ALBERTA ENERGY

OIL SANDS PRODUCTION PROFILE: 2004-2014

Energy Technical Services
Resource Development Policy Division

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2004 - 2014

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Introduction

Canada is endowed with significant crude oil resources, in the order of two trillion barrels of oil in place. Although these oil deposits are some of the most challenging in the world to develop, innovative research and production technologies have enabled them to move from resources to proven reserves. Canada is a net exporter of oil, and is consistently the top supplier of oil imports to the United States. As of 2014, Canada is responsible for 19 percent of oil exports to the United States[1], of which 77 percent is from Alberta's Oil Sands[2].

The purpose of this report is to provide a detailed overview of oil production volumes from the oil sands region based on production information submitted to the Ministry of Energy[3]. Specifically, this report will provide an analysis of production volumes based on (1) region, and (2) production technology as defined by the Alberta Energy. The report also shows steam-to-oil ratios trends for thermal in-situ projects from 2004 - 2015.

[1] http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/sttstc/crdlndptrlmprdct/crdlndptrlmprdct-eng.html, Retrieved October 9, 2015

[2] http://www.neb.gc.ca/nrg/sttstc/crdlndptrlmprdct/index-eng.html, Retrieved September 22, 2014

[3] The ministry consists of the Department of Energy, the Alberta Energy Regulator (AER), the Alberta Utilities Commission (AUC), the Alberta Petroleum Marketing Commission (APMC) and the Post-Closure Stewardship Fund. The AER regulates the safe, efficient, orderly and environmentally responsible development of Alberta's energy resources. This includes allocating and conserving water resources, protecting the environment and managing public lands, which benefit Alberta's economy and environment. The AUC regulates the utilities sector, natural gas and electricity markets to protect the social, economic and environmental interests of Alberta where competitive market forces do not. The APMC is a provincial agency that markets the Crown's crude oil royalty barrels. The APMC supports projects that economically benefit the province through improving market access or maximizing the value of Alberta's non-renewable resources. The Post-Closure Stewardship Fund, financed by carbon-capture and storage operators in Alberta, is a liability fund that has been established to ensure that carbon-capture and storage sites are properly maintained in the long-term after carbon-capture operations cease. *Alberta Energy Business Plan 2015-18, October 15, 2015*

Methodology

The main objectives of the Oil Sands Production Profile (OSPP) are to identify the growth trend in different production technologies over the past 10 years, how these technologies have been applied to different Oil Sands Areas and energy efficiency of thermal projects. The total production volumes given in this profile are reflective of the Alberta Energy Regulator (AER) data, which includes experimental commercial and freehold Oil Sands projects. Growth trends were measured and assessed for accuracy ($R^2 \geq 0.99$ for total Oil Sands production)[4].

Production data is categorized by operators, area (Athabasca North, Wabiskaw, Conklin, Peace River and Cold Lake), and production technology (Primary/Enhanced Oil Recovery, Cyclic Steam Simulation, Steam Assisted Gravity Drainage, and Surface Mining).

[4] *See Appendix II – Growth trends*

Oil Sands Areas

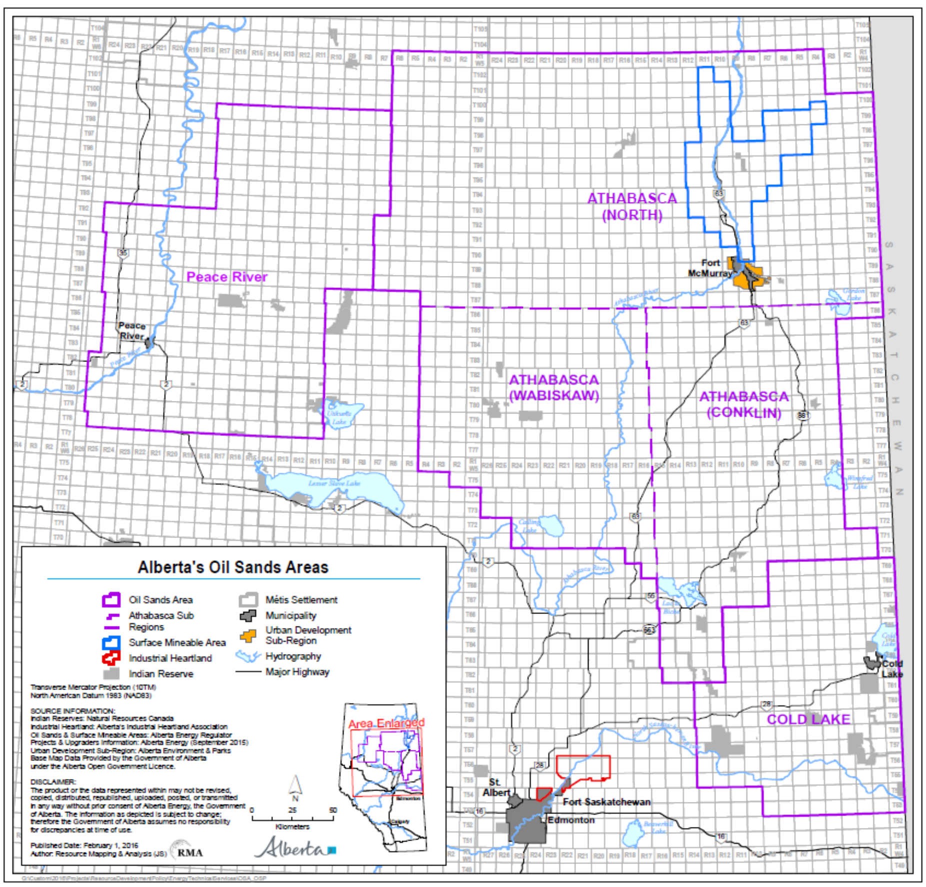
In Alberta, there are three main Oil Sands Areas. These areas are as follows:
1. Athabasca
2. Cold Lake
3. Peace River

To identify with greater clarity where growth is occurring, the Athabasca Oil Sands Area (AOSA) is divided into three sub-areas or segments:
1. Athabasca (North) – The AOSA, North of Township 86 (known hereafter as "Athabasca North Area")
2. Athabasca (Wabiskaw) – The AOSA, South of Township 86, from Range 16 West (known hereafter as "Wabiskaw Area").
3. Athabasca (Conklin) – The AOSA, from Township 86 South, East of Range 16 (known hereafter as "Conklin Area").

The map in Figure 1-i shows the locations of these areas. The reservoir characteristics vary significantly among these areas, as shown in Figure 1-ii.

Figure 1

i. Alberta Oil Sands Areas[5]



[5] Map modified from http://www.energy.alberta.ca/LandAccess/pdfs/OSAagreeStats.pdf

Production Technologies

There are four generalized extraction methods outlined as the main production technologies currently used in the Oil Sands Areas: Primary/Enhanced Recovery, Cyclic Steam Stimulation, Steam Assisted Gravity Drainage, and Surface Mining. The resource quality determines the recovery technology to be used as it is critical to match the recovery process to the unique characteristics of a reservoir such as location, geology, etc.

Primary/Enhanced Oil Recovery

Primary recovery from a reservoir is typically the first method of producing oil from a given reservoir. It uses energy which is already in the reservoir, such as gravity, and water or gas pressure (also known as waterdrive or gasdrive), to displace oil and drive it to surface facilities.

Enhanced Oil Recovery (EOR) is typically any form of technology for producing oil after primary production is no longer economically viable. Some examples of EOR include: water-flooding, gas injection, and polymer/chemical flooding. In some cases, these EOR production technologies are applied at the start of production, rather than being used as the secondary or tertiary recovery mechanism, in order to increase the ultimate recovery of oil from the reservoir.

Cyclic Steam Stimulation

Cyclic Steam Stimulation (CSS), or "huff and puff" as it is sometimes called, is a thermal production technology in which one well is used to both inject steam and produce oil. Steam is injected at pressures high enough that the hydraulic fractures are induced in the reservoir, allowing steam to access and heat new areas of the reservoir. After weeks or even months, the injection cycle is completed; a few days are allowed for the steam to condense and then the production of oil and water begins. Production initially occurs due to increased reservoir pressures, but later, cycles require artificial lift technologies to produce the remaining oil during the production cycle. This cycle is then repeated after the production rates become too small (as determined by the producer).

CSS is a viable option for deeper reservoirs that have a thick, capping shale to manage the high steam injection pressure. The high injection pressure and multiple recovery mechanisms enable CSS to work effectively with a broader range of reservoirs, especially with heterogeneous characteristics.

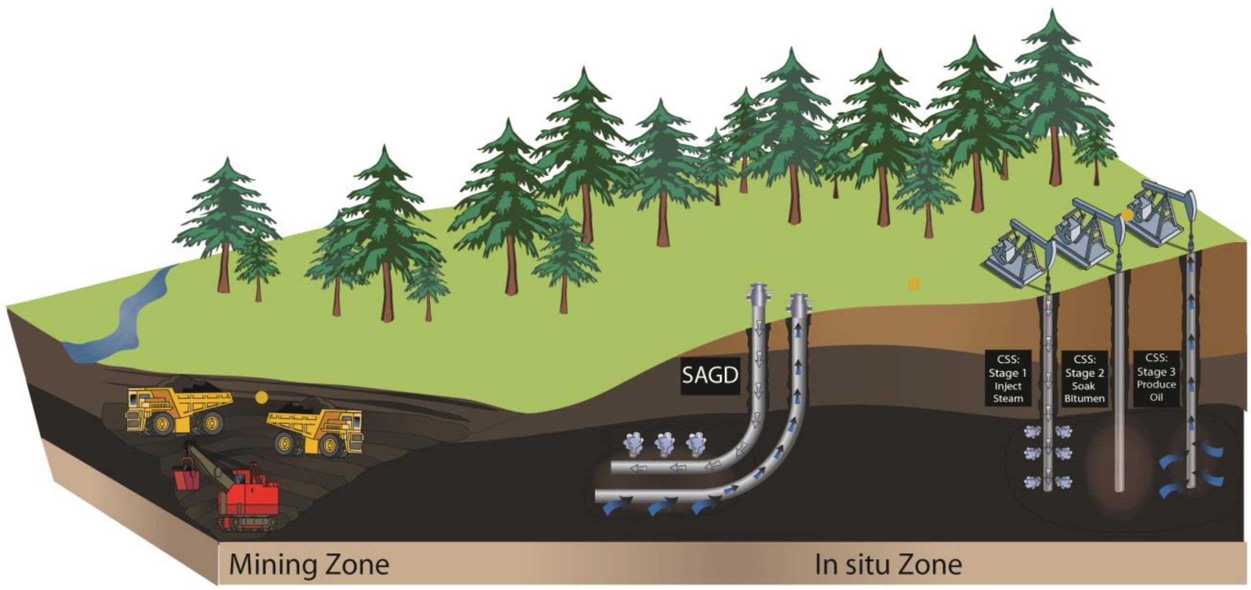
Steam Assisted Gravity Drainage

Steam Assisted Gravity Drainage (SAGD) is a thermal production technology which utilizes two parallel horizontal wells, known as a well pair, one to inject steam, and the other to produce water and oil. Initially, steam is circulated in both wells to establish communication between the wells. The top horizontal well then continuously injects steam to heat the reservoir, creating a steam chamber. The oil from the chamber drains to the production well below to allow for production initially through pressure drive, and then by artificial lift or gas lift. The steam injection and oil production happen continuously and simultaneously once production starts. This technology has a high ultimate recovery of oil from the reservoir relative to other in situ production technologies.

Surface Mining

Truck and shovel technology is used to move sand saturated with bitumen from the mining area to an extraction facility. Surface mining is used to recover oil sands deposits less than 75 meters below the surface, while in-situ technologies are used to recover deeper deposits. The bitumen is then treated to remove the sand, mineral fines and other impurities in processes which vary among industry competitors. Once the extraction process is completed, it is ready for refining or upgrading, depending on the company's objective and the treatment process used.

Diagram of different production technologies:



Source: Government of Alberta

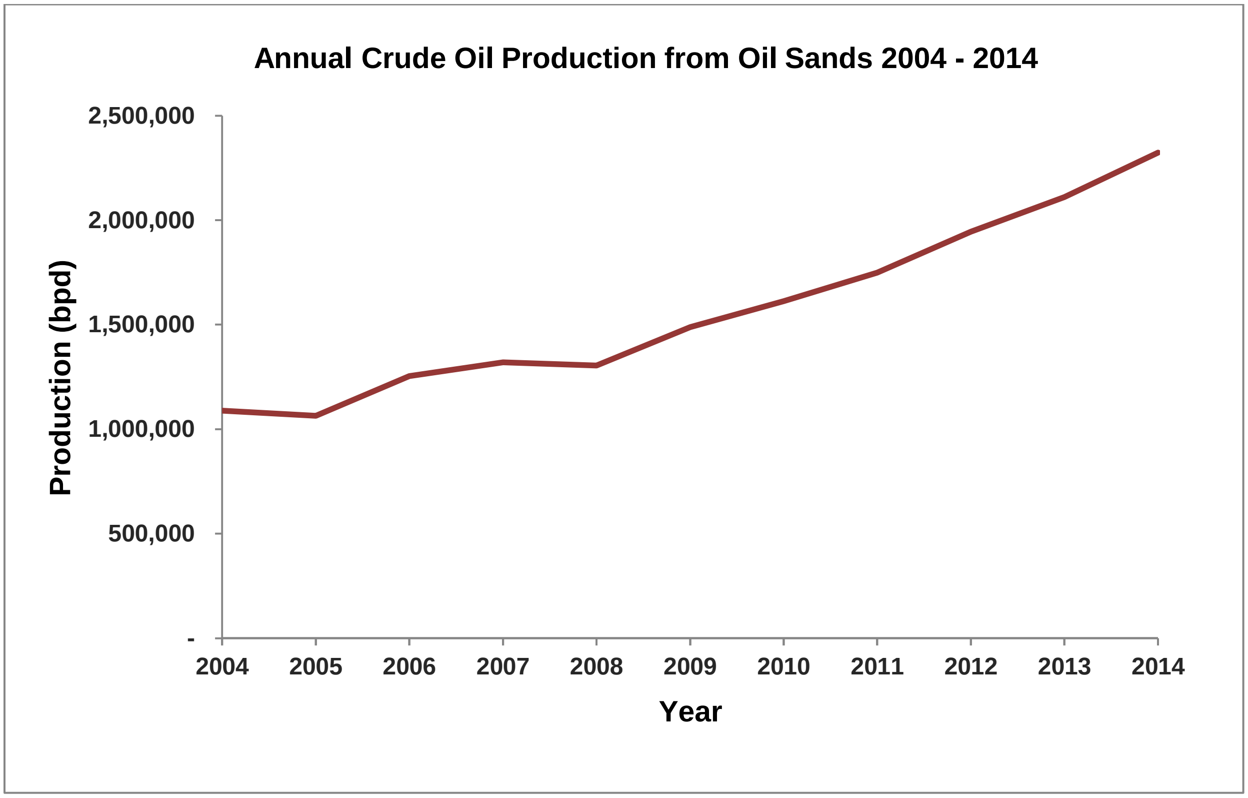
Data & Analysis

Annual Oil Sands Production

Crude Oil production from Oil Sands was calculated on an annual basis for 2004-2014 production years[6] and is presented in Figure 2.

Figure 2

i) Annual Crude Oil Production from Oil Sands



ii) Annual Crude Oil Production from Oil Sands

Annual Crude Oil Production from Oil Sands 2004 - 2014											
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
bpd	1,088,799	1,063,639	1,254,226	1,320,271	1,304,546	1,488,843	1,612,127	1,748,296	1,956,031	2,142,264	2,323,535

Figure 2 shows growth in total crude production for all of the oil sands areas. The average annual growth was determined to be 121,526 bpd with a 7.8 percent Compounded Annual Growth Rate (CAGR)[7].

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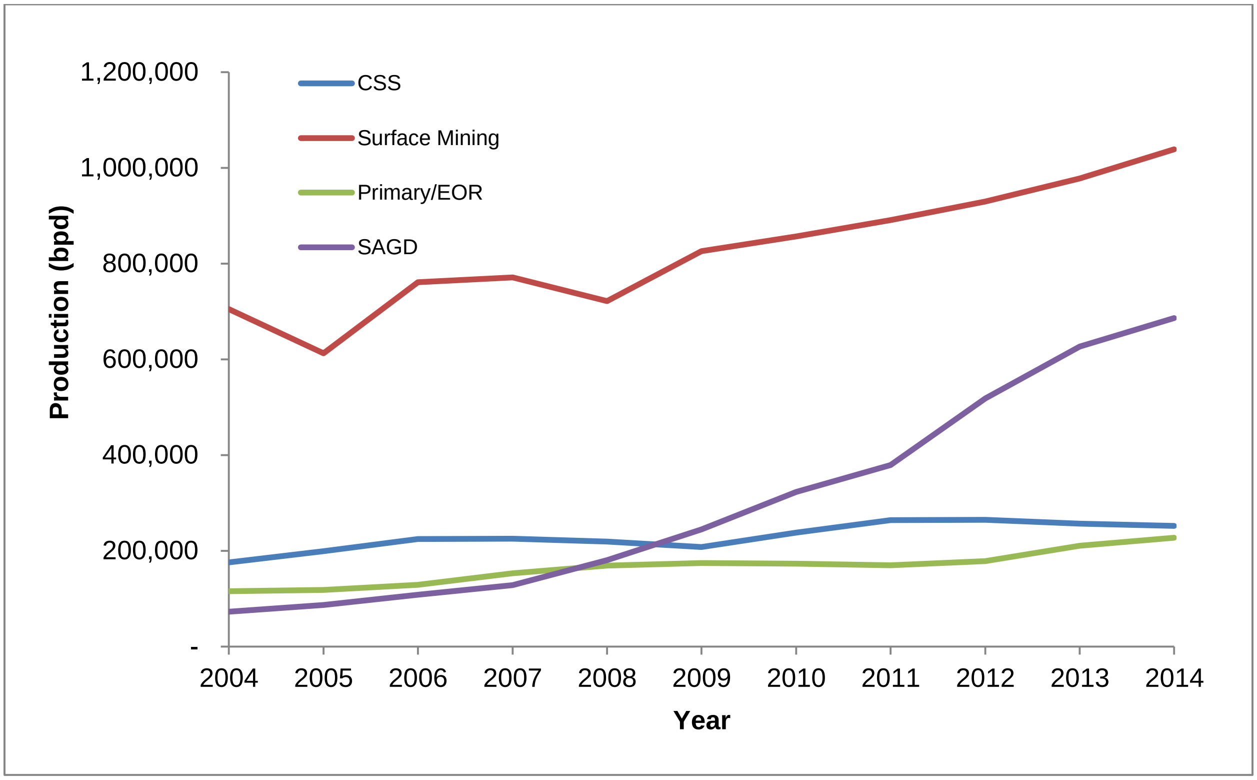
[6] See *Methodology* and *Appendix I*
[7] See *Appendix II* for sample calculation

Annual Oil Sands Production by Technology

To emphasize the growth of separate technologies over the past decade, annual production was further analyzed based on the four generalized commercial production technologies: 1) Primary/EOR, 2) CSS, 3) SAGD, and 4) Surface Mining[8]. Figure 3-i and 3-ii shows production by the various technologies.

Figure 3

i) Annual Crude Oil Production from Oil Sands by Technology



ii) Annual Crude Oil Production (bpd) from Oil Sands by Technology

Technology	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CSS	175,535	198,860	224,277	225,218	219,029	207,947	237,892	264,064	264,705	256,531	251,666
Surface Mining	704,777	612,751	760,839	770,835	721,491	825,842	856,876	890,940	929,662	978,208	1,038,479
Primary/EOR	115,537	117,970	128,878	153,296	169,131	174,422	173,145	169,660	178,442	210,810	226,964
SAGD	72,627	86,440	108,398	128,212	180,248	244,507	322,644	378,853	518,542	626,403	686,324
Total	**1,068,476**	**1,016,021**	**1,222,393**	**1,277,561**	**1,289,900**	**1,452,718**	**1,590,557**	**1,703,517**	**1,891,351**	**2,071,952**	**2,203,433**

[8] As described in *Methodology* and *Appendix I*

iii) Crude Oil Growth Rates from Oil Sands by Technology

Technology	Average Growth (bbl/year)	Compounded Annual Growth (CAGR)
CSS	7,613	3.7%
Surface Mining	33,370	4.0%
Primary/EOR	11,143	7.0%
SAGD	61,370	25.2%
Total	**113,496**	**7.5%**

Separating production allowed for calculation of the individual CAGR of the technologies, and showed the corresponding trends. Growth rates can be seen in Figure 3-iii. CAGR for CSS (3.7%), Mining (4%) and Primary (7%) exhibited growth trends[9], similar to total annual production (7.5%) as shown in Figure 2-i and 2-ii, while SAGD production exhibited more growth with a significantly greater CAGR (25.2%) than all other production technologies.

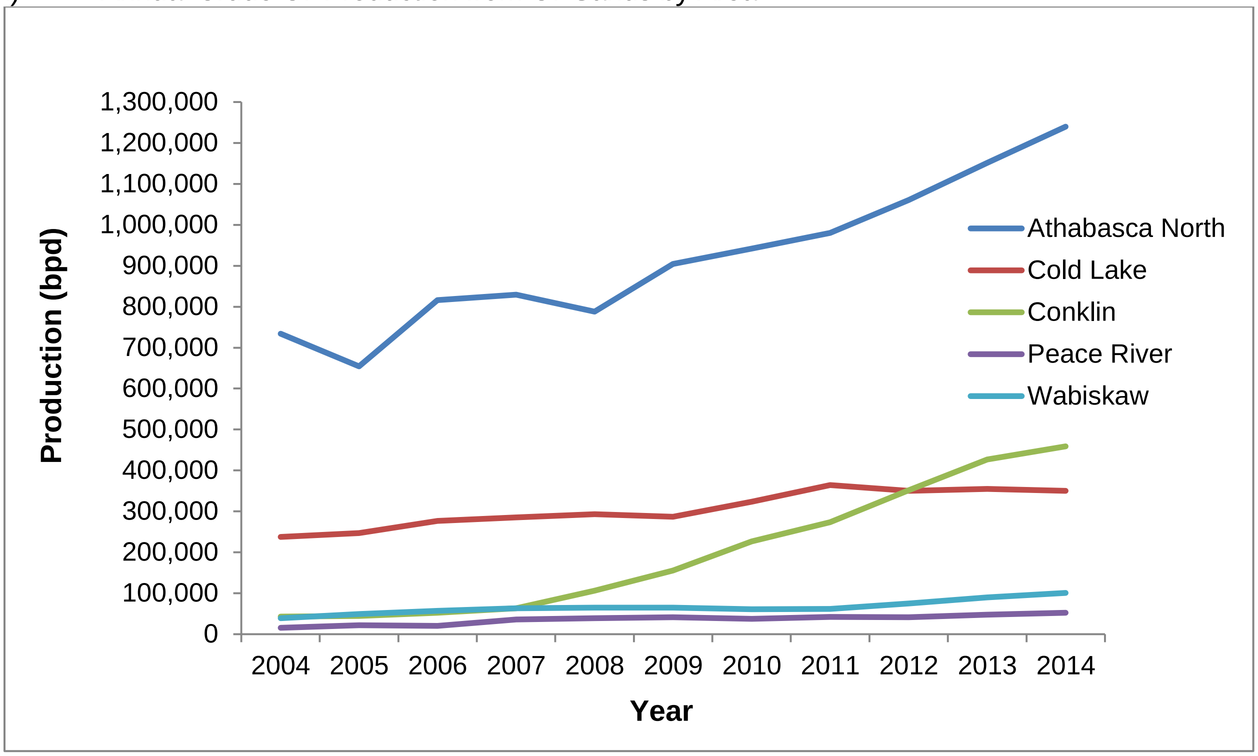
[9] Appendix II-i

Annual Oil Sands Production by Area

Production trends were also examined within the distinct Oil Sands Areas[10]. Annual crude production was determined for: 1) Athabasca North, 2) Cold Lake, 3) Conklin, 4) Peace River, and 5) Wabiskaw areas[11]. Figure 4-i and 4-ii shows the annual production volumes for the various regions.

Figure 4

i) Annual Crude Oil Production from Oil Sands by Area



ii) Annual Crude Oil Production (bpd) from Oil Sands by Area

Annual Crude Oil Production from Oil Sands by Area											
Area	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Athabasca North	733,869	654,428	816,442	829,825	787,655	904,831	941,981	980,539	1,060,921	1,151,935	1,240,106
Cold Lake	237,534	246,594	276,332	285,400	293,347	286,669	323,505	364,004	349,944	354,521	350,473
Conklin	42,741	44,129	52,304	62,897	105,840	155,543	226,811	273,600	351,535	427,104	459,162
Peace River	15,167	21,864	20,077	36,087	38,633	41,133	37,037	41,807	41,634	47,659	52,608
Wabiskaw	39,165	49,006	57,238	63,351	64,425	64,542	61,223	61,567	75,294	89,837	101,084
Total	**1,068,476**	**1,016,021**	**1,222,393**	**1,277,560**	**1,289,900**	**1,452,718**	**1,590,557**	**1,721,517**	**1,879,328**	**2,071,056**	**2,203,433**

[10] See *Oil Sands Areas*
[11] As described in *Methodology* and *Appendix I*

iii) Annual Crude Oil Growth Rates from Oil Sands by Area

Annual Crude Oil Growth Rates from Oil Sands by Area		
Area	**Average Annual Growth Rate Growth (bpd/year)**	**Compounded Annual Growth Rate (CAGR)**
Athabasca North	50,624	5.4%
Cold Lake	11,294	4.0%
Conklin	41,642	26.8%
Peace River	3,744	13.2%
Wabiskaw	6,192	9.9%
Total	**113,496**	**7.5%**

CAGRs were calculated for Athabasca North (5.4%), Cold Lake (4%), and Wabiskaw (9.9%) areas (Figure 4-iii). All areas exhibited CAGRs less than 10%, with the exception of the Peace River (13.2%) area, and the Conklin area which exhibited larger growth (26.8%)[12].

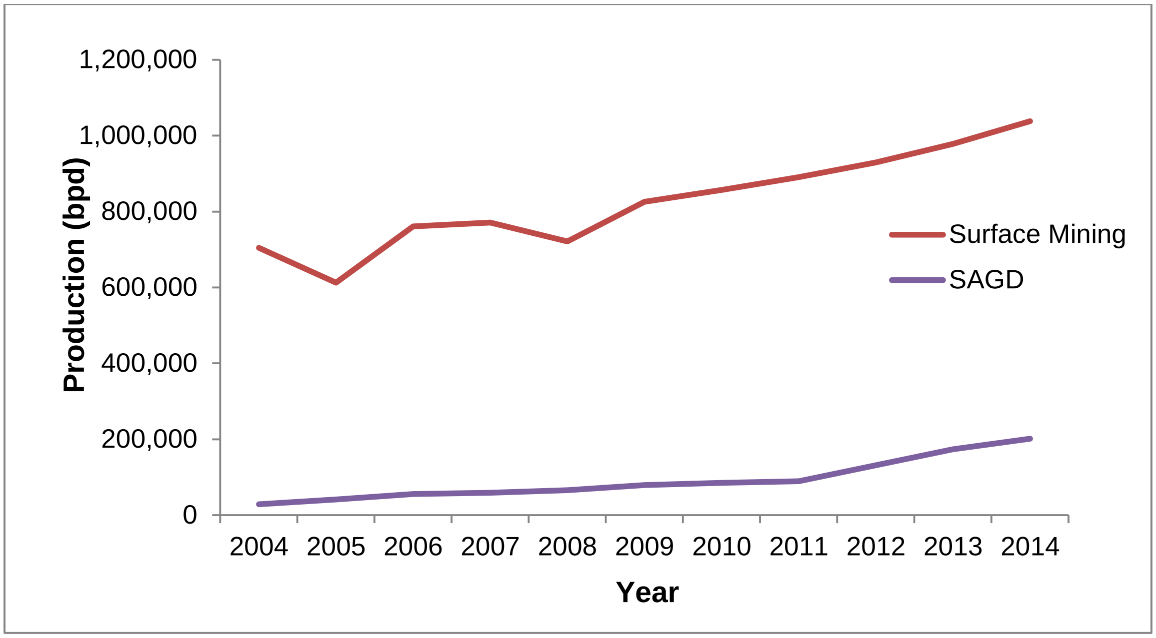
[12] *Appendix II-iii* and *II-iv*

Annual Oil Sands Areas Production by Technology

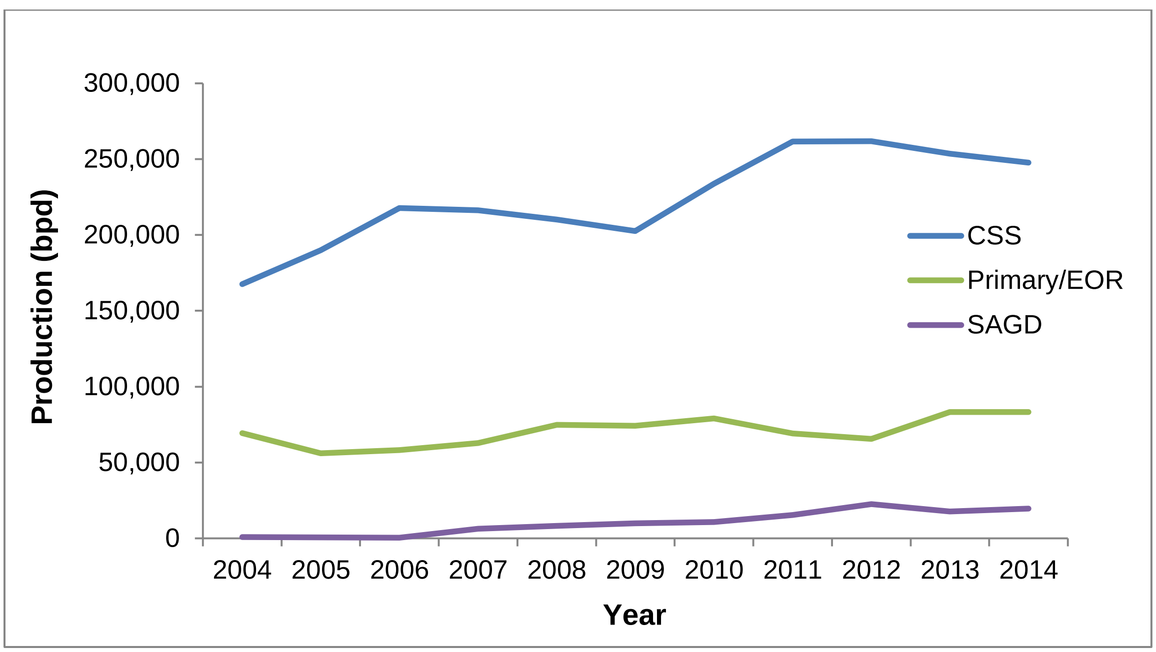
Regional production volumes were further sub-divided on the basis of technology to determine production trends in each area. Results are shown in Figure 5-i to 5-vi.

Figure 5

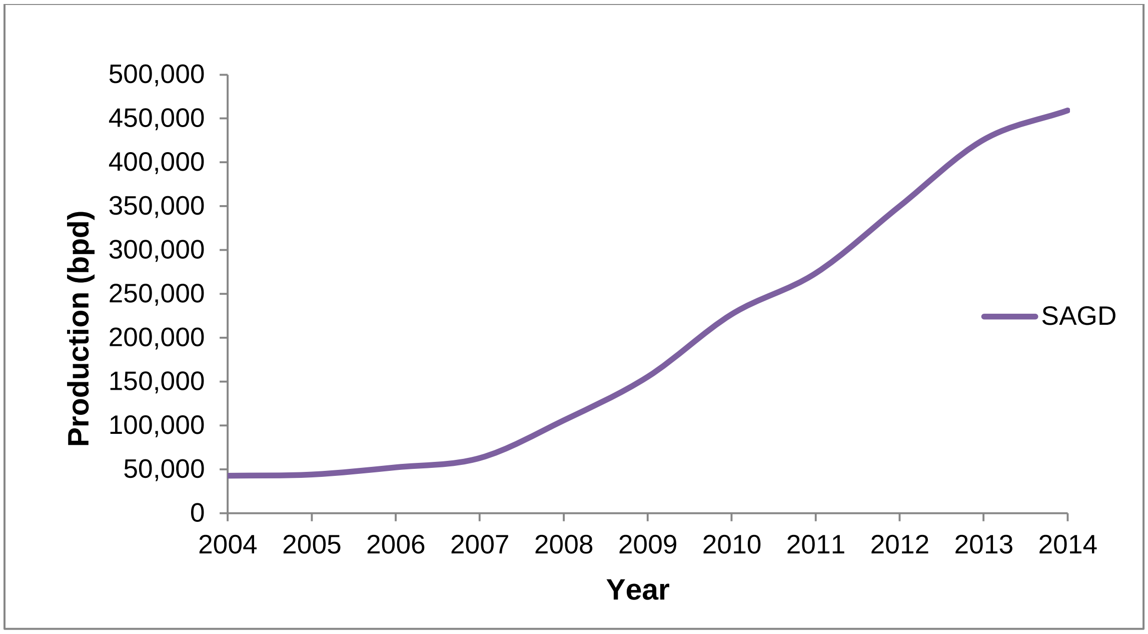
i) Annual Crude Oil Production from Oil Sands by Area – Athabasca North



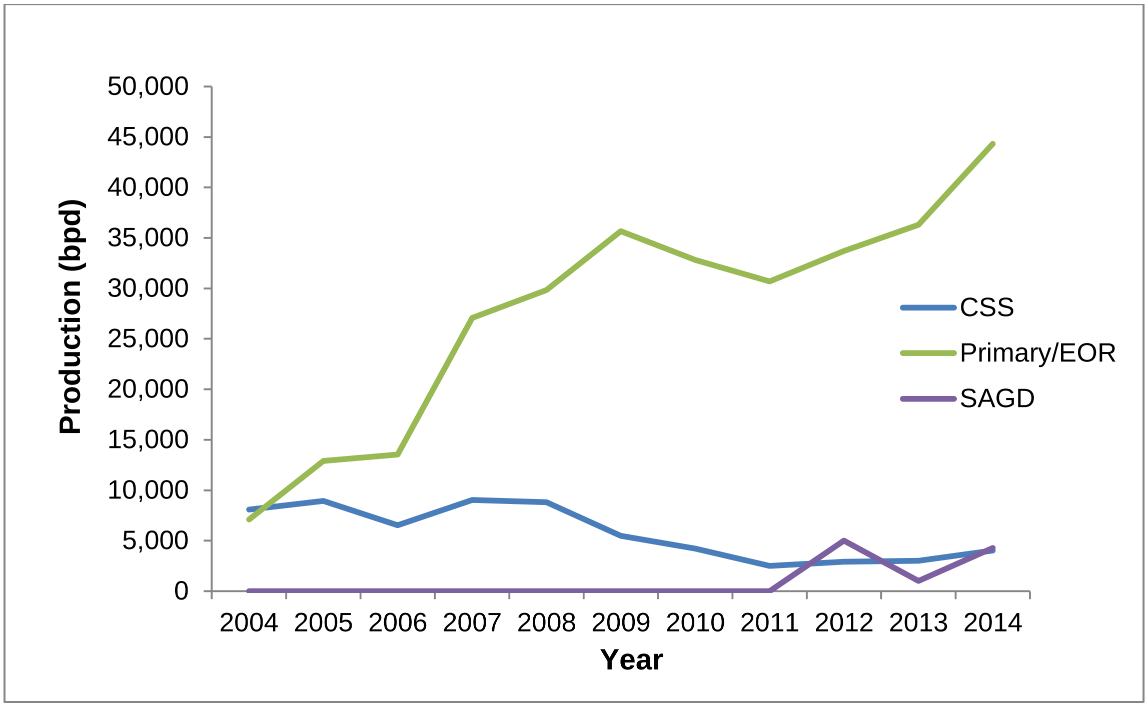
ii) Annual Crude Oil Production from Oil Sands by Area – Cold Lake



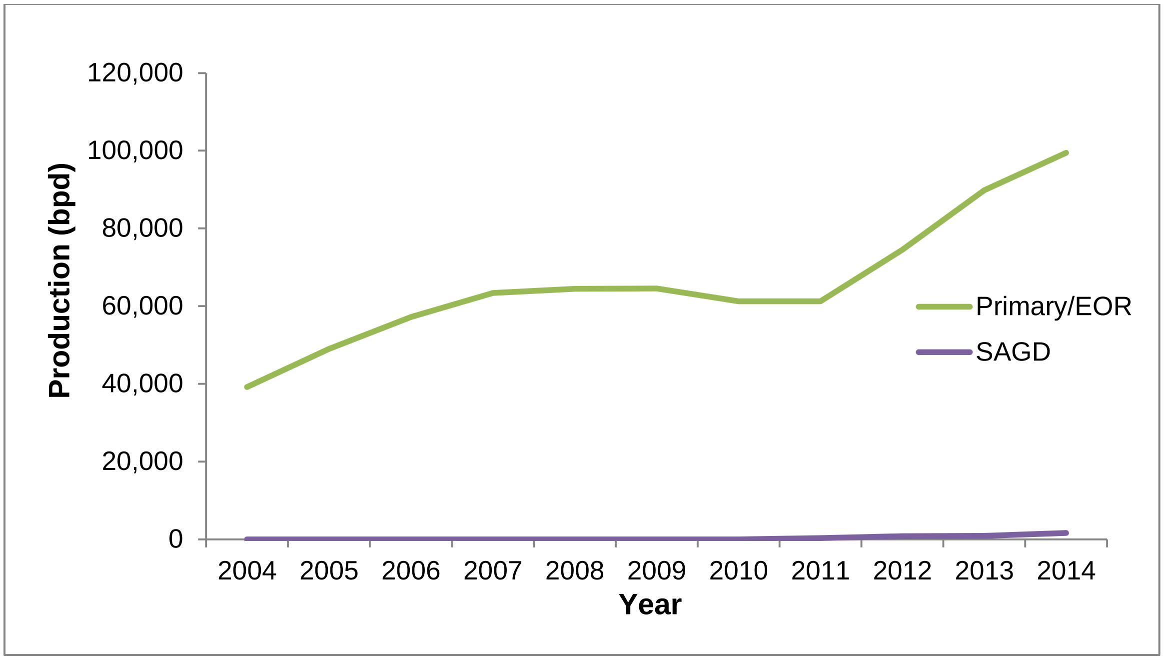
iii) Annual Crude Oil Production from Oil Sands by Area – Conklin



iv) Annual Crude Oil Production from Oil Sands Area by Area – Peace River



v) Annual Crude Oil Production from Oil Sands Area by Region – Wabiskaw



vi) Annual Crude Oil Production (bpd) and Growth Rates from Oil Sands Regions by Technology

Athabasca												
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	wth (bbl/y	CAGR
Surface Mining	704,777	612,751	760,839	770,835	721,491	825,842	856,876	890,940	929,662	978,208	1,038,479	33,370	4.0%
SAGD	29,092	41,677	55,585	58,990	66,164	78,989	85,105	89,597	131,255	173,725	201,627	17,254	21.4%

Cold Lake													
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	wth (bbl/y	CAGR
CSS	167,455	189,912	217,747	216,196	210,217	202,468	233,681	261,552	261,787	253,536	247,656	8,020	4.0%
Primary/EOR	69,285	56,048	58,093	62,879	74,885	74,226	79,097	69,093	65,520	83,344	83,225	1,394	1.9%
SAGD	794	634	492	6,325	8,245	9,975	10,728	15,359	22,637	17,641	19,592	1,880	37.8%

Conklin													
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	wth (bbl/y	CAGR
SAGD	42,741	44,129	52,304	62,897	105,840	155,543	226,811	273,600	350,047	425,787	459,162	41,642	26.8%

Peace River													
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	wth (bbl/y	CAGR
CSS	8,080	8,948	6,530	9,021	8,812	5,479	4,212	2,512	2,918	2,995	4,010	-407	-6.8%
Primary/EOR	7,087	12,916	13,548	27,066	29,821	35,654	32,825	30,674	33,698	36,310	44,313	3,723	20.1%
SAGD	-	-	-	-	-	-	-	9	5,019	1,003	4,285	1,425	*

***Not enough data to determine CAGR**

Wabiskaw													
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	wth (bbl/y	CAGR
Primary/EOR	39,165	49,006	57,238	63,351	64,425	64,542	61,223	61,279	74,497	89,837	99,426	5,478	9.8%
SAGD	-	-	-	-	-	-	-	288	797	897	1,658	457	*

***Not enough data to determine CAGR**

CAGRs for technologies in all regions exhibited similar growth displayed by technologies in the overall oil sands area (Figure 5-vi), with SAGD based production showing major growth in most producing regions.

Annual Oil Sands Production - SAGD

To further examine the growth trends for SAGD operations[13], annual SAGD production was further analyzed to determine the steam-oil ratio (SOR).

SOR is a measure of efficiency for thermal projects. It measures the average volume of steam needed to produce one barrel of bitumen. SOR is based on the amount of steam injected at a project site per barrel of oil produced. There are two ways to measure SOR:

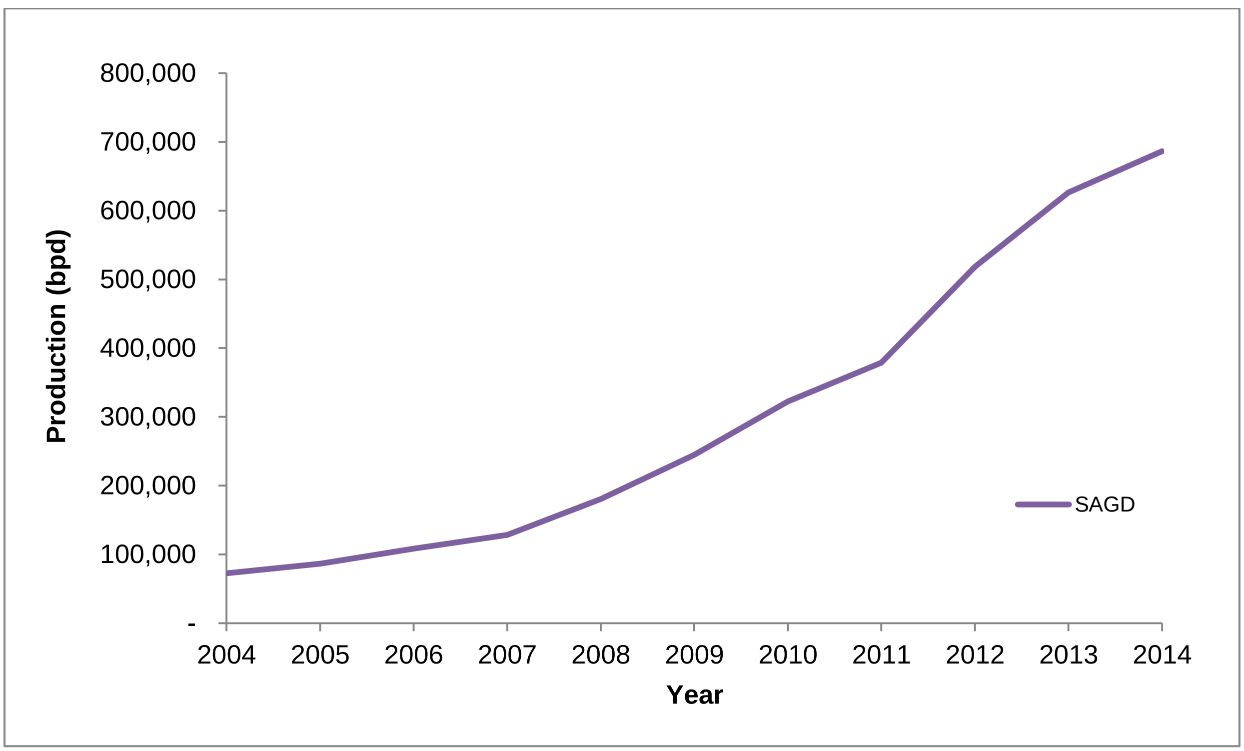
1. *Instantaneous steam-oil ratio (ISOR):* measures the current or instantaneous rate of steam required to produce one barrel of bitumen.

2. *Cumulative steam-oil ratio (CSOR):* measures the average volume of steam (over the life of the operation) required to produce one barrel of bitumen.

The annual (calendar year – January 1st to December 31st) SOR for SAGD projects were examined to identify ISOR and CSOR (Figure 6-ii and iii). A low SOR indicates that steam is more efficiently utilized and, as a result, the associated costs related to fuel and water is lower.

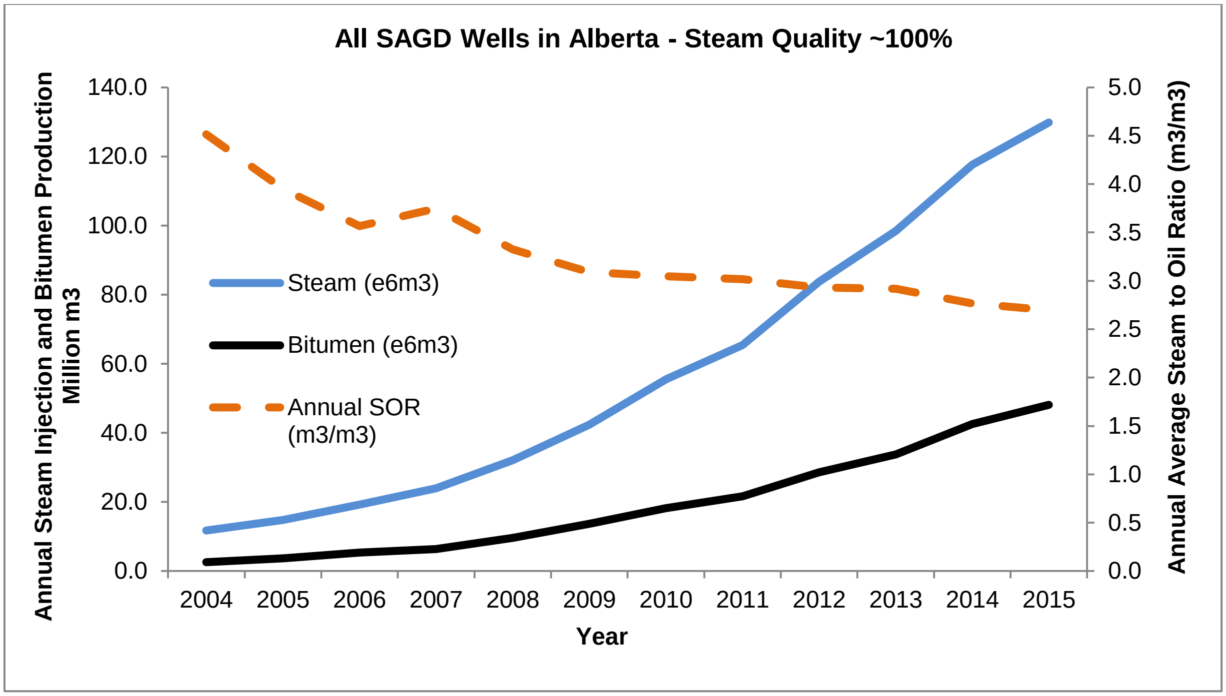
Figure 6

i) Annual Crude Oil Production from Oil Sands - SAGD Production

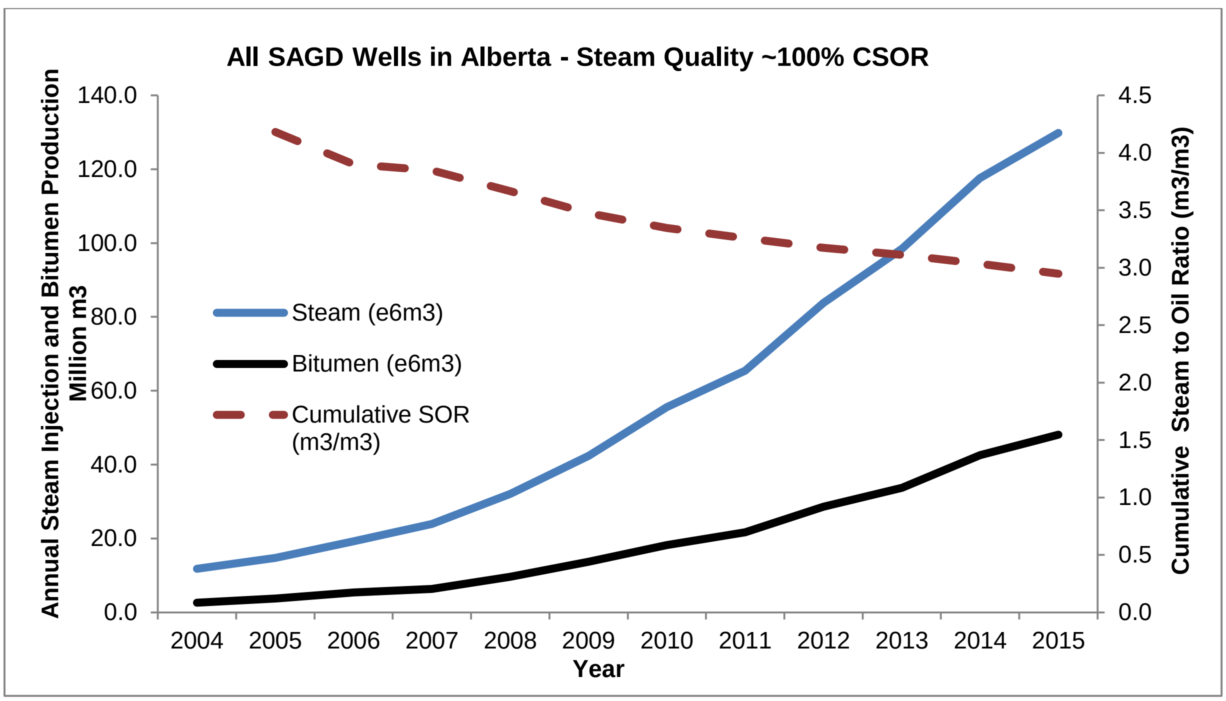


[13] Appendix II-ii

ii) Annual Crude Oil Production from Oil Sands SAGD – Annual Weighted Average ISOR



iii) Annual Crude Oil Production from Oil Sands SAGD – CSOR



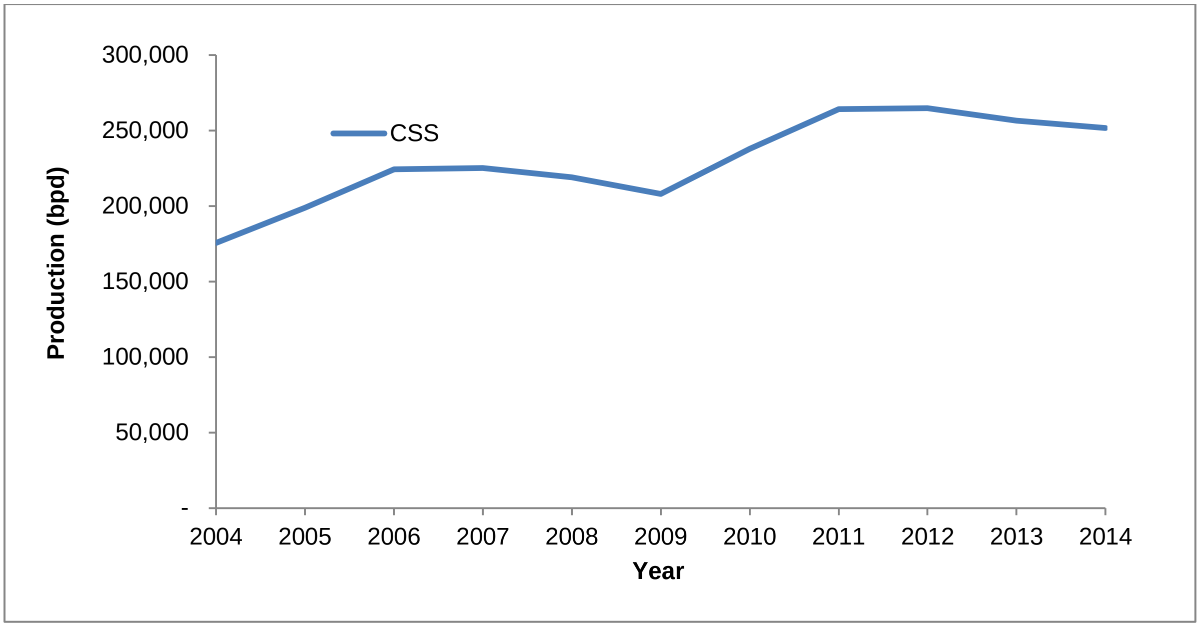
Comparing the CSOR from 2004 to 2014 shows a steady decline in steam use per barrel of bitumen produced for all SAGD projects operating in Alberta. In 2014, the average CSOR for SAGD bitumen production has dropped to 2.7.

Annual Oil Sands Production - CSS

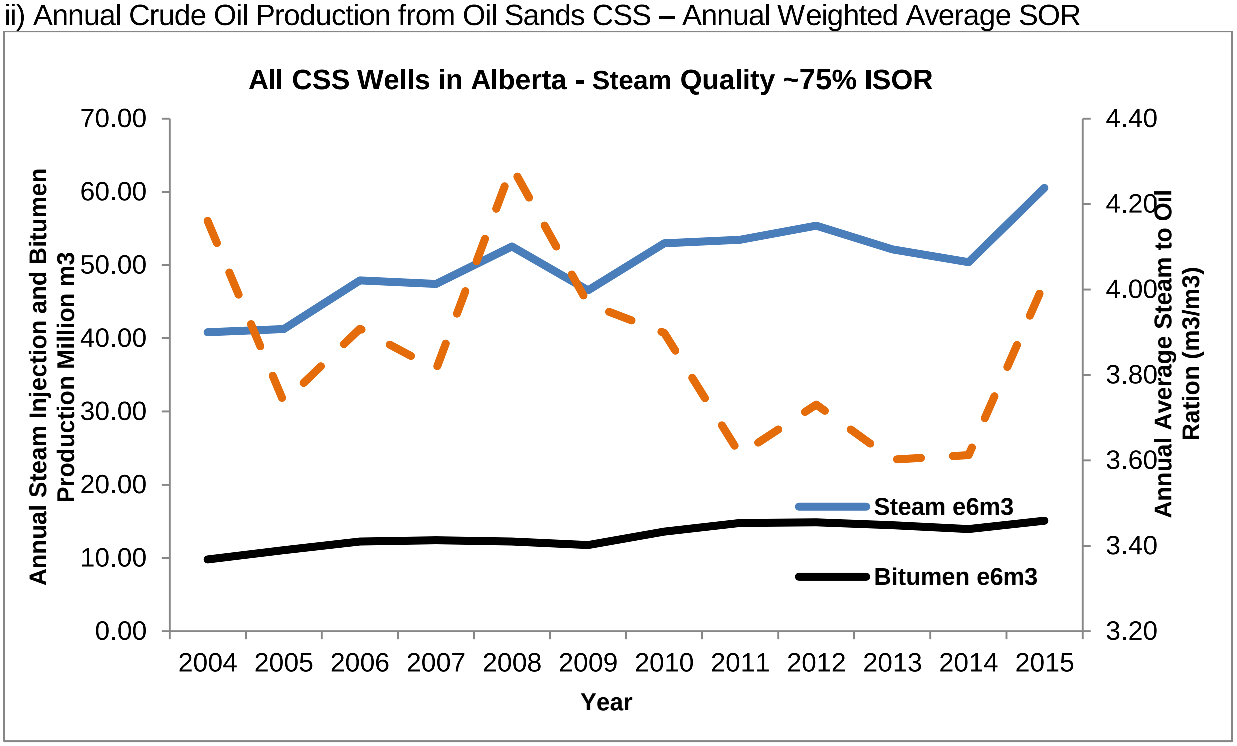
As Alberta operators also use CSS as a thermal technology, annual CSS production was further analyzed to determine the ISOR and CSOR on absolute production.

Figure 7

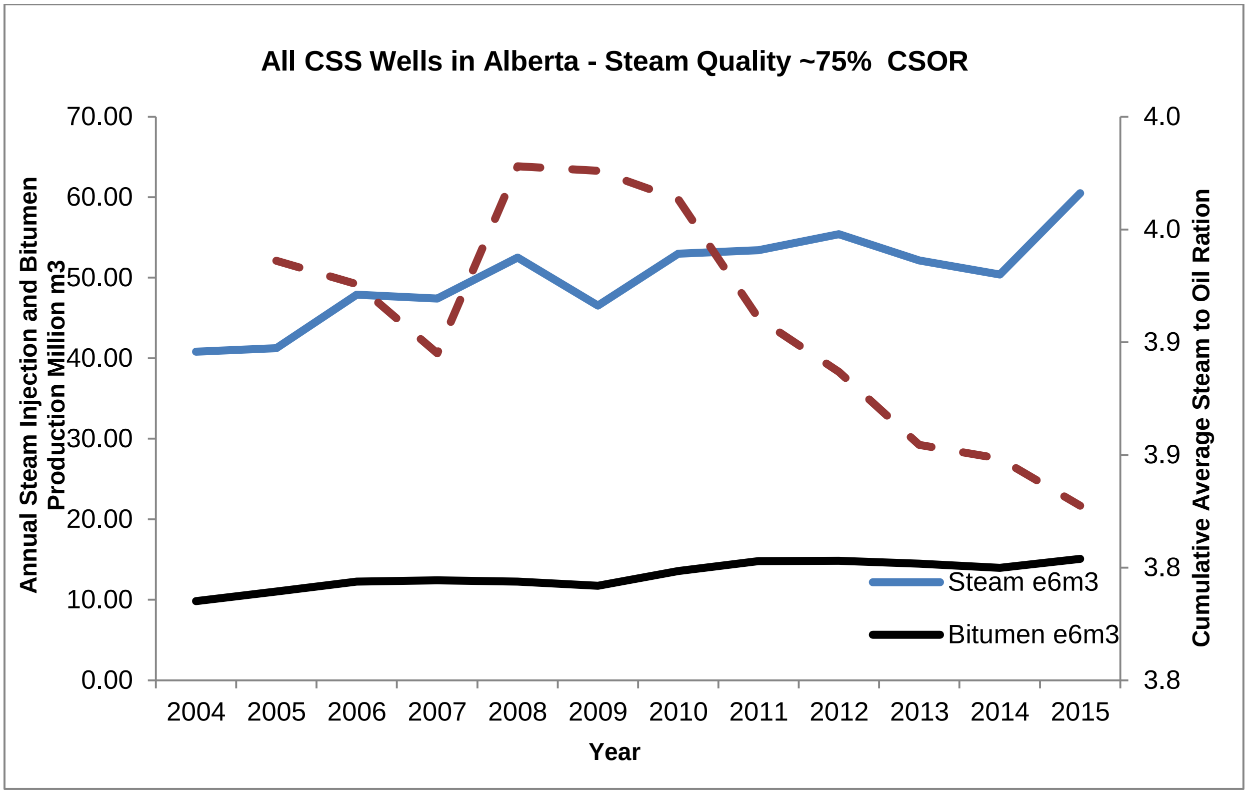
i) Annual Crude Oil Production from Oil Sands - CSS Production



ii) Annual Crude Oil Production from Oil Sands CSS – Annual Weighted Average SOR



iii) Annual Crude Oil Production from Oil Sands CSS – CSOR



Comparing the CSOR from 2004 to 2014 shows a decline in steam use per barrel of bitumen produced for all CSS projects operating in Alberta. In 2015, the average CSOR for CSS bitumen production is around 3.8.

It is important to note that CSS and SAGD SORs are not comparable on an energy basis as 75 percent quality steam for CSS contains less energy than the same water volume of steam at 100 percent quality for SAGD. Therefore, SAGD is not necessarily more energy efficient than CSS.

Steam quality is the proportion of saturated steam (vapour) in a saturated liquid/vapour mixture. A steam quality of 0 percent indicates 100 percent liquid (condensate), while a steam quality of 100 percent indicates 100 percent of steam[14].

[14] Definition of steam quality - https://www.swagelok.com/~/media/Distributor%20Media/C-G/Chicago/Services/ES%20-%20Steam%20Quality_BP_23.ashx, retrieved January 5, 2016.

Appendix I

2004 – 2014 Oil Sands Project Production Volumes

Please note - Appendix I has been removed due to confidential industry information.

Appendix II

Calculations

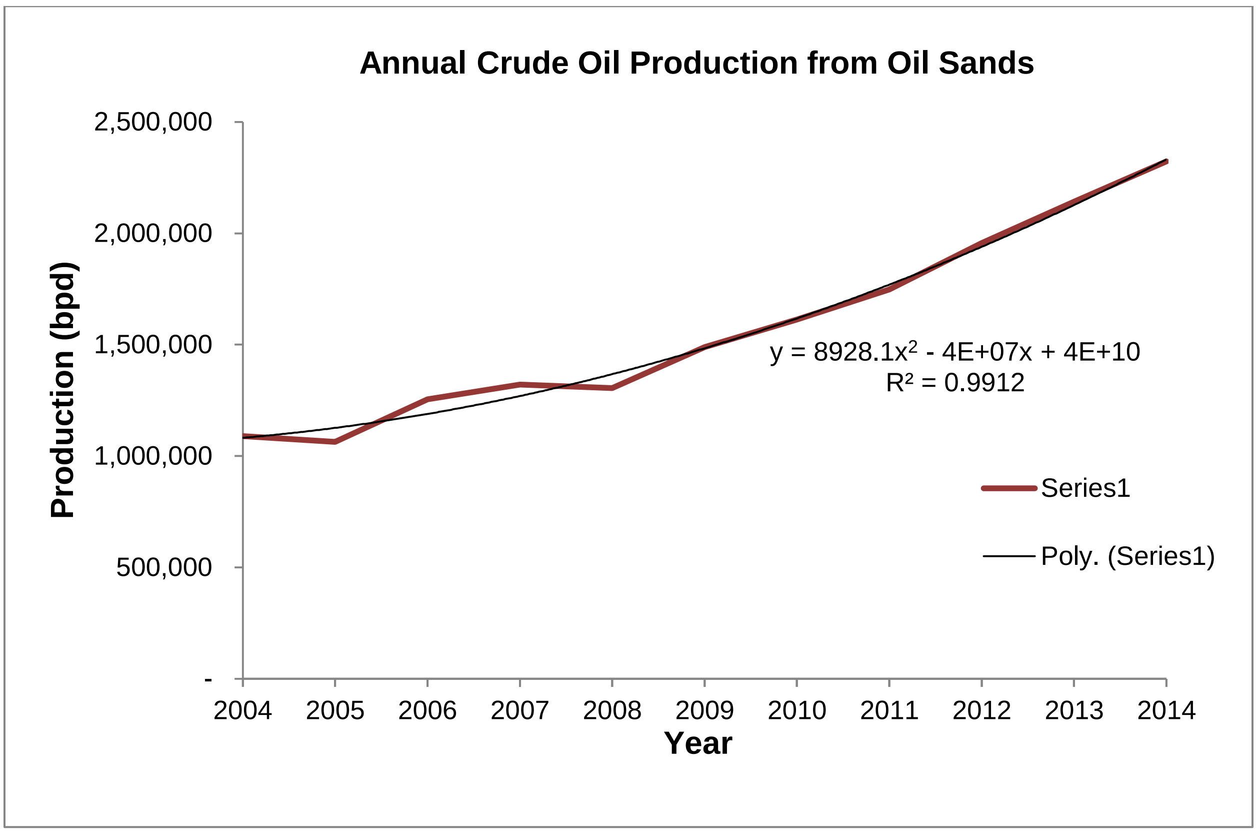
Growth rates were calculated using Compounded Annual Growth Rate (CAGR) calculation:
$r = [(x_1/x_2)^{(1/n)}] – 1$

Where:

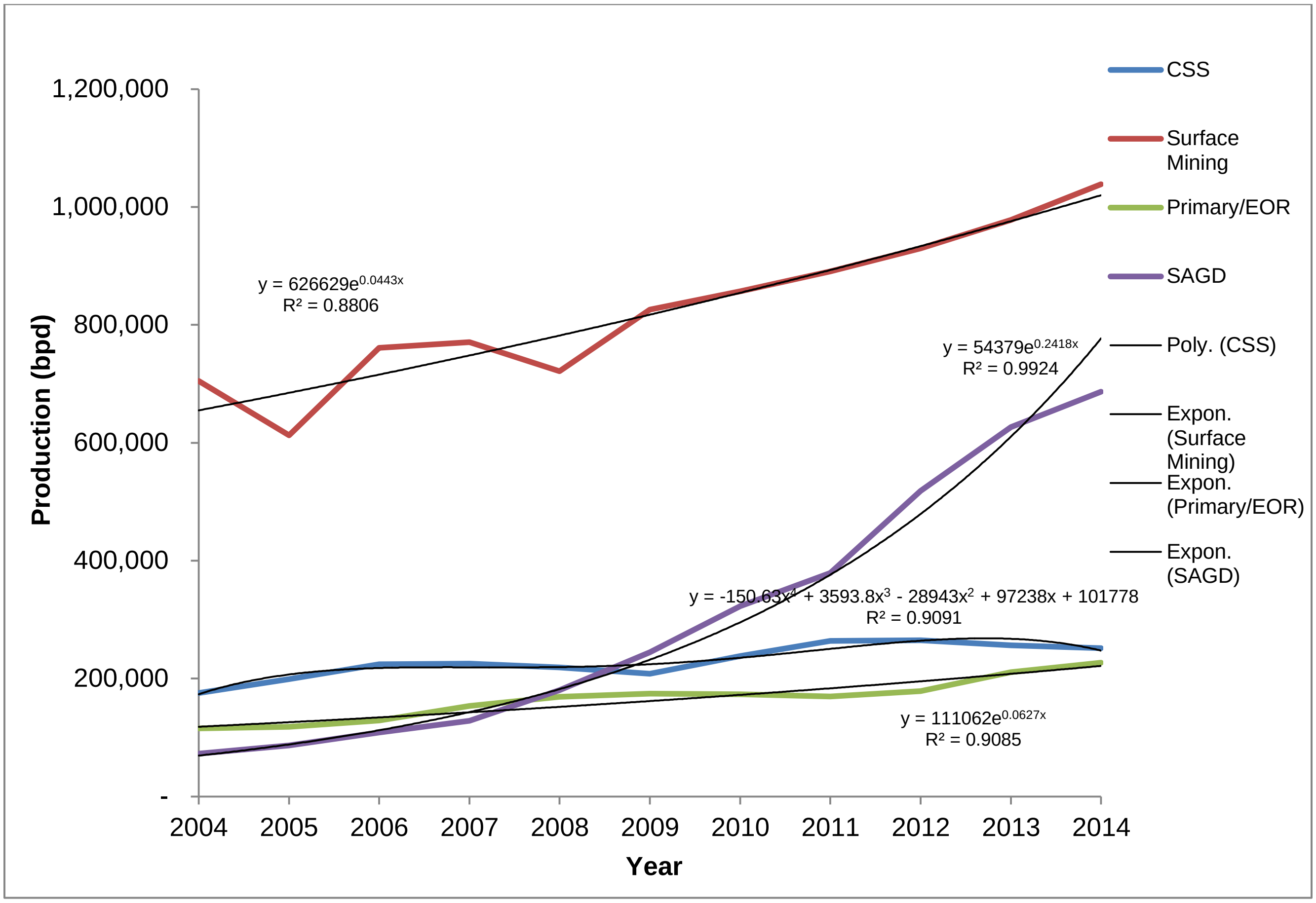
r = Compounded annual growth rate
x_1 = 2014 annual production volume
x_2 = 2004 Annual Production volume
n= Production Years/Periods

Trend types and R-squared values were generated using Microsoft Excel. Please see figures below for corresponding equations.

i) Annual Crude Oil Production from Oil Sands



ii) Annual Crude Oil Production from Oil Sands by Technology



iv) Annual Crude Oil Production from Oil Sands by Area