A Symbiotic Systems 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 systems approach for the development of Canadian Oil Sands: for example, if 10 % of Canadian Oil Sands income (for US$75 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.

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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]. There are 170.4 billion barrels of recoverable oil in the oil sands deposits of Northern Alberta. There are 315 billion barrels of potentially recoverable oil in the oil sands. Approximately 80% of oil sands are recoverable through in-situ production, with only 20% recoverable by mining [29].

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 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.

In this paper, we demonstrate how reclamation efforts for mined oil sands land that focus on investment in Wind Turbines and/or Photovoltaic (PV) installations not only could result in significant long term reduction of CO_2 emissions by providing power for cleaner extraction methods and enabling coal fired power generation stations to be phased out, but also 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 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. Poisson *et al* [4] 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 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.*

Figure 1 below 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 funded by oil revenues and a $0.05/kWh reinvestment from the wind power generated. More modest although still significant results are obtained with 30% of the land area reclaimed using arrays of PV cells as shown in Figure 2.

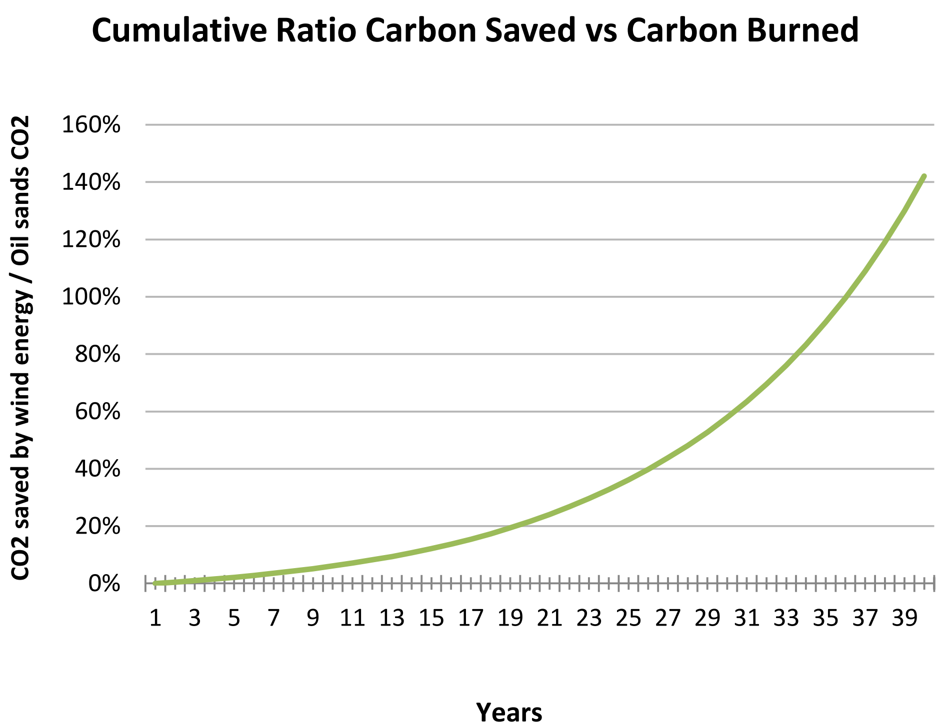

Figure 1. Amount of CO_2 offset by $7.5/bbl investment in wind turbines based on $2/Watt installed, and a $0.05/kWh reinvestment from the wind power generated. This graph assumes ultimately 50% of the total oil sands land area being reclaimed with wind turbine installations. We could achieve carbon neutrality in approximately 36 years with this approach. More in depth analysis is provided in section 3 of this paper.

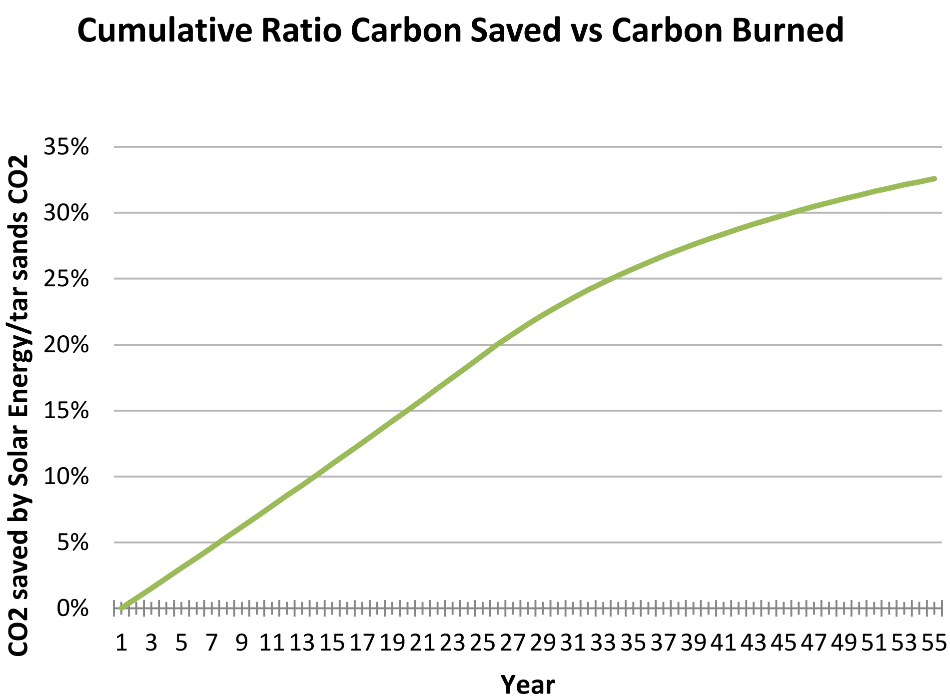

Figure 2. Amount of CO_2 offset by $7.5/bbl investment in PV solar panels based on $2/Watt installed, 15% net system efficiency, and a $0.05/kWh reinvestment from the solar power generated. This graph assumes 30% of land area being reclaimed with PV solar cell installations.

1.3 Renewables as a Potential Solution

It was believed that the primary factor for the research and development of renewables were the fact that conventional fuels were too high and that the price was to rise over time. With the dramatic decline of oil in the past year, many thought that it was no longer viable and profitable to look at renewable energy. This belief is incorrect. Oil companies were making more profit when oil prices were lower [35]. The price for a barrel was above US$100 in 2013 [36], however, companies were making their highest profits back in 2007 when the price of a barrel of oil was US$54 [37]. Therefore, many corporations were making four times as much profit was they were making it today. As the price of a barrel of oil went up, so did all the supplier costs and third party services. Currently, the price is significantly down compared to 2013, however the cost of suppliers and other vendors is not down, they have remained the same. The increase in oil prices were never the principal motivator for exploring alternative energy.

The oil sands industry has experienced two challenging events in the past months. First of all, the continuous drop of oil price and the rejection of Keystone XL by the Obama administration. As a consequence, oil companies started to pull the plug on Alberta expansions and cutting down the expenses under a break-even threshold analyst say is needed to justify a brand new oil sand expansion [38]. However, a recent study conduction by *THEnergy*, a Munich, Germany-based energy consultancy finds that while lower oil prices might slow down the momentum of mining companies switching to renewables, projects planned already will still go ahead [34]. As a consequence, oil companies must prepare themselves to transition to a low-carbon economy and energy system. This transition to low carbon energy is needed as soon as possible and should exclude new coal burning plants. This paper addresses this transition by implementing a symbiotic development approach to the oil sands development.

John Gingrich, chairman and president of Advanced Explorations, believes that the impact of lower oil prices will be felt in the short term, but not over the long term. It is unlikely that oil is going to be at US$40 or US$50 per barrel in the long term as many analysts believe that the price will be close to US$75 down the road.

Renewables are a potential solution. They represent an appealing solution for off-grid mines that ship diesel long distances in order to run generators. Furthermore, mining emits CO_2, hence renewables are part of the necessary solution of energy development and consumption to lower emissions.

Companies can only invest in renewables if they are given a tax incentive and are economically robust enough to invest outside their core businesses. The cost of wind and solar energy is continuously decreasing making these new sources of energy attractive. Moreover, this improves the competitiveness for the industries to self-investing in research and application of Renewables as a long-term strategy for development.

In addition to improving EROI, this proposed investment discussed in section 1.2 represents an alternative to a potential carbon tax because companies are investing in their own future and they benefit from the power generated. 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 small nuclear reactors [5] 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 to develop the oil sands.

2 Alberta's Oil Sands Analysis

2.1 CO_2 Emissions Overview

Each day, oil sands mining operations release as much CO_2 as all the cars in Canada [6]. In 2011, production of oil sands released an estimated of 47.1 million metric tonnes of CO_2 into the air [7]. Considering that in 2011, 1.8 million barrels a day were produced, Table 1 estimates the CO_2 emissions from oil sands production and oil use:

CO_2 from Oil Sands Production and Oil Use

Production	Use
Oil produced (Million barrels per year)	693.5
CO_2 to produce the oil (Mega-tonnes/Year)	50
CO_2 attributed to the mining	0.07
CO_2 attributed to consumption of oil sands oil	0.43
CO_2 from oil use (Mega-tonnes/Year)	298.2
Total CO_2 from Oil sands (Mega-tonnes/Year)	348

Table 1. Estimated total amount of CO_2 from Oil Sands Production and Oil Use

2.2 The Keystone XL Pipeline

One of the biggest challenges in Alberta's Oil Sand industry is sufficient pipeline access to transport the oil to Western Canada and Southern 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 than pipeline costs [8]. The Keystone XL environmental review included a wide variety of cost estimates that with rail shipments to the Gulf Coast, it costs between US$15 to US$20 a barrel [9]. This further justifies the investment in renewable energy systems as part of land reclamation if it helps overcome objections to the Keystone XL pipeline.

The Keystone XL 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. However, the US has recently refused the pipeline to be built as there is significant public opposition. The projected impact of Keystone XL by the U.S Department of State in the "Final Environmental Impact Statement" (FEIS) [10] is stated as:

- Projected 830,000 barrels/day flow
- An additional 147 to 168 million metric tons of greenhouse gas emissions would be annually released by the oil sands

The Canadian Association of Petroleum Producers (CAPP) 2015 Crude Oil Forecast, Markets and Transportation forecasts Canadian crude oil production will almost double to 5.3 million barrels per day by 2030 from 3.7 million barrels per day in 2014 [11]. Meanwhile in the US, 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 [12].

These opposing points of view may be resolved, we hypothesize, with the renewable electric power and long term CO_2 reduction that would result from the reclamation methods proposed in this paper.

Another benefit of generating significant electric power in-situ from renewable resources is reduced pipeline pumping costs. It has been estimated current transport costs including extra lubricants needed to pump the thick oil through thousands of miles of pipeline add about $18 a barrel to get oil sands crude from Western Canada down to the US Gulf Coast on the Keystone XL [8]. If plentiful electric power were available, the case could be made for at least partially refining the oil on site so lighter crude could be more easily pumped through the pipeline.

Furthermore, if we extend our way of thinking to include lessons from history in other related industry areas, considering the lessons of tanker ships could mitigate concerns about environmental damage from a spill. For many years industry insisted single hull tankers were sufficient and double hull tankers too expensive, but after repeated accidents, double hull tankers have become the norm. For a pipeline, we could borrow from landfill technology and line the trench with an impermeable membrane, and then the oil-carrying pipe would rest in a bed of sand and very course rock with drain lines alongside it. In the event of a spill the oil could be contained and rapidly pumped out. Large tanks periodically placed along the pipeline could hold water for irrigation, or in the event of a spill, they could be rapidly emptied and used as receptacles. Once again more symbiotic thinking could help provide solutions to our more difficult problems.

3 Oil Sands EROI Analysis

3.1 Oil Sands EROI Overview

Higher oil prices have boosted oil sands revenues, but operating costs have also increased significantly with the rise in energy prices.

Natural gas requirements for the oil sands industry are projected to increase to 2.1 billion cubic feet per day in 2015 [14]. Natural gas is combusted on site to fuel steam generation units to provide steam which is pumped underground to reduce the viscosity of the bitumen so it can then be more easily extracted, and the process bitumen that is mined. However, the use of natural gas exposes production to economic risk through the highly variable nature of natural gas cost. Furthermore, natural gas combustion for steam production is the primary source of greenhouse gas emissions for an in-situ project [15]. If natural gas prices increased to $8/GJ, oil sands production cost would increase by $6.30 per barrel [16].

Higher 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 installation of newly proposed Molten Salt Nuclear Reactors [15]. In 2013, there was discussion about including small nuclear reactors from Toshiba to mine oil sands with initial deployment projected by 2020 [5].

Every dollar invested in the oil sand's industry creates about $8 dollars' worth of economic activity [30]. Oil sands related investments is expected to generate 79.4 billion dollars in federal and provincial government revenues between 2012 and 2035 [30]. Oil sands investment will total hundreds of billions over the next 25 years (2012-2035) with 162.3 billion dollars to be invested in maintenance infrastructure [30].

We hypothesize that a better EROI would be obtained by investing in renewable energy systems emplaced on land to be reclaimed from mining activities. In the short term, companies would be able to insert electric heaters in the ground to make the oil flow instead of having to inject steam, and refining of the heavy oil could be done to be sent through the pipeline in lighter more valuable form. 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.

3.2 CO_2 Offset by Investing in Wind Energy

Our first model is the study of CO_2 offset by investing in wind energy only. The installation of one 5MW wind turbine per square kilometer of reclaimed land up to a total of 70,100 square kilometers (50 % of the Alberta Oil sands area), would require an annual investment of about $7.5/bbl with $0.05/kWh reinvestment policy into purchasing more wind turbines. The number of wind turbines installed would grow rapidly over the years, which would offset the CO_2 created by mining and using the oil sands oil in approximately 36 years.

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]. The turbines have a 20-year expected life, and the eventual replacement cycle would help ensure a robust wind energy business which is a source of high quality jobs.

Installing wind turbines in this region also need not reduce the amount of forest being replanted because the surface footprint of a large wind turbine is relatively small and tall towers enable the turbine to be placed high above the treeline 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 CO_2 captured from the boreal forest is about 26.2 tonnes/km^2 [18] compared to a CO_2 offset by having a large wind turbine, which saves 8500 tonnes/year/MW by not burning coal to produce energy generated by wind. Therefore, there 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.

There is the issue of migrating birds and local birds of prey which needs to be studied and considered; however, given the northern location, other options can be considered such as brightly coloured blades and poles to visually warn birds. During periods of large migration, radar can be used to identify flock positions and selected turbines can be turned off.

The initial reinvestment and reclamation hypothesis appears promising, and Figures 3 and 4 show different scenarios for different percentage of investments that will need to be considered by a more detailed investigation. Table 2 shows the modeling assumptions and Table 3 shows the years to achieve 100% cumulative CO_2 offset by various investment strategies.

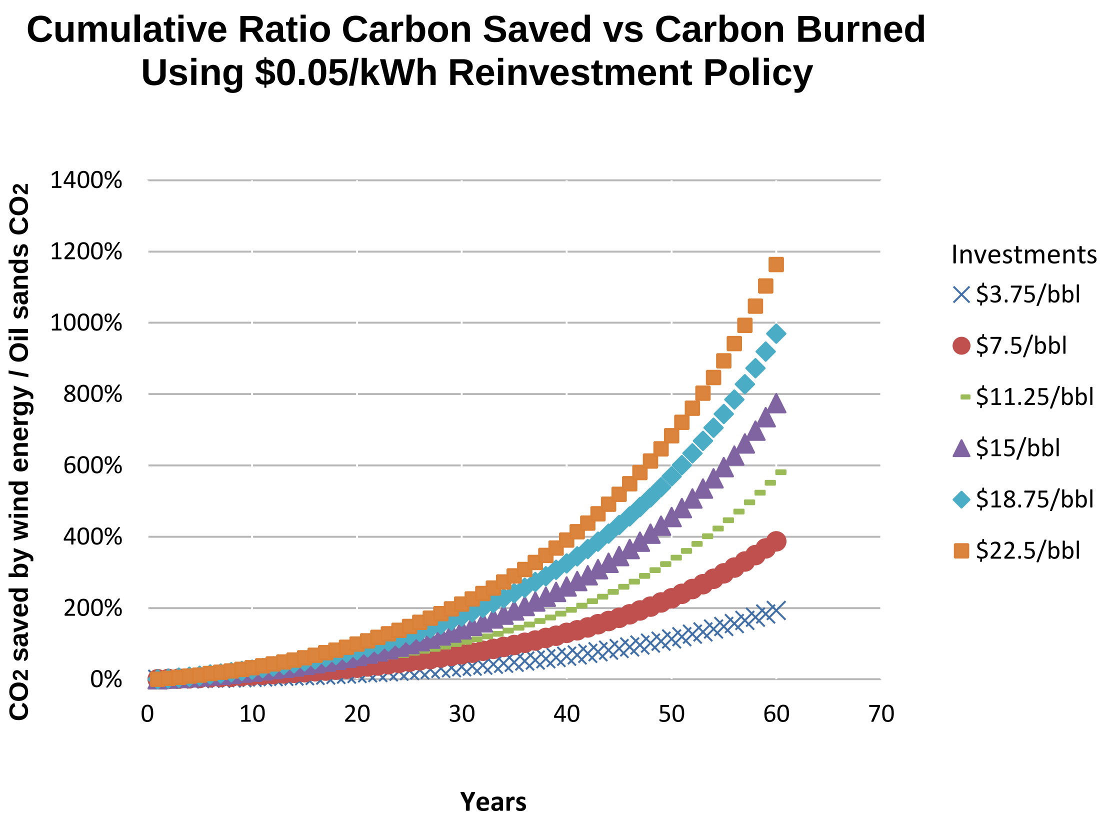

Figure 3. Amounts of CO_2 offset with different investments in Wind Energy, assuming a wind turbine life expectancy of 20 years, one wind turbine per km^2, $2/Watt cost, and a $0.05/kWh reinvestment into purchasing more wind turbines.

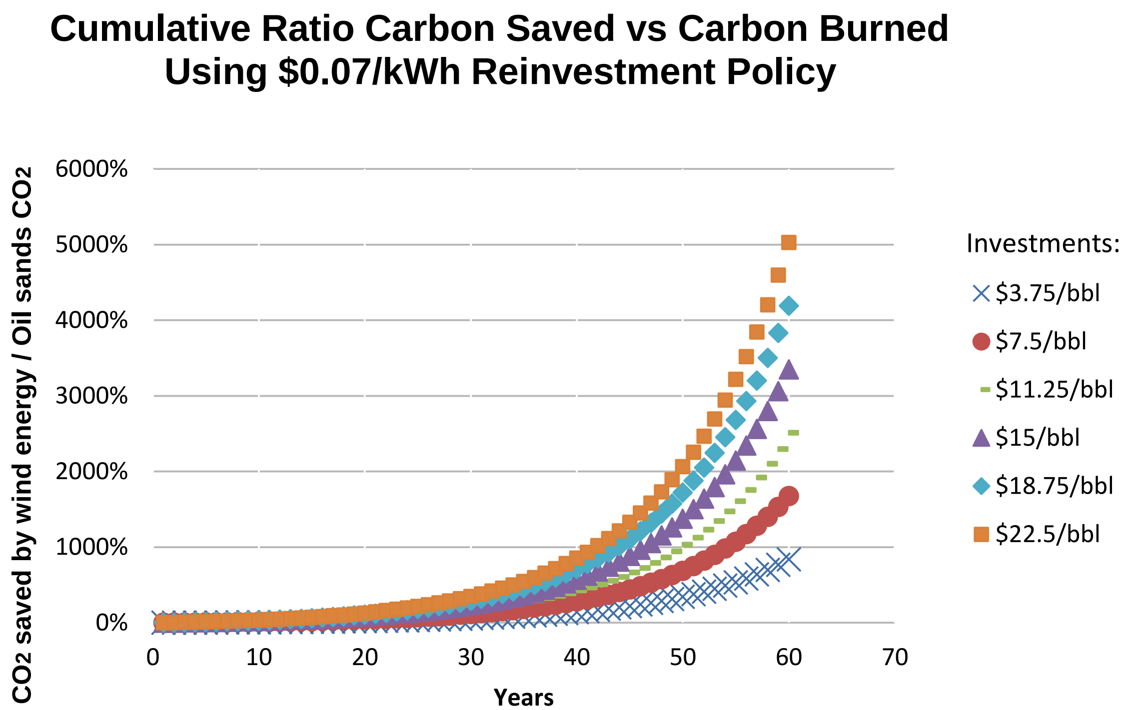

Figure 4. Amounts of CO_2 offset with different investments in Wind Energy, assuming a wind turbine life expectancy of 20 years, one wind turbine per km^2, $2/Watt cost, and a $0.07/kWh reinvestment into purchasing more wind turbines.

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 not burning coal to produce energy generated by wind (Mega-tonnes/year)	1,684

Table 2. Modelling assumptions for determining amount of CO_2 saved by Wind Turbines

		Reinvestment Policy	
		\$0.05/kWh	\$0.07/kWh
Percent Amount (out of US\$75 bbl)	Investment Amount (\$X/bbl)	Estimated Time (Years)	Estimated Time (Years)
5	3.75	48	36
10	7.5	36	29
15	11.25	30	25
20	15	26	22
25	18.75	23	20
30	22.5	20	18

Table 3. Estimated timeline for 100% CO_2 offset for Wind Energy based on \$X/bbl and \$0.05/kWh or \$0.07/kWh Reinvestment Policy.

These scenarios are dependent on four parameters: the percentage of investment per barrel of oil sand (\$/bbl), the life expectancy of wind turbines, \$/Watt cost, the choice of wind turbine peak power, and the reinvestment 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 \$45/bbl to ultimately reach 100% ever.

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 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 km^2 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 km^2).
- Reinvestment Policy
    - Assumption to reinvest \$0.05/kWh or \$0.07/kWh into wind turbine purchase and maintenance.

3.3 CO_2 Saved from Investing in Solar Energy

Our second model is the study of CO_2 offset by investing on solar energy only. If one were to invest $3.75/bbl into PV panels to create solar electric generating stations on up to 5% of the total oil sand's region, assuming 30% coverage by PV panels of the land allocated to the solar electric generating station, then this approach 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 is presented here for completeness. Figure 5 and Figure 6 show different scenarios for different percentage of investments and Table 4 presents modelling assumptions.

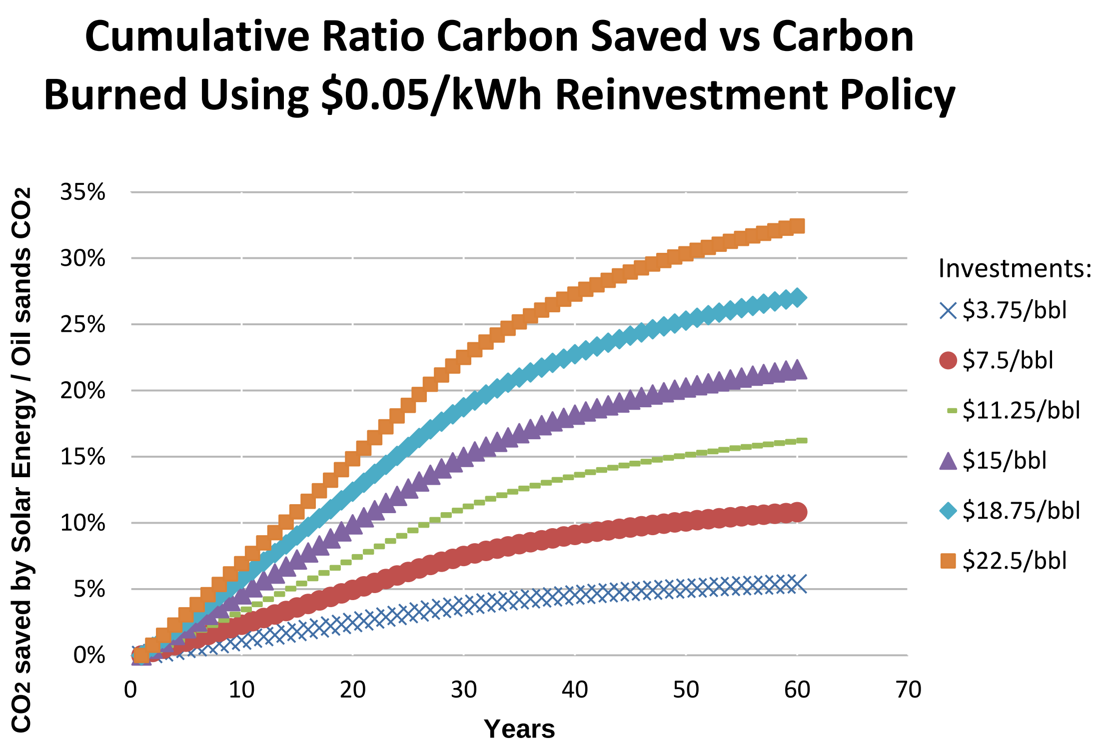

Figure 5. Amounts of CO_2 offset with different investments in Solar Energy, assuming a solar panel life expectancy of 25 years, $2/Watt cost, and a $0.05/kWh reinvestment from the solar power generated for purchasing more solar panels.

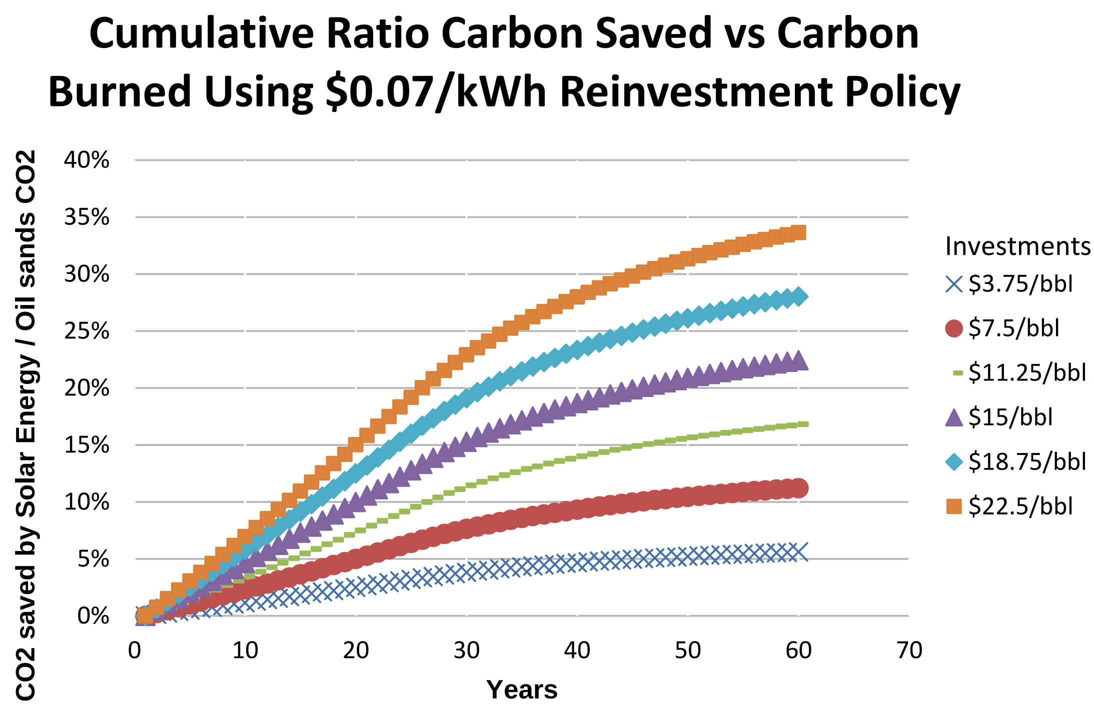

Figure 6. Amounts of CO_2 offset with different investments in Solar Energy, assuming a solar panel life expectancy of 25 years, $2/Watt cost, and a $0.07/kWh reinvestment from the solar power generated for purchasing more solar panels.

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 made possible with storage technology) (GW)	
June	164
January	37
Average	100.405
CO_2 saved by not burning coal to produce energy generated by solar (Mega-tonnes/year)	854

Table 4. 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 ($/bbl) investment, the life expectancy of the solar cells, the peak power of the solar cells, and the ($/kWh) reinvestment into purchasing more solar cells.

Other model considerations include:

- Peak Power of PV cell
  - Assumption to be a 200W peak power solar photovoltaic panel.
- Percent land covered by PV fields
  - Assumption to cover 15% of land area (21,030 km^2)
- Density of coverage on land designated for PV fields
  - Assumption to cover 30% of land area (6,309 km^2)
- Efficiency of PV fields
  - For this analysis, OPV efficiency was estimated to be a conservative 15%.
  - PV cell efficiency is expected to reach 23% by 2015 [19]
- Cost of installation of PV fields
  - Estimated to be $4/W installed
- Reinvestment Policy
  - Assumption to reinvest $0.05/kWh or $0.07/kWh into solar equipment purchasing. This also includes the maintenance of solar panels

The assumptions appear reasonable, but readers can investigate the results from other values using the spreadsheet provided as part of the supplemental materials.

3.3 CO_2 offset Calculation

The CO_2 offset percentage is obtained with the following formula:

$$Carbon_{offset} = \frac{Amount\ of\ CRCS\ (Cumulative\ Ratio\ Carbon\ Saved)}{Amount\ of\ CB\ (Carbon\ Burned)}$$

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

$$CRCS_{t+1} = CRCS_t + \frac{\#\ installed\ wind\ turbines_t}{\#\ total\ turbines\ to\ be\ built\ for\ land\ area} \times \alpha$$

Where:

- $\alpha = CO_2\ saved\ by\ not\ burning\ coal\ to\ produce\ energy\ generated\ by\ wind$
- $t = time\ (years)$

To compute the standard CB (Carbon Burned) term:

$$CB_{t+1} = \sum_{i=0}^{t} CB_t$$

Where:

- $CB_t = Total\ CO_2\ per\ year\ from\ oil\ sands\ (megatonnes/year)$ from Table 1

4 Possible Uses of Excess Power Generated

With the availability of large amounts of electric power as more and more wind turbines come on line, the potential for revenue generation from other applications of the power increase, thereby furthering the case for investment.

4.1 Selling Electricity Back to the Grid

About 41% of Alberta's installed electricity generation capacity is from coal, 40% from natural gas, and 8% from wind [20]. On a long term basis, it would possible to send excess power generated by reclaimed land renewable energy systems out along same power lines that currently are bringing power into the oil sands region.

4.2 Cleaning Contaminated Water

The Athabasca River is part of the third largest watershed in the world. Processing one barrel of bitumen requires approximately three barrels of water [6]. The contaminated water is then pumped into giant man-made tailings ponds alongside the shore with no plans for their eventual cleanup. The contaminated water is 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 [21].

These waters are contaminated with Polycyclic Aromatic Hydrocarbons (PAHs) [31]. These aromatic organic molecules can be hydrocracked by adding hydrogen to enable the PAHs to be turned into useful products such as plastics and pesticides. The renewable energy harvested by the wind and solar systems could be used to power the cracking process and clean up the contaminated water. This potential application for water cleaning can be further explored with more studies.

4.3 Powering Underground Electric Heaters as an Alternative to Pumping Steam Underground for Bitumen Extraction

Another use for the excess wind power could use lessons learned from Shell Oil's patent on installing heaters encased in pipe to liquefy the oil, so that it can be pumped to the surface [22, 23]. Wind power varies with the wind, which is relatively slowly changing variable, while solar power can change suddenly with a passing cloud. In either case, to be part of a base load supply of power sent out along power lines, excess power must be stored or used immediately. The former can be accommodated over power lines with pumped storage hydro-systems or batteries. The latter is often more difficult, however underground electric heaters can often be used with greatly fluctuating power to generate heat that is diffused slowly through the ground to lower bitumen viscosity so it can flow and be extracted from wells. The nature of some underground strata gives it a very long time constant to absorb and diffuse the energy [24, 25]. Where constant temperature is needed, large capacitor banks can be employed.

4.4 Exploring the possibility using Pumped-Storage Hydroelectricity

The hilly nature of the oil sands region represents a suitable site to consider Pumped-storage Hydroelectricity (PSH), the largest-capacity form of grid energy storage available. This hydroelectric energy storage could be implemented by oil sands electric power systems for load balancing. With this method, low-cost off-peak power generated by the surplus energy of the wind turbines could be used to run the pumps. During peak-hours electrical demand, the stored water is released through the turbines to produce electric power. The system could be used to increase revenue by selling more electricity during these peak demands periods when electricity prices are at the highest levels.

The following graph represents the elevation map of the oil sands region [32]. Observe that can take advantage of the change in altitude from red to blue regions. The distance to the oil sands regions is near 60 km and it could be an interesting development to power hydroelectric pumps.

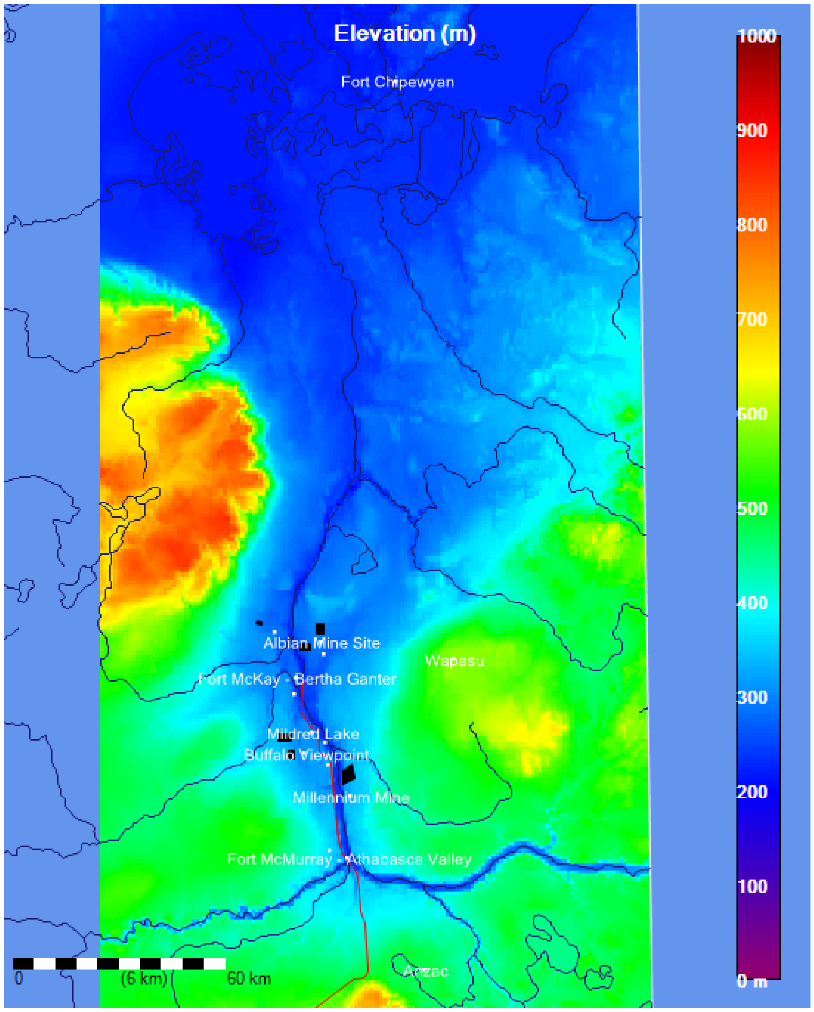

Figure 7. Elevation map of the oil sands region in Alberta, Canada.

4.5 Implementing UPM's Advanced Biofuels

Finnish company UPM is currently implementing new technology to produce wood-based biodiesel, refining the treacly residue that is left over when wood chips are cooked into pulp. This means processing husks, inedible grasses, municipal waste, and the litter from the logging industry. This technology is environmental-friendly and designed to give Europe a competitive edge in the clean energy business.

In research published in February, 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].

However, the economic and societal fruits of this innovation may be harvested somewhere other than in Europe. Policy makers in Brussels are now sidelining rules on transport fuels. As a result, biofuels companies are threatening to constrain the waste-to-biofuels industry by leaving Europe for the US, China and Brazil.

If UPM technology were used at oil sands to process the slash from land cleared to mine the oil sands, then this would result in a competitive diesel price, it would advance cutting-edge clean technology research in Canada, and it would significantly expand the energy ecosystem for investments in Alberta as companies are interested in harvesting their innovation somewhere other than Europe. Thus, this creates a huge profitable business for Alberta while positioning the province as a world leader in clean energy business.

5 Carbon Tax

5.1 An Alternative to a Carbon Tax or Increased Oil Royalties

The percentage of oil revenues to be invested ($/bbl) into renewable energy systems as part of land reclamation efforts is a business and an environment friendly alternative to a 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.

Similarly to the carbon tax fee, the New Democratic Party (NDP) in Alberta is reviewing the oil royalties' case for a possible increase by the end of the summer [33]. Considering the likely scenario that royalties increase in a near future, oil companies would rather prefer to self-invest in their long-term strategy rather than to pay an increased fee to the government.

Currently, 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 [13]. Critics claim a carbon tax would damage the economy, however Sweden's carbon tax is priced at $140 per tonne of carbon pollution. Since the carbon tax was introduced, Sweden's economy has grown by more than 100 per cent, and the country recently ranked fourth in the world on economic competitiveness [40]. On the other hand, the CO_2-intensive nature of oil sands mining and production incites many to call for a carbon tax that could add at least $2 to a barrel of Western Canadian heavy crude, which the US might consider as a concession to pipeline opponents in order to be able to approve the Keystone XL [8].

Note there are about 0.5 tonnes of CO_2 that can be attributed to the mining (0.07 tonnes) and consumption (0.43 tonnes) of oil sands oil (from Table 1), and some put the cost of CO_2 to be up to $34/tonne or more [26]. If indeed as weather patterns continue to deteriorate and the latter cost were to come to be, a direct investment in renewables as an alternative to the tax would be much easier to justify.

A "carbon tax" in where oil producers investing in renewables (anywhere in the country) be 100% deductible would be an enormous win. This would allow to implement energy efficiency and renewable energy strategies, bring in a stronger environmental standard, monitoring, and enforcement.

5.2 CO_2 Footprint as a function of Carbon Tax (unfinished)

A "carbon tax" that is possibly coming soon could be thought as a "carbon reinvestment" that companies that generate the carbon themselves apply instead of sending money to the government. Industry could benefit from not paying a tax to government, but rather self-investing for long term gain in renewables given the option.

Define:

$$carbon\ footprint = f(Sweden's\ carbon\ tax)$$

$$carbon\ released = f(time)$$

$$Sweden's\ carbon\ tax = f(time)$$

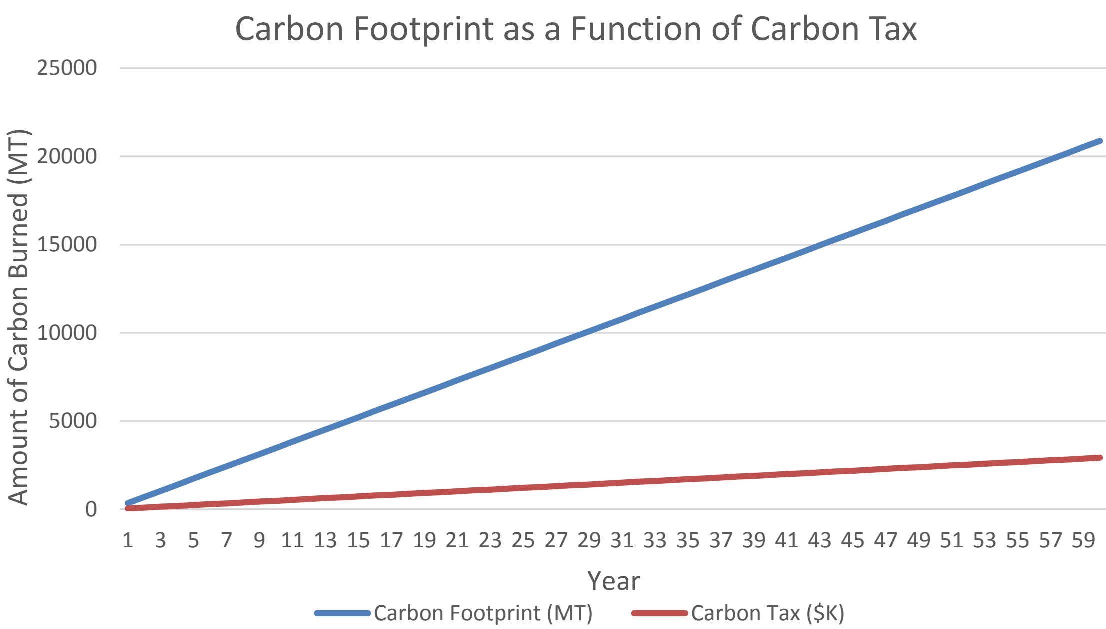

Figure 8. Oil Sands Carbon Footprint as a function of Sweden's Carbon Tax.

FIXME: Look at the correlation between carbon released and carbon tax. Then, estimate using linear regression. Need to add the "carbon reinvestment" vs "carbon tax" graph.

Section 6 - Symbiotic Approach with the Labour Unions

6.1 Labour's Role in Harvesting Natural Resource Wealth

Canadian union members play an essential role harvesting their natural resource wealth, adding value to it, and delivering it to consumers. Canadian union Unifor, like all Canadians, have a vast stake in the future prosperity of Canada's resource industries. The union is intensely concern that Canada's resource wealth is managed in the long-term interests of working people, their communities, and the environment. The prosperity of the nation depends on how resources are harvested, how the environmental consequences of resource industries are regulated and managed, how the benefits of resource production are shared, and how successfully resource bases are used to leverage other jobs and economic opportunities.

Unifor represents workers in the energy sector including a small share of those who work in bitumen extraction, and also some who work in pipelines, refineries, and other energy-related operations. As we confront the economic, social and environmental challenges associated with resource developments, several core progressive principles should be applied: build a productive and sustainable energy resource sector.

6.2 Mitigations, Transitions, and Adjustments

Unifor, just like many other Canadians, is opposed to Keystone XL, not just for environmental reasons, but also for economic reasons as well. However, the union is not opposed to the expanded development of the oil sands. They strongly believe that further development must take place within the constraints of binding greenhouse gas limits, proper environmental and First Nations' approvals, and a commitment to more processing of the resource in Canada.

The ups and downs of resource development impose tremendous strains on workers, who face job insecurity, pressure to relocate, and disrupted lives. 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 and there is no guarantee that renewable jobs would happen in Alberta (and Canada) regardless of whether the pipeline gets built or not.

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

In the possible scenario that Keystone XL is approved under the next US presidency, the idea of a transition fund not only for the environment, but also for workers and their communities would help mitigate these effects. Efforts to create good, sustainable jobs in our resource industries will require pro-active training and skills programs. A solid transition funding in place will be necessary to train workers and keep jobs implementing the green solution outlined in this paper. In order to gain support from workers that extract and refine oil there would need to be provisions to help those workers transition into the green jobs such as building wind and solar solutions.

These transitions would help workers retain their jobs by assisting affected workers and communities to take advantage of the new opportunities within the energy industry. Furthermore, it would align perfectly with the long-term vision of the Government of Alberta with respect to advancing and improving our research and development of green technologies in Canadian soil. There is no reason why employment and security should be threatened by the transition to a greener economy: in fact, if done correctly, workers will benefit.

6.3 Stronger Environmental Standards Could Lead More Jobs

A key concern is the impact of unregulated bitumen expansion on Canada's overall greenhouse gas emissions. Without a national strategy to regulate and reduce emissions, the expansion of bitumen production will more than offset all other emissions-reduction efforts in other parts of Canada such as the important phase-out of coal-fired electricity generation, and hence defeat the overall goal of contributing to global efforts to slow and limit climate change.

Export pipelines such as Keystone XL would facilitate a massive expansion in bitumen production in Alberta, but this would be done at a time when Canada still has no credible plan or targets for reducing greenhouse gas emissions. Improving the environmental performance of resource industries will require many strong measures, including careful limits on the scale of operations and the pace of expansion; imposing strict regulations on emissions and waste; fostering energy conservation and green energy sources; and requiring resource companies to internalize the cost of environmental clean-up.

Resource industries face a special challenge, and bear a special responsibility. However, the process of harvesting and processing resources must change to become sustainable, fair, and socially beneficial. In section 5, we discussed how a "carbon reinvestment" tax is a symbiotic approach that would benefit oil companies, the government, and the environment instead of a "carbon tax". In many instances, stronger environmental standards can lead to more work and more stable work in the long-run. 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. Working people need both secure jobs and a healthy, sustainable environment. Enormous economic benefits would be generated by a green economic strategy.

7 Conclusion

This paper showed that a symbiotic approach to short and long term energy needs can lead to an overall reduction in atmospheric CO_2. 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.

In addition, a more detailed business analysis (short and long term return of investment ROI) of the hypotheses presented here should be developed, including:

a) The requirement of investing a significant percentage of gross income from oil sands into renewable energy sources as part of land reclamation and to provide electricity for extracting and processing oil sands, cleaning up contaminated water, and selling excess electricity back to the grid.
b) The time effect cost of releasing more CO_2 in the short term in exchange for a longer-term greater cumulative reduction in CO_2.
c) The ability of a) above to encourage the US to approve of the Keystone XL pipeline which would save significant rail transportation costs.
d) A symbiotic approach to pipeline design should also be investigated that considers using landfill liner techniques and water storage tanks normally for irrigation and as emergency spill receptacles.

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