A Symbiotic System Model 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 model for the development of Canadian Oil Sands: for example, if 10% of Canadian Oil Sands income (priced at US\$75 per barrel of oil) were to be invested in renewable-energy machines as part of reclamation efforts for the land that is mined, then three significant results can follow. First, we estimate that in 36 years as much CO_2 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, the investment is a better and more productive alternative to a "Carbon Tax" because the money is put directly to use to benefit oil sands development in the short term and renewable power generation in the long term, and the resources remain on the development companies balance sheets. Finally, during periods of peak electrical power generation, the power can be sold back to the grid, power electric underground heaters for liquefying bitumen for extraction without mining operations, or to power operations for cleaning contaminated water of Poly-Aromatic Hydrocarbons (PAH), which can be hydrocracked into useful compounds.

1 Introduction

1.1 Motivation

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 about 140,200 square kilometers [1]. It is also estimated that these regions hold proven reserves up to 1.75 trillion barrels of bitumen [2]. In addition, 173 billon barrels (10%) are estimated to be recoverable at current prices using existing mining technology. About two

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tonnes of oil sands must be dug up, moved, and processed to produce 1 barrel of synthetic oil [3].

Detractors hypothesize that mining, processing, and using the oil from the oil sands will greatly exacerbate global CO_2 problems, and extend this argument as a reason for the US to deny permission to grant approval for the Keystone XL pipeline. Proponents say that global CO_2 impact will be no different than from other sources of oil, and the pipeline is safer than rail shipments.

1.2   Problem Observation

The Province of Alberta is currently operating a modest at best energy return per area invested: oil sands are being mined over a vast area which destroy large swaths of forests releasing even more carbon into the atmosphere while also generating large lagoons of heavily polluted water. In the spirit of increasing the Energy Return on Investment (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 planned and invested 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 excess power can also be sold to the grid or be used to clean contaminated. Another possible scenario could include significant coverage of the land to be reclaimed by PV solar panels.

1.3   Method

We propose a hypothetical economic model which implements renewable energy systems deployed in reclamation lands which offsets CO_2 in the long-term. In this model, we calculate the CO_2 offset percentage by finding ratio between the amount of Cumulative Ratio Carbon Saved and the amount of Carbon Burned. The Cumulative Ratio Carbon Saved changes according a set of parameters:

- The choice of renewable system to offset the CO_2: wind energy system or solar energy system

- Deployment of the systems to be located in a percentage area of the oil sands region to be reclaimed

- Peak Power for a wind turbine or a solar panel

- The cost per watt (\$/Watt) of the renewable system with the installation included

- The Reinvestment Policy amount to be either \$0.05/kWh or \$0.07/kWh per year into purchasing more equipment for the deployed energy system

- The approximate decommission rate of a wind turbine or solar panel

- Different amounts of yearly investments in the renewable energy system based on:

    - **Case 1:** A portion of the oil sands income (a percentage of a barrel of oil) to be invested in the model instead implementing a Carbon Tax (described in Section 3.1 of this paper)

    - **Case 2:** A portion of the Carbon Tax as a Carbon Reinvestment Tax (described in Section 3.2 of this paper)

2 Results

2.1 CO$_2$ Offset by Investing in Wind Energy

Our first economic model is the study of CO$_2$ offset by investing in wind energy only. The initial reinvestment and reclamation hypothesis appears promising, and Figures 1 and 2 show different scenarios for different percentage of investments for US\$75/bbl that will need to be considered by a more detailed investigation. Table 1 shows the modeling assumptions and the amount of CO$_2$ saved by wind turbines
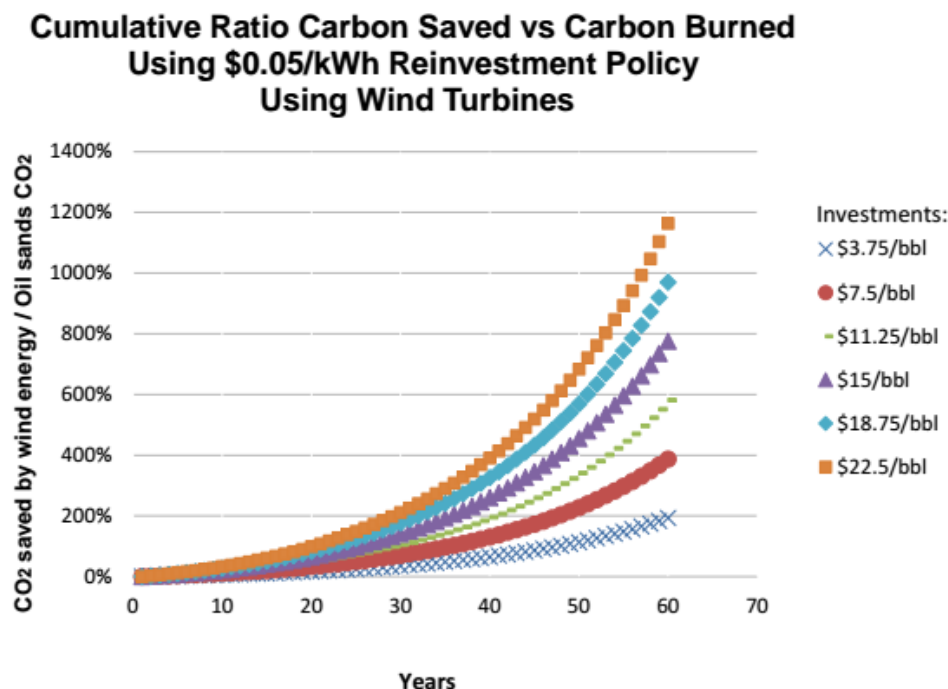
Figure 1. Amounts of CO$_2$ offset with different investments in wind energy systems, assuming a wind turbine life expectancy of 20 years, one wind turbine per square kilometer of reclaimed land up to a total of 70,100 square kilometers (50% of oil sands region), \$2/Watt cost including installation of the wind turbine, and a \$0.05/kWh Reinvestment Policy into purchasing more wind turbines every year.
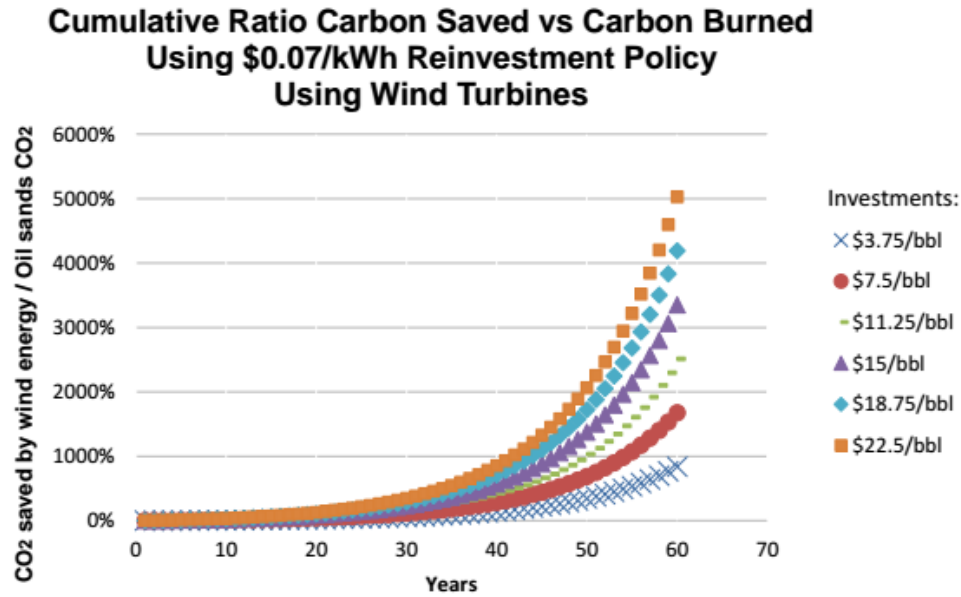
Figure 2. Amounts of CO_2 offset with different investments in wind energy systems, assuming a wind turbine life expectancy of 20 years, one wind turbine per square kilometer of reclaimed land up to a total of 70,100 square kilometers (50% of oil sands region), \$2/Watt cost including installation of the wind turbine, and a \$0.07/kWh Reinvestment Policy into purchasing more wind turbines every year.

Wind Energy System Model Specifications

Description	Value
Turbine Peak Power (MW)	5
Capacity factor	40%
Land area per turbine (km^2)	1
Percent land area for wind turbines	50 %
area of wind farm (km^2)	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
CO$_2$ saved by wind turbines (Megatonnes/Year)	**1,684**

Table 1. Modelling assumptions for determining amount of CO_2 saved by Wind Turbines

Other model considerations include:

- **Wind Turbine Peak Power**

  - The choice of 5 MW/km^2 is conservative as forthcoming are 7 MW turbines, although they will require larger spacing. Even 10 MW turbines are under consideration for production.

- **Wind Turbine Capacity Factor**

  - NREL's 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% (70,100 km^2).

- **Land area per turbine**

  - Land area assumed to cover 1 km^2 per turbine, many wind farms actually place up to two turbines in this area.

- **Percent land area for wind turbines**

  - Assumption to cover 50% of the total Alberta tar sands area

- **Cost of installation of wind turbines**

  - Estimated to be \$2/W with the installation.

- **Reinvesment Policy**

  - Assumption to reinvest \$0.05/kWh or \$0.07/kWh into wind turbine purchase and maintenance.

2.2 CO$_2$ Offset by Investing in Solar Energy

Our second model is the study of CO$_2$ offset by investing on solar energy systems. A more modest, but still significant results are obtained with 30% of the land area reclaimed using arrays of PV cells in Table 2.

Solar Energy System Model Specifications

Description	Value
Percent land area assumed covered by PV fields	15 %
Area of PV farm (km^2)	14,020
(Square miles)	5,477
Square Size (miles x miles)	74
Density of coverage on land designated for PV fields	30%
Area of PV cells (m^2)	6,309,000,000
PV Cell efficiency	15 %
Average 24/7 solar insolation April (WH/m^2/day)	
June	6,250
January	1,389
Average power (assumes 24/7 operation with storage technology) (GW)	
June	164
January	37
Average	100.405
Total CO$_2$ saved by PV cells (Megatonnes/Year)	**854**

Table 2. Amount of CO$_2$ saved by not burning coal to produce energy by PV solar panels

Similarly, the behavior of these results are controlled by the amount investment (\$US/bbl), the life expectancy of the solar cells, the peak power of the solar cells, and the (\$/kWh) Reinvestment Policy into purchasing more solar cells.

3 Discussion

3.1 Economic Models

We hypothesize that a better EROI would be obtained by investing in renewable energy systems emplaced on land to be reclaimed from mining activities. Figure 1 shows an example of the cumulative effect on CO_2 emissions over the years with this land reclamation plan, where 50% of the total oil sands land area being reclaimed include wind turbine installations, one wind turbine per square kilometer, funded by oil revenues and a $0.05/kWh reinvestment from the wind power generated. Table 3 shows the years to achieve 100% cumulative CO_2 offset by various investment percentage strategies

Approximate CO_2 Offset Timelines Using the Wind Energy System Model

| Investment Amount ($US/bbl)	Estimated Time with $0.05/kWh Reinvestment (Years)	Estimated Time with $0.07/kWh Reinvestment (Years)
3.75	48	36
7.5	**36**	**29**
11.25	30	25
15	26	22
18.75	23	20
22.5	20	18

Table 3. Estimated timeline for 100% CO_2 offset for wind energy systems based on specific investment amounts ($US/bbl) and a $0.05/kWh or $0.07/kWh Reinvestment Policy into buying more wind turbines.

These scenarios are dependent on four parameters: the percentage of investment per barrel of oil sand ($US/bbl), the life expectancy of wind turbines, the cost per watt ($/Watt), the choice of wind turbine peak power, and the Reinvestment Policy amount for new equipment ($/kWh). If we invest the same amount each year eventually we hit a steady state for number of turbines vs. carbon emissions. The ability to achieve a 100% offset is sensitive to the $/kWh reinvestment from power generated. For example, with 20-year life expectancy and $0/kWh of reinvestment we need the percentage of investment per barrel to be bigger than $25/bbl to ultimately reach 100% ever. The solar model presented in Section 2.2 would in fact never totally offset the CO_2 created by mining and using the oil sands oil. This is due to the decommission period of the solar panels. Current panel technology and effective installation costs prevent being able to offset the CO_2 attributed to oil sands. However, a significant amount of CO_2 reduction could be accomplished and therefore the analysis of this scenario was presented for completeness.

In the long term, it would be possible to send power generated out along the power lines that recently have been built to provide power to the oil sands region, thus enabling coal-fired power plants in the other regions to be phased out. Furthermore, it is common for the return on investment (ROI) period for a wind turbine to be about 15 years [4], which means the $7.5/bbl invested is actually fully recouped in 10 years and then onward the wind turbine becomes a net income producer and a profitable source of income for the company operating the wind turbine
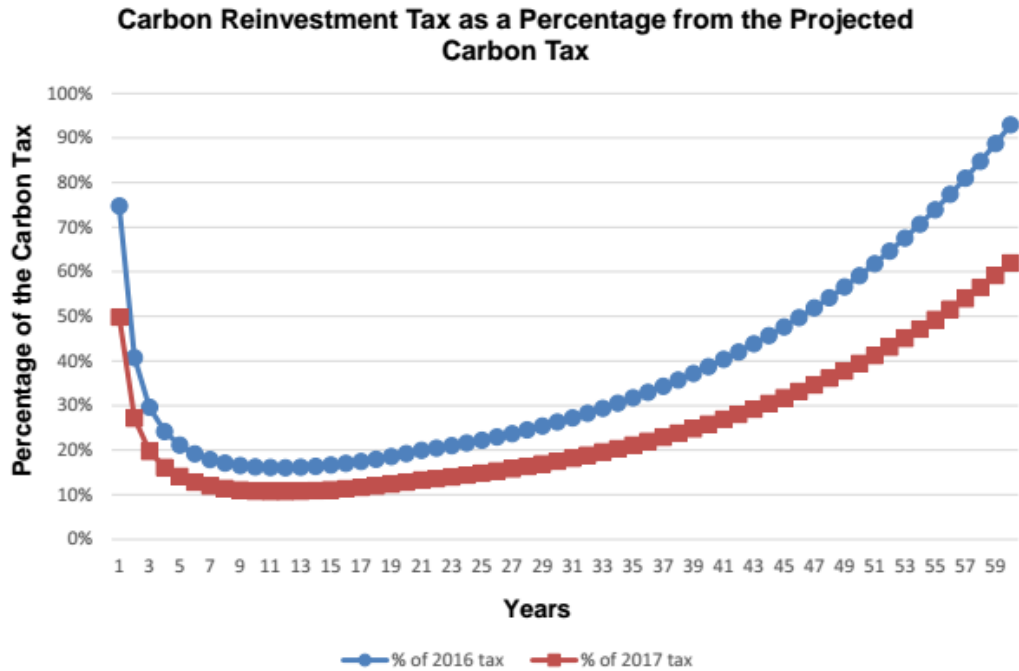
3.2 Carbon Reinvestment Tax

We can think of the economic models from Figure 1 and Figure 2 from a carbon footprint as a function of a carbon reinvestment tax perspective.

Carbon Tax vs Carbon Reinvestment Tax
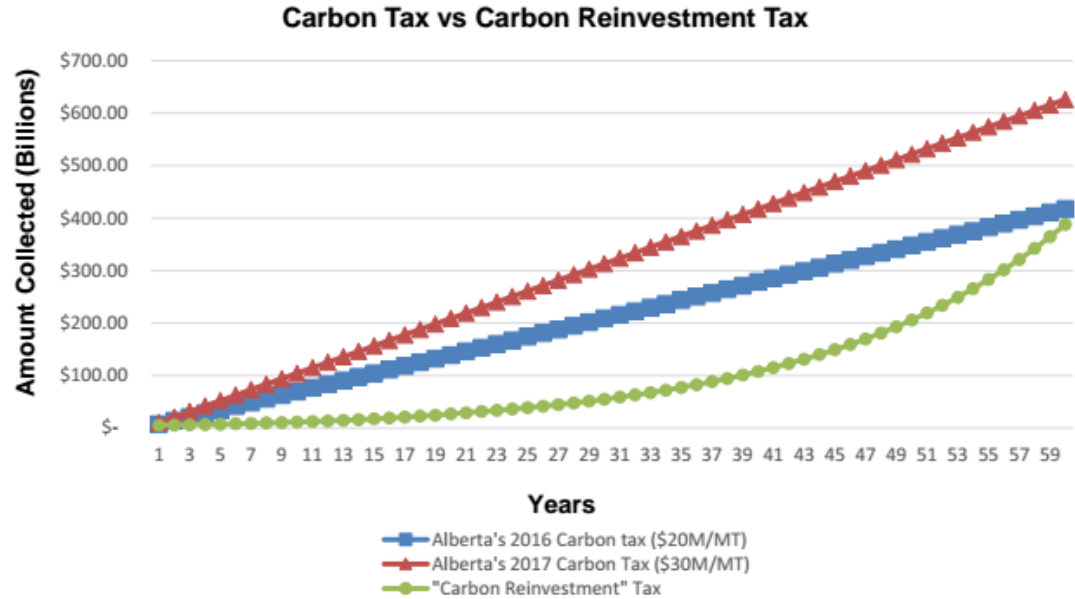
Figure 3. A Carbon Reinvestment Tax is more affordable in the long term.

We can look at the Carbon Reinvestment Tax as a fraction from the Carbon Tax that companies invest in themselves.

Carbon Reinvestment Tax as a Percentage from the Projected Carbon Tax

Figure 4. A Carbon Reinvestment Tax as a Percentage of the Carbon Tax

Figure 4 shows how we can take a fraction amount of the proposed Carbon Tax to fund the energy systems. This proportion amount out of a Carbon Tax will increase over time, but proves to be a better solution in the long term. Considering the economic model investment of $7.5/bbl with a Reinvestment Policy of $0.05/kWh

3.3   Possible Uses of Excess Power Generated

Companies could benefit from the extra power generated by the wind turbines. It 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 small nuclear reactors [5] to bring power in for which they then have to pay to use.

In research published in February 2014, the International Council of Clean Transportation and NNFCC, a consultancy, concluded that biofuels made from waste could provide 16% of Europes transport fuels by 2030 [6] and it would create an entirely new industry sector as current production is close to zero. In addition, the International Energy Agency (IEA) calculates that the cost of producing regular gasoline will rise from $0.54 per litre of gasoline equivalent in 2010 to $0.82 per litres of gasoline equivalent in 2030. By contrast, the cost of advanced biofuel production will fall from $1.05-$1.15 per litre of gasoline equivalent in 2010 to $0.80-$1 in 2030 [7].

Other potential applications include selling electricity back to the grid, cleaning contaminated water, exploring the possibility using pumped-storage hydroelectricity, and powering underground electric heaters as an alternative to pumping steam underground for bitumen extraction

3.4   Mitigations, Transitions, and Adjustments with Labour Unions

Unions are opposed to building the Keystone XL pipeline not just for environmental reasons, but also for economic reasons as well. The model presented here constitutes a symbiotic approach to mitigate the situation in case the pipeline ever gets built. The mitigation development we present in this paper could be treated, politically, as a way of "forward planning" as we would already have a model that could mitigate the situation beforehand. This would save significant time and speed up the negotiation process for the parties involved.

The overall goal of the economic model presented is to contribute to global efforts to slow and limit climate change. Resource industries face a special challenge, and bear a special responsibility.

4   Conclusion

This paper showed that a symbiotic model to short and long term energy needs can lead to an overall reduction in atmospheric CO_2. In Section 3.1, we discussed that we could found our economic model by taking from a percentage of the oil sands income instead of having a Carbon Tax. In Section 3.2, we explored a Carbon Reinvestment Tax as a function of a Carbon Tax and we argued that the reinvestment tax is better suited than a Carbon Tax.

It is appears to be economically and politically prudent to undertake as soon as possible a project to install a reasonable number of wind turbines on reclaimed oil sands land in order to better investigate the hypothesis presented here to ascertain true costs, risks, and benefits with respect to ultimately widespread application of this reclamation strategy.

Acknowledgments

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