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Learning from the Past - Evaluating Forecasts for Canadian Oil Sands Production with Data

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Abstract

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Crude oil plays an important role for the global energy system. As there is ample evidence that conventional oil production will have peaked by 2020, unconventional oil has attained a stronger focus. In particular, oil derived from bitumen from Canadian oil sands has been proposed as a possible remedy to global oil depletion.

This study aims to test the hypothesis that forecasts on the Canadian oil sands published between about 2000 and 2010 have been overestimating production significantly.
A large compilation of oil sands projects, prognoses and production data has been established using openly available databases and reports. Conversion, standardization and analysis of the data was done using the statistical programming language R. The resulting programming code and databases have been compiled into a package available free and open-source online.

The statistical analysis shows a significant bias of the prognoses towards an overestimation of oil sands production. The compilation shows that most authors tend to overestimate the rate of expansion of the industry. Therefore, any prognosis on the expansion of the industry should be examined thoroughly before use.

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Uppsala Universitet
Institutionen för geovetenskaper
Global Energy Systems

Master thesis

Utvärdering av historiska prognoser av oljesand i Kanada

av

Friedrich Hehl

Ämnesgranskare: Mikael Höök
Handledare: Simon Davidsson

Uppsala, 2013

Sammanfattning

Råolja spelar en viktig roll för våra globala energisystem. Då det finns tydliga tecken på att produktionen av konventionell olja kommer att ha haft sitt produktionsmaximum innan 2020, har okonventionell hamnat i fokus. Särskilt olja producerat från bitumen från oljesanderna i Kanada har föreslagits som potentiell botemedel mot den globala nedgången av oljeproduktionen.

Denna studie ska undersöka om tidigare prognoser angående produktion av olja från oljesanderna i Kanada har överskattat produktionen. En stor samling av oljesand-projekt, prognoser och produktionsdata har sammanställds med hjälp av öppna databaser och rapporter. Konvertering, standardisering och och analys gjordes med hjälp av det statistiska programmeringsspråket R. Koden och databaserna samlades i ett paket som har publicerats på nätet. Paketet har öppen källkod och är gratis.

Den statistiska analysen visar en signifikant lutning av prognoserna åt att överskatta produktionen. Sammanställningen visar att de flesta författarna har hittills förutsett industrins produktionsökning med för höga värden. Därför borde även idag prognoser angående utvecklingen av oljesands-industrin granskas ordentlig innan de används för att fatta beslut.

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Keywords: oil sands, unconventional oil, analysis, heavy oil

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Contents

1. Introduction

1.1. Peak oil

> "The term Peak Oil refers to the maximum rate of the production of oil in any area under consideration, recognising that it is a finite natural resource, subject to depletion."
>
> Colin Campbell [ASPO International, 2013]

Oil is a finite resource. Production commenced at a rate of zero and will terminate at the same rate. This inevitably leads to the conclusion that there must be a point of maximum production.

There is ample evidence that the peaking of *conventional* oil production is imminent [Owen et al., 2010] and will have occurred before 2020. According to World Energy Outlook [Birol and International Energy Agency, 2012], this might already have happened. As figure 1 shows, mankind has been consuming conventional oil at a higher rate than new discoveries were added since the end of the 70s. There is no sign of a reversion of this trend and a thorough analysis of the most important oil fields has shown that the decline due to geological reasons will be unfeasible to offset by new discoveries of conventional oil [Robelius, 2007; Höök et al., 2009].

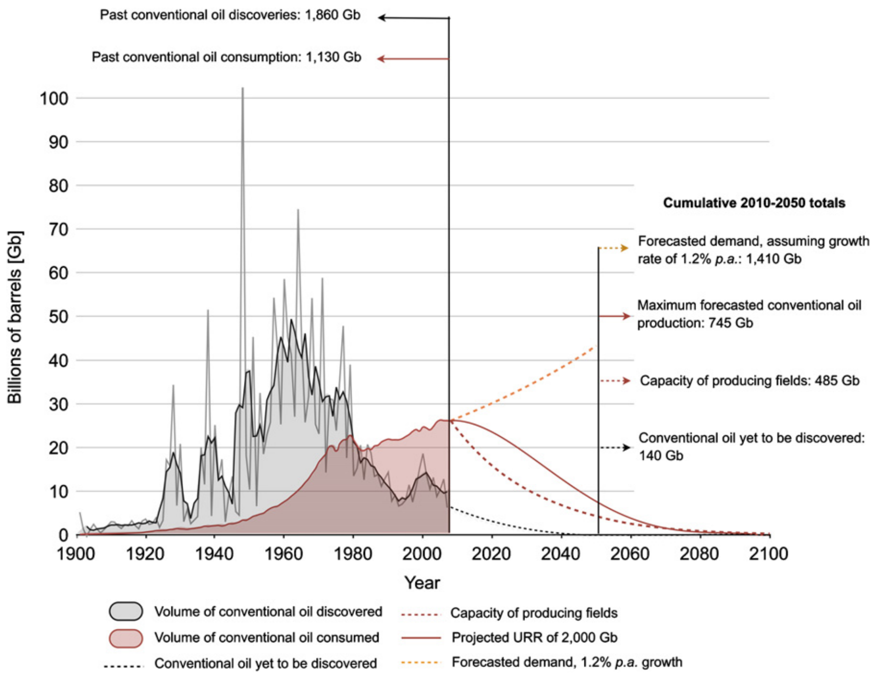

Figure 1: Proven and probable reserve consumption, taken from [Owen et al., 2010].

1.2. Focus on Canada

Oil produced from Canadian oil sands has been pointed out as a possible remedy to mitigate a future decline of conventional oil production. Since the so-called *Hirsch-report* [Hirsch and Bezdek, 2005], which proposed the further expansion of the industry as a means to sustain global economic welfare, numerous articles, publications and comments have been submitted to the public for evaluation. Oil sands production has historically been assigned values such as *"A new era of opportunity"*[National Task Force on Oil Sands Strategies and Alberta Chamber of Resources, 1996], *"a dangerous mythology"* [Woynillowicz, 2005] or *"Scraping the bottom of the barrel"* [Brandt and Farrell, 2007; World Wide Fund for Nature, 2008].

Especially in the context of the peak oil debate, unconventional oil, i.e. oil that is not produced by conventional methods, has gained the attention of researchers. One of the main topics of dicussion is by how much production of unconventional oil will increase. Determinining the future contribution of unconventional oil to total oil production would represent an important milestone in modeling global energy systems. [Aleklett et al., 2012; Hirsch, 2008; Greene et al., 2006; de Castro et al., 2009]

The Canadian oil sands industry is expanding rapidly and expectations on its future production are varying wildly. It is obvious that not all expectations can become true. In an effort to extend and update Söderbergh's compilation of projects and forecasts [Söderbergh et al., 2007], this report attempts to deliver a critical summary of historical, recent and current views and forecasts on future oil sands production.

1.3. Aims of this study

This study aims to test the hypothesis that forecasts on the Canadian oil sands published between about 2000 and 2010 have been overestimating production significantly. Furthermore, the study will evaluate recent claims made on future oil sands production. It will therefore make a contribution to the discussion by how much unconventional oil will be able to mitigate the depletion of conventional oil.

In addition, a program for the analysis of prognoses and production values is provided for the research community. This program is open-source, free of charge and adaptable to other areas than oil sands.

Limits of this study. There has been a lot of speculation about the future role of oil from the Orinoco Belt in Venezuela. Although the oil properties and the geological situation are rather similar and many of the technical difficulties can be compared to Canada [Dusseault, 2001], an attempt to do a similar analysis as done on Canada has failed painfully. The low quality, credibility and the lack of data have rendered an analysis too difficult and meaningless. There seems to be a heavy mixup between oil sands, bitumen and heavy oil in the litterature regarding Venezuela. [Titman, 2010]

Therefore, no numerical analysis has been conducted on Venezuela.

2. Background

2.1. Properties of Oil Sands and Bitumen

Oil sands, *tar sands* or *bituminous sands*[1] are unconventional petroleum deposits. They mainly contain sand, water and extra heavy oil, especially bitumen. [National Energy Board Canada, 2011] The sand is surrounded by a thin water layer, and these sand-water droplets are emersed in a bitumen film, as depicted in figure 2. Bitumen, on the other hand, is a hydrocarbon that fulfills two conditions, according to World Energy Council [2010]:

$$\eta \geq 10\,\mathrm{Pa} \cdot s$$
$$\rho \geq \rho_{(H_2O)}$$

η and ρ are viscosity and density, respectively. A comparison to other fluids can be seen in figure 3. In more colorful words, bitumen is more fluid than chocolate, but less fluid than peanut butter and it sinks in water. It is important to understand that bitumen is confined by its density *and* viscosity, whereas heavy oil is petroleum with $\rho > 900kg/m^3$ irregardless viscosity. Therefore, all bitumen is heavy oil, but not all heavy oil is bitumen. [Centre for Energy, 2013a]

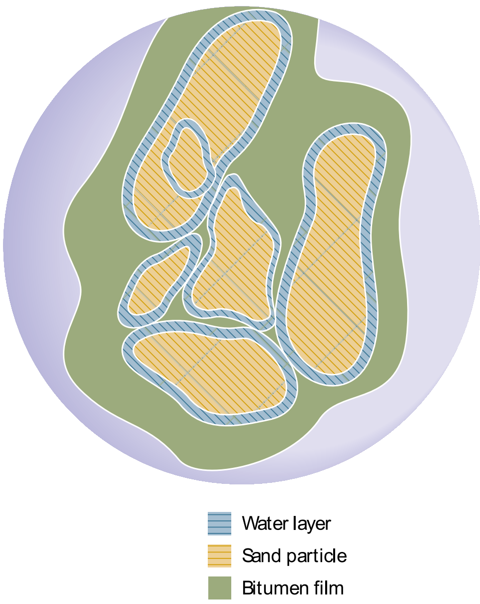

Figure 2: Oil sand structure. Adapted from [Centre for Energy, 2011]

Consisting of long chains of carbon, bitumen is characterized by a low ratio of hydrogen-to-carbon. Thus, the chemical binding energy stored per mass is rather low,

[1]The three terms are synonyms. According to [Dembicki, 2011], the choice of terms has historically been cause of political debate.

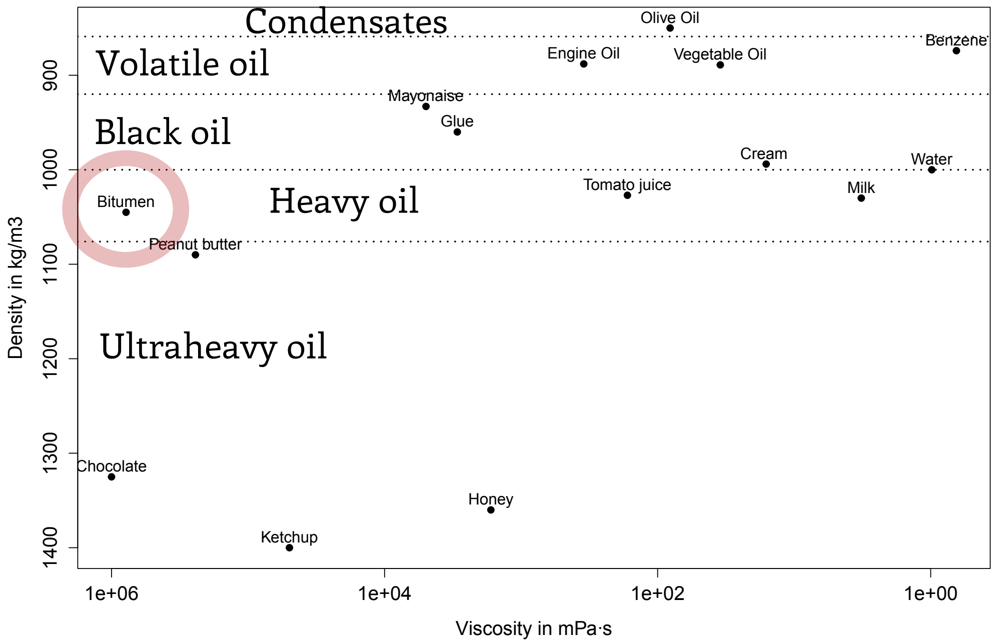

Figure 3: Gravities and viscosities of various liquids. The lines indicate the classification of densities of hydrocarbons according to [McCain, 1990]. Data partly taken from [Curtis and Kopper, 2002], own estimations and other sources. Values should be used as guidance only.

which makes bitumen less attractive for energy purposes than most other hydrocarbons. For the first time in a long row of annual publications, well-cited *World Energy Outlook* [Birol and International Energy Agency, 2012] classifies bitumen and heavy oil extracted from oil sands as an own subcategory within the category of *unconventional oil*. The latter is petroleum that is produced by non-conventional means. *Conventional means* include, for example, traditional oil wells. See figure 4 for a classification tree of liquid fuels.

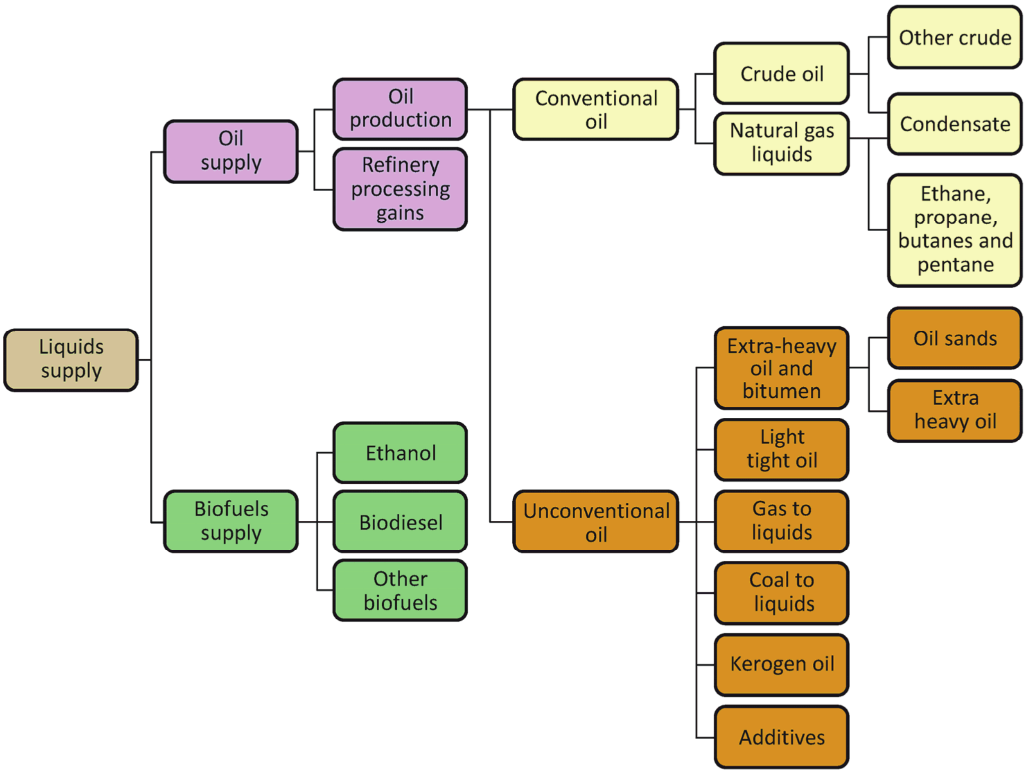

Figure 4: Liquid fuels schematics. Reproduced from *World Energy Outlook* [Birol and International Energy Agency, 2012]. Although the schema might have some insufficiencies, it is published by a large organization, and thus has a lot of readers. Insuffiencies (among others) are *a)* a graphical suggestion that "Unconventional oil" belongs to "Biofuels supply", *b)* its use of "Other" without explicitly explaining the reason and *c)* establishing a division of "Extra-heavy oil and bitumen" into "Oil sands" and "Extra heavy oil". This division is misleading and wrong: There is no such product as "Oil sands" and almost all of the oil produced from oil sands is extra-heavy.

2.2. Occurrence, reserves and resources

2.2.1. Resources and Reserves

Prior to explicating the whereabouts and quantities of oil sands, a few clarifications of terms might be beneficial. Oil is usually measured in barrels. 1 barrel $\approx 0.159m^3$. *Barrel* is abbreviated *bbl*, due to rather unknown reasons.

Year	Author	Estimate in EJ	Estimate in Gbbl
1974	Thomas	1840	298
1977	MIT	1840	298
1978	WEC Delphi Poll	1360	221
1978	Ezra	502	81.4
1981	Qadeer	918	149
1982	Fraas	1800	292
1985	Edmonds and Reilly	3790	614
2002	Bentley	4900	794

Table 1: Estimates of global ultimately recoverable resources of bitumen according to Dale [2012]. Barrels are calculated assuming an energy content of 6,16 GJ per barrel following The Oil Drum [2008].

Resources are discovered and undiscovered volumes of a certain raw material within a certain area, irregardless of any feasibility of recovery.

Reserves are those discovered volumes that are assumed to be recoverable profitably at certain market conditions.

Ultimately Recoverable Resources is an estimate of those volumes of a certain raw material that will have been produced by humanity, past and future.

These definitions and other frequent terms follow, among others, Aleklett et al. [2012] and ASPO International [2012]. A graphical categorization can be found in figure 5.

Estimates of remaining resources bring along a few difficulties: Estimates seldomly distinguish between extra heavy oil and bitumen. Since bitumen *is* heavy oil exceeding a certain viscosity, a geological survey focusing *only* on bitumen is probably impractical. Furthermore, only relatively few estimates of total *ultimate resource potential* are available. The largest compilation of global estimates so far has been conducted by [Dale, 2012] and cites 8 different estimates, ranging from 50 to 800 Gbb (table 1).

Additionally, there are estimates for global oil sands and oil shale resources, given in table 2. Although the total quantities do not give much information about possible production rates, the picture is clear: Canada, the US and Venezuela have the largest part of global reserves of bitumen.

Regarding Canadian resources and reserves, the latest estimate can be found in [National Energy Board Canada, 2011]. Its numbers are reproduced in table 3. It may be interesting to point out that the estimate assumes no undiscovered resources. This correlates well with the fact that oil sands are comparably easy to find. Since the large numbers in the table may be hard to grasp, figure 6 aids as a visualization.

The conclusion derived from the numbers should be that *(a)* Canada has vast amounts of oil sands left, and *(b)* the discussion should not be about the size of the resources, but about *the development of the production rate* and about *energy content after deduction of energy input*. The latter concept has recently been introduced as *EROI* (Energy Return on Investment). Since products produced from oil sands lack good estimates of EROI, this report will treat the topic barely superficially. See Hansen and Hall [2011] for a proper introduction to the topic.

Country/Region	Reserves in Gbbl	Remarks
Canada	2520	Ultimate volume in place
	1630	Initial volume in place
	308	Ultimately recoverable
	162	Proven reserves
US	2000	Ultimate volume in place
	100	Proven reserves
Venezuela	1180	Volume in place
	235	Recoverable volume
Former Soviet Union	1170	Initial volume in place
Morocco	700	
Jordan	350	
Australia	50	
Nigeria	43	Initial volume in place

Table 2: Estimates of global oil sands and oil shale resources according to Oil and Energy Trends [2006].

Category	Gbbl
Discovered resources	315
Undiscovered resources	0
Ultimate potential	315
Remaining ultimate potential	307
Initial reserves	177
Cumulative production	7.51
Remaining reserves	169

Table 3: Canadian Resources and Reserves of oil sands. Taken from [National Energy Board Canada, 2011]

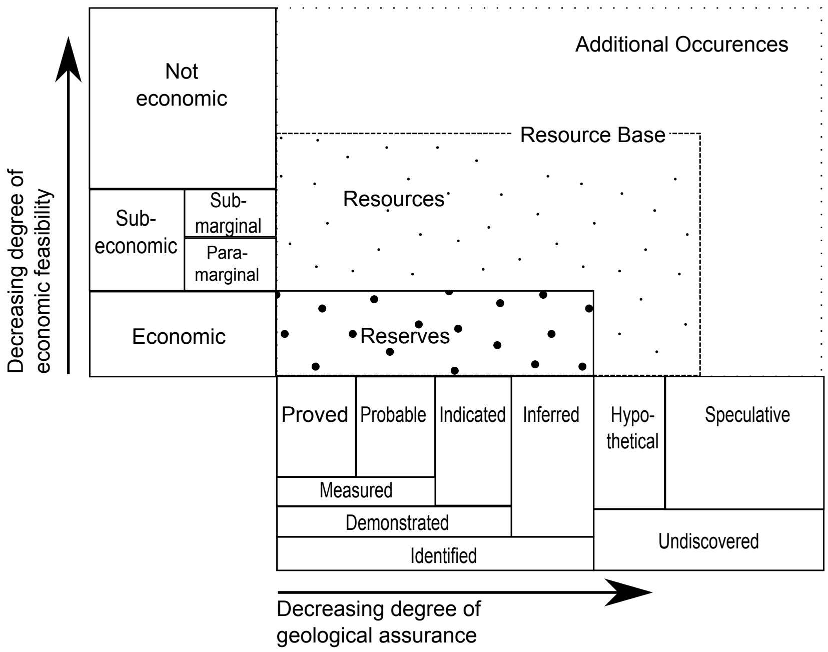

Figure 5: McKelvey box explaining the relationship of quantities and costs of hydrocarbons. Copied and redesigned from [Rogner, 1997], who adapted the box from [McKelvey, 1972].

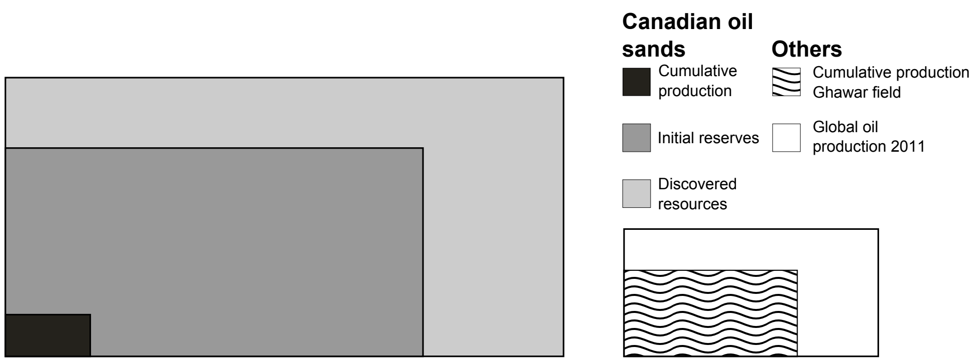

Figure 6: Oil sand resources, reserves, cumulative production and two other values in scale for comparison. Numbers from table 3. Values of the Ghawar field taken from [EPC Engineer, 2012]. Value of global oil production from [Birol and International Energy Agency, 2012].

2.2.2. Locations of oil sand projects in Canada

The heavy oil found in the Albertan oil sands is assumed to be "old oil" that has migrated more than about 100 kilometres eastward (see figure 7). This happened rather recently seen in geological time scales, about 50 million years ago. As the sandstone formations of Alberta provided very suitable environments, the mix of hydrocarbon chains stayed there and the lighter, shorter and energy rich parts of the mix were consumed by micro-organisms converting it into the heavy oil we can find today. The loss of volume during this"digestion" is estimated to be between 50% and 70%. The remains are still large in quantity, but consist of longer hydrocarbon chains and resources are more scattered. While conventional oil is accumulated under layers of impermeable cap rock in reservoirs, heavy oil is not constrained to these reservoirs and can be found in immediate proximity to ground level. [Centre for Energy, 2012; Baturin-Pollock et al., 2010]

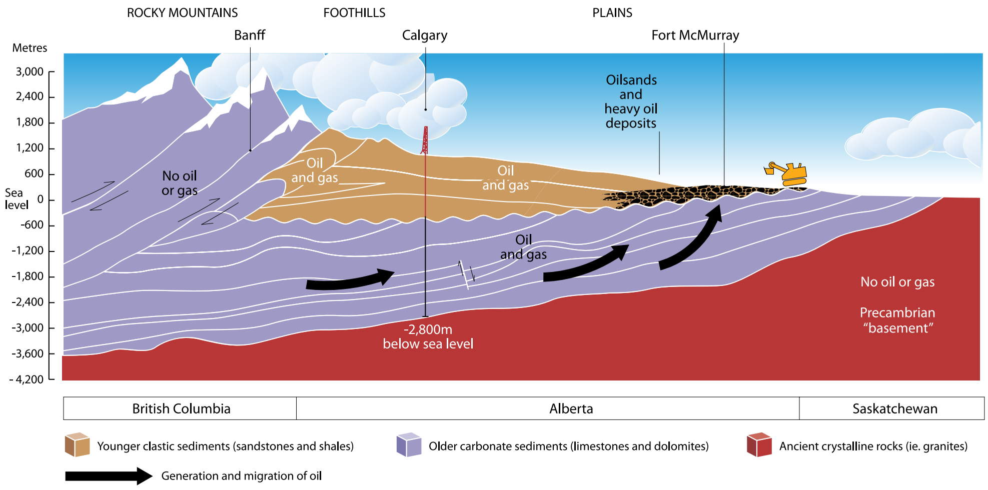

Figure 7: Illustration of the migration of oil and the formation of of Canadian oil sands. Adapted from [Centre for Energy, 2011]

The Canadian oil sands are almost exclusively located in the province of Alberta. As the map in figure 8 shows, the oil sands cover large areas of the province. For the purpose of this report, a number of projects have been located and their locations are provided online as a file [Hehl, 2012]. This file is encoded in xml and is readable by any geographical information software, for example Google Earth or ArcGis[2]. Though not as open source as desirable, the *Oil Sands Information Portal* [Alberta Environment and Sustainable Resource Development, 2012] is a recent undertaking in assisting to find and learn about projects.

[2]If travelling to Alberta is too time consuming, expensive or difficult, it is highly recommended to inspect a few projects using satellite pictures. Simply open the file within Google Earth and get a feeling for the impact of the industry on the landscape or the size of the projects

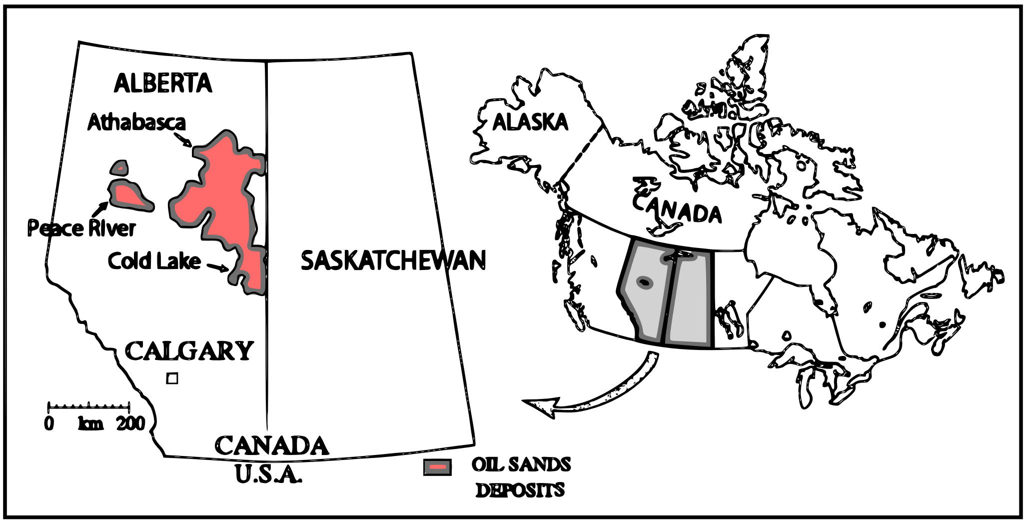

Figure 8: Map of oil sands deposits in Canada. Adapted from [World Energy Council, 2010]

2.3. *Extraction of hydrocarbons from Oil Sands*

In contrast to conventional oil, the extraction of bitumen from oil sands and its conversion to useful products follows more complex patterns.

2.3.1. *History*

The bituminous oil, sticky and viscous, has been known to the aboriginal peoples of Canada for an uncertain amount of time, probably since the first settlements. The first European record is from 1719, when Henry Kelsey, Manager of York Factory on Hudson's Bay, received a sample of oil-saturated, bituminous sand from a Native. But it was not until 1875 that the first geological survey of the Athabasca region was conducted, which registered locations for possible production. But interest remained low until the 1950s when an Alberta Government report proposed a probable profitability of oil sands production. In 1967 the *Suncor project* commenced production and became the world's first oil sands operation. [CAPP, 2012c; Syncrude Canada Ltd., 2012; Hein, 2000]

The Canadian oil sands have been considered to be explored in great detail for several decades. In fact, since the large survey by Dusseault [1977], not much information had to be added or supplemented as can be seen in the more recent geological assessment done by Baturin-Pollock et al. [2010].

2.3.2. *Extraction: Mining*

Mining the oil sands of Canada utilizes some of the biggest machines known to mankind and impacts some of the largest areas on earth. Where the layers of oil drenched sand are not to deep, surface mining is possible. As depicted in figure 9, the process follows several steps. [Alberta Chamber of Resources, 2004; Centre for Energy, 2012]

1. Before commencing the mining process, the forest on top is cleared.
2. The overburden is removed with truck and shovel and disposed of in the pit or outside of the pit.

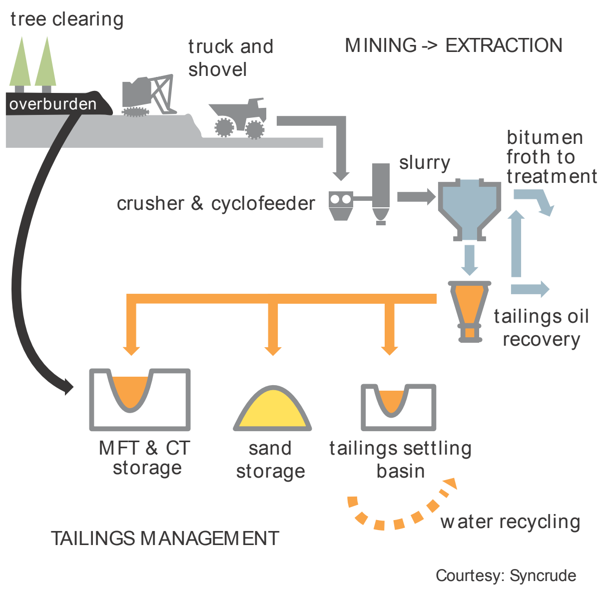

Figure 9: Mining process. Adapted from [Alberta Chamber of Resources, 2004]

3. The sand is transported to the crusher, where it is crushed into smaller parts, mixed with water, heated and *slurried*[3] to enable hydrotransport through large pipes. The temperature of slurry during that transport ranges between 35°C and 50°C.
4. At the seperator, the slurry is sometimes mixed with caustic soda to facilitate the separation into sand, water and *froth*[4].
5. After primary separation, the fraction of bitumen in the froth is further increased by inclined-plate-separation or centrifugal forces.
6. Additionally, the sand and water go through cleaning processes and are then recycled into sand dumps to go back into the transport process. Waste water is let into retailing ponds where it remains for several years.

2.3.3. Extraction: In-Situ

In-situ extraction is the extraction of hydrocarbons without removing the sedimental layer of the reservoir. The most common of the methods applied is *Steam Assisted Gravity Drainage* (SAGD) and will be described here. To follow the reading, an illustrative animation has been produced by Statoil Canada [2012].

The idea to the method was first presented in 1978 and reached commercial viability at the end of the 90s. Since then, this type of extraction has dominated the expansion process of the industry and will soon surpass mining production. [Deutsch and McLennan, 2005]

The process is relatively straight-forward and is depicted in figure 10:

[3] *slurry* is a suspension of insoluble particles in water
[4] *froth* is a foam-like substance

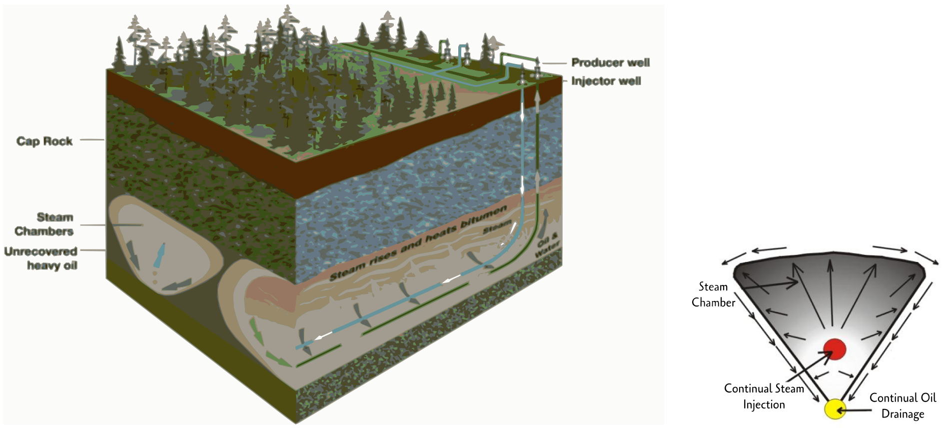

Figure 10: The *Steam Assisted Gravity Drainage* (SAGD) process. Adapted from [Desiderata Energy Consulting Inc., 2012]. Schematics of SAGD. Adapted from [Deutsch and McLennan, 2005]

1. Using horizontal drilling techniques, two parallel bore holes are drilled with a few meters vertical distance and create two wells.
2. Steam is pumped down the upper well to create a steam chamber.
3. The bitumen in between the sand grains is heated, which reduces its viscosity.
4. Due to its high relative density, the bitumen flows down towards the lower well.
5. The bitumen is pumped up to the surface and transported to the next seperator.

Historically, the steam has been produced using natural gas as an energy source. Since natural gas often has been an unwanted byproduct of conventional oil production, it has been rather cheap. Currently small-scale fission reactors are developed to replace the natural gas. The feasibility is discussed in section 5.2.

2.3.4. Upgrading

Conventional oil refinieries are not designed to treat oil with high densities[5]. Therefore, a large fraction of the bitumen is upgraded into *Synthetic crude oil* (SCO) to increase value and enable transportability.

The upgrading-process is depicted in figure 11. Bitumen contains hydrocarbon-molecules with a molar mass of $\geq 400\ u$ with a very low hydrogen-carbon ratio, so one of the main goals of the upgrading process is to *crack* these molecules and add hydrogen at the "open ends" to increase the intrinsic binding energy per mass. This cracking is done by either *coking* (reducing carbon content) or *ebullated bed hydroprocess* (adding hydrogen taken from natural gas).

In addition, the sulfur-, nitrogen, vanadium- and nickel-content of the products is reduced. Then naphta (light oil with about 5-12 carbon atoms) is added to decrease viscosity. A more detailed description of the process can be found at [Gray, 2001].

[5] more specific, they are designed to be able to treat oil with a density $\leq 950 \frac{kg}{m^3}$.

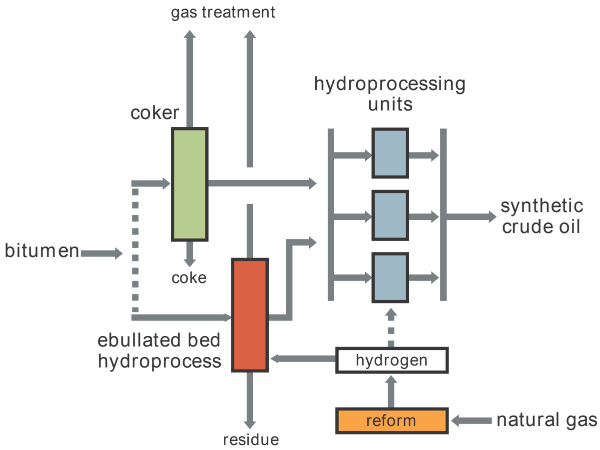

Figure 11: Production of Synthetic Crude Oil. Adapted from [Alberta Chamber of Resources, 2004]

Due to the character of the upgrading process, upgraders use large amounts of natural gas and/or energy. The volume ratio V, defined by

$$V = \frac{\text{produced SCO}}{\text{used bitumen}}$$

is estimated to be $V \approx 85\%$ [Méjean and Hope, 2008]. This should be kept in mind when comparing SCO-production volumes with bitumen production volumes.

2.3.5. Transportation

Pipelines are the most efficient way to transport oil products, and in fact, 95% of the Canada's oil and gas is transported via pipelines [Centre for Energy, 2013b]. To give a detailed description of the many pipelines and refineries in North America would exceed the scope of this report, but a comprehensive and exhaustive map is given in the appendix of CAPP [2012b]. In the same report, proposed pipelines are listed.

But, as Aleklett [2013] recently has pointed out, transport capacity should be analyzed with caution: Since bitumen uses naphta as a diluent, a lot of the pipeline capacity is used just for the transport fluid, which in turn should not be confused with production volumes.

3. Evaluation of historical prognoses

3.1. Oil Sands Tools

Since there are a large variety of standards among the data sets, the largest task has been to standardize available data into a single set. To achieve this and to reduce the amount of work for possible future additions to the data set, the development of a software package within the *R*-environment [R Core Team, 2012] was considered appropriate. The resulting package OilSandsTools is open-source and can be inspected and downloaded from GitHub [Hehl, 2013].

The main work flow of the program is depicted in figure 12 and will be described below.

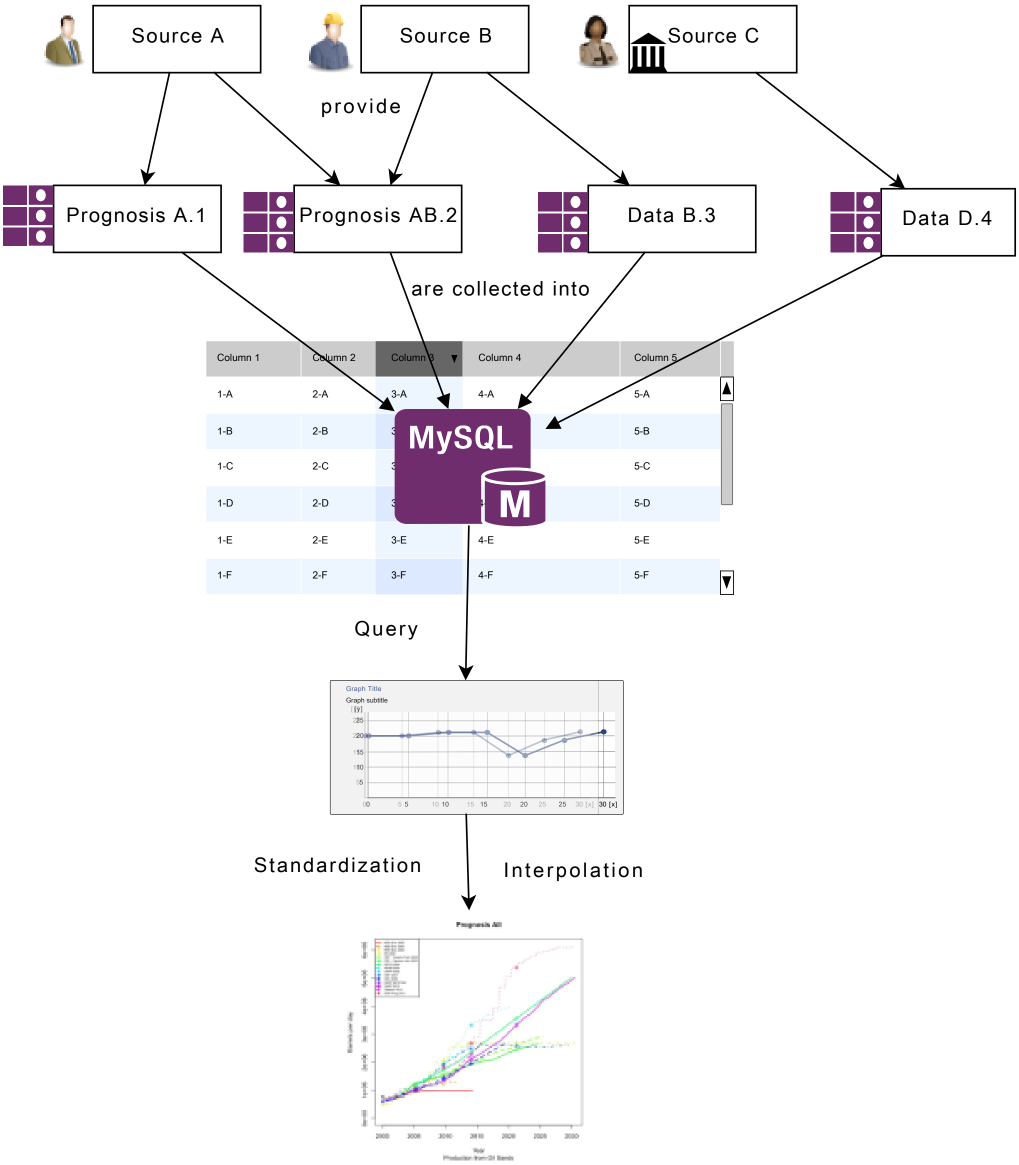

Figure 12: Work flow of OilSandsTools

3.1.1. Data gathering

The largest fraction of OilSandsTools is devoted to collecting data from several sources and creating a common database for all of them. The sources are handled in more detail in section 3.2.

To add the data from a certain source into the database, several steps have to be done.

1. Determine the date, author and origin of the source. Sometimes reports don't mention their date of publishing (e.g. [TD Securities, 2002]), sometimes reports cross-reference to or copy from other reports without explicitly mentioning. Sometimes the original source is not freely available, but is reproduced in a presentation or executive summary, e.g. the prognosis of Millington and Mei [2011] can be found in a presentation given by Millington [2011].
2. Determine the most usable data given by the source. In some cases, the same data is given at different places within the same report or on the same website with varying accuracy, units, temporal frequency, or in respect to different definitions of product types.
3. Copy & paste the data into a text-file, depending on how data is given:
   (a) If the data is given as a table, it usually can be pasted directly into a textfile and conversion will happen later on.
   (b) If the data is given graphically, first a picture has to be extracted using a pdf-reader. Then the numbers can be extracted using the extraction tool WebPlotDigitizer [Rohatgi, 2011].
4. Write a script that converts the content of the text file into unique data rows as depicted in figure 13 and test the script for consistency.
5. Reconcile[6] the names of companies and projects into a single, unique value using Google Refine [Google Project Hosting, 2012a].
6. Attach each project or row to a *Main Compilation* to be part of a larger compilation.

Main.Compilation	Project	Company	Dates	Value	Unit.Def	Product	Data.Source	Time.Interval	Data.Source.Year	Data.Type
environment.alberta.ca 2012	Cliffdale Pilot	Baytex Energy Ltd.	2007-07-01	1,878.00	Production (m3) - Bitumen (per year)	Bitumen	http://environment.alberta.ca/	12	2012	Historical
environment.alberta.ca 2012	Cliffdale Pilot	Baytex Energy Ltd.	2008-07-01	7,003.00	Production (m3) - Bitumen (per year)	Bitumen	http://environment.alberta.ca/	12	2012	Historical
environment.alberta.ca 2012	Cliffdale Pilot	Baytex Energy Ltd.	2009-07-01	426	Production (m3) - Bitumen (per year)	Bitumen	http://environment.alberta.ca/	12	2012	Historical
environment.alberta.ca 2012	Cliffdale Pilot	Baytex Energy Ltd.	2010-07-01	2,835.00	Production (m3) - Bitumen (per year)	Bitumen	http://environment.alberta.ca/	12	2012	Historical
environment.alberta.ca 2012	Cliffdale Pilot	Baytex Energy Ltd.	2011-07-01	6,756.00	Production (m3) - Bitumen (per year)	Bitumen	http://environment.alberta.ca/	12	2012	Historical

Figure 13: Sample data rows of the database.

3.1.2. Update of Data

Some of the sources update their data regularly and for these the script has been programmed to be adaptive. A description of how to update data is given the header of those text files that are updateable. The text files are found in the subfolder *sources* and updateable files contain the suffix *updateable* in the file name.

As a lot of the input data changes shape, place and often hides behind manual query interfaces, the project of implementing a method to automatically download data and update the database had to be given up. Enquiries to ease server access for dynamic and automatic html-download remain unanswered.

[6] "a semi-automated process of matching text names to database IDs" [Google Project Hosting, 2012b]

3.1.3. Conversion

Since input data is not standardized, conversions have to be made to allow for comparison and compilation.

- All the units are converted to *barrels per day of bitumen* (where 1 bbl $\approx$ 0.159 m^3).
- Values reported as the cumulative production of a certain time period or as an average daily production of a certain time period are converted into the production value of the middle point of that time period, using the shortest period available. Although this gives the improper impression of high accuracy, it proves to be most practical when trying to compare data later.

3.1.4. Interpolation

To estimate production at times between data points, interpolation is necessary. To keep the calculations robust and to use as few assumptions as possible, a linear interpolation was considered sufficient for production values.

In the case of the compilation of *project plans* given by TD Securities [2002] and Oilsands Review [2012], a different method has been applied: Each project with a given startup date and a value of nominal production was considered to commence production at startup with the full nominal rate. Where no startup date was given, a rather arbitrary delay of 3 years since commencement of the previous stage of the project was assumed. All projects had a nominal production, so no assumptions had to be made.

These scenarios are thus *"Crash programmes"* as described by Söderbergh et al. [2007] and resemble a maximum scenario. Since the model lacks a project's decline of production, its predictions of upper limits are only valid for short term forecasts.

3.1.5. Combination of production values

In some cases, production data of the oil sands is given as a sum of several different products. In other cases, the data is split into several subgroups of products. To arrive at a total production value, adding and subtracting these values is implemented in the code. For example, [Alberta Energy and Utilities Board, 2005] has given values for their prognosis in terms of *"Mining+In-Situ"* and *"Mining"*. By subtraction, the values for *"In-Situ"* can be found for a potential later study.

In this recombination, the differentiation between values that are zero, and values that are not available, is of importance. If the total production at a certain date is a sum of known and non-existent values, the algorithm has to decide whether the non-existent value should be replaced by `NA` (not available) or *0*. In the former case, the result of the sum will be `NA`, in the latter a valid number. Since many sources do not provide information about the cause of their lacking data, human interpretation is needed. See table 4 for an example.

3.1.6. Calculation of Correlations

To estimate a performance rating of a prognosis, it has to be compared to the actual events during the time it refers to. In the case of OilSandsTools, a script compares an older prognosis of production data to the actual production data that followed the prognosis.

	2008	2009
Mined Synthetic Crude	30492	36112
Mined Bitumen	7831	8097
In-situ Synthetic Crude		274
In-Situ Experimental and Crude Bitumen	31767	33259

Table 4: *CAPP 2012* as an example for a misleading table that needs human interpretation. Is the missing value in 2008 due to missing data or due to no production? Inserting *0* would have been more helpful.

To keep the performance ratio at a rather robust level with as few assumptions as possible, the performance rating is based on a simple linear model:

If X_t is the *predicted production* at the date t and Y_t is the *real production* at t, the relation between Y and X can be formulated as

$$Y_t = \beta_0 + \beta_1(X_t) + \varepsilon_t \qquad t = t_1, \cdots, t_n$$

where ε_t represent errors, β_0 represents the intercept and β_1 represents a real valued factor. The number of data points with a common date is denoted with n.

A linear model minimizes the cumulative error squares $\sum_{t=t_1}^{t_n} \varepsilon_t^2$ and thus, in terms of production, estimates by how much the prognosis deviates from reality. To avoid using a bivariate model, the deviation *historic production data* $\Leftrightarrow$ *reality* was assumed to be small in comparison to the deviation *prognosis* $\Leftrightarrow$ *historic production data*. In the subsequent process, the program derives a linear model for each of the older prognoses in comparison to each of the historical data and stores the model's parameters in a file for later use.

3.1.7. Adjustment of Prognoses

When establishing a prognosis, an author is always bound to have errors in the assumptions or in the model used. If several prognoses are produced over a certain time period by this author, and if the errors in the assumptions or model are introduced randomly, the prognoses will also vary randomly.

Though more likely, the errors in the assumptions or model are introduced with a certain bias. This does *not* necessarily mean that these errors are introduced deliberately. On the contrary: implicit assumption are by definition harder to detect and alter than explicit assumptions.

Since most sources do not give account for or clarify the assumptions used for their prognoses, the only most credible basis for an *"adjustment"* is to use the performance rating of the source and apply this rating on a current prognosis that doesn't bear a rating yet. Applying the linear model based on the available *a priori* knowledge on the prediction that is assumed to bear the same implicit (and imperfect) assumptions will yield both a new estimate for future production and an estimated variance. This method is based on *Bayesian inference* [Gelman, 2004].

The updated *"forecast"* should under no circumstances be considered as an actual forecast, but only as an illustration of historical prognosis performance ratings applied to a recent prognosis. It visualizes the answer to the question:

If source *A* continues to be as inaccurate as it has been, how will future production develop in comparison to Source A's current prognosis?

The results of this adjustment script should be handled with care. Reasons are:

- It neglects a change of the assumptions used, for example new information.
- It neglects the length difference between the time frames of the *base model* and the *adjusted prognosis*.

3.1.8. Plotting

With the help of a manually adjustable spreadsheet, the user can easily define which curves are to appear within the same plot. For each desired *compilation*[7], the user simply needs to add a column title and mark all rows that belong to a certain curve with the letter *"x"*.

When started, the script will automatically plot all compilations with several different time frames and save the plots as pdf-files into different folders in the folder *plots*. More than one thousand pdf-files are created this way, so choosing the right compilations afterwards is essential.

3.2. Sources

Any source that provides numbers, either actual or hypothetical, should be evaluated regarding possible bias or inclination towards certain policies. It is only natural to assume that an industry association might come to other conclusions on a certain topic than an evironmental organization. With no need of accusing any institution of delivering false data, it can be assumed that the differing assumptions on parameters or probabilities of future circumstances can lead to different results.

Therefore all sources are presented below with a short quote from their respective *About Us*-webpage with all wordings removed that can be considered challengable and subjective, such as "wide range of experience".

NEB *National Energy Board*
: Independent federal agency. Purpose: regulate pipelines, energy development and trade in the Canadian public interest.

TD Securities *TD Bank Group*
: Provider of capital market products and services to corporate, government and institutional clients.

CERI *Canadian Energy Research Institute*
: Independent, non-profit research establishment. The Board consists of a politician and members of: Confer Consulting Ltd., Alberta Department of Energy, Imperial Oil Limited, NEXEN Inc., Natural Resources Canada, OSUM Oil Sands Corporation and the University of Calgary.

ACR *Alberta Chamber of Resources*
: Resource based cross-sectoral industry association.

[7] e.g. "In-Situ Prognosis" or "SCO Historical"

Source	Type	Page	Year	Institution/Affiliation
National Energy Board Canada, 2000	D	43,44	2000	NEB
TD Securities, 2002	T	19-24	2002	TD Securities
National Energy Board Canada, 2003	D	56	2003	NEB
Dunbar et al., 2004	T	138-150	2004	CERI
Alberta Chamber of Resources, 2004	D	8	2004	ACR
Alberta Energy and Utilities Board, 2005	D	4, 2.16	2005	AEUB
CAPP, 2006	T	App tabl 1	2006	CAPP
National Energy Board Canada, 2007	D	24	2007	NEB
National Energy Board Canada, 2009	D	20	2009	NEB
National Energy Board Canada, 2011	T	App A3.31	2011	NEB
Millington and Mei, 2011	D	33, 40	2011	CERI
Millington, 2011	D	3	2011	CERI
CAPP, 2012b	T	App B.1	2012	CAPP
Doshi et al., 2012	D	26	2012	Citibank
Statistics Canada, 2012	T	Tab 4.2-2	2012	Statistics Ca
Government of Alberta, 2012	T		2012	Government
CAPP, 2012a	T		2012	CAPP
Oilsands Review, 2012	T		2012	OSR
Birol and International Energy Agency, 2012	T	107, 3.5	2012	IEA

Table 5: Sources of data. *Type* will indicate whether the corresponding data was extracted via **T**ables or **D**iagrams. See 3.2 for further explanations of the sources.

AEUB *Alberta Energy and Utilities Board*
Head of Energy Resources Conservation Board (ERCB), that regulates the development of Alberta's energy resources.

CAPP *Canadian Association of Petroleum Producers*
Voice of Canada's upstream oil, oil sands and natural gas industry.

Citibank Provider of financial solutions in corporate and investment banking, credit cards, consumer finance, investment, leasing and private banking.

Statistics Ca *Statistics Canada*
Canada's central statistical office.

Government *Government of Alberta*
Head of Alberta Environment and Sustainable Resource Development. Protects and enhances Alberta's natural environment, ensures clean and healthy environment.

OSR *Oilsands Review*
Publication on oilsands industry coverage. Reflects interests of oilsands sector and its stakeholders in Canada and around the world including project owners, service and supply companies, investors, governments, communities, First Nations, and environmental groups.

3.3. Evaluable prognoses

In this report, only projections, prognoses and forecasts for the total oil sands production will be reproduced. Although OilSandsTools can distinguish between *Mining*- and *In-Situ*--production and contains plenty of data in its database for each of the production types, the definitions used have differed too much between sources. Some sources distinguished between SCO and bitumen, some between In-Situ and Mining, some between Upgraded and Crude Bitumen and some presented both production from upgraders and individual projects, leading to redundancy when summing up.

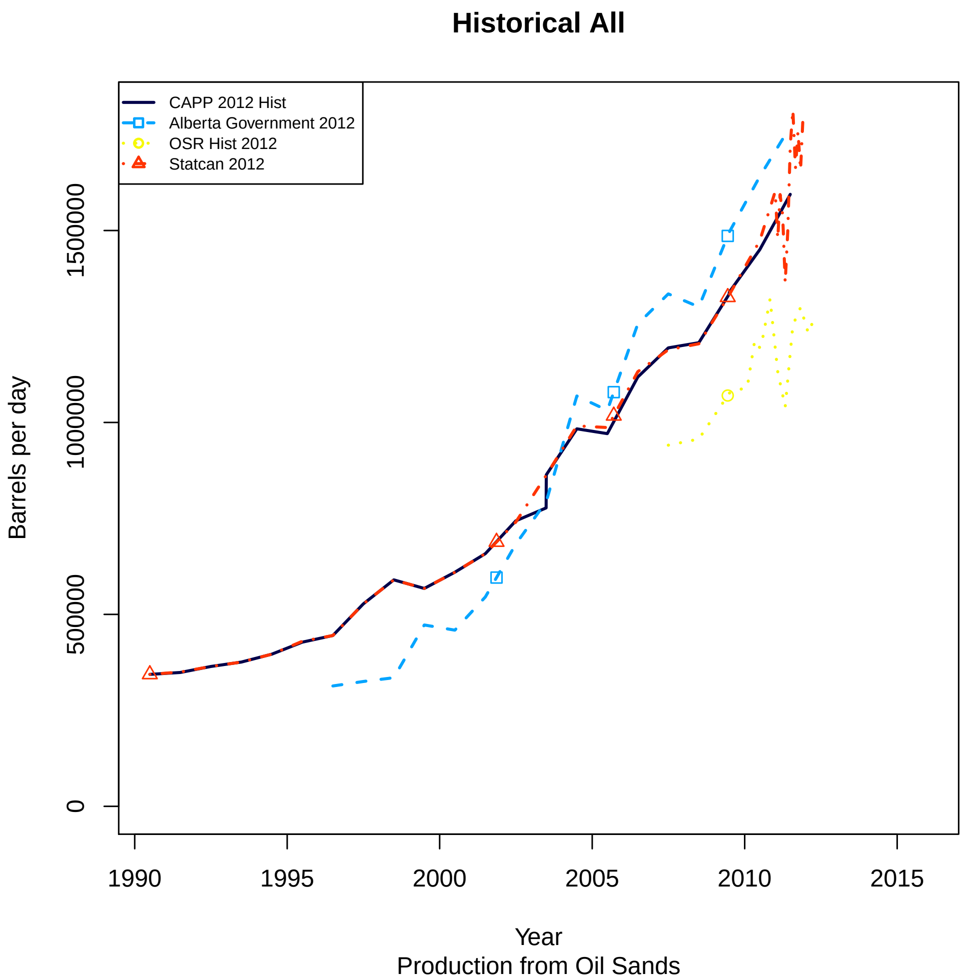

Figure 14: Comparison of the different sources of historical output.

It is unquestionably worth mentioning that some prognoses use differing values for the production that *already was historical at the time of publication.* In other words, sources do not agree on historical production! For example, in figure 15, CERI [Dunbar et al., 2004] has other values for production in the year 2004 than the source that is used for reference throughout this paper, [CAPP, 2012a]. A comparison of the main reporters of historical output can be seen in figure 14. Attempts to find the source of these deviations have been fruitless, but speculations are possible. Varying definitions for the product acoounted for might apply or possibly one of these sources uses estimates without explicitly stating so.

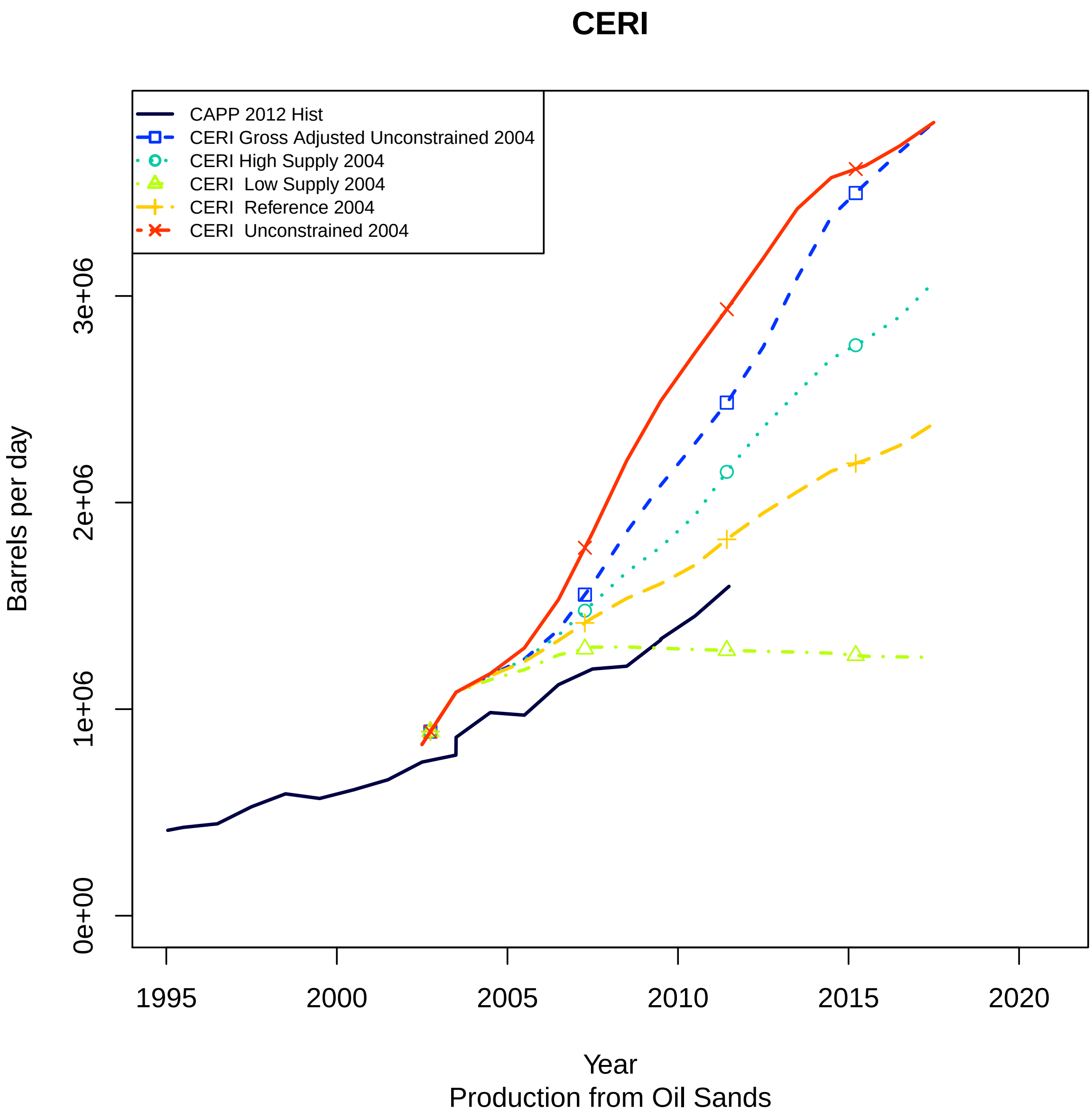

Figure 15: Historical prognoses by the Canadian Energy Research Institute from 2004 in contrast to actual production. The actual production is *CAPP 2012 Hist*.

CERI. As figure 15 indicates, all four scenarios by the Canadian Energy Research Institute from 2004 were severely incorrect. Although the two *Unconstrained*-scenarios were meant to be irrealistic and just were supposed to state an upper limit, neither *High supply* nor *Reference* resembled reality and were over-optimistic. Although the correlation between real production and the *Reference*-scenario is stunning, the catagorical deviation remains unexplained.

NEB. The prognoses of the National Energy Board Canada can be seen in figure 16. The NEB has named their prognoses according to different scenarios: The prognosis from 2000 was build upon varying assumptions of certain margin prices (see 5.2 on page 34), whereas the prognosis from 2003 was specifying different political or intentional scenarios. Since 2007, there has been no scenario differentiation.

Equivalent to CERI, the majority of prognoses has been expecting too much from the expansion. Except for the very old $14-prognosis scenario, all scenarios lie above the reality. Well worth noting is the CEF 2007- scenario, that has missed by large percentages.

Others. See figure 17.

IIR 2002 was at the time of its creation a compilation of all the projects known up to that point. The project plan assumes a certain start date for each project (either the one given or with an algorithm) and lets each project start off at its full capacity. Delays or cancellations do not occur and no production declines. That, of course, creates values well above any realistic scenario, but can nevertheless be used as a maximum case of an expansion. There is a realistic risk of stakeholders quoting these maximum values without further consideration of probabilities, but the comparison of *IIR 2002* with the real production should suffice as a retort to falsify the realism of these scenarios.

OSTR 2004 The prognosis in the report *Oil Sands Technology Roadmap* should be examined with caution: It simply assumes a linear increase between 2000 and 2030. This is, by all means, highly unlikely and the curve has only been included to show that extreme simplifications do occur among prognoses.

AEUB 2005 This prognosis is done by the Government of Alberta and is rather optimistic. A close examination shows that it differs on the volumes produced already *before* the date the prognosis was made. The reason for this deviation is unclear.

CAPP 2006 Not very surprisingly, yet comfortingly, CAPP's prognosis does *not* deviate from its own values on historical production while reproducing values before its publication date. This is evidence for the theory that the inconsistencies in historical data are not produced by the analysis program itself, but lie within questions of definitions of oil sand production. CAPP's prognosis forecasted a rapid expansion of the market. But a quick inspection gives an overestimate by the factor 1.6 for the year 2012, which translates to about 1 Megabarrel per day error over 6 years.

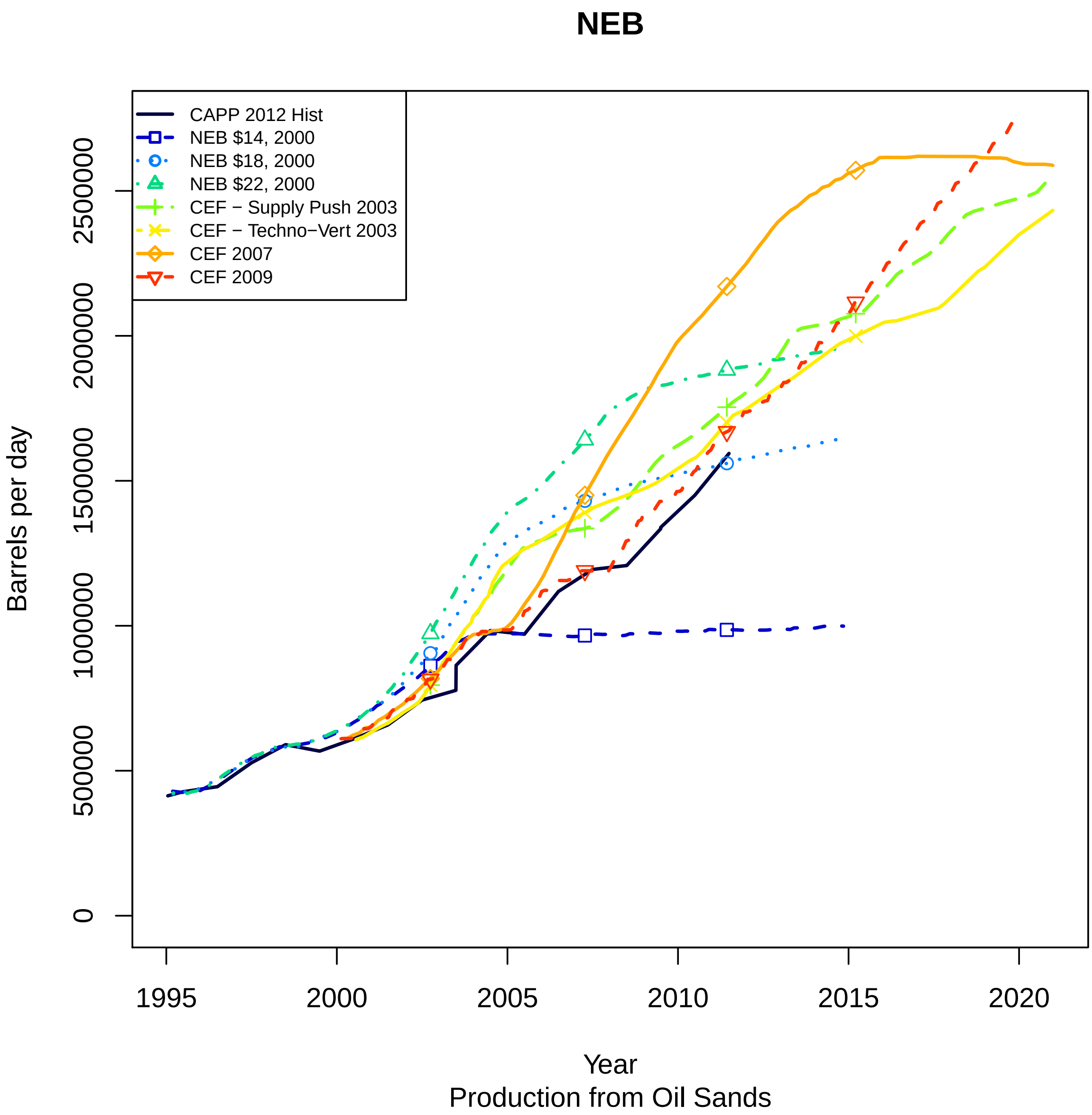

Figure 16: Historical prognoses in contrast to actual production. The abbreviation “CEF” refers to “Canada’s Energy Future”, a report regularly published by the NEB. The actual production is *CAPP 2012 Hist.*

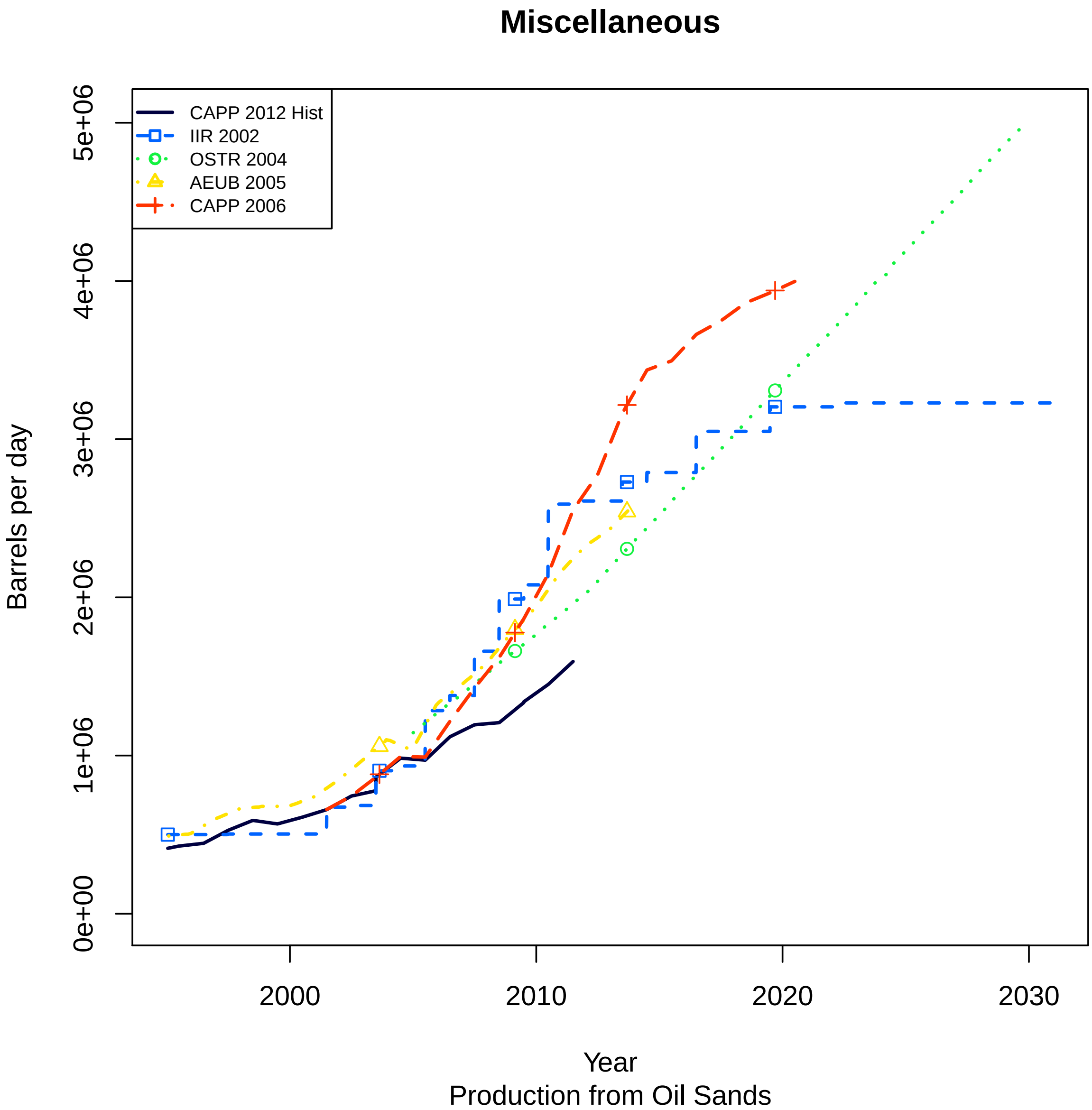

Figure 17: Historical prognoses in contrast to actual production. The actual production is *CAPP 2012 Hist*. Observe the longer time scale.

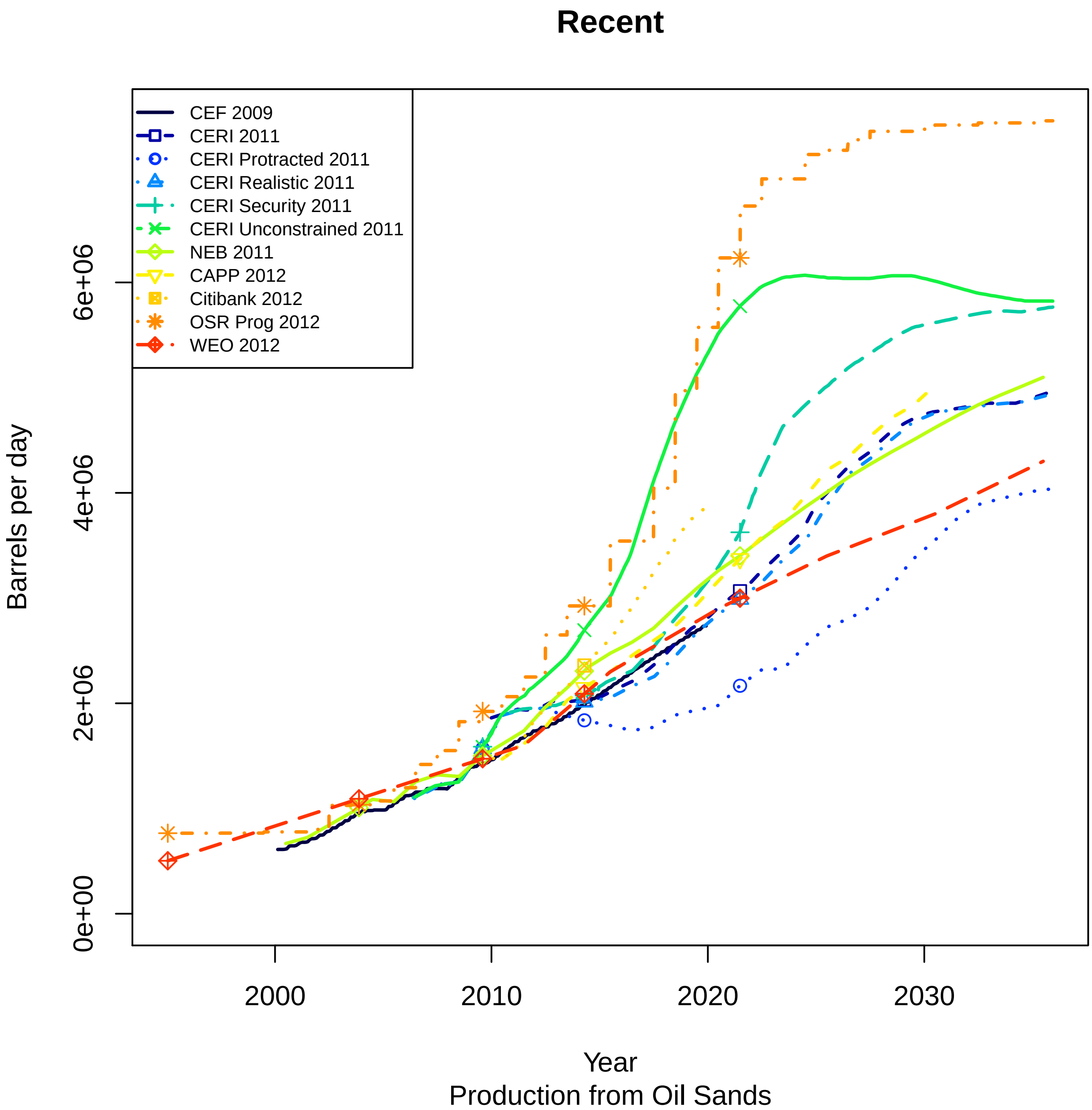

Figure 18: Recent prognoses on the oil sand production. In the middle of 2012, the production was 1,6 Gb.

4. Recent expectations on future production

The overview over the current expectations on the future oil sand production in figure 18 shows that all authors agree on an increased production during the coming decades. Although some scenarios are explicitly marked as hypothetical (CERI Unconstrained 2011), special cases (CERI Security) or simply are a accumulation of all projects that are at least announced starting at a given or simulated date (see section 3.1.4 for more details), there is little doubt that the gross of prognoses can be called “optimistic”. Discounting the special cases above, CAPP 2012 is the most optimistic one expecting about 3 Gb in 2020 and more than 5 Gb in 2030. CERI Protracted 2011 is a “crisis”-scenario, accounting for a situation where the industry faces serious problems. Although constituting the lower end of expectations, in this scenario the production is still at about 3.5 Gb in 2030.

5. Own expectations on future production

While this report will show no own simulation or forecast due to the complexity of economical, geological, political and social systems, a re-simulation of certain prognoses is undertaken. In addition, the most important factors for the expansion are presented and commented on.

5.1. Adjustments of recent expectations

The re-simulation is based on very simple assumptions:

> Assuming that the recent prognosis A, formulated by author/instituion B performs as well as an earlier prognosis C formulated by author/instituion B performed when compared to real production D, in which interval could we find real production A with a certainty of 95% ?

The results are presented in figure 19.
A few clarifying comments:

1. The interval proposed does *not* take into account temporal development of the systems, but treats all value-pairs (prognosis vs real production at a certain time) with the same weight. As the picture should naturally resemble a wedge, i.e. the interval should increase in size as time increases, it incorrectly resembles a constant interval. This is due to the simplicity of the evaluation, giving an error 5 years ahead in time the same value as an error 1 day ahead in time.
2. Some intervals may seem too narrow, given that the older prognosis deviated heavily from the real production. But since the prediction-algorithm works with a linear model, two curves are considered having a good correlation as long as they differ by a rather constant factor. If, for example, the old prediction C can be expressed by $C \approx \alpha D$ (with D being the real production), the interval of uncertainty around the adjusted curve
$$A_{\text{corr}} = \frac{A}{\alpha}$$
will be very narrow.

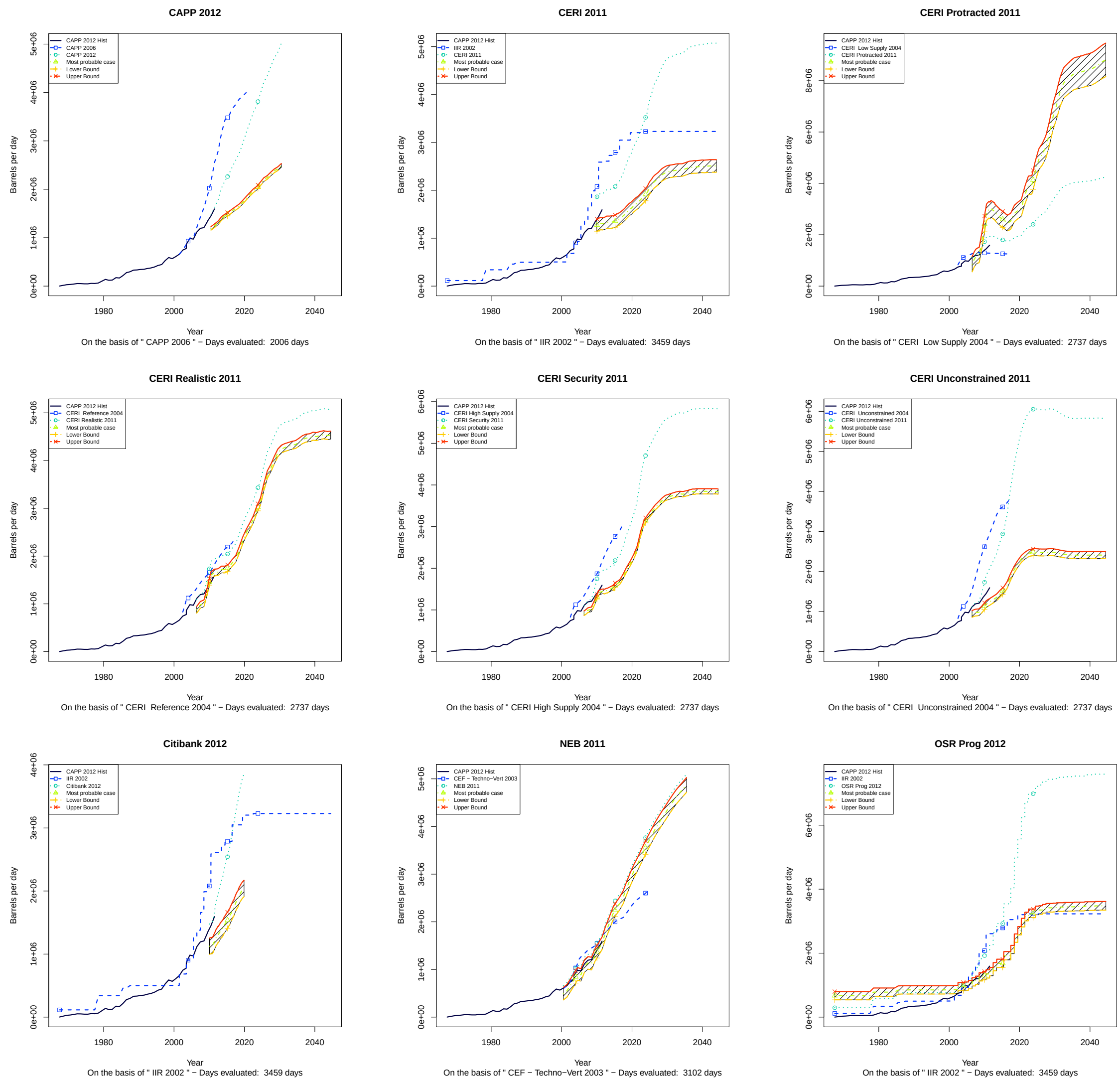

Figure 19: Adjustments of all estimates that could be linked to a historical prognosis. Only *CERI Protracted 2011* was adjusted upwards, i.e. real production was higher than *Ceri Low Supply 2004* predicted. All other prognoses were adjusted downwards, i.e. a similar older prognosis was expecting too high production. Under each graph, the older prediction is given and the number of days of the interval that was evaluated. A larger number of days mean a higher accuracy for the linear model. In the digital version, included and to be found at [Hehl, 2013], this page is zoomable.

3. Strictly speaking, the adjustment should rather be seen as a visualization of the performances of the historical prognoses, than as real “corrections”. The adjustment doesn’t account for corrections and adjustments made by the authors/institutes between subsequent prognoses.

A closer inspection of the adjusted graphs uncovers a clear trend among the older prognoses to overestimate the production. One out of nine prognoses is adjusted upwards. This is evidence for a positive bias of the cited authors towards a high expected production.

5.2. Factors of importance for the industry

The oil sands industry is influenced by a few important factors that limit and influence the development of the expansion. These factors that will be examined here. A very recent report by CERA [2013] has examined this topic profoundly.

Pipelines. The cheapest way to transport SCO is via pipelines. As the local market is to small, most of the products have to be transported long distances, mostly through the Rocky Mountains or to the USA. Very soon the transport capacities will have reached their limits. CERA’s report as well as [CAPP, 2012b] mention 10 pipeline projects related to oil sands going on with a total distance of about 11,000 km. The largest are the *Keystone XL* from Alberta to Texas, the *Northern Gateway* and the *Trans Mountain Expansion*, both from Alberta to the coast of British Columbia for further shipping. All these projects have received major criticism and protests from different stakeholders such as First Nations, locals and environmental organizations. Although American governments do not have a very impressive record of taking these interests into account[8], changing politcal circumstances could have a deep impact on the future of these plans. [Reuters, 2012; Environmental Defence, 2011; CBC News, 2012]

Upgrader and refineries. As [CERA, 2013] evaluates, missing upgraders and refineries could render huge problems for the expansion of the industry: As the US expand their condensate- and shale gas production, only few capacities will be left over for oil derived from Canadian bitumen. Building refineries is very costly and takes many years, so a lack of refining capacity can and probably will impede the rapid expansion of the industry.

Oil Price. As Canadian oil sands are produced at the margins of the current oil price, expansion is highly dependent on the world market. There have been varying estimates on the oil price at which oil sand production is commercially viable, but given the estimate of Méjean and Hope [2008] reporting treshhold prices of lower than US$15, the margin price[9] might not be the most constraining factor for a foreseeable future. On the other hand, investments are heavily dependent on expectations. Regrettably, modelling the expectations of shareholders is beyond the scope of this report.

[8]see [Calgary Herald, 2008] for some insights on Alberta’s former premier Ed Stelmach’s views, that among others include the fascinating quote “It’s my belief that when government attempts to manipulate the free market – bad things happen.” [Katz-Rosene, 2007]

[9]the *margin price* excludes exploration, investments, refinery, taxes and all costs that do *not* arise from the immediate production of bitumen

On the other hand, according to CERA [2013], there are possibilties to export bitumen directly to China and other Asian countries with a growing economy in the future. This can only happen if Asian refining capacity expansion includes the possibility to treat bitumen.

Access to cheap natural gas. Natural gas is used at two stages in the production chain: The steam used in SAGD is usually produced by residual natural gas and in the cracking process at the upgrader. Table 8 shows that current SAGD-projects have to invest about 20% worth of energy content of natural gas into each energy unit of bitumen. Access to cheap natural gas may soon be at risk due to the decline of natural gas production in Canada with a lack of connectivity to the US where gas production has seen a recent upsurge.

As an answer to the possible decline of cheap natural gas, Toshiba and CRIEPI[10] are currently developing a small-scale fission reactor with an estimated output of 40 MW (thermal power accounts for 30MW). It is supposed to be cooled with sodium and will, according to the project plans, have a fuel cycle of 30 years. [International Atomic Energy Agency, 2011; Nishi, 2004]

In a report prepared for the Minister of Energy of Alberta by the Nuclear Power Expert Panel Andre et al. [2009], the use of nuclear energy, regardless of purpose, is highly advocated. In an journalistic analysis, CEO of "U.S.-Central Asia Biofuels Ltd" John Daly Daly [2013] concludes:

> "[...] it seems likely that mini reactors in the Great White North are most likely a done deal."

Additionally, [The Daily Yomiuri, 2013] concludes that the reactors are viable by 2020. Neither the former nor the latter author comment on potential political opposition after the Fukushima Daiichi nuclear disaster.

(a) View over open pit mining area. ©[Romm, 2012]

(b) View over Mildred Lake region. ©[Dodge, 2012]

Figure 20: Views over the mining industry, showing the visual impact on the environment.

Environmental awareness. As with all energy production, oil from the oil sands comes with a price. Although greenhouse gas emissions from in-situ production is substantially

[10] Central Research Institute of Electric Power Industry (Japan)

Conventional oil	0.1
Oil Sands - mining	3.9
Oil Sands - in-situ	0.04

Table 6: GHG emissions per energy output (kg CO2e/GJ) directly linked to land use. This does *not* include the usage of the oil. Numbers according to [Yeh et al., 2010]. Median values of several estimates are given.

lower compared conventional oil production regarding land use (see figure 6), it is still oil that is produced. Contributing to oil production inexorably increases global greenhouse gas emissions. Canada has been one of the driving forces in establishing the Kyoto protocol, but expanding the oil sand industry has made any effort into reducing GHG-emissions futile [Flannery, 2009]. One could argue that in fact the US consume most of the oil produced by Canada's oil sands, but this question goes more into ethics.

An inevetible consequence of the industry is the impact on the environment. As figure 20 impressively shows, during production, not much is left of the boreal forest. Although reclamation is mandatory for companies, there is little doubt that the environment will never return to its initial state. [Woynillowicz, 2005]

To evaluate the impact of in-situ production, table 7 gives key values about the current state-of-the-art production facility, the Leismer project.

6. Discussion

Availability of data. As proposed by [Elliott, 2005], a common, openly accessible database for Oil Sands production should be available. Although Canada's institutions are eager to publish data, a quick and automatic access to a database comparable to *Freebase* [Google, 2012] would simplify the process of making quick and automated analysis. As of today, characteristic numbers such as conversion factors of application status change, production volumes by type of well, performance rating of prognoses, refinery capacity and other interesting features of the oil sands are only available to insiders of the businesss or hidden within reports and non-standardized tables.

It is implausable that the rise of *Big Data* [Executive Office of the President of the US, 2012; White, 2012] should delude the important area of energy projects.

Impact on Peak Oil. The models used in this report are rather simple and work with a lot of assumptions. But they are open and accessible, in contrast to the black boxes of *all* other sources available. It may seem as an “unfair” method to evaluate older prognoses solely on their immediate performance and there are probably some mistakes in the mehtod, but there is no better method available right now. Institutions, authors or companies do not present their algorithms and only very few even provide error bars.

Of course, the financial crisis that started in 2008 had not been foreseen economists and a lot of the prognoses had assumed a constant economic growth and were therefore wrong. But the question remains: Why should a potential expansion of the oil sands industry happen at the rapid pace that many of the presented authors estimate? Why do so few evaluate their old prognoses and see that they were wrong? Which change in their algorithms should give their current prognoses the desired credibility?

Bitumen production	bbl	3 685 738
	bbl/d	10 098.00
Energy consumption		
Natural gas consumption	1000 m^3	131 982
	m^3 / bbl	35.8
Electricity consumption	GWh	48.9
	kWh / bbl	13.3
Flare gas consumption	1000 m^3	90
	l / bbl	24.4
Air		
CO2 emissions	t	267 993
	kg/bbl bitumen	72.71
SO2 emissions	t	48.84
NO2 emissions	t	158.75
Water		
Fresh water use	m^3	357 611
- liquid water	vol (water/bitumen)	0.61
- steam	vol (steam/bitumen)	2.65
Produced water recycle	%	79.61
Disposal water	m^3	160 715
	bbl/bbl bitumen	0.27

Table 7: Key values for the Statoil Leismer project for the year 2011. Taken from [Statoil Canada, 2011].

Energy balance			
1	Feedstock energy of bitumen	MJ/kg	42
2	density of bitumen	kg/bbl	168.54
3	Feedstock energy of bitumen	MJ/bbl	7078.68
4	Energy content, natural gas	GJ/m3	0.0364
5	Natural gas used	m3/bbl	35.8
6	Energy input, natural gas	MJ/bbl	1303.12
7	Ratio Energy (natural gas/bitumen)	%	18.4
8	Electricity consumption	Wh/bbl	13280
9	Electricity consumption	MJ/bbl	47.808
10	Ratio Energy (electricity/bitumen)	%	0.68

Table 8: Energy balance of Leismer project. **1)** [Hammond and Jones, 2011]; **2)** 1060 kg/m^3 * 0.159 m^3/bbl ; **3)** (1) · (2); **4)** [natural-gas.com.au, 2013]; **5)** [Statoil Canada, 2011]; **6)** (4) · (5) · 1000; **7)** (6)/(3) **8)** [Statoil Canada, 2011]; **9)** ((8)·3600 s/h)/10^6 J/MJ; **10)** (9)/(3)

Looking at the data, there is little evidence that an imminent decline of global oil production can be averted by the expansion of the Canadian oil sands.

Applicability to Venezuelas Heavy Oil. As mentioned above, Venezuela's reserves are reported to be 235 Gigabarrels, an amount more than 3 times of what the world's largest oil field has produced up to today [EPC Engineer, 2012]. From the example of Canada, it should be clear that reports of large reserves shouldn't fuel hopes or fears of a large production rate. [Titman, 2010]

7. Conclusions

The hypothesis that *forecasts on the Canadian oil sands published between about 2000 and 2010 have been overestimating production significantly* could be shown to be valid. The compilation shows that most authors tend to overestimate the rate of expansion of the industry. There is little evidence that this over-optimism has changed towards more realistic attitudes, or at least do authors not provide sufficiently good reasons to assume this change.

Therefore, any prognosis on the expansion of the industry should be examined thoroughly before use. As possibilities of use include policy making, global energy systems research or economic decisions, there is reason to believe that the choice of prognosis can be biased towards those prognoses that support a certain cause, for example a dismissal of peak oil theory or assumptions of unrestrained economic growth.

7.1. Suggestions for further research

As mentioned before, there are no clear standards for the publication of production data. Without a consistent interface language usable on the internet, the analysis and compilation of data and prognosis will remain a hideous undertaking prone to errors and misinterpretations. It is therefore advisable to cooperate, comparable to open-source programming projects like *Wikipedia*. As long as the compilation of data involves many manual steps and prognoses are presented without disclosure of any intermediate steps of reasoning, only few people will be able to verify and refine the methods used.

Moreover, research should focus on *datamining* the data available and trying to find interesting patterns. A question to be answered could be "How does In-Situ compare with mining?" or "What are the probabilities of a certain project to achieve x % of its stated nominal output within y *years*?" The latter question would enable Markov Chain simulations or enable boot-strap methods in order to give estimates of confidence intervals.

Last, but not least, the expansion of the oil industry in other areas, mainly Venezuela, should be forecasted with all available knowledge. For this project, and others, the presented program OilSandsTools is offered as a basis for a collaboration on *one* working prognosis, not dozens.

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My two favourite quotations are

> "Quidquid latine dictum sit, altum sonatur."

and

"If I have seen further it is by standing on the shoulders of giants."

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