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Sustainable Energy Solutions

BACKGROUNDER
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The Climate Implications of Canada's Oil Sands Development

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0. Introduction

Years of delay by federal and provincial governments in implementing policies and measures to reduce greenhouse gas (GHG) emissions have left Canada precious little time to meet its initial, near-term GHG reduction target set by the Kyoto Protocol. The world's governments are now beginning to discuss how to achieve the much deeper, long-term reductions in emissions that will be essential if we are to prevent the catastrophic impacts of climate change.[2]

Against this background of urgent efforts to make major cuts in GHG emissions, 28 new GHG-intensive projects in Alberta's oil sands are expected to come on stream in the next ten years. While the Government of Canada begins to implement its plan to meet its Kyoto target, which applies to the period 2008–12, and the world aims for much deeper emission cuts after 2012, oil sands production is rapidly adding huge volumes of *additional* annual emissions to Canada's total.

This stark contradiction between deep GHG emission reductions and rapid oil sands development demands urgent attention. This document aims to make a start by

- providing the best possible estimate of GHG emissions from the oil sands between now and 2020, and
- examining whether and how oil sands development can be reconciled with a responsible climate policy for Canada in the short and the long term.

Section 1 provides a brief introduction to the oil sands and their projected development. Section 2 presents a newly detailed and up-to-date set of projections for future GHG emissions from the oil sands. Section 3 examines how oil sands production is addressed in the Government of Canada's Kyoto plan, and Section 4 makes recommendations on the treatment of oil sands in Canada's longer-term climate policy. Our emission projection methodology and a list oil sands projects and associated emissions are provided respectively in Appendices A and B.

1. Oil sands fever – and why it threatens the climate

The vast majority of Canada's oil sands are located in Alberta, underlying an area of boreal forest larger than Florida. Oil sands are found in three deposits: Peace River, Cold Lake and Athabasca. The Alberta Energy and Utilities Board estimates that the oil sands contain approximately 1.7 trillion barrels of crude bitumen (the tar-like oil extracted from the oil sands), of which 174 billion barrels could be recovered using today's technology and under current and

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[2] Bramley, M. 2005. *The Case for Deep Reductions*. David Suzuki Foundation and Pembina Institute, http://www.pembina.org/publications_item.asp?id=202.

anticipated economic conditions.[3] Canada's oil reserves – virtually all of them in the oil sands – are now officially recognized as second only to those of Saudi Arabia.[4]

Commercial development of the oil sands began in 1967, helped by billions of dollars in federal subsidies, but until the mid-1990s it was still considered risky and unprofitable. In 1995, the Alberta Chamber of Resources' National Oil Sands Task Force laid out a strategy that envisioned tar sands production doubling or tripling to reach between 800,000 and 1.2 million barrels per day by 2020.[5] Introduction of a generous provincial royalty regime, federal tax breaks and rising oil prices created strong motivation for rapid re-investment and expansion. As a result, oil sands production more than doubled between 1995 and 2004 to approximately 1.1 million barrels per day – 16 years ahead of the anticipated timeline.[6]

With increasing confidence that oil prices will remain high, wild speculation abounds regarding potential production. The Canadian Association of Petroleum Producers has projected that production could reach 2.7 million barrels per day by 2015.[7] In 2004, the Alberta Chamber of Resources put forward a vision of producing five million barrels per day by 2030.[8] More recently, the Government of Canada has envisioned producing six million barrels per day of production by 2030, and some energy analysts have projected production as high as eleven million barrels per day by 2047.[9,10]

Oil sands deposits are composed of sand, silt and clay, water and about 10–12% bitumen.[11] Oil sands are either surface mined from open pits or heated so the bitumen can flow to a well and be pumped to the surface (in situ extraction). Approximately 93% of Alberta's oil sands can only be developed using in situ recovery.[12] Special recovery methods, most commonly the injection of high-pressure steam, are needed to separate the bitumen from the sand. After being separated from the sand, the bitumen must be upgraded through the addition of hydrogen to convert it into synthetic crude oil that can be sent to refineries.

Because of the extra energy needed to melt the bitumen and separate it from the sand – obtained by burning natural gas – and because of emissions from the upgrading process, production of a barrel of synthetic crude oil from oil sands generates, on average, more than three times more GHG emissions than production of a barrel of conventional light or medium crude oil.[13] GHG

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[3] Alberta Energy and Utilities Board. 2005. *Alberta's Reserves 2004 and Supply/Demand Outlook/Overview*. Statistical Series (ST) 2005-98, p.2.

[4] Oil and Gas Journal, December 2004.

[5] National Oil Sands Task Force. 1995. *The Oil Sands: A New Energy Vision for Canada*. p.33.

[6] Source of 1995 data: Alberta Energy and Utilities Board. 2004. ST98-2004 – Graphs and Data – Section 2 Crude Bitumen, http://www.eub.gov.ab.ca/bbs/products/STs/st98-2004-data-2-bitumen.ppt; Source of 2004 data: Alberta Energy and Utilities Board, *ibid.*, p.2-2.

[7] Canadian Association of Petroleum Producers. 2005. *Canadian Crude Oil Production and Supply Forecast 2005-2015*. p.2.

[8] Alberta Chamber of Resources. 2004. *Oil Sands Technology Roadmap – Unlocking the potential*. p.2.

[9] First Energy Capital Corp. July 7, 2005. *Multicyclic Hubbert Curve Theory and Canada's Future Oil Outlook: Could Oil Sands production reach 11 million barrels per day?*

[10] Source: http://www.bloomberg.com/apps/news?pid=10000082&sid=aGEiywJ8Yr8s&refer=canada.

[11] Alberta Energy. 2004. *What is Oil Sands*, http://www.energy.gov.ab.ca/100.asp.

[12] Alberta Energy. 2004. *Facts on Oil Sands*, http://www.energy.gov.ab.ca/docs/oilsands/pdfs/FactSheet_OilSands.pdf.

[13] Woynillowicz, D., C. Severson-Baker and M. Raynolds. 2005. *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*, p.22. Pembina Institute, http://www.pembina.org/publications_item.asp?id=203.

emissions from the oil sands are therefore rising rapidly as production of synthetic crude oil from the oil sands offsets the steady decline in Alberta's production of conventional oil and, more importantly, supplies rapidly increasing oil exports.

As documented in the box below, upward revisions to projected oil sands development have caused repeated additions to Canada's projected "business-as-usual" total of future GHG emissions. The projections presented in Section 2 below confirm that oil sands are the single largest contributor to GHG emissions growth in Canada, contributing close to one-half of the projected business-as-usual growth in national emissions between 2003 and 2010.

Oil sands and Canada's ever-increasing "Kyoto gap"

The federal government regularly produces projections of Canada's future GHG emissions under a so-called business-as-usual scenario in which governments implement no policies or measures to reduce emissions. The difference between projected business-as-usual emissions in 2010 (the middle year of the five-year period to which the Kyoto target applies) and the Kyoto target is commonly referred to as the Kyoto gap. The Kyoto gap measures the amount by which annual emissions must be reduced below the business-as-usual level to reach the Kyoto target. The federal government has repeatedly increased its estimate of Canada's Kyoto gap, to a considerable degree because of increased projections of oil sands production:

The emissions projection produced by the federal government in April 1997 showed a Kyoto gap of 138 Mt.[14]

In October 1998, the Kyoto gap was updated to 185 Mt, with 45% (21Mt) of the increase attributed to new projections for oil sands production.[15]

In December 1999, a further update resulted in a Kyoto gap of 199 Mt.[16]

In February 2002, the Kyoto gap was further revised to 238 Mt, with 18 Mt of the new increase attributed to an additional rise in projected oil sands production.[17]

In April 2005, the government stated that the Kyoto gap is "likely in the area of 270 Mt."[18] It is widely understood that yet more increases in future oil sands production were, once again, a key factor in this latest increase to the gap.[19]

It should be noted that the details of why the business-as-usual scenarios needed revision in February 2002 and April 2005 have never been published (see Section 3).

Beyond its impacts on the climate system, oil sands development consumes large amounts of fresh water; creates enormous toxic tailings ponds and large volumes of harmful sludge; drastically alters the landscape, fragmenting and removing large areas of natural habitat, notably wetlands; and produces large increases in emissions of toxic and acidifying contaminants to the atmosphere. These impacts are beyond the scope of this document, but are described in detail in

[14] Natural Resources Canada. 1998. *Canada's Emissions Outlook – an "Events-Based" Update for 2010*, p.1, http://www.nrcan.gc.ca/es/ceo/CEO-2010.PDF.
[15] Natural Resources Canada. 1998. *Canada's Emissions Outlook – an "Events-Based" Update for 2010*, p.11, http://www.nrcan.gc.ca/es/ceo/CEO-2010.PDF.
[16] National Climate Change Process Analysis and Modelling Group. 1999. *Canada's Emissions Outlook – an Update*, p.42.
[17] Analysis and Modelling Group. 2002. *The Magnitude of the Challenge: Revising the Gap* (powerpoint presentation to Joint Ministers Meeting, February).
[18] Government of Canada. 2005. *Moving Forward on Climate Change – A Plan for Honouring our Kyoto Commitment*, p.12, http://www.climatechange.gc.ca/kyoto_commitments/.
[19] See, for example, Calamai, P. 2005. *An elusive pollution target.* Toronto Star, February 12.

the Pembina Institute's recent report *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush.*[20]

2. New GHG emission projections

Publicly available projections of future GHG emissions from Canada's oil sands are few and far between. As noted in the box in Section 1, the federal government makes such projections, but the last one to be made publicly available dates from December 1999, six years ago.

The Pembina Institute recently published projections of GHG emissions from the oil sands up to 2030 in its report *Oil Sands Fever*. However, those projections were relatively crude "top down" estimates based on the application of generic GHG intensity factors (specifying emissions per barrel of synthetic crude oil) to rough estimates of total production volumes.

In this document we present far more detailed GHG emission projections up to 2020 constructed "bottom up" from a database of all the individual oil sands projects that have been publicly announced.[21] The database, which specifies year-by-year production volumes, was published in July 2005, and we have updated it based on subsequent announcements of additional expansions by three companies.

We have calculated GHG emissions by multiplying annual production volumes by project-specific GHG intensity factors when available, and generic but technology-specific intensity factors otherwise. All intensity factors are reduced, starting in 2004, at an annual rate of either 2.3% (low emission projection) or 1% (high emission projection). A 2.3% annual improvement in GHG intensity is a relatively rapid rate, equivalent to the Alberta government's target of a 50% improvement in GHG intensity over 30 years (1990–2020).[22] Although the oil sands industry achieved a 3% annual average improvement in GHG intensity in the decade up to 2002,[23] this seems unlikely to be sustainable without technology breakthroughs. A 1% annual improvement in GHG intensity is at the upper end of the range commonly used by energy modellers to represent the natural, non-price-induced change in energy efficiency over time.[24]

Additional details of our methodology are provided in Appendix A. To our knowledge, the resulting emission projections are the most detailed and up-to-date currently available.

Our emission projections, in units of megatonnes of carbon dioxide equivalent (Mt CO_2e), are presented in Table 1 and Figure 1. They show that emissions from the oil sands were 3.4% of Canada's total emissions (740 Mt[25]) in 2003, the most recent year for which actual measured

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[20] Woynillowicz, D., C. Severson-Baker and M. Raynolds. 2005. *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*, Chapter 4. Pembina Institute, http://www.pembina.org/publications_item.asp?id=203.
[21] Mawdsley, J., J. Mikhareva and J. Tennison. 2005. *The Oil Sands of Canada – The World Wakes Up: First to Peak Oil, Second to the Oil Sands of Canada*, p.20–21. Calgary: Raymond James Ltd.
[22] Alberta Environment. 2002. *Albertans & Climate Change: Taking Action*, p.2, http://www3.gov.ab.ca/env/climate/plan.html. $0.977^{30}=0.50$.
[23] Government of Canada. 2002. *Climate Change Plan for Canada*, p.29, http://www.climatechange.gc.ca/english/publications/plan_for_canada/plan/. This document reports an intensity improvement of 26% over a decade (10 years); $0.97^{10}=0.84$.
[24] Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: Mitigation*, Section 3.5.5.6, http://www.grida.no/climate/ipcc_tar/wg3/113.htm#3556.
[25] Environment Canada. 2005. *Canada's Greenhouse Gas Inventory, 1990–2003*, Annex 8, http://www.ec.gc.ca/pdb/ghg/inventory_report/2003_report/ann8_e.cfm.

data is available.[26] The projections then show emissions from the oil sands rising, by 2010, to 7.5–8.2% of Canada's business-as-usual emissions (830 Mt[27]) in that year, or 11.0–12.1% of Canada's annual average Kyoto target emissions (560 Mt[28]) during 2008–12. They also show that oil sands contribute 41–47% (36.7–42.7 Mt) of the projected business-as-usual growth (90 Mt = 830–740 Mt) in Canada's total annual emissions between 2003 and 2010, as illustrated in Figure 2.[29] Emissions from the oil sands are projected to increase by a factor of 3.3–3.7 between 2003 and 2012 (the final year of the period to which our Kyoto target applies), and by a factor of 4.5–5.6 between 2003 and 2020.

The Pembina Institute and the David Suzuki Foundation recently presented a detailed case[30] for why Canada, if it is to assume its international responsibilities, must reduce its annual GHG emissions to 25% below the 1990 level (i.e., 447 Mt[31]) by 2020. If Canada met this target by 2020, and emissions from the oil sands emissions still increased as projected here, the oil sands would account for 25–32% of Canada's emissions in 2020.

Projected emissions (low and high projections) associated with each oil sands project are presented in Appendix B.[32]

Table 1. Annual GHG emissions (Mt CO_2e) from Canada's oil sands, 2003–2020, low and high projections.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Low	25.2	27.8	26.6	32.2	39.3	45.8	52.3	61.9	72.4	83.6	89.9	99.8	108.0	112.1	114.4	113.8	113.7	113.1
High	25.2	28.1	27.3	33.5	41.4	48.9	56.6	67.9	80.5	94.1	102.7	115.4	126.5	133.1	137.6	138.8	140.5	141.6

[26] The emissions level we calculate for 2003 is in good agreement with a recent unpublished federal government estimate according to which the industry emitted 23.3 Mt in 2000 (information provided by Environment Canada to Robert Collier, *San Francisco Chronicle*, May 5, 2005, and then provided to the authors).

[27] This figure has been obtained by adding 270 Mt to Canada's Kyoto target level of 560 Mt. The source for the 560 Mt is provided in the following footnote. The 270 Mt is stated as the gap between Canada's business-as-usual emissions in 2010 and our Kyoto target, in Government of Canada. 2005. *Moving Forward on Climate Change – A Plan for Honouring our Kyoto Commitment*, p.12, http://www.climatechange.gc.ca/kyoto_commitments/.

[28] 560 Mt is calculated as 6% less than Canada's emissions of 596 Mt in 1990, obtained from Environment Canada. 2005. *Canada's Greenhouse Gas Inventory, 1990–2003*, Annex 8, http://www.ec.gc.ca/pdb/ghg/inventory_report/2003_report/ann8_e.cfm.

[29] This comparison should be treated with some care, since it is not clear to what extent the assumptions about growth in emissions from the oil sands in the federal government's projection of growth in Canada's total emissions are similar to our projections of growth in emissions from the oil sands. However, the box in Section 1 does suggest that the government's assumptions about growth in emissions from the oil sands are not dissimilar to our projections of that growth.

[30] Bramley, M. 2005. *The Case for Deep Reductions*. David Suzuki Foundation and Pembina Institute, http://www.pembina.org/publications_item.asp?id=202.

[31] 447 Mt is calculated as 25% below Canada's emissions of 596 Mt in 1990, obtained from Environment Canada. 2005. *Canada's Greenhouse Gas Inventory, 1990–2003*, Annex 8, http://www.ec.gc.ca/pdb/ghg/inventory_report/2003_report/ann8_e.cfm.

[32] Emissions in Appendix B do not sum to the totals in Table 1 because Appendix B does not include emissions from upgrading in Canada but outside of the oil sands (see Appendix A).

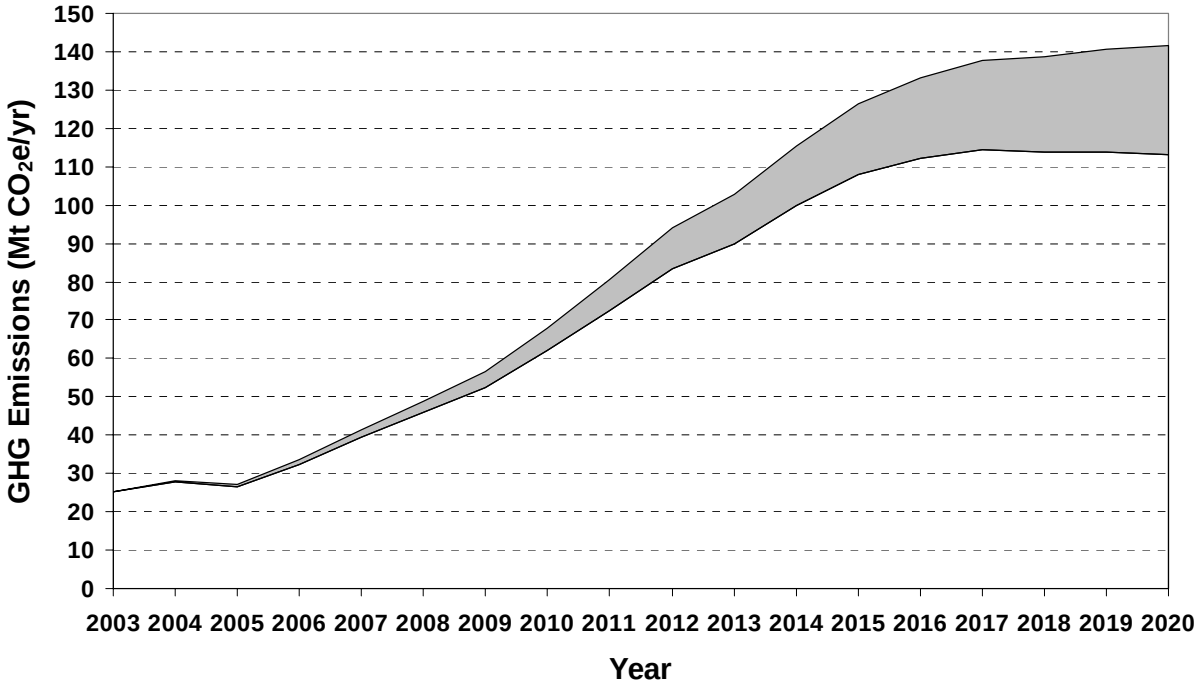

Figure 1. Annual GHG emissions (Mt CO_2e) from Canada's oil sands, 2003–2020, showing the range between low and high projections.

These emission projections are subject to the following caveats.

- The production volumes underlying our projections reach 4.2 million barrels of synthetic crude per day in 2015, and 4.8 million in 2020. This represents faster growth in total production than many projections that have been made to date (see Section 1). Some announced projects may be delayed, reducing expected total production in 2020 by a few percent below the level we have assumed.[33]
- However, past experience suggests that new projects or expansions not taken into account in our projections will continue to be announced.
- In addition, the emission levels we calculate are based on the use of natural gas as the main source of energy. Emissions will be up to 50% higher[34] if bitumen or coke is used as an energy source, something that many companies are considering.
- Our projections assume there will be no use of carbon capture and storage technology[35] to capture CO_2 emissions from the oil sands and inject them underground.
- Our projections do not take into account the purchase by oil sands producers of credits representing GHG emission reductions achieved outside oil sands operations. As

[33] Mawdsley, J., J. Mikhareva and J. Tennison. 2005. *The Oil Sands of Canada – The World Wakes Up: First to Peak Oil, Second to the Oil Sands of Canada*, p.22–23. Calgary: Raymond James Ltd.
[34] Woynillowicz, D., C. Severson-Baker and M. Raynolds. 2005. *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*, p.20. Pembina Institute, http://www.pembina.org/publications_item.asp?id=203.
[35] For more information on this topic, see Griffiths, M., P. Cobb and T. Marr-Laing. 2005. *Carbon Capture and Storage: A Canadian Primer*. Pembina Institute, http://www.pembina.org/publications_item.asp?id=201.

discussed in Sections 3 and 4, use of credits to offset emissions is a critical tool for reducing the climate impact of the oil sands industry.

- Last but not least, this document considers only "upstream" emissions from the production of synthetic crude oil. It does not consider emissions "downstream" as crude oil is transported, refined and then burned as gasoline and other refined petroleum products. Downstream emissions account for approximately 75–80% of total lifecycle GHG emissions from oil sands. In other words, downstream emissions are three to four times greater than the emissions calculated in this document.

3. Oil sands in Canada's Kyoto plan

Oil sands production is included in the federal government's Large Final Emitter (LFE) system,[36] under which companies will face mandatory GHG intensity targets during the period 2008–12. Targets will be set for existing facilities at 15% below projected business-as-usual (BAU) emissions intensity for the year 2010 for all emissions except "fixed process emissions,"[37] for which targets will be set equal to BAU levels. Further adjustments will then be made to ensure that no sectoral target is set at more than 12% below BAU levels. Targets for new facilities and "facilities undergoing major transformations or expansions" will be set at the level of "best available technology economically achievable" (BATEA). The date of first production after which a facility will be considered "new" has not yet been decided, although the government has suggested the years 2000 and 2002.

If we assume that the oil sands sector will face a target to reduce emissions by 12% below the projected 2010 emissions of 61.9–67.9 Mt calculated in Section 2, then the sector would be required to contribute just 7.4–8.1 Mt of reductions in annual emissions towards Canada's Kyoto effort. While some of these reductions may be achievable on-site, it is likely that most would be achieved through the purchase of credits representing GHG emission reductions achieved outside oil sands operations. This can be interpreted by saying that the sector would be required to take responsibility, through the purchase of credits, for only 19–20% of its projected 36.7–42.7 Mt increase in annual emissions between 2003 and 2010. Liability for offsetting the remaining four-fifths of this increase would be transferred to the federal government and Canadian taxpayers.

In reality, the government and taxpayers may be liable for an even greater share of the increase in emissions from the oil sands. There are three main reasons for this. First, under the LFE system companies will be allowed to meet their targets in part by making payments into "technology investment vehicles." This is not expected to result in significant emission reductions during 2008–12, i.e., reductions that Canada can count towards its Kyoto target.

Second, the government has not published the BAU levels that it will use to calculate 12% reduction targets. There is a possibility that the BAU GHG intensities that the government is using for the oil sands could be higher than the GHG intensities that the sector is actually planning to achieve, in which case a portion of the 12% reduction will exist only on paper.

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[36] *Notice of intent to regulate greenhouse gas emissions by Large Final Emitters*, Canada Gazette Part I, July 16, 2005, p.2489.

[37] These are emissions for which there is no technical way of changing the emissions intensity.

Third, the industry is expecting the government to deem new and expanded facilities already to be meeting BATEA levels.[38] If it does so, then the very segment of the industry that is responsible for the emission increases calculated in this document will be required to contribute no meaningful reductions whatsoever towards Canada's Kyoto effort.

Will the oil sands industry will be required to make a meaningful contribution to Canada's Kyoto effort? It will not be possible to answer this question until the government publishes the BAU GHG intensities used for setting targets for existing facilities, and explains how it proposes to set targets for new and expanded facilities. The Pembina Institute urges the government to set BAU intensities at a realistic level, to define BATEA at a level significantly below the planned intensities for new and expanded facilities, and to make all relevant information public.

It should be noted that even if oil sands producers do face a full 12% reduction target, the cost of meeting the target by purchasing credits would be extremely small. Taking the example of Shell Canada's Muskeg River project, with a GHG intensity of 62 kg CO_2e/barrel (see Appendix A), offsetting 12% of the emssions by purchasing credits at $15/tonne CO_2e (the price that the federal government has guaranteed during 2008–12) would cost just 11 cents per barrel.[39]

4. Oil sands post-2012: can development be reconciled with deep GHG reductions?

The Pembina Institute and the David Suzuki Foundation have demonstrated that if Canada is to assume its responsibilities in the global effort to prevent catastrophic climate change impacts, it must reduce its annual GHG emissions to 25% below the 1990 level by 2020, and go on to reduce emissions to 80% below the 1990 level by 2050.[40] In other words, industrialized countries must embark on a trajectory of deep emission reductions after 2012. By 2020, we need to have made significant progress down that trajectory.

Canada's current energy policies, which include support for rapid expansion of highly GHG-intensive activities such as oil sands production, are sharply at odds with a responsible climate policy of deep GHG emission reductions. Canada urgently needs to adopt a new energy strategy that is consistent with a deep, long-term GHG reductions. As part of such a strategy, federal tax advantages for the oil and gas sector must be eliminated[41] and provincial royalty regimes must be reformed to ensure that citizens are properly compensated for the utilization of publicly owned, non-renewable oil resources.[42]

According to Environment Minister Stéphane Dion, "there is no minister of the environment on Earth who can stop this [oil sands development] from going forward, because there is too much

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[38] Massive oil sands project exposes Canada's Kyoto risk. *Point Carbon*, November 9, 2005. In this article, a Canadian Natural Resources Limited spokesperson is quoted as saying "It's quite likely that (the Horizon project) will be exempted from the first commitment period."

[39] 0.062 tonnes per barrel × $15 per tonne × 12% = $0.11.

[40] Bramley, M. 2005. *The Case for Deep Reductions*. David Suzuki Foundation and Pembina Institute, http://www.pembina.org/publications_item.asp?id=202.

[41] Taylor, A., M. Bramley and M. Winfield. 2005. *Government Spending on Canada's Oil and Gas Industry: Undermining Canada's Kyoto Commitment*. Pembina Institute, http://www.pembina.org/publications_item.asp?id=181.

[42] Taylor, A. et al. 2004. *When the Government is the Landlord*. Pembina Institute, http://www.pembina.org/publications_item.asp?id=171.

money in it."[43] But there are two potential ways in which the oil sands industry could take responsibility for its GHG emissions without stopping development. The first is for the industry to seek technology breakthroughs that significantly cut the GHG intensity of oil sands production. The second is for the industry to offset emissions by purchasing credits that represent genuine GHG emission reductions achieved elsewhere. Shell Canada has demonstrated how this could be feasible by committing to reduce or offset 50% of the emissions from its Muskeg River project.[44]

To ensure that oil sands development does not prevent Canada achieving deep emission reductions, the Pembina Institute recommends that the governments of Canada and Alberta require all existing and new oil sands operations to be "carbon neutral" (net zero GHG emissions) by 2020 through a combination of actual reductions and genuine emission offsets.

Oil sands producers have a leadership opportunity to show they can be part of a deep GHG reduction scenario by pledging to become "carbon neutral" in advance of government requirements.

[43] Collier, R. 2005. *Canadian oil sands: Vast reserves second to Saudi Arabia will keep America moving, but at a steep environmental cost.* San Francisco Chronicle, May 22.
[44] Shell Canada Limited. 2005. *Managing GHG Emissions*, p.5,11, http://www.shell.ca/code/values/climate/climate.html.

Appendix A. Additional details of our emissions projection methodology

In addition to the information provided in Section 2, the emission projections reported there were calculated using the following methodology.

- The Raymond James Ltd database of announced oil sands projects cited in Section 2 was updated based on announcements of additional expansions by Canadian Natural Resources Limited,[45] EnCana[46] and Devon Energy Corporation.[47]
- Almost all companies were contacted in an attempt to obtain project-specific GHG intensity factors. The companies/projects for which we were able to use specific factors were Suncor[48] and Syncrude[49] (company-wide factors), Canadian Natural Resources Limited (Horizon project)[50] and Shell Canada Limited (Muskeg River project).[51] However, many companies are unwilling to disclose GHG intensity factors based on competitiveness concerns.[52] The Pembina Institute would welcome any additional project-specific information that companies can provide to help further refine our calculations.
- Where company/project-specific GHG intensity factors could not be obtained, generic factors were used as follows.[53] These factors are based on the use of natural gas as the main source of energy.

Activity	GHG intensity (kg CO_2e/barrel)
Mining of bitumen	35
SAGD[54] production of bitumen	55
THAI[55] production of bitumen	65
Cyclic Steam production of bitumen	90
Upgrading of bitumen[56]	45

[45] Canadian Natural Resources Limited. 2005. *Canadian Natural Resources Limited Announces Quarterly Dividend.* News release, 2 November, http://www.cnrl.com/client/whats_new/353/356/1102dividend.pdf.
[46] EnCana. 2005. *EnCana looks to expand oilsands production to 500,000 barrels per day*. News release, 7 November, http://www.encana.com/investor/news_releases/news_2005/pdfs/1107.pdf.
[47] Devon Energy Corporation. 2005. *Jackfish Project General Update, Vol. 4 – Fall 2005*, http://www.devonenergy.com/operations/canada_pages/Jackfish_Project_Update_Fall2005.pdf.
[48] Suncor Energy. 2005. *2005 Report on Sustainability*, p.37, http://www.suncor.com/data/1/rec_docs/616_Suncor%20SD%20Report_2005%20.pdf. This document specifies a GHG intensity in 2004 of 0.62 tonnes CO_2e/m^3.
[49] Syncrude Canada Ltd. 2004. *2004 Sustainability Report*, http://sustainability.syncrude.ca/sustainability2004/environment_health_safety/air.shtml. This document reports a GHG intensity in 2004 of 117 kg CO_2e/barrel.
[50] Canadian Natural Resources Limited. 2002. *Horizon Oil Sands Project – Application for Approval*. A GHG intensity factor of 90.5 kg CO_2e/barrel was calculated based on planned total emissions of 7.6952 Mt and production of 233,000 barrels per day.
[51] Shell Canada Limited. 2005. *Managing GHG Emissions*, p.2,5,11, http://www.shell.ca/code/values/climate/climate.html. A GHG intensity factor of 62 kg CO_2e/barrel was calculated based on planned total emissions of 3.5 Mt and production of 155,000 barrels per day.
[52] Phone conversation with EnCana's Corporate Responsibility Department, November 16th, 2005
[53] These factors were provided by Len Flint of LENEF Consulting Limited.
[54] Steam Assisted Gravity Drainage.
[55] Toe-Heel Air Injection.
[56] The GHG intensity factor is based on the upgrading of bitumen to a mixed quality synthetic crude oil.

- Many of the smaller in situ projects do not have any upgrading capacity; the bitumen produced from these operations therefore requires upgrading either outside the oil sands or outside Canada. Emissions from upgrading in Canada were included in our projections even where upgrading takes place outside of the oil sands, but emissions from upgrading outside Canada were not included. For these projects, the proportion of upgrading occurring in Canada was estimated based on 70% of bitumen being upgraded in Canada in 2002[57] and the expectation that about 75% will be upgraded in Canada in 2020.[58] A linear interpolation between 70% in 2003 and 75% in 2020 was used.

[57] National Energy Board. 2004. *Canada's Oil Sands – Opportunities and Challenges to 2015, An Energy Market Assesment*, p.34.
[58] Len Flint, LENEF Consulting Limited, personal communication, November 2005.

Appendix B. List of oil sands projects and associated emissions

Table 2. Annual GHG emissions (Mt CO_2e) from Canadian oil sands projects, 2003–2020, low projection.

Company/project	Process	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BlackRock Ventures Inc.																			
Orion	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.17	0.16	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.14
Canadian Natural Resources Limited																			
Primrose	Cyclic Steam	1.24	1.41	1.53	1.72	1.68	1.64	1.60	1.56	1.53	1.49	2.24	2.95	3.63	4.27	4.89	5.47	6.02	6.55
Horizon	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	1.67	3.16	4.35	5.31	6.22	6.94	7.63	8.28	8.90	9.48	10.04	10.56	11.05
Primrose East	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.62	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.75	0.74
Gregoire or Horizon	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.58	0.85	0.83	0.81	0.79	0.77	0.75	0.74
Connacher Oil and Gas Limited																			
Great Divide	SAGD	0.00	0.00	0.00	0.00	0.00	0.09	0.17	0.17	0.25	0.41	0.40	0.39	0.38	0.37	0.36	0.35	0.35	0.34
ConocoPhillips and TotalFinaElf																			
Surmont	SAGD	0.00	0.00	0.00	0.00	0.09	0.45	0.87	0.85	1.25	1.22	1.59	1.55	1.52	1.48	1.45	1.42	1.38	1.35
Deer Creek Energy Limited																			
Joslyn	SAGD	0.00	0.00	0.02	0.04	0.29	0.50	0.76	0.94	1.18	1.20	1.17	1.15	1.12	1.10	1.07	1.05	1.02	1.00
Joslyn	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	1.43	1.45	1.77	2.71	2.70	2.64	2.90	3.73	3.99
Devon Canada Corporation																			
Jackfish	SAGD	0.00	0.00	0.00	0.00	0.09	0.63	0.61	1.19	1.17	1.14	1.11	1.09	1.06	1.04	1.01	0.99	0.97	0.95
EnCana Corporation																			
Foster Creek	SAGD	0.44	0.56	0.63	0.99	1.28	1.25	1.92	1.88	1.97	2.05	2.13	2.21	2.28	2.23	2.17	2.12	2.08	2.03
Christina Lake	SAGD	0.08	0.08	0.08	0.19	0.18	0.18	0.17	0.17	0.97	1.73	2.45	3.14	3.80	3.71	3.62	3.54	3.46	3.38
Borealis	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	1.48	1.45	1.42	1.38	1.35
Husky Energy Inc.																			
Tucker Lake	SAGD	0.00	0.00	0.00	0.00	0.25	0.49	0.63	0.93	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.75	0.74
Sunrise	SAGD and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.79	1.55	1.52	2.96	2.89	4.24	4.14	5.39	5.27	5.15	5.03	4.92
Imperial Oil Resources Limited																			
Cold Lake	Cyclic Steam	4.25	4.05	4.52	4.44	4.49	4.68	4.86	4.75	4.64	4.53	4.43	4.32	4.22	4.13	4.03	3.94	3.85	3.76
Kearl (ExxonMobil 0.3 WI)	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21	2.37	2.31	2.26	3.31	4.32	4.22	4.12	4.02	3.93
Japan Canada Oil Sands																			
Hangingstone	SAGD	0.10	0.10	0.10	0.09	0.09	0.13	0.17	0.17	0.17	0.16	0.16	0.31	0.30	0.30	0.29	0.28	0.28	0.27
MEG Energy																			
MEG SAGD Project	SAGD	0.00	0.00	0.00	0.00	0.00	0.05	0.38	0.43	1.00	0.98	1.27	1.48	1.44	1.78	1.88	1.84	1.80	1.76
Nexen Inc. and OPTI Canada Inc.																			
Long Lake	SAGD and Upgrader	0.00	0.00	0.00	0.31	2.10	1.95	1.93	1.89	2.30	3.28	3.49	5.09	4.97	4.86	6.32	6.18	6.04	5.90
Newmont Mining Corporation																			
Black Gold	SAGD	0.00	0.00	0.00	0.00	0.18	0.18	0.35	0.34	0.33	0.49	0.48	0.47	0.61	0.59	0.58	0.57	0.55	0.54
Paramount Resources Limited																			
Paramount SAGD Project	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.49	0.48	0.47	0.46	0.45	0.43	0.42	0.42	0.41
Petrobank Energy and Resources Ltd.																			
Orion	THAI	0.00	0.00	0.00	0.00	0.00	0.21	0.37	0.56	0.75	0.89	0.86	0.84	0.83	0.81	0.79	0.77	0.75	0.73
Petro-Canada																			
MacKay River	SAGD	0.21	0.32	0.44	0.49	0.55	0.54	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.43	0.42	0.42	0.41
SAGD Phase II	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.25	0.33	0.56	0.54	0.53	0.52	0.51	0.50	0.48	0.47

Petro-Canada and UTS Energy Corporation																			
Fort Hills	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	2.04	1.99	2.40	3.80	3.71	3.63	3.54	3.46	3.38
Shell Canada Limited																			
Shell Peace River	Cyclic steam	0.30	0.26	0.31	0.31	0.30	0.29	0.29	0.84	0.82	1.33	1.30	2.54	2.48	2.43	2.37	2.32	2.26	2.21
Shell Chevron Western Muskeg River	Mine and Upgrader	1.67	3.00	3.23	3.48	3.51	3.83	4.43	4.52	5.17	5.14	5.02	4.91	4.88	4.77	4.66	4.55	4.44	4.34
Shell Chevron Western Jackpine One	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.48	2.42	2.37	2.31	2.26	2.21	2.16	2.11	2.06	2.01	1.97
Shell Chevron Western Jackpine Two	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.16	2.26	2.21	2.16	2.11	2.06	2.01	1.97
Suncor Energy Inc.																			
Suncor Base Mine and Millennium	Mine and Upgrader	7.89	7.99	5.41	7.58	7.41	7.24	7.07	6.91	6.75	6.59	6.44	6.43	6.29	6.14	6.00	5.86	5.73	5.60
Suncor Voyageur	Mine, SAGD and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	2.05	3.87	3.78	3.69	3.60	3.65	3.57	3.49	3.41
Suncor Firebag	SAGD and Upgrader	0.00	0.07	0.69	1.25	2.14	3.38	3.36	3.84	4.20	4.10	4.01	3.92	3.83	3.74	3.65	3.57	3.49	3.41
Syncrude Canada Ltd.																			
Stages One and Two: Base and Aurora 1	Mine and Upgrader	9.05	9.94	8.80	9.96	9.73	8.93	8.73	8.53	8.33	8.14	7.95	7.77	7.59	7.42	7.25	7.08	6.92	6.76
Stage Three: Aurora 2/UE1	Mine and Upgrader	0.00	0.00	0.00	0.45	2.73	4.37	4.27	4.17	4.08	3.98	3.89	3.80	3.71	3.63	3.55	3.46	3.38	3.31
Stage Four: Aurora 3/UE2	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.45	2.13	2.08	2.03	1.98	1.94	1.89	1.85	1.81	1.77	1.73
Stage Five: Aurora South	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.62	3.16	3.70	3.61	3.53	3.45
Synenco Energy Inc.																			
Northern Lights	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.82	2.37	2.31	2.26	2.21	2.16	2.11	2.06	2.01	1.97

Table 3. Annual GHG emissions (Mt CO_2e) from Canadian oil sands projects, 2003–2020, high projection.

Company/project	Process	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BlackRock Ventures Inc.																			
Orion	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.19	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17
Canadian Natural Resources Limited																			
Primrose	Cyclic Steam	1.24	1.42	1.57	1.79	1.77	1.75	1.73	1.72	1.70	1.68	2.56	3.41	4.25	5.07	5.88	6.67	7.44	8.20
Horizon	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	1.78	3.42	4.77	5.90	7.00	7.92	8.82	9.70	10.57	11.41	12.24	13.05	13.84
Primrose East	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.68	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92
Gregoire or Horizon	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.66	0.98	0.97	0.96	0.95	0.94	0.93	0.92
Connacher Oil and Gas Limited																			
Great Divide	SAGD	0.00	0.00	0.00	0.00	0.00	0.10	0.19	0.19	0.28	0.46	0.45	0.45	0.44	0.44	0.44	0.43	0.43	0.42
ConocoPhillips and TotalFinaElf																			
Surmont	SAGD	0.00	0.00	0.00	0.00	0.10	0.48	0.95	0.94	1.39	1.38	1.82	1.80	1.78	1.76	1.74	1.73	1.71	1.69
Deer Creek Energy Limited																			
Joslyn	SAGD	0.00	0.00	0.02	0.04	0.31	0.53	0.82	1.03	1.31	1.35	1.34	1.33	1.31	1.30	1.29	1.27	1.26	1.25
Joslyn	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	1.61	1.65	2.04	3.18	3.20	3.17	3.53	4.61	5.00
Devon Canada Corporation																			
Jackfish	SAGD	0.00	0.00	0.00	0.00	0.10	0.67	0.66	1.31	1.30	1.28	1.27	1.26	1.25	1.23	1.22	1.21	1.20	1.18
EnCana Corporation																			
Foster Creek	SAGD	0.44	0.57	0.65	1.03	1.35	1.34	2.08	2.06	2.19	2.31	2.43	2.55	2.67	2.64	2.62	2.59	2.56	2.54
Christina Lake	SAGD	0.08	0.08	0.08	0.19	0.19	0.19	0.19	0.19	1.07	1.94	2.80	3.63	4.45	4.40	4.36	4.32	4.27	4.23
Borealis	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.78	1.76	1.74	1.73	1.71	1.69
Husky Energy Inc.																			
Tucker Lake	SAGD	0.00	0.00	0.00	0.00	0.26	0.52	0.69	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92
Sunrise	SAGD and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.86	1.70	1.68	3.33	3.30	4.90	4.85	6.41	6.34	6.28	6.22	6.15
Imperial Oil Resources Limited																			
Cold Lake	Cyclic Steam	4.25	4.10	4.64	4.62	4.73	5.00	5.26	5.21	5.15	5.10	5.05	5.00	4.95	4.90	4.85	4.80	4.75	4.71
Kearl (ExxonMobil 0.3 WI)	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	2.67	2.64	2.61	3.88	5.12	5.07	5.02	4.97	4.92
Japan Canada Oil Sands																			
Hangingstone	SAGD	0.10	0.10	0.10	0.10	0.10	0.13	0.19	0.19	0.19	0.18	0.18	0.36	0.36	0.35	0.35	0.35	0.34	0.34
MEG Energy																			
MEG SAGD Project	SAGD	0.00	0.00	0.00	0.00	0.00	0.06	0.42	0.47	1.11	1.10	1.45	1.71	1.69	2.11	2.27	2.24	2.22	2.20
Nexen Inc. and OPTI Canada Inc.																			
Long Lake	SAGD and Upgrader	0.00	0.00	0.00	0.32	2.21	2.08	2.09	2.07	2.55	3.69	3.99	5.88	5.82	5.77	7.61	7.53	7.46	7.38
Newmont Mining Corporation																			
Black Gold	SAGD	0.00	0.00	0.00	0.00	0.19	0.19	0.38	0.37	0.37	0.55	0.54	0.54	0.71	0.70	0.70	0.69	0.68	0.68
Paramount Resources Limited																			
Paramount SAGD Project	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.37	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.51	0.51
Petrobank Energy and Resources Ltd.																			
Orion	THAI	0.00	0.00	0.00	0.00	0.00	0.23	0.40	0.62	0.83	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92
Petro-Canada																			
MacKay River	SAGD	0.21	0.33	0.46	0.51	0.58	0.57	0.57	0.56	0.56	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.51	0.51
SAGD Phase II	SAGD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.37	0.64	0.63	0.62	0.62	0.61	0.60	0.60	0.59
Petro-Canada and UTS Energy Corporation																			
Fort Hills	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	2.29	2.27	2.77	4.45	4.41	4.36	4.32	4.28	4.23

Shell Canada Limited																			
Shell Peace River	Cyclic steam	0.30	0.26	0.32	0.32	0.32	0.31	0.31	0.92	0.91	1.50	1.49	2.94	2.91	2.88	2.85	2.83	2.80	2.77
Shell Chevron Western Muskeg River	Mine and Upgrader	1.67	3.04	3.32	3.62	3.70	4.09	4.79	4.96	5.74	5.79	5.73	5.67	5.72	5.66	5.60	5.55	5.49	5.44
Shell Chevron Western Jackpine One	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.72	2.69	2.67	2.64	2.61	2.59	2.56	2.54	2.51	2.49	2.46
Shell Chevron Western Jackpine Two	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	2.61	2.59	2.56	2.54	2.51	2.49	2.46
Suncor Energy Inc.																			
Suncor Base Mine and Millennium	Mine and Upgrader	7.89	8.09	5.56	7.89	7.81	7.73	7.65	7.58	7.50	7.43	7.35	7.44	7.37	7.29	7.22	7.15	7.08	7.01
Suncor Voyageur	Mine, SAGD and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	2.31	4.41	4.37	4.32	4.28	4.39	4.35	4.31	4.26
Suncor Firebag	SAGD and Upgrader	0.00	0.07	0.71	1.30	2.26	3.61	3.64	4.21	4.67	4.62	4.58	4.53	4.48	4.44	4.39	4.35	4.31	4.26
Syncrude Canada Ltd.																			
Stages One and Two: Base and Aurora 1	Mine and Upgrader	9.05	10.08	9.04	10.36	10.26	9.54	9.45	9.35	9.26	9.17	9.08	8.99	8.90	8.81	8.72	8.63	8.54	8.46
Stage Three: Aurora 2/UE1	Mine and Upgrader	0.00	0.00	0.00	0.47	2.88	4.67	4.62	4.58	4.53	4.49	4.44	4.40	4.35	4.31	4.27	4.22	4.18	4.14
Stage Four: Aurora 3/UE2	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59	2.36	2.34	2.32	2.29	2.27	2.25	2.23	2.20	2.18	2.16
Stage Five: Aurora South	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.89	3.75	4.45	4.41	4.36	4.32
Synenco Energy Inc.																			
Northern Lights	Mine and Upgrader	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	2.02	2.67	2.64	2.61	2.59	2.56	2.54	2.51	2.49	2.46