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Canada's oil sands industry from a sustainability perspective

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The present study aims to investigate the impacts of oil sands development in Canada on the economy, society and the environment as the three pillars of sustainability. Factors such as aquatic ecosystems, land disturbance and reclamation, air quality, public health, safety, aboriginal and local communities, gross domestic product, employment rate and job creation, government revenues and demographic changes have been considered. Based on a review of the available literature, this study shows that the oil sands industry has so far fallen short in keeping a balance among the three pillars of sustainability, with the negative impacts on society (e.g. changing the lifestyle of Aboriginal people) and the environment (e.g. land disturbance) overweighing the relatively positive economic impacts. This, along with the current pace of remedies (e.g. land reclamation), makes it hard to conclude that the oil sands industry is sustainable.

Introduction

The global demand for energy is expected to increase by 30% by 2040 (CAPP, 2018). Of this demand, 27% is expected to be met by oil as the largest single source of energy, where Canada can play a major role with its abundant oil sands deposits (170 billion barrels). Oil sands are a mix of bitumen, sand and water (Figure 1), which must be heated to be extracted.

After Saudi Arabia and Venezuela, Canada has the largest oil reserves in the world (175 billion barrels), with 97% of these reserves in the form of oil sands deposits in the Athabasca, Peace River and Cold Lake regions in Alberta and Saskatchewan (Ernst & Young, 2011). Compared with conventional crude oil, which is traditionally extracted from oil wells, oil is extracted from oil sands by way of surface mining, if not too deep (about 20% of reserves, mainly located near Fort McMurray in the Athabasca area), or in situ methods for deposits located deeper than 70 m below the surface (about 80% of reserves) (CAPP, 2018).

In in situ methods – for example, steam-assisted gravity drainage (SAGD) – low-pressure steam is injected into horizontal wells to heat oil sands and lower the viscosity of bitumen so that it can be pumped out through recovery wells. Through surface mining, which is usually more expensive than in situ methods, the oil sands, which are covered by thin layers of dirt, are excavated, mixed with hot water and transported to extraction plants, where oil can be extracted from oil sands in separation vessels (Figure 2).

Over the past 37 years, Canadian oil sands production has increased from 0.1 million barrels per day in 1982 to 3.68 million barrels per day in May 2019. This is mainly due to the development of oil sands projects. Oil derived from the oil sands is sent to refineries across North America (almost 99% of it is exported to the USA) to make gasoline, diesel and jet fuel (65% of supply), propane, asphalt and petrochemical feedstocks (21% of supply) and heavy and light fuel oil (14% of supply) (CAPP, 2018).

Equivalent to 170 billion barrels of accessible oil sands is 500 years of Canadian consumption, and given a production rate of 10 million barrels per day, this would take 50 years to deplete. Despite the positive impact on the regional and provincial economy, oil sands projects have given rise to environmental and social issues as well as economic concerns, which have raised questions as to whether oil sands are in compliance with the pillars of sustainability (Poveda and Lipsett, 2013). Greenhouse gas (GHG) emissions, damage to Canadian boreal forests (potentially up to 4800 km^2) due to mining projects (so far, 901 km^2), damage to wildlife due to toxic tailing ponds (CBC, 2010), damage to the manufacturing industry, turning the Canadian dollar into a volatile petrodollar, the increasing cost of housing, health issues and adverse impacts on Aboriginal and local communities are some of the issues, among others, attributed to oil sands development.

The goal of sustainability is to 'create and maintain conditions, under which humans and nature can exist in productive harmony, that permit meeting the social, economic, and other needs of the present without compromising the ability of future generations to meet theirs' (EPA, 2015: p. 1). Considering the three pillars of sustainability, the present study aims to review briefly the impacts of Canada's oil sands industry, based on the available literature, on the environment (see the section headed 'Environmental impacts of the oil sands method'), society (see the section headed 'Social impacts of oil sands') and economy (see the section headed 'Economic impacts of oil sands'). The study is concluded by the section headed 'Conclusions'.

Environmental impacts of the oil sands method

The environmental pillar often gains the most attention when it comes to sustainability assessment. Reducing carbon dioxide footprints, chemical wastes and contaminants and water usage is

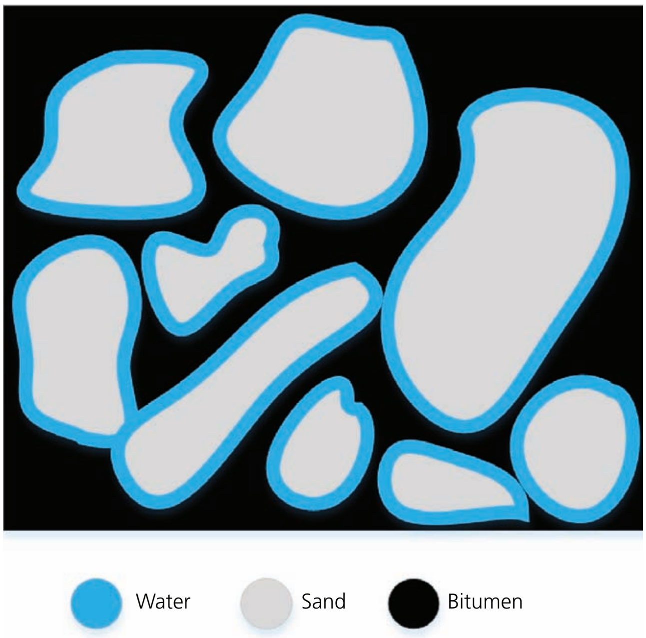

Figure 1. Oil sands formation

among the most common measures taken by companies to reduce their adverse environmental impacts. However, one of the challenges with the environmental pillar is that environmental impacts cannot be fully quantified since, for instance, items such as waste water, carbon dioxide (CO_2) and land reclamation are not easy to calculate due to many uncertain factors involved (Finkel, 2018). For instance, the crude oil spill from TransCanada's pipeline in eastern North Dakota in October 2019 turned out to have affected ten times more land than first thought (CBC, 2019).

The procedures of extraction and processing of the oil sands may place significant irreversible harm on public health and the environment. The effects of oil sands development on the hydrology and aquatic habitants, lands and air quality are controversial and need further research (Kelly *et al.*, 2009; Percy, 2013). A recent investigation of the impacts of oil sands projects has confirmed that major changes are required to the existing guidelines and practices to monitor and manage the environmental impacts of oil sands projects (Finkel, 2018).

Impact on aquatic ecosystems

The release of toxic pollutants from oil sands operations may change the aquatic ecosystems. The water produced in oil-sands-processing facilities contains residual bitumen, organic acids and polycyclic aromatic hydrocarbons (PAHs) (Colavecchia *et al.*, 2009). Experimental surveys confirm the existence of PAHs at the Athabasca River in the vicinity of the oil sands mining and processing facilities (Hodson, 2013; Kelly *et al.*, 2009). High levels of PAHs have been reported in six different lakes in the Fort McMurray area, Alberta, since the oil sands mining development started in the region (CBC, 2013). Contaminants such as arsenic

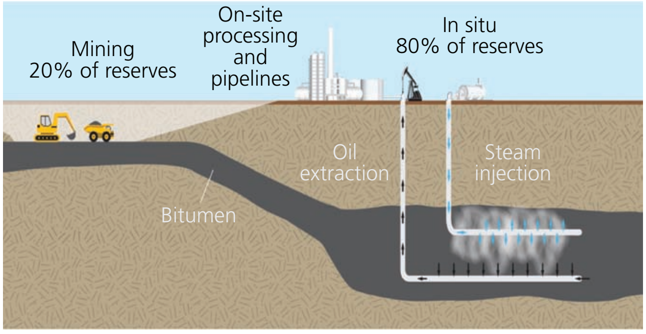

Figure 2. Extraction of oil from oil sands by way of mining and in situ methods

(As), mercury (Hg), selenium (Se), vanadium (V) and PAHs in the water and aquatic sediments have also been reported by several researchers (Chambers *et al.*, 2018; Tenenbaum, 2009).

Managing the operational effects of oil sands, including improving the monitoring quality of surface water and groundwater, is critical and needs more detailed research (Chambers *et al.*, 2018; Green *et al.*, 2017; Jordaan, 2012). Researchers believe the current monitoring programmes in the oil sands region in Alberta are not sufficient to fulfil the needs for tracing the impact of the released chemicals on different water bodies and aquatic habitants (Dillon *et al.*, 2011; Dowdeswell *et al.*, 2010).

Impact on land

The main challenge of this type is the amount of land disturbed (Grant *et al.*, 2013). The land disturbance is due not only to the mining processes but also to the provisional and permanent housing and buildings and roads as a part of oil sands development. It is reported that up to 2013, 715 km^2 of boreal forest was disturbed due to oil sands developments (Poveda, 2015).

A disturbed forest may directly affect carbon dioxide sequestration through irreversible land use change and deforestation (Audet *et al.*, 2015; Rosa *et al.*, 2016). The companies involved are obliged to undertake land reclamation under the Land Surface Conservation and Reclamation Act 1973 (The Land Surface Conservation and Reclamation Act, 1973) and the Environmental Protection and Enhancement Act 1992 (Environmental Protection and Enhancement Act (1992); Rowland *et al.*, 2009). Research studies on natural ecosystems in pre- and post-mining activities confirm that actions to reclaim the lands to their initial conditions, by different companies, are undoubtedly greenwashing (Rooney *et al.*, 2012).

Impact on ambient air quality

According to Environment and Climate Change Canada (ECCC, 2018a), the oil and gas sector is the largest contributor to total GHG emissions in Canada. Emissions from oil sands significantly contribute to the total GHG emissions from the oil and gas sector. As can be seen in Figure 3, while the GHG emissions of natural gas and conventional oil seem to have remained about constant

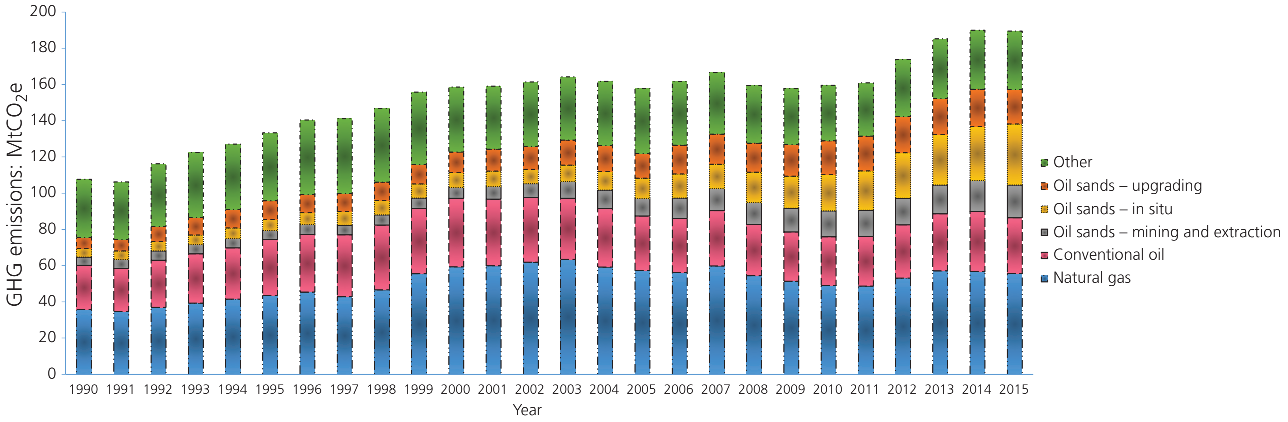

Figure 3. GHG emissions from the oil and gas sector in Canada, 1990–2015. $MtCO_2e$, megatonnes carbon dioxide equivalent (ECCC, 2018a)

since 1990, the GHG emissions of oil sands have notably increased in accordance with the development of the oil sands projects.

The process of producing synthetic crude oil from oil sands contributes significantly to the GHG emissions. Most of the GHG emissions are related to the energy required to extract bitumen and upgrade it into synthetic crude oil, and this is higher than conventional crude production (Katta *et al.*, 2019). Oil sands production is also a known source of volatile organic carbon (VOC) emissions (Simpson *et al.*, 2010). Timoney and Lee (2009) reported that one of the major sources of VOC emission is evaporation from tailing ponds as part of oil sands facilities.

Recent studies confirm that oil sands facilities can also be a source of secondary organic aerosol (Liggio *et al.*, 2016). McLinden *et al.* (2012) measured air quality, including nitrogen dioxide (NO_2) and sulfur dioxide (SO_2), by using satellite remote sensing over Canadian oil sands. Their observations between 2005 and 2010 confirm that the rate of nitrogen dioxide has consistently increased with the increase in annual bitumen production.

The increase in the level of sulfur dioxide during similar years has not been significant. This was not confirmed by Davidson and Spink (2018), who reported a significant increase in the concentration of nitrogen dioxide, sulfur dioxide and fine particulate matter (PM2.5) between 1998 and 2018 in Fort McKay, Alberta. However, the amount of emissions from Canadian oil sands decreased from 2010 to 2015 due to technological and efficiency improvements and less venting emissions and also due to a decrease in the total percentage of the crude bitumen upgraded to synthetic crude oil (ECCC, 2018b). Suncor, a large Canadian petroleum company, reported 51% reduction in GHG emissions from oil sands between 1990 and 2006 (Charpentier *et al.*, 2009). This trend, however, is not fully supported by the data presented by ECCC (2018a).

Social impacts of oil sands

Similar to the environmental issues, the social issues are also hard to measure partly due to the qualitative nature of measuring criteria and partly due to the chronic nature of some social impacts, which may be disclosed long after a business is decommissioned (Poveda and Lipsett, 2013).

The development of the oil sands industry, of course, has some positive effects in the region – for example, low rate of unemployment among the local and Aboriginal community and secured investment (over C$5 billion (C$1 = US$0.87)) in the form of contracts by Aboriginal-owned companies. However, there have been adverse impacts, too, such as higher living expenses in the area, negative health effects due to the release of harmful substances to the environment and occupational as well as process safety issues. This section briefly reviews different perspectives on the social impacts of the oil sands industry in three major terms: public health, impact on Aboriginal and local communities and process safety.

Public health

Health effects caused by environmental changes and exposure conditions of the oil sands industry in the Regional Municipality of Wood Buffalo, Canada, were investigated by Gosselin *et al.* (2010). The human exposure pathways in their report were identified as water, air and food.

Large volumes of process-affected waters with elevated levels of salinity (60–80 mg/l higher than natural surface waters), containing carcinogens such as PAHs or polycyclic aromatic compounds (PACs), have been generated due to extraction of bitumen from the oil sands. Water consumption and eating contaminated fish are likely exposure routes in the case of water pollution. Gosselin *et al.* (2010) reported that dissolved PACs in water do not persist downstream of the oil sands fields – that is, Athabasca River Delta and Fort Chipewyan (Kelly *et al.*, 2009). Hence, the health risk due to water consumption is not likely in these areas, while individuals residing in Fort McKay may potentially be exposed to slightly higher levels of contaminants.

Due to its size, the oil sands industry is identified as the major source of air emissions in Alberta, including pollutants such as sulfur dioxide and nitrogen dioxide. The issue was raised by Timoney and Lee (2009) that 'present levels of some contaminants pose an ecosystem or human health risks'. Their observations were supported by Guidotti (2014) where the history of air quality monitoring in the province of Alberta was challenged. Tackling air issues must be treated much more seriously in the province of Alberta, which is economically dependent on the oil and gas industry. Guidotti (2014) argued that the design based on the simple principle 'no excessive exposure levels, no health issue' is effective only in addressing acute exposure while ignoring chronic effects. This design strategy is therefore 'not completely responsive to community concerns because they do not address the central question of health outcomes associated with actual exposures' (Guidotti, 2014).

A human health risk assessment study (Cantox Environmental, 2007) for an oil sands development project (the Suncor Voyageur project) reported that 'local Aboriginal people may be exposed to an incremental lifetime cancer risk (ILCR) attributable to arsenic exposure'. Approximately 450 extra cases of cancer for an exposed population of 100 000 people were observed. Based on their findings, indigenous residents of Wood Buffalo, Canada, were exposed to inorganic arsenic by drinking water and eating sport fish, which were 27 and 31% of the total exposure (Cantox Environmental, 2007). The other contaminant of concern is mercury. Mercury concentration is high in the wetlands covered by the oil sands. When these wetlands are drained, mercury is released into the surrounding water bodies. An elevated level of mercury in the local fish was observed and mentioned as a major health concern (Timoney and Lee, 2009).

PAHs or PACs were identified as another contaminant in connection with health issues, particularly through food exposure (through fish). It was, however, concluded that PAHs were metabolised more quickly, which made them not bioaccumulate within a food web to the level of other persistent pollutants (Jonsson *et al*., 2004). Increasing levels of hydrogen sulfide (H_2S) and total reduced sulfur (S) are the cause of another issue in the nearby community of Fort McKay, odours. Odour is generally addressed as a nuisance rather than a health issue. However, the community well-being is affected strongly by odour, which in fact can lead to increasing level of stress following by its associated health effects (Gosselin *et al*., 2010). Growing evidence has also shown that short-term exposure to oil sands/diluted bitumen can increase the risk of neurological disease (Finkel, 2018).

Aboriginal and local communities

Environmental damages have a 'knock-on effect' on the communities residing in the surrounding area. Such effects may include disturbing local communities with respect to their traditional ways of life, increasing warnings of health issues, autoimmune diseases, rare cases of cancers and so on. Indeed, one important argument could be that while the oil sands industry is a huge source of economy for Canada, a balance between the economic benefits and insufficient understanding of negative effects on local communities must be reconsidered (Farmer, 2017).

The lands exploited due to production and further expansion of oil sands fields will exist for a long time (for the next three generations or longer). Hence, for now and within the distant future, the First Nations communities are likely to be restricted in use of these lands (Gosselin *et al*., 2010). Ignoring this balance, the quick development of the oil sands industry reached the point where the capacity to deal with negative social impacts was lacking. Unaffordable housing in the province of Alberta (and the high demands for skilled workers, which make housing even more expensive), substance abuse, gambling, family violence in neighbouring towns and destruction of the traditional way of life of the local communities (Farmer, 2017) are just a few among negative social impacts.

Approximately 4% of Canada's population are Aboriginal communities, First Nations, Metis and Inuit, of which 23 000 live in the oil sands area of Alberta (CAPP, 2014). From 1998 to 2010, at least 10% of the workforce employed by the oil sands industry was Aboriginal. Many companies were owned by Aboriginals, with over C$5 billion secured in the form of contracts within the region. During the same time, there was no unemployment in Fort McKay thanks to the oil sands projects. More Aboriginals also moved from other parts of Canada to the region to work in the oil sands industry. According to Farmer (2017), in 2010 there were about 1700 Aboriginal people permanently employed in north-east Alberta in the oil sands fields, at present considered to be a benefit to them.

The main issue is that economic growth is usually predominant over the two other pillars of sustainable development – that is, social and environmental elements. The concern is looking not just at their present benefit but also at what happens when these operations are finished. The Aboriginal communities need to return to their traditional way of living, but perhaps on their lands, which are no longer useable (Evans, 2006; Woynillowicz, 2007).

The land is very important to the Aboriginal communities in this area. They heavily rely on water and wildlife for hunting, fishing, trapping, gathering, harvesting, bathing and cooking. These are not just simple daily actions but a way of living that is jeopardised due to the scale of oil sands field development (Droitsch and Simieritsch, 2010). Due to the contaminant concerns, it is reported that First Nations no longer feed from the fish from the Athabasca River.

Woodland caribou are predicted to disappear completely from north-eastern Alberta due to clear-cutting, pit mining and giant tailing ponds being developed in the region. This also affects other species used as a source of food in these communities. Black bears, deer, red foxes, coyotes, moose, muskrats, beavers, voles, martens, wolves and bats are decreasing due to oil sands operations. Hence, intensive use of land by the oil sands industry accompanied with the extinction of the wildlife in the region reduces, if not eliminates, the ability of First Nations to hunt, fish, eat and in general live in their traditional way (Glick, 2011).

A recent study by Baker and Westman (2018) argue for improved public participation in consultation, impact assessment and accommodation of the First Nations and Metis interests. They have claimed that the traditional land use consultation needs adaptation, as in the current form it does not fully support Treaty and Aboriginal rights and falls short in assessing the actual impacts of oil sands developments on Aboriginal life. MacLean (2015) concluded in his article that Canadian oil sands pipeline projects do not foster democracy but undermine it.

Safety

The issue of fires and explosions at wildland–industrial interfaces has recently been raised by some researchers (Khakzad, 2018; Khakzad *et al*., 2018; Nolan, 2014). As much as wildfires can impact the operation and safety of oil sands facilities, the ignitions and fires in the oil sands facilities are likely to trigger the onset of wildfires in nearby wildlands.

Oil sands industries rely on two very flammable substances – namely, natural gas and a very light petroleum product 'diluent' (Khakzad, 2018). Natural gas is used as the source of energy to provide enough heat for liquefying bitumen. Liquefied bitumen is still thick; hence, a diluent is employed to dilute crude bitumen runny enough to be transported through pipelines. Diluted bitumen or 'DilBit' is transported using conventional pipeline technology. DilBit is more acidic and corrosive than conventional crude oil and thus more damaging to pipelines. A possible leak from a damaged pipeline can lead to catastrophic fire and explosions.

Further, the crude oil derived from oil sands contains a higher amount of abrasive quartz sand particles than conventional oil. Hence, pipeline failure due to the combination of chemical corrosion and physical erosion increases the failure rate of pipelines. This latter issue is exacerbated by the relatively high temperature and pressure in pipelines that are essential to make the thick DilBit move through the pipe (Swift *et al*., 2011). Due to the specific characteristics of DilBit, leaks from pipelines are difficult to detect. For instance, during the release incident of the Kalamazoo River, the monitoring data of the Enbridge pipeline indicated a column separation and not a leak, leaving the pipeline to leak for 12 h before being shut down (Swift *et al*., 2011).

The natural gas liquid condensate that is used to dilute the DilBit is also a potential hazard itself. A low flash point combined with a high vapour pressure increases the risk of explosion. At temperatures above 0°F (−17.8°C), DilBit can form a highly ignitable and explosive vapour. DilBit explosion is not only destructive due to the generation of high overpressure and temperature but is also dangerous due to the formation of hydrogen sulfide, a gas that may cause suffocation when present at concentrations above 100 parts per million. Hydrogen sulfide was identified as a potential risk to the personnel during the clean-up operation of the Kalamazoo River (Swift *et al*., 2011).

Economic impacts of oil sands

The economic pillar of sustainability seems to be the easiest to measure. To be sustainable, a business must be profitable but not at the cost of compromising the other two pillars, which unfortunately is often not the case. The economic impacts of a business are usually measured using a variety of leading indicators, such as changes in the housing market, manufacturing activity and stock market, as well as lagging indicators, such as changes in the gross domestic product (GDP), income and wages, unemployment rate, consumer price index (or inflation), currency strength and corporate profits.

Discussions on the economic impacts of Alberta's oil sands industry differ from study to study. Nevertheless, findings, particularly those published by Alberta's government and the oil industry itself, always point towards positive economic impacts, which is not surprising since the oil industry has been the main beneficiary of oil sands developments. Reported positive impacts have mainly been supported by economic indicators such as GDP, employment rate, labour income and government revenue.

Positive economic impacts

According to the Canadian Environmental Assessment Agency's report, Canada's oil and gas GDP is about C$1.7 trillion per year, 90% of which comes from Alberta. Additionally, the Canadian government has collected, in total, C$123 billion between the years 2000 and 2020 in the form of direct and indirect revenues, including direct royalty and corporate taxes, personal income taxes, property taxes, land sales and taxes paid by those supplying goods and services to the oil sands projects and those paid by their employees. With a forecast growth in the production of oil sands from 2.6 million barrels/day in 2017 to 4.2 million barrels/day in 2035, the industry is also expected to pay C$1.7 trillion in provincial and federal taxes over the next 15 years, resulting in Alberta's royalties to increase to C$65.2 billion (CAPP, 2018).

In 2017, oil sands created 528 000 direct and indirect jobs across Canada (CAPP, 2019). The share of the provinces and territories from the job market is shown in Figure 4. Given the approval and completion of the announced pipeline projects, this number is expected to rise to 1 600 000 jobs in the year 2035.

Besides the major oil and gas companies and refineries in Alberta, about 3400 companies outside Alberta (mainly in Ontario and Quebec) supply the oil sands with goods (tires, trucks, gauges, valves, pumps etc.) and services. The global demand for fossil fuel is growing (expected to grow 36% by 2035), and Canada, as the world's sixth largest crude oil producer with 170 billion barrels of oil sands reserves, can play a major role in the future market. Since approximately 75% of Canadian oil supply is exported to refineries in the USA, similar impacts on GDP and job creation could also be expected in the USA.

Negative economic impacts

Many economists believe that the easy revenue of oil sands has had detrimental impacts on Canada's economy particularly by

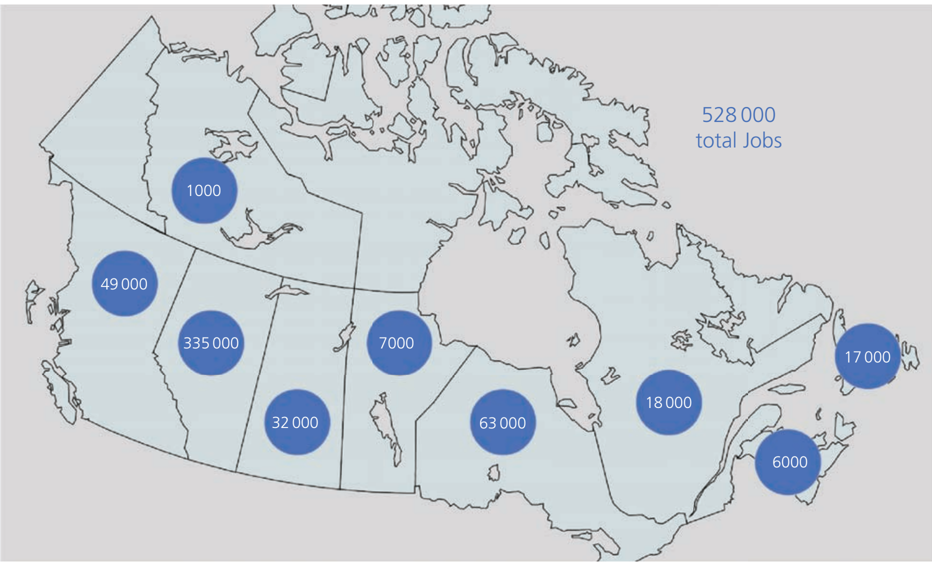

Figure 4. Number of jobs created due to the oil sands industry across Canada in 2017 (CAPP, 2019)

transforming the Canadian dollar into a volatile petrodollar, destabilising the country's manufacturing and exporting thousands of value-added jobs to the US refineries (Dobson *et al*., 2013; Nikiforuk, 2010).

Among the negative economic impacts of oil sands development, Dutch disease could be the worst. In economics, Dutch disease refers to a case where due to the economic development of a specific sector (e.g. natural resources) and the subsequent increase in revenues, the country's currency becomes stronger compared with those of other countries. As such, the country's other sectors such as manufacturing or agriculture find it hard to export to other countries, resulting in deindustrialisation.

According to Bergevin (2006), Canada appears to have some symptoms of Dutch disease, being the relatively high value of the Canadian dollar and manufacturing job losses. Beine *et al*. (2012) showed that between 33 and 39% of the manufacturing employment loss between 2002 and 2007 was related to Dutch disease. Such loss of manufacturing jobs was also evident from the decline in manufacturing GDP, particularly between 2004 and 2008, the years of high oil sands activity (Nikiforuk, 2010).

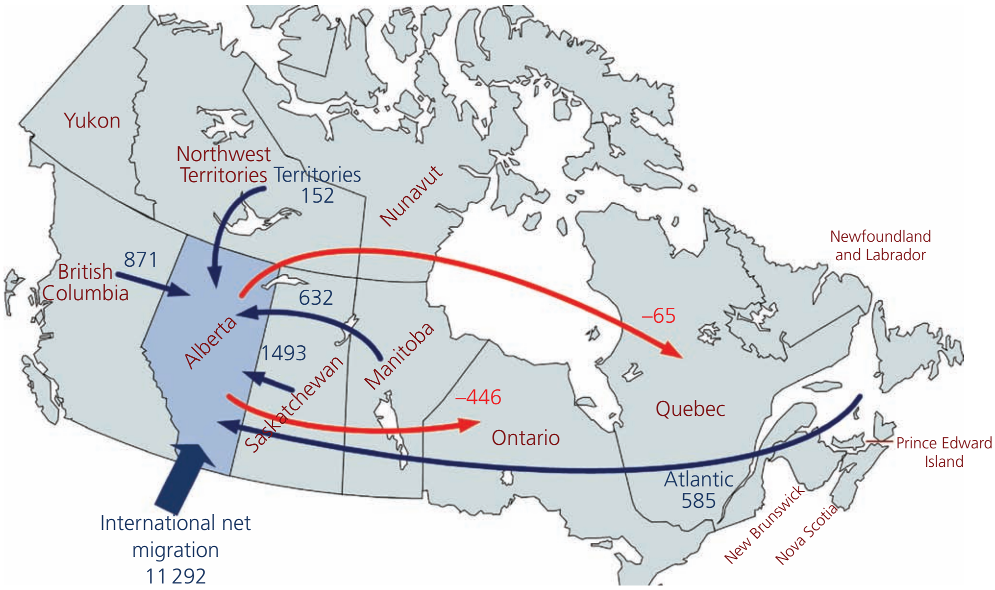

Figure 5. Net population movement for Alberta from 1 July to 30 September 2018 (Government of Alberta, 2019)

Nevertheless, Bergevin (2006) argues that the decline in manufacturing jobs is a common trend in most industrialised countries and could be part of a normal adjustment towards a more service-oriented economy rather than Dutch disease.

As pointed out by Nikiforuk (2010), every 1 cent rise in Canada's dollar due to oil sands development has led to losses of C$160 million and C$50 million from the forestry and mining sectors, respectively. Between 2007 and 2008, British Columbia's forestry sector alone lost C$2.5 billion due to the appreciation of the Canadian dollar. Aside from the foregoing impacts on the national level, oil sands have impacted the economy on regional levels as well. Oil sands megaprojects in Alberta have been attracting thousands of skilled workers from across Canada and internationally (Figure 5).

This, in turn, has led to an increased cost of living and subsequent challenges in providing suitable and affordable accommodation for new residents, increased cost of building materials, increased cost of tradespersons and high building maintenance costs, affecting those with low-paying jobs (Poveda and Lipsett, 2013).

Conclusions

In the present study, the authors briefly reviewed the impacts of Canada's oil sands industry on the economy, society and the environment. The oil sands industry was demonstrated to have had both positive and negative impacts on the economy and the society, with the negative impacts (e.g. Dutch disease and disturbance of Aboriginal and local communities) tending to overweigh the positive impacts.

In the domain of the environment, however, the negative impacts seem to have been dominant particularly that remedies such as land reclamation have so far fallen short in meeting the benchmarks. For one thing, the oil sands industry claims that only 0.2% of Canada's boreal forest would be disturbed by oil sands mining projects, adding that the industry is committed to a 100% reclamation of the disturbed land (NRCan, 2016). On the other hand, the evidence shows that since 1967 only 0.1% (1 km^2) of disturbed land has been reclaimed (Lothian, 2017). Such negative impacts have shed more doubts on the sustainability of oil sands.

Considering the conflicts among the pillars of sustainability, it is hard to conclude that the Canadian oil sands industry is sustainable. However, as argued by Kermisch and Taebi (2017), sustainability is not dichotomous, implying that the sustainability of oil sands is more like a grey area that can move towards the brighter or darker ends of the spectrum depending on the pace of remedies (e.g. land reclamation) and project development.

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