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**

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 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, the investment is a better and more productive alternative to the 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.

Contents

[1 Introduction 2](#_Toc427215678)

[*1.1 Motivation* 2](#_Toc427215679)

[*1.2 Problem Observation* 2](#_Toc427215680)

[4 Possible Uses of Excess Power Generated 7](#_Toc427215681)

[5 Carbon Reinvestment Tax 7](#_Toc427215682)

[Section 6 - Symbiotic Approach with Labour Unions 8](#_Toc427215683)

[7 Conclusion 9](#_Toc427215684)

[Acknowledgments 9](#_Toc427215685)

# 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 [2]. It is also estimated that these regions hold proven reserves up to 1.75 trillion barrels of bitumen [3]. In addition, 173 billon barrels (10%) are estimated to be recoverable at current prices using existing mining technology. About two tonnes of oil sands must be dug up, moved, and processed to produce 1 barrel of synthetic oil [29].

Detractors hypothesize that mining, processing, and using the oil from the oil sands will greatly exacerbate global 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.

## *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 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 modest 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 water. Another possible scenario could include significant coverage of the land to be reclaimed by PV solar panels*

*.*

**METHOD**

In this model, 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 of this paper)
  + **Case 2**: A portion of the Carbon Tax as a Carbon Reinvestment Tax (described in Section 5 of this paper)

Furthermore, it is common for the return on investment (ROI) period for a wind turbine to be about 10 years [17], 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 [17] and a profitable source of income for the company operating the wind turbine.

**RESULTS**

Investments:

**Figure 3**.Amounts of CO2 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.

Investments:

**Figure 4.** Amounts of CO2 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 (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 (Mega-tonnes/year) | 1,684 |

**Table 2.** Modelling assumptions for determiningamount of CO2 saved by wind turbines

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

|  |  |
| --- | --- |
| Reinvestment Policy | |
| $0.05/kWh | $0.07/kWh |
| Estimated Time  (Years) | Estimated Time  (Years) |
| 48 | 36 |
| **36** | **29** |
| 30 | 25 |
| 26 | 22 |
| 23 | 20 |
| 20 | 18 |

**Table 3.** Estimated timeline for 100% CO2 offset for wind energy systems based on specific investment amounts ($X/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 ($X/bbl), the life expectancy of wind turbines, the cost per watt ($/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.

Other model considerations include:

* Wind Turbine Peak Power
  + The choice of 5 MW/km2 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 is 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 place up to two turbines in this area.
* Percent land area for wind turbines
  + Assumption to ultimately cover 50% of the total Alberta oil sands area (70,100 km2).
* Cost of installation of wind turbines
  + Estimated to be $2/W with the installation
* Reinvestment Policy
  + Assumption to reinvest $0.05/kWh or $0.07/kWh into wind turbine purchase and maintenance.

Our second model is the study of CO2 offset by investing on solar energy systems

**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 (Mega-tonnes/year) | 854 |

**Table 4.** Amount of CO2 saved by not burning coal to produce energy by PV solar panels

**DISCUSSION**

# 4 Possible Uses of Excess Power Generated

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 Europe’s transport fuels by 2030 [27] 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 [28].

# 5 Carbon Reinvestment Tax

Note there are about 0.5 tonnes of CO2 that can be attributed to the mining (0.07 tonnes) and consumption (0.43 tonnes) of oil sands oil

We can think of the economic models from Figure 3 to Figure 6 from a carbon footprint as a function of a carbon reinvestment tax perspective.

**Figure 8**. 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. Considering the economic model investment of $7.5/bbl with a Reinvestment Policy of $0.05/kWh

# Section 6 - Symbiotic Approach with Labour Unions

Although unions, not just Unifor, are strongly opposed to building the pipeline, 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.

overall goal of contributing to global efforts to slow and limit climate change. Resource industries face a special challenge, and bear a special responsibility. In Section 3, 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 5, 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. A carefully managed, sustainable approach to resource production is much better than in the short-run boom-and-bust employment cycles so typical of resource industries in the past.

# 7 Conclusion

This paper showed that a symbiotic model to short and long term energy needs can lead to an overall reduction in atmospheric CO2. It is appears to be economical 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

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.

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)