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

Prof. Alexander H. Slocum[[1]](#footnote-1) (slocum@mit.edu)

Massachusetts Institute of Technology

David James Taylor (dtaylor@mit.edu)

Massachusetts Institute of Technology

Kevin Patrick Simon (kevinpsi@mit.edu)

Massachusetts Institute of Technology

Santiago Paiva (santiago.paiva@mail.mcgill.ca)

McGill University

Mark Bartlett (mbartlett@uni444.ca)

Unifor Windsor Regional Environment Council

**Abstract**

After examining multiple embodiments of symbiotic systems, we found the most promising system to be one where oil companies are required to invest $7.5 per barrel of oil sold to building wind turbines on their land. This progressive type of tariff benefit oil companies, the power grid, and the environment. As opposed to a standard type of Carbon Tax, the applied tariff would remain on the oil companies’ balance sheets and address their need for distributed power. The power grid would benefit from additional generation and the transmission lines servicing the oil sands would eventually bring electricity from the oil sands towards the rest of the grid. Finally, we estimated that in 36 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.

# 1 Introduction

The Northern Alberta region contains 98% of the Canadian oil sands, covering 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]. About two 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 carbon dioxide (CO2) 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 CO2 impact will be no different than from other sources of oil, and the pipeline is safer than rail shipments. All parties must agree however, that the Energy Return on Investment (EROI) from oil sand extraction is lower than conventional oil extraction [4].

We hypothesize that through a symbiotic system, we can mitigate environmental concerns and facilitate the development of the Keystone XL pipeline. Specifically, we propose a system where oil companies are required to invest a portion of their revenues in renewable energy generation on site and are further required to reinvest some of the money saved by that renewable generation.

# 2 Method

Our proposed symbiotic system would require oil companies to invest in renewable energy generation as a part their land reclamation. The investment amount is a function of the number of barrels of oil sold and the amount of renewable energy generated by the generation capacity installed as part of this system. We investigated investments into wind and solar generation capacity and the impact of 6 different required investment rates and 2 different reinvestment policies:

|  |  |  |
| --- | --- | --- |
| **Investment Rates** | **Reinvestment Policy** | |
| US$3.75/bbl | $0.05/kWhr | $0.07/kWhr |
| US$7.5/bbl | $0.05/kWhr | $0.07/kWhr |
| US$11.25/bbl | $0.05/kWhr | $0.07/kWhr |
| US$15/bbl | $0.05/kWhr | $0.07/kWhr |
| US$18.75/bbl | $0.05/kWhr | $0.07/kWhr |
| US$22.5/bbl | $0.05/kWhr | $0.07/kWhr |

**Table 1.** Case studies investigated in this paper

We evaluated the efficacy of each evaluated system by its Carbon Mitigation Ratio, defined as the total amount of CO2 offset by the system, divided by total amount of Carbon Burned due to oil extraction and use. Table 2 shows the modeling assumptions and the amount of CO2 saved by wind turbines.

**Wind Energy System Model Specifications**

|  |  |
| --- | --- |
| **Description** | **Value** |
| Turbine Peak Power (MW) | 5 |
| Capacity factor | 40% |
| Land area per turbine (km2) | 1 |
| Oil sands 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 not burning coal to produce energy generated by wind (Megatonnes/Year) | 1,684 |

**Table 1.** Modelling assumptions for determiningamount of CO2 saved by wind turbines

The model specifications are mainly dependent on the following parameters: the wind turbine peak power which is set to be at a conservative value of 5 MW/km2; the wind turbine capacity factor to be 40% according to NREL’s median capacity for onshore wind turbines; the land area to cover up to 1 km2 per turbine; the percent land area for wind turbines to cover up to 50% of the total Alberta oil sands area (70,100 km2); the estimated cost per watt including installation of the wind turbines to be $2/Watt; and the Reinvestment Policy to be either $0.05/kWh, or $0.07/kWh into wind turbine purchase and maintenance.

# 3 Results

## *3.1 CO2 Offset by Investing in Wind Energy*

We first evaluated the hypothesis by considering an investment in wind energy only. Two parameters were found to dramatically affect the impact of the tariff scheme: the required investment (dollars per barrel) and the required reinvestment (dollars per kWh of renewable generation). The initial reinvestment and reclamation hypothesis appears promising, and Figures 1 and 3 show different scenarios for different percentage of investments for US$75/bbl that will need to be considered by a more detailed investigation.

Investments:

**Figure 1**.Amounts of CO2 offset with different investments in wind energy systems implementing a $0.05/kWh Reinvestment Policy into purchasing more wind turbines every year.

**Figure 2.** Amount of power generated by Figure 1.

Investments:

**Figure 3.** Amounts of CO2 offset with different investments in wind energy systems implementing a $0.07/kWh Reinvestment Policy into purchasing more wind turbines every year.

**Figure 4.** Amount of power generated by Figure 3.

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 CO2 emissions over the years with this land reclamation plan, where up to a 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 CO2 offset by various investment percentage strategies

**Approximate CO2 Offset Timelines Using the Wind Energy System Model**

|  |  |  |
| --- | --- | --- |
|  | **Reinvestment Policy** | |
| $0.05/kWh | $0.07/kWh |
| **Investment Amount**  **($US/bbl)** | **Estimated Time**  **(Years)** | **Estimated Time**  **(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% CO2 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). The models used here do not account for growth in the total production of oil. Therefore without a reinvestment policy, the total renewable generation hits a steady-state in each model when the number of units being commissioned and decommissioned is the same.

**Figure 5.** The ability to achieve a 100% offset is sensitive to the $/kWh reinvestment from power generated.

With 20-year life expectancy wind turbine and $0/kWh of reinvestment we need the percentage of investment per barrel to be bigger than US$25/bbl to reach a carbon mitigation ration 100%.

The Cumulative Ratio Carbon Saved changes according a set of parameters:

* The choice of renewable system to offset the CO2: 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)

## *3.2 CO2 Offset by Investing in Solar Energy*

An equivalent analysis was done for solar power, but in all cases it never reached a carbon mitigation ratio of 100% due to the decommission period of the solar panels. Current panel technology and effective installation costs prevent being able to offset the CO2 attributed to oil sands. It is therefore our strong recommendation that wind should be pursued over solar in northern Alberta. Table 3 shows the modeling assumptions and the amount of CO2 saved by solar panels.

**Solar Energy System Model Specifications**

|  |  |
| --- | --- |
| **Description** | **Value** |
| Oil sands percent land area covered by PV fields | 15% |
| Area of PV farm (km2) | 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 (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 (Megatonnes/Year) | 854 |

**Table 2.** Amount of CO2 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.

## *3.3 Economic Models*

The percentage of oil revenues to be invested (US$/bbl) into renewable energy systems as part of land reclamation efforts is a business and an environment friendly alternative to the proposed Carbon Tax. Instead of paying a tax to the government, which removes value from a company ledger, this approach allows companies to invest in assets for its own present and future value, and thus could negate the perceived need by many for a Carbon Tax.

[DISCUSSION ABOUT THE TRANSMISSIONS DETAILS]

One immediate criticism of the models presented here would be that the total amount of power generated far exceeds the electricity demands of the oil sands. In fact, in some scenarios (it reaches XX% of Canada’s total electricity needs). However, major power lines have recently been built to provide power to the oil sands region, and these could be used to send power back to the grid and offset less renewable generation sources across the province.

## *3.4 Carbon Reinvestment Tax*

In Section 3.1, we proposed funding for our economic models to come as a portion of the oil sands income (a percentage of a barrel of oil) and we argued that it was a better solution than forcing a Carbon Tax on the oil companies. In this section, we explored the alternative possibility of using a portion of the proposed Carbon Tax as a “Carbon Reinvestment Tax” instead of a portion of oil sands income.

The Government of Alberta now plans to introduce a Carbon Tax priced at $20 per tonne in 2016 and $30 per tonne in 2017 [6] as part of the climate change plan. We believe that a “Carbon Reinvestment Tax” is a better alternative to a Carbon Tax. We can think of the economic models from Figure 1 and Figure 3 from a carbon footprint as a function of a carbon reinvestment tax perspective.

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

We could consider taking a portion of the Carbon tax as a Carbon Reinvestment Tax that companies that generate the carbon themselves apply instead of paying the tax directly to the government, this self-investing approach is a better and more specific long-term plan for oil companies (as a Carbon Reinvestment fee) instead of paying the total proposed Carbon Tax fee to the government.

**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 wind turbines. The annual amount to be invested in renewables has a changing reinvestment amount per year and thus expose this behaviour, the reinvestment is not linear, but rather exponential over the long-term. For instance, in 60 years, the proposed amount for the Carbon Reinvestment Tax would equal the proposed amount for Alberta’s 2016 projected Carbon Tax.

This proportion amount (percentage) out of Alberta’s proposed Carbon Tax will increase over time, but proves to be a better solution in the long term. This case scenario is the equivalent to the investment of US$7.5/bbl with a Reinvestment Policy of $0.05/kWh as shown in Figure 1.

## *3.5 Possible Uses of Excess Power Generated*

About 41% of Alberta’s installed electricity generation capacity is from coal, 40% from natural gas, and 8% from wind [7]. With the availability of large amounts of electric power as more and more wind turbines come on line in our model, the potential for revenue generation increases, thereby furthering the case for investment.

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 [8] to bring power in for which they then have to pay to use.

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

## *3.6 Mitigations, Transitions, and Adjustments with Labour Unions*

Several unions, such as Unifor, 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. If Keystone XL were to be built, the oil will be sent to Texas for refining. As a result, refining jobs in Canada will be reduced or stagnate. Construction jobs are temporary within the oil sands industry, however transitions to green technologies would help workers retain their jobs by assisting affected ones and communities to take advantage of the new opportunities within the energy industry. The idea of a transition fund not only for the environment, but also for workers and their communities would help mitigate these effects. This would save significant time and speed up the negotiation process for the parties involved.

# 4 Conclusion

This paper explored economic models to short and long term energy needs in the Canadian oil sand region that can lead to an overall reduction in atmospheric CO2. In Section 3.1, we proposed that we could found our economic models by taking from a percentage of the oil sands income instead of having a Carbon Tax. In Section 3.2, we considered a “Carbon Reinvestment Tax” as a function of Alberta’s proposed Carbon Tax.

We conclude that current oil sand development and future project expansions, such as the Keystone XL pipeline, could be accomplished while benefiting oil industries, the government, and the environment by implementing the reclamation strategy described in this paper. We propose to install a small 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.

# Acknowledgments

The co-authors of this paper would like to deeply thank Professor Alexander H. Slocum for providing the vision behind this project and the idea that shaped the economic models for wind and solar energy presented in this paper. His passion and uncanny love for energy systems to solve humanity’s grand challenges makes him a truly remarkable role model and a great source of inspiration.

We would also like to show our gratitude to Canadian labour union Unifor who saw the vision of this project and provided insightful ideas that were key in this paper. Finally, we also thank economist Jim Stanford who gave us comments that greatly improved this paper.

# References

1. Alberta Energy. “About Oil Sands: Facts and Statistics”. Retrieved on March 13, 2014 from Alberta Energy Website: http://www.energy.alberta.ca
2. Alberta Environment. (2008). “[Alberta's Oil Sands: Opportunity, Balance](http://www.environment.alberta.ca/documents/Oil_Sands_Opportunity_Balance.pdf)”. Retrieved on March 19, 2014 from Alberta Environment Website: http://environment.alberta.ca
3. Alberta Energy. “Oil Sands 101”. Retrieved on August 20, 2014 from Alberta Energy Website: <http://www.energy.alberta.ca>
4. [Brandt A.R., J. Englander and S. Bharadwaj (2013). The energy efficiency of oil sands extraction: Energy return ratios from 1970 to 2010. Energy](http://www.sciencedirect.com/science/article/pii/S0360544213002776)
5. Moloney, C. (2014). “Small Wind Turbine: What Is the Payback Period”. Retrieved on June 26, 2014 from Poplar Network Website: http://www.poplarnetwork.com
6. Wood, J. (2015). “Alberta boots carbon tax to $20 a tonne starting in 2016 as part of climate change place”. Retrieved on July 22, 2015 from The Financial Post Website: www.business.financialpost.com
7. Alberta Energy. “Electricity Facts”. Retrieved on April 1, 2014 from Alberta Energy Website http://www.energy.alberta.ca
8. Daly, J. (2014). “Canada Considering Nuclear Reactors in Alberta Tar Sands Fields”*.* Retrieved on April 2, 2014 from Oil Price Website: http://oilprice.com

1. Professor, corresponding author, [slocum@mit.edu](mailto:slocum@mit.edu), +001.617.0012, MIT Room 3-344, 77 Massachusetts Avenue, Cambridge, MA 02139, USA [↑](#footnote-ref-1)