In situ	Operating	Peace River2
Baytex Energy Ltd.	Harmon Valley	Pilot In situ	Suspended	Peace River2
Cavalier Energy Inc.	Hole	Commercial In situ	Approved	Athabasca
OSUM Oil Sands Corp	Sepiko Kesik	Commercial In situ	Applied	Athabasca
Birchwood Resources Inc	Sage	Pilot In situ	Applied	Cold Lake
Grizzly Oil Sands ULC	Thickwood	Commercial In situ	Suspended	Athabasca
Imperial Oil Resources	Aspen	Commercial In situ	Applied	Athabasca
Value Creation Inc. (VCI)	Audet	Pilot In situ	Closed	Athabasca
Prosper Petroleum Ltd	Rigel	Commercial In situ	Applied	Athabasca
Koch Oil Sands Operating ULC	Dunkirk	Commercial In situ	Withdrawn	Athabasca
Syncrude	Mildred Lake	Oil Sands Mine	Operating	Athabasca
Syncrude	Aurora North	Oil Sands Mine	Operating	Athabasca
Suncor Energy Inc.	Fort Hills Oil Sands Project	Oil Sands Mine	Approved	Athabasca

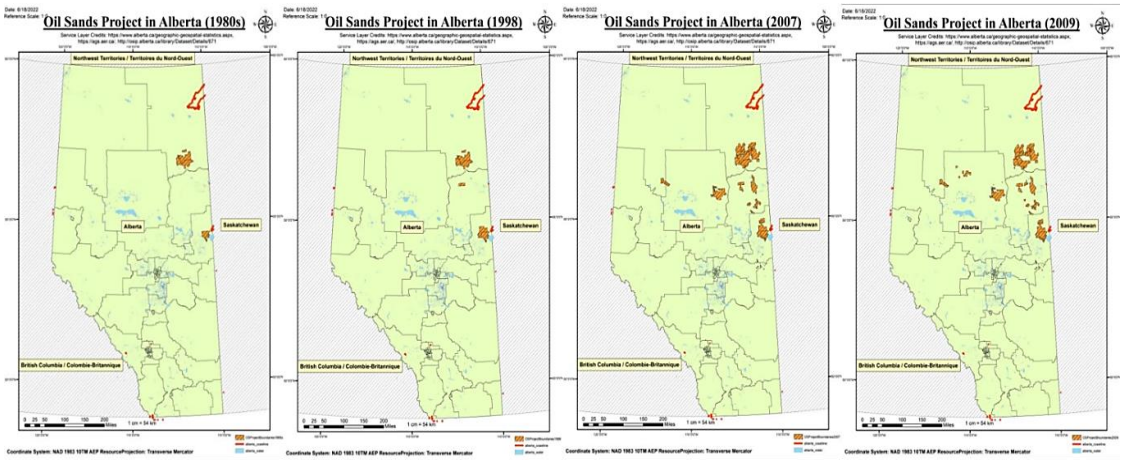

Fig. 3. Maps showing oil Sands development project phases from 1980 to 2009 (OSIP - Data Library, 2017)

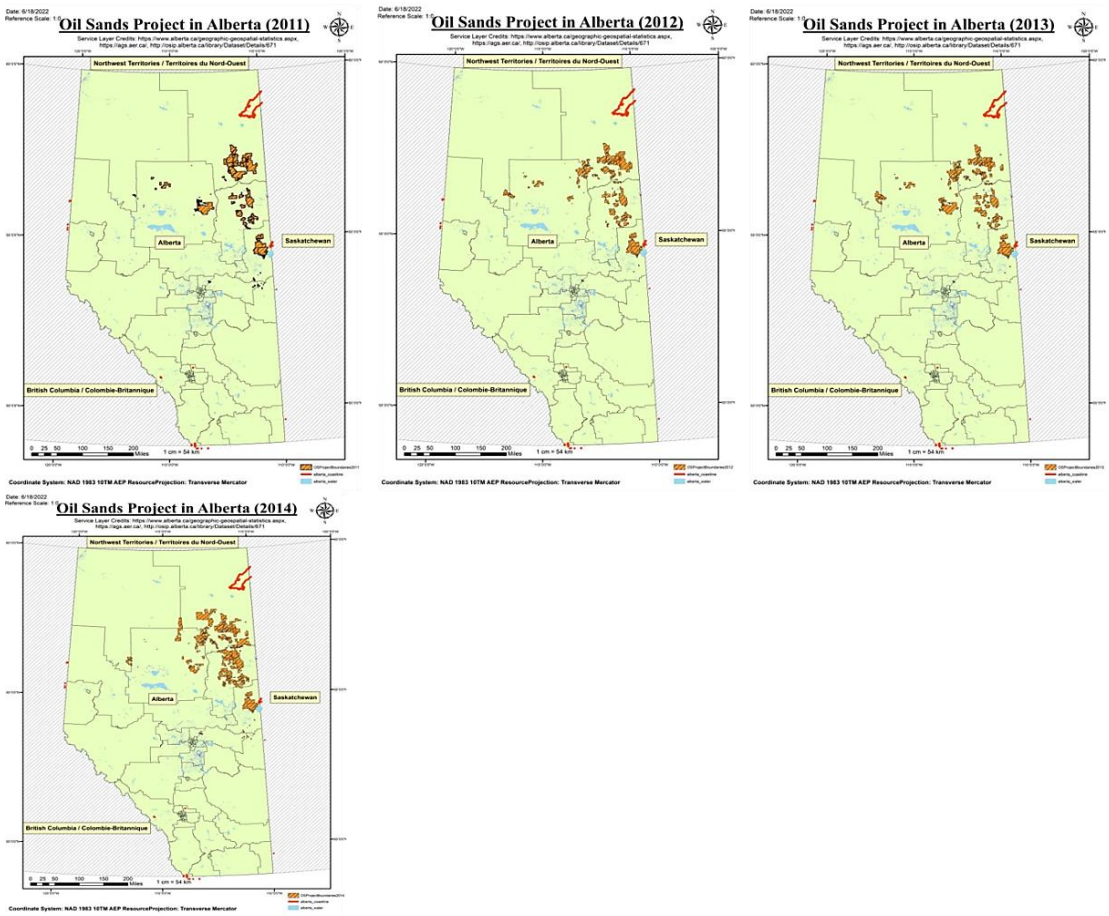

Fig. 4. Maps showing oil Sands development project phases from 2011 to 2014 (OSIP - Data Library, 2017)

3.6. Future Outcomes

Bitumen from the local can be recovered and extracted by two methods: in situ or surface (open-pit) mining. The Athabasca deposit is the largest and the only location where oil sand deposits are shallow enough to be accessed by open-pit mining. The remaining reserves are deeper and are recovered by reducing the viscosity of the oil to a point where it can be pumped to the surface, primarily through steam injection. Future industry development is anticipated to be dominated by in situ approaches (Dub et al., 2021). In 2017, there were eight operating open-pit mines managed by four companies (Suncor, Syncrude, Canadian Natural Resources Limited, and Imperial), with a total active mining footprint of 953 km² (Baiton and Crombie, 2022). Looking ahead, the projection of oil sands industry development faces challenges due to declining oil prices, divestment driven by global warming concerns, and other climate impacts. The COVID-19 pandemic also played a role in moderating investments. However, the Canadian oil and gas extraction industry has nearly recovered from the oil price crisis and the pandemic in terms of production, employment, and export. By April 2021, the industry had reached 95.4% of the GDP level from the previous year, along with 95.7% of the employment and 102.5% of the export levels. Despite this recovery, capital expenditures in the industry have been on the decline since 2014, falling by 55% from 2014 to 2019 and then by an additional 36% in 2020 (Flach and Hein, 2001).

Oil is Canada's top export, and the mining and energy sector accounts for nearly a quarter of Alberta's provincial economy. However, the energy-intensive extraction processes have made the oil and gas sector Canada's largest source of greenhouse gas emissions. Despite the significant environmental costs and the growing need for countries to transition away from fossil fuels, the mines continue to expand, excavating nearly 500 Olympic swimming pools worth of earth every day (Hassanpour, 2009). Scientists assert that oil production must start decreasing immediately. Canada's tar sands are among the most climate-polluting sources of oil, making them a clear target for

reduction efforts. The largest oil sands companies have pledged to reduce their emissions, relying heavily on government-subsidized carbon capture projects (Kerr et al., 2014). Nevertheless, both oil companies and the government anticipate that output will continue to rise well into the 2030s. Even a new proposal by Prime Minister Justin Trudeau to cap emissions in the oil sector does not include a plan to reduce production (Hassanpour, 2009). Despite these agreements, the ecological impacts of the mines are so vast and profound that they have significantly affected Indigenous communities, even as the industry has provided jobs and revenue to Native businesses and communities (Aaron, 2008).

4. Conclusion

In conclusion, Alberta's oil sands industry represents a complex intersection of economic prosperity and environmental responsibility. The significant reserves of bitumen have positioned Canada as a leading global energy producer and exporter, contributing substantially to the national and provincial economies. Despite advancements in extraction technologies and regulatory efforts to mitigate environmental impacts, the industry's continued expansion raises concerns about its long-term sustainability. Moving forward, balancing economic benefits with environmental and social responsibilities will be crucial. This necessitates a robust transition towards more sustainable energy sources, reinforced by comprehensive policies and innovations aimed at reducing the industry's ecological footprint.

Acknowledgment

This article was not under any financial support.

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