A Symbiotic System Approach for the Development of Canadian Oil Sands

And The Potential For Positive Impact On The Decision To Build The Keystone Pipeline

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**Abstract**

We propose a symbiotic system approach for the development of Canadian Oil Sands. We show, for example, if 20% of Canadian Oil Sands income were to be invested in renewable-energy machines as part of reclamation efforts for the land that is mined for, then three significant results will follow. First, we estimate that in 50 years as much CO2 will have been kept from the air from burning coal to make electricity as was released into the air from mining the oil sands and consuming the oil. Second, this proposed investment can be regarded as better alternative to a “Carbon Tax”. Finally, we show that in a period of excess electricity power generation, the power can be used to sell it back to the grid, or clean contaminated water of Poly-Aromatic Hydrocarbons (PAH) and hydrocrack PAH into useful compounds.

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# 1 Introduction

## 1.1 Motivation

Beneath the boreal forest in Northern Canada lies the world's 2nd largest oil reserve, known as the oil sands. The oil sands are a mixture of sand and a heavy crude oil called bitumen. Natural bitumen is reported in 598 deposits in 23 countries, with the largest deposits in Canada, Kazakhstan, and Russia. Bitumen reserves are estimated at 249.67 billion barrels out of which 178 billion barrels (70.8%) are in Canada (Alberta) [1].

The Northern Alberta region contains 98% of the Canadian oil sands and they are divided into three regions:

* The Athabasca-Wabiskaw deposits region
* The Cold Lake deposits regions
* The Peace River deposits region

Together, they cover 140,200 square kilometers [2]. It is also estimated by the Government of Canada that these regions hold proven reserves up to 1.75 trillion barrels of bitumen in place [9]. In addition, 173 billon barrels (10%) estimated to be recoverable at current prices using current technology.

The plans for building the Keystone XL pipeline have been thwarted because of environmental concerns. In this paper, we demonstrate how better alternatives such as investment in Wind Turbines and Photovoltaic (PV) Solar Cells not only will result in a significant reduction of CO2 emissions, but prove to be a profitable green option for the future of Alberta and the country.

## 1.2 Problem Observation

The Province of Alberta is currently operating on poor energy return per area invested. Alberta's Oil Sands are being mined over a vast area which will destroy large swaths of forests releasing even more carbon into the atmosphere. Just mining the oil and consuming it could have a huge impact on climate change.

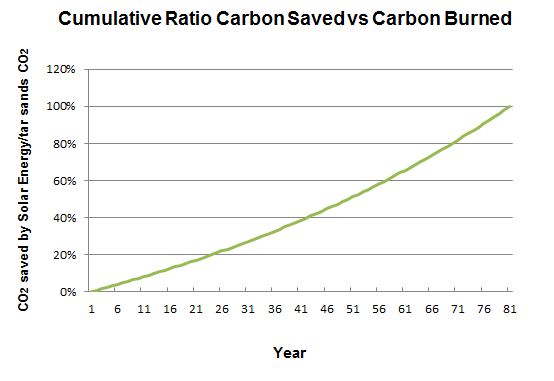
Poisson *et al* [17] recently demonstrated that since the 1990s, the total energy used (invested) in the Canadian oil and gas sector increased approximately 63%, while energy production (return) increased only 18% resulting in a decreased total energy return on investment (EROI) from 16:1 to 11:1. In the spirit of increasing the EROI from this vast resource, we present a possible better EROI for the area and the country.

**Hypothesis:**

*The effect of oil sands utilization on climate change does not have to be negative if, as part of land reclamation of the mined oil sands area, developers of the oil sands resource were required to plan and invest for when the oil sands are depleted. One scenario could include, for every square kilometer of land to be reclaimed, a 5 MW wind turbine is installed. The power from the turbine can be used for oil sands production, and it can also be sold to the grid or be used to clean contaminated water in moments of excess power generation. Another possible scenario could include, for 30% of the land to be reclaimed, PV solar cells are installed.*

Figure 1 below shows an example cumulative effect on CO2 emissions over the years of this land reclamation plan, with 50% of the total oil sands land area being reclaimed with wind turbine installations, with a policy of $0.05/kWh reinvestment in purchasing more wind turbines. Similar results are obtained with 15% of the area reclaimed using arrays of PV cells and similar reinvestment policy in purchasing more solar cells in Figure 2.

**Figure 1.** Amount of CO2 offset by $20/bbl investment in wind turbines based on $4/Watt installed, with a policy of $0.05/kWh for purchasing more wind turbines. This graph assumes 50% of the total oil sands land area being reclaimed with wind turbine installations. See supplemental materials in the spreadsheet to enter different values.



**Figure 2.** Amount of CO2 offset by $20/bbl investment in PV Solar Cells based on $4/Watt installed, with a policy of $0.05/kWh reinvestment for purchasing more solar cells, with up to a maximum of 15% efficiency. This graph assumes 30% of land area being reclaimed with PV solar cell installations. See supplemental materials in the spreadsheet to enter different values.

Both scenarios require oil sands developers to invest a portion of sales, $20/bbl for the scenario here, into renewable energy production. In addition to improving EROI, this proposed investment represents an alternative a carbon tax because companies are investing in their own future.

This benefits the oil sands companies directly and immediately because they can use the electric power for production of the oil sands instead of having to build more transmission lines, or install mini nuclear reactors [23], to bring power in for which they then have to pay to use. Furthermore, once the number of turbines increases to a point, they can start sending power out on the same power lines they initially had installed to bring power in (are in the process of installing) to develop the oil sands.

# 2 Alberta's Oil Sands Analysis

## 2.1 CO2 Emissions Overview

Per day, oil sands operation release as much CO2 as all the cars in Canada

[8]. According to a report released in 2011 [3], production of oil sands released an estimated of 47.1 million metric tonnes of CO2 into the air. Considering that in 2011, 1.8 Million barrels a day were produced, we estimate the CO2 emissions from oil sands production and oil use:

**CO2 from Oil Sands Production And Oil Use**

|  |  |
| --- | --- |
| **Production** | **Use** |
| Oil produced (Million barrels per year) | 693.5 |
| CO2 to produce the oil (Mega-tonnes/Year) | 50 |
| CO2 from oil use (Mega-tonnes/Year) | 298.2 |
| **Total CO2 from Oil sands (Mega-tonnes/Year)** | **348** |

**Table 1. Total amount of CO2 from Oil Sands Production And Oil Use**

The recent announcement of the Keystone XL pipeline would allow the oil sand oil industry to propel mining and production to a whole new level.

## 2.2 The Keystone XL Pipeline

The pipeline is a major milestone in the next phase of extracting oil sands under Canada's Boreal Forest to reach higher prices of overseas markets.

Here is the projected impact of Keystone XL by the U.S Department of State in the “Final Environmental Impact Statement” (FEIS) [4]:

* Projected 830,000 barrels/day flow
* Add between 147 to 168 million metric tons of greenhouse gas emissions annually

The Canadian Association of Petroleum Producers (CAPP) 2013 Crude Oil Forecast, Markets and Transportation estimates forecasts Canadian crude oil production will more than double to 6.7 million barrels per day by 2030 from 3.2 million barrels per day in 2012. This includes oil sands production of 5.2 million barrels per day by 2030, up from 1.8 million barrels per day in 2012 [19].

In a recent article by Environment News Service, two senators called on the Secretary of State John Kerry and the Obama Administration to conduct “an immediate and comprehensive study" of the public health risks to communities from the proposed Keystone XL pipeline would carry diluted bitumen from Alberta across the US-Canada border to refineries on the Texas Gulf Coast [5].

Canada's position has been clear: oil sands will be mined whether or not Keystone XL ever gets built. However, in addition to directly benefitting citizens of Canada and the US with renewable electric power and long term CO2 reduction, the proposed option presented here might turn many US opponents of the pipeline into supporters.

Mark Lewis, one of the new Keystone report’s co-authors, estimates that between the transport costs and the extra lubricants needed to coax the oil through thousands of miles of pipeline, it would cost about $18 a barrel to get oil sands crude from Western Canada down to the Gulf Coast on the Keystone XL [26].

## 2.3 Oil Sands EROI Analysis

Higher oil prices have boosted revenues, but operating costs have also increased significantly with the rise in energy prices. Currently the cost of production of a barrel of oil sand is in the $40/bbl range and capital costs add another $10-$20/bbl [21].

Natural gas requirements for the oil sands industry are projected to increase to 2.1 billion cubic feet per day in 2015 [22]. Natural gas is combusted on site to fuel steam generation units which generates two problems. First, it exposes production to economic risk through the highly variable nature of natural gas cost. Second, natural gas combustion is the primary source of greenhouse gas emissions for an in-situ project [24]. If natural gas prices increased to $8/GJ, supply cost would increase to $6.30 per barrel, while production costs would increase by $5.35 per barrel [28].

High natural gas prices have encouraged companies to use natural gas more efficiently and to look for alternative fuels. Many attempts have been made in the past to show how nuclear power may be used to supply the energy demand created by the growth of development in the oil sands regions, including the proposed Molten Salt Nuclear Reactors [24]. In 2013, there has been discussion about including mini nuclear reactors from Toshiba to mine oil sands with the initial deployment projected by 2020 [23].

We propose better EROI by investing in renewable energy. On a short term, companies would be able to insert electric heaters in the ground to make the oil flow instead of having to inject steam. On a long term, it is possible to send the power out along big power lines via HVDC lines to coasts.

# 3 CO2 Saved From Investing in Renewable Energy

## 3.1 CO2 Offset by Investing in Wind Energy

The debate does not have to be so difficult, however, if a system’s perspective is pursued; hence herein is proposed the following scenario:

If one were to install one 5MW wind turbine per kilometer square in a total of

70,100 kilometers square land area (50 % of the Alberta Oil sands area), it would require an investment of about 20% of the portion of oil sales (e.g., $20/bbl with $0.05/kWh reinvestment into purchasing more wind turbines). This approach would offset the CO2 created by mining and using the oil sands oil in approximately 54 years.

Furthermore, it is common for the return on investment (ROI) period for a wind turbine to be about 10-15 years, which means the $20/bbl invested is actually fully recouped in 10-15 years and then onward the wind turbine becomes a net income producer.

Installing wind turbines in this region would reduce the amount of forest being replanted. However, the surface footprint of a large wind turbine is relatively small. Comparing the net carbon captured by the forest area of a turbine’s footprint compared to the carbon offset of a turbine, we find that the CO2 captured from the boreal forest is about 26.2 tonnes/km2 [13]. This value is small compared to CO2 offset by having a large wind turbine (8500 tonnes/year/MW by not burning coal to produce energy generated by wind). Therefore, this is a strong motivation for oil sands land mining reclamation to not to just replant the forest, but to plant forest *and* a large high hub height wind turbine every square kilometer.

Figure 3 and Figure 4 show different scenarios for different percentage of investments.

**Figure 3.** Amounts of CO2 offset with different investments in Wind Energy, assuming a life expectancy of 20 years, and a $0.05/kWh reinvestment into purchasing more wind turbines.

**Figure 4.** Amounts of CO2 offset with different investments in Wind Energy, assuming a life expectancy of 20 years, and a $0.07/kWh reinvestment into purchasing more wind turbines.

**Technical Details**

|  |  |
| --- | --- |
| **Description** | **Value** |
| Turbine Peak Power (MW) | 5 |
| Capacity factor | 40% |
| Land area per turbine (km2) | 1 |
| Percent land area for wind turbines | 50 % |
| Area of wind farm (km2) | 70,100 |
| (Square Miles) | 27,383 |
| Square size (miles x miles) | 165 |
| Number of turbines to be built for land area | 70,100 |
| Average Power generated (GW) | 198 |
| Average annual energy produced (TWHr) | 1,734 |
| **CO2 saved by wind turbines (megatonnes/year)** | **1,684** |

**Table 2.** Amount of CO2 saved by Wind Turbines

**Estimated Results For Wind:**

**With $0.05/kWh Reinvestment Policy:**

* $10/bbl Investment will produce an offset of CO2 in 58 years
* $15/bbl Investment will produce an offset of CO2 in 48 years
* $20/bbl Investment will produce an offset of CO2 in 41 years
* $25/bbl Investment will produce an offset of CO2 in 36.5 years
* $30/bbl Investment will produce an offset of CO2 in 33 years

**With $0.07/kWh Reinvestment Policy:**

* $10/bbl Investment will produce an offset of CO2 in 61 years
* $15/bbl Investment will produce an offset of CO2 in 48 years
* $20/bbl Investment will produce an offset of CO2 in 40 years
* $25/bbl Investment will produce an offset of CO2 in 34 years
* $30/bbl Investment will produce an offset of CO2 in 30 years

These above results are dependent on three parameters: the percentage of investment per barrel of oil sand ($/bbl), the life expectancy of wind turbines, and the reinvestment amount for new equipment ($/kWh). If we invest the same amount each year eventually we hit steady state for number of turbines vs. carbon emissions. The ability to achieve a 100% offset is very sensitive to the $/kWh reinvestment. For example, with 20 year life expectancy and $0/kWh of reinvestment we need the percentage of investment per barrel to be bigger than $45/bbl to reach 100% ever.

**Assumptions**

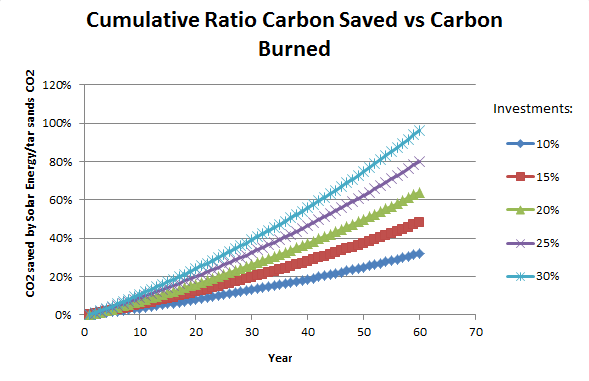
* **Wind Turbine Peak Power**
  + The choice of 5 MW/km2 is conservative and forthcoming are 7 MW turbines, although they will require larger spacing. Even 10 MW turbines are under consideration for production.
* **Wind Turbine Capacity Factor**
  + NRELs median capacity factor to be 40% for onshore wind turbines
  + With higher hub heights, up to 140m, wind turbine net capacity factor could rise to 50%
* **Land area per turbine**
  + Land area assumed to cover 1 km2 per turbine, many wind farms actually would place up to two turbines in this area.
* **Percent land area for wind turbines**
  + Assumption to cover 50% of the total Alberta oil sands area
* **Revenue generated** 
  + All revenue generated gets reinvested into wind equipment purchasing. This also includes the maintenance of wind turbines

## 

## 3.2 CO2 Saved from Investing in Solar Energy

Wind power can produce energy 24/7 as long as the wind blows. For some regions, PV solar cells, even as far North as the oil sands region, might be an option.

If one were to invest 20% of the portion of the sales ($20/bbl for this scenario) covering 30% of the total PV Solar area farm (15% of the total Oil Sand Region), then this approach would offset the CO2 created by mining and using the oil sands oil in approximately 80 years while producers could once again benefit from the use of electric power for mining and production of the oil sands. Figure 5 shows different scenarios for different percentage of investments.



**Figure 5.** Amounts of CO2 offset with different investments in Solar Energy, assuming a 25 year life expectancy, and a $0.05/kWh reinvestment into purchasing more solar cells.

**Technical Details**

|  |  |
| --- | --- |
| **Description** | **Value** |
| Percent land area assumed covered by PV fields | 15% |
| Area of PV farm (km2) | 14,020 |
| (Square miles) | 5,477 |
| Square size (miles x miles) | 74 |
| Number of solar panels to be built for land area | Depends of Size |
| Density of coverage on land designated for PV fields | 30% |
| Area of PV cells (m2) | 6,309,000,000 |
| PV cell efficiency | 15% |
| Average 24/7 solar insolation April (Wh/m2/day) |  |
| June | 6,250 |
| January | 1,389 |
| Average power (assumes 24/7 operation made possible with storage technology) (GW) |  |
| June | 164 |
| January | 37 |
| Average | 100.405 |
| **CO2 saved by not burning coal to produce energy generated by solar (Mega-tonnes/year)** | **854** |

**Table 4.** Amount of CO2 saved by not burning coal to produce energy by Solar

**Estimated Results For Solar:**

**With $0.05/kWh Reinvestment Policy:**

* $10/bbl Investment will produce an offset of CO2 in 58 years
* $15/bbl Investment will produce an offset of CO2 in 48 years
* $20/bbl Investment will produce an offset of CO2 in 41 years
* $25/bbl Investment will produce an offset of CO2 in 36.5 years
* $30/bbl Investment will produce an offset of CO2 in 33 years

**With $0.07/kWh Reinvestment Policy:**

* $10/bbl Investment will produce an offset of CO2 in 61 years
* $15/bbl Investment will produce an offset of CO2 in 48 years
* $20/bbl Investment will produce an offset of CO2 in 40 years
* $25/bbl Investment will produce an offset of CO2 in 34 years
* $30/bbl Investment will produce an offset of CO2 in 30 years

Similarly, the behavior of these results are controlled by the ($/bbl) investment, the life expectancy of the solar cells, and the ($/kWh) reinvestment into purchasing more solar cells.

**Assumptions**

* **Peak Power of PV cell**
  + Assumption to be 1.3kW solar photovoltaic system. In Alberta, a cell will typically produce between 1000 and 1400 kWh per year [10]
  + Most solar panels come at roughly two sizes. We assume that this solar panel is 1600mm x 1020mm. [11]
* **Percent land covered by PV fields**
  + Assumption to cover 15% of land area
* **Density of coverage on land designated for PV fields**
  + Assumption to cover 30% of land area
* **Efficiency of PV fields**
  + For this analysis, OPV efficiency was estimated to be only 15%.
  + Dave DeGraaff, SunPower’s general manager, estimates PV cells efficiency to achieve 23% by 2015 [20]
* **Cost of installation of PV fields**
  + Estimated to be $4/W
* **Revenue generated**
  + All revenue generated gets reinvested into purchasing solar equipment. This includes the maintenance of solar panels

## 3.3 CO2 offset Calculation

The CO2 offset percentage is obtained with the following formula:

To compute the amount of CRCS (Cumulative Ration Carbon Saved):

Where:

* from Table 2

To compute the amount of CB (Carbon Burned):

Where:

* from Table 1

# 4 An Alternative to a Carbon Tax

The percentage to be invested per barrel of oil sand ($/bbl) is an alternative to a carbon tax. Instead of paying a tax, this approach allows companies to invest into its own future and prevent forestall a carbon tax.

According to Cenovus, there are no tax incentives available that are specific to oil sands production. There may be industry-wide tax breaks, but they are the same for conventional oil production and for bitumen production [21].

  A carbon tax would add about $2 to a barrel of Western Canadian heavy crude, and that’s a conservative estimate, says Mark Lewis, one of the new Keystone report’s co-authors, who mentions the possibility of President Obama using a carbon tax as a concession to his base if he were to approve the Keystone XL [26].

# 5 Market Expansion and Supply Cost Reduction

The biggest challenge in Alberta’s Oil Sand industry is that there not enough pipelines to transport the oil to Western Canada and down to U.S. refiners. Consequently, much of the oil is finding its way out of Alberta on trains and even trucks, which can be [two or three times more expensive](http://www.businessweek.com/articles/2013-06-13/amid-u-dot-s-dot-oil-boom-railroads-are-beating-pipelines-in-crude-transport) than sticking it into a pipeline [26]. Producers are now using expensive options such as trucking and railroads to move their crude. The environmental review included a wide variety of cost estimates that with rail shipments to the Gulf Coast, it costs between $15-$20 a barrel [27]. We propose two market expansion ideas that help reduce supply cost reduction.

## 5.1 Selling Electricity Back to the Grid

About 41 percent of Alberta’s installed electricity generation capacity is from coal, almost 40 percent from natural gas, and almost 8 percent from wind [25]. On a long term basis, it would possible to send the excess power out along big power lines via HVDC lines to coasts. Expand this point.

## 5.2 Cleaning Water Contamination

The Athabasca River is part of the third largest watershed in the world. Processing one barrel of bitumen requires approximately three barrels of water [8]. The contaminated water is then pumped into giant tailings ponds alongside the shore.

The Province of Alberta is creating man-made lakes to store the contaminated water produced from the process used to turn bitumen into diesel and other fuels. Reservoirs filled with oil sands wastewater are predicted to cover almost 62,000 acres by 2020 [14].

In these contaminated waters we find high levels of “[Polycyclic Aromatic Hydrocarbons](http://en.wikipedia.org/wiki/Polycyclic_aromatic_hydrocarbons)” or PAHs. We want to make something useful with these compounds in the contaminated water. Every time you have an Aromatic Organic Molecule, you have the potential to crank it which means that breaking the hydrogen and making something useful such plastics and pesticides like Mothballs. The excess wind power could be used as part of the cranking process.

There are times that the grid does not want the excess power generated by the turbines, like at night, hence the cranking plants would run at night. So, during the day the plant runs on battery power. At night, it runs on the excess power from turbines that the grid does not want.

.

Some of the potential applications of cranking the PAHs compounds are possible production of plastics and pesticides.

**Insert Kevin’s point:**  it could make a lot of sense to use the mines for underground pumped hydroelectric storage if there is a good water supply nearby. By adding storage capacity, we can get over the 10% penetration rule of thumb because storage handles the intermittency issues.

If companies are already setting up pumps to pressurize the wells, they could plan ahead to use those same pumps to pull the water back out of the wells - decreasing the capital investment for a pumped-storage facility. The pumps from the Steam Assisted Gravity Drainage used to collect deep tar sands can still be shipped to a new site to be used to store renewable energy.

# 6 Conclusion

It is appears to be economical and politically prudent to undertake as soon as possible a project to install 10 wind turbines on reclaimed land and study the project to ascertain true costs, risks, and benefits with respect to ultimately widespread application of this reclamation strategy.

In parallel, it would be good to conduct a detailed business analysis (short and long term return of investment ROI) of the hypotheses presented here, including:

1. The requirement of investing 20% of gross income from oil sands into renewable energy sources as part of land reclamation and to provide electricity for processing the oil sands, and then selling excess electricity back to the grid.
2. The ability of a) above to encourage the US to approve of the Keystone pipeline
3. The time effect cost of releasing a lot more CO2 now in exchange for a long term greater reduction.

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