**A Symbiotic System Model for the Development for Canadian Oil Sands**

**1- Introduction**

The Northern Alberta region contains 98% of the Canadian oil sands, covering about 140,200 square kilometers. It is also estimated that these regions hold proven reserves up to 1.75 trillion barrels of bitumen. About two tons of oil sands must be dug up, moved, and processed to produce 1 barrel of synthetic oil. 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.

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- Methods**

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:

Carbon Ratios: To account for the environmental benefits of the proposed symbiotic system, we considered the ratio of the carbon offset by wind power, to the carbon produced by the oil sands. Specifically we considered the marginal carbon impact of the oil sands compared to conventional oil, deemed ‘Production,’ and the total carbon cost of producing and consuming oil from the oil sands, deemed ‘Total.’ Further, we considered both the instantaneous carbon ratio (ICR) of these numbers at any given point in time, and the cumulative carbon ratio (CCR), which considers the total amount of emissions and offset emissions since the start of the project.

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**

The proposed symbiotic system considers the potential environmental benefits of installing wind turbines as a part of oil sands reclamation efforts. With enough 4160 wind turbines, the marginal climate damage caused by oil sands compared to conventional oil is offset. This amount of electricity generation is equivalent to that of Alberta’s 2012 electricity consumption. If 70,000 turbines or one per square kilometer were installed, the total carbon emissions of production and consumption of the oil sands could be offset, as in Table X.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Turbines Installed | 1000 | 4160 | 10000 | 30000 | 70000 |
| Density (Turbines/(km)^2) | 0.014 | 0.059 | 0.14 | 0.43 | 1.00 |
| Name Plate Capacity (GW) | 5 | 20.8 | 50 | 150 | 350 |
| Generation (GW) | 2 | 8.32 | 20 | 60 | 140 |
| Annual Carbon Offset (MT) | 12.76 | 53.08 | 127.58 | 382.75 | 893.09 |
| Total Instantaneous Carbon Ratio | 0.04 | 0.15 | 0.37 | 1.10 | 2.57 |
| Production Instantaneous Carbon Ratio | 0.26 | 1.07 | 2.57 | 7.70 | 17.96 |
| Percent of Alberta's Electricity | 0.24 | 1.00 | 2.40 | 7.21 | 16.82 |
| Percent of Canada's Electricity | 0.02 | 0.06 | 0.15 | 0.46 | 1.07 |

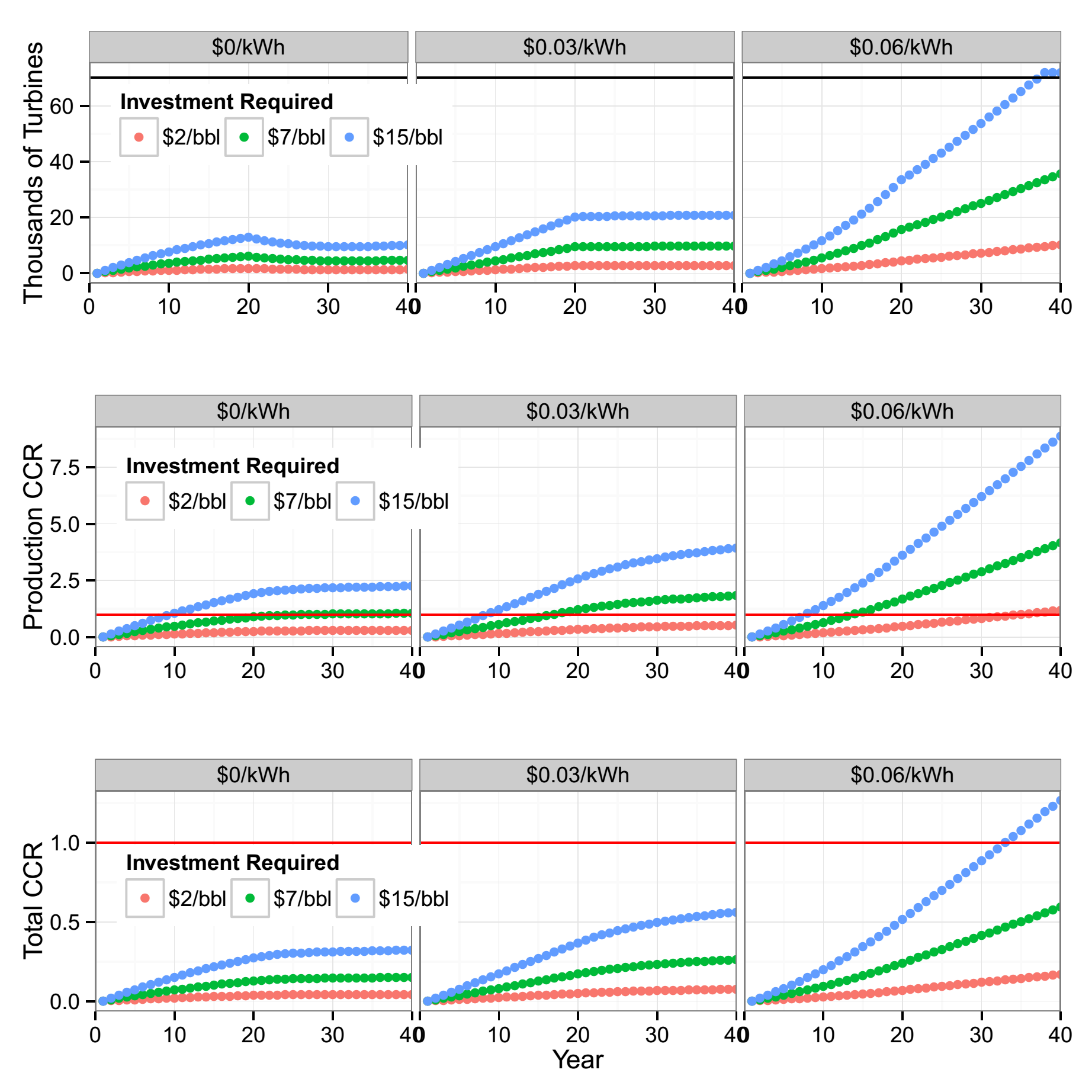
Despite what may be an immediate reaction of ‘Impossible!’ or ‘Unaffordable!’, through imposing a levy per barrel of oil to fund the construction of wind turbines and by further reinvestment a portion of their revenue into building more turbines, this plan is achievable. The feasibility depends strongly on how much companies are required to reinvest of the wind turbine revenues; for reference, Fig Y shows investment amounts of $2, 7$, and $15/bbl, and reinvestment requirements of $0, $0.03, and $0.06/kWh. $2/bbl is equivalent to the proposed Alberta carbon tax applied to the production emissions of the oil sands, while $15/bbl is equivalent to the proposed tax applied to the production and end use emissions. $0.06/kWh was our estimate [ref needed!] for the cheapest grid electricity pricing and therefore serves as an upper limit to the feasibility of reinvestment charges.

If the goal is to achieve a production CCR of one within the next 40 years, the current carbon tax could be used with a reinvestment level of $0.06/kWh, or higher per barrel rates with lower per kWh charges, as in Fig Y. The only shown scenario to reach a total CCR of one was the $15/bbl with $0.06/kWh. One method of framing this investment charge would be as a carbon tax applied at the time of production for the production and consumption of the oil, or as a flat rate tariff.

Many of these scenarios would generate more electricity than currently required by the oil sands, to achieve a total ICR of one would require enough wind to supply 45% of Canada’s electricity requirements. Methods of using and distributing this excess power is discussed in the SI.

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)



**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.