# EMD Oil (Tar) Sands Committee

## EMD Oil (Tar) Sands Committee Commodity Report - November, 2012

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## Contents



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## Introduction

This commodity commonly consists of heavy oil (tar) in unlithified sand; however, heavy oil reservoirs can also include porous sandstone and carbonates. Oil sands petroleum is named bitumen, tar, and extra-heavy oil, although these accumulations can also contain some lighter hydrocarbons and even gas. Bitumen API gravity is less than $10^{o}$ and viscosity is generally greater than 10,000 centipoises (cP) at reservoir temperature and pressure ; heavy oil API gravity is between $10^{o}$ and $25^{o}$ with viscosity greater than 100 cP (Danyluk et al., 1984; Schenk et al., 2006). Heterogeneity in reservoirs occurs at microscopic through reservoir scales, and includes sediments of variable depositional energy and hydrocarbon composition. Viscosity gradients of hydrocarbons in the Athabasca oil sands of Alberta primarily reflect differing levels of biodegradation (Adams, 2008; Gates et al., 2008; Larter et al., 2008, Fustic et al., in press). Heavy and extra-heavy oil deposits occur in more than 70 countries across the world, with the largest accumulations located in Canada and Venezuela (Dusseault et al., 2008; Hein and Marsh, 2008; Hernandez et al., 2008; Marsh and Hein, 2008; Meyer et al., 2007; Villarroel, 2008).

## Bitumen Resources and Production

Almost all of the bitumen being commercially produced in North America is from Alberta, Canada. Canada is an important strategic source of bitumen and of the synthetic crude oil (SCO) obtained by upgrading bitumen. Bitumen and heavy oil are also characterized by high concentrations of nitrogen, oxygen, sulfur, and heavy metals, which results in increased costs for extraction, transportation, refining, and marketing

than for conventional oil (Meyer and Attanasi, 2010). Research and planning are ongoing for transportation alternatives for heavy crude, bitumen, and upgraded bitumen using new and existing infrastructure of pipelines and railways. Such integration has been called a virtual "pipeline on rails" to get the raw and upgraded bitumen to U.S. markets (Perry and Meyer, 2009). Synthetic crude oil from bitumen and (or) partially upgraded bitumen is being evaluated for potential long-distance transport to refineries in the Midwest and Gulf states of the USA and to existing or proposed terminals on the west coast of North America. Associated concerns include effects on the price of crude oil, and the environmental impacts that are associated with land disturbance, surface reclamation, habitat disturbance, and oil spills or leaks with associated potential pollution of surface and ground waters.

A U.S. goal for energy independence could include production from existing U.S. oil sands deposits using surface mining or *in-situ* extraction. Current U.S. bitumen production is mainly for local use on roads and similar surfaces, partly because the states do not have the infrastructure of the Alberta oil sands area. Schenk et al. (2006) listed total measured plus speculative in-place estimates of bitumen at about 54 billion barrels (BB) for 29 major oil sand accumulations in Alabama, Alaska, California, Kentucky, New Mexico, Oklahoma, Texas, Utah, and Wyoming.

Alabama in-place oil sand resources are about 1.76 BB (measured) and 4.6 BB (speculative) from Mississippian sandstone and limestone over an area of about 2 million acres in the northern third of the state (IOCC, 1983). The North Slope of Alaska is estimated to contain 10 BB of in-place tar sand and heavy oils in Cretaceous and Tertiary sands over an area of about 200 square miles of, based on limited data (IOCC, 1983).

The total in-place Alaska resources are 15 BB based on Schenk and others (2006). California in-place oil sand resource estimates are about 1.91 BB measured and 2.56 BB speculative (IOCC, 1983; Schenk and others, 2006). Most of the tar deposits are within Upper Miocene shale to sandstone strata and proximal to the southwest coast (IOCC, 1983). In-place tar resources within Late Mississippian and Early Pennsylvanian sandstone outcrops cover an area of more than 600,000 acres in the western half of Kentucky and are estimated to exceed 1.7 BB (IOCC, 1983) to 3 BB (Noger, 1999). Oil sand accumulations in east central New Mexico total in-place measured and speculative resources of 130 million barrels (MB) and 190 to 220 MB, respectively, within Triassic Santa Rosa Sandstone (IOCC, 1983; Schenk and others, 2006) at depths of less than 2,000 ft. (Broadhead, 1984). Speculative in-place oil sands resources total 800 MB for Oklahoma (IOCC, 1983; Schenk and others, 2006). Oil sands are located mostly within Ordovician Oil Creek Formation sandstones and Viola Group limestones, with lesser accumulations in Mississippian through Permian sandstones (IOCC, 1983). A bibliography of Oklahoma asphalt references through 2006 (B. J. Cardott, compiler) is downloadable from http://www.ogs.ou.edu/fossilfuels/pdf/bibOkAsphalt7_10.pdf . Measured in-place bitumen in southwestern Texas is 3.87 BB and speculative is 910 to 1,010 MB, from three major deposits in Cretaceous limestone and sandstone (IOCC, 1983; Schenk and others, 2006). Utah has the largest number of occurrences and total size of U.S. oil sands; they are located mainly in the Uinta Basin of northeastern Utah (Blackett, 1996), and in central southeastern Utah (http://geology.utah.gov/emp/tarsand/index.htm). Utah oil (tar) sands in-place resources range from about 11.9 BB measured and 6.8 BB speculative (IOCC, 1983) to 14-15 BB

in place and 23-28 BB potential (Gwynn, 2007; Gwynn and Hanson, 2009). Resources are primarily within Permian, Triassic, Eocene, and Oligocene non-marine sandstones (IOCC, 1983, Gwynn, 2007; Gwynn and Hanson, 2009). In-place resources for two oil sand accumulations in Wyoming total 120 MB measured and 70 MB speculative (IOCC, 1983; Schenk and others, 2006). The larger accumulation is within Pennsylvanian-Permian sandstones of the Minnelusa Formation in northeastern Wyoming, and the smaller is within Cretaceous sandstones in the Wind River Basin, central Wyoming (IOCC, 1983).

Excellent sources of information on Alberta oil sands are the resource assessments and regulatory information by the Alberta Energy Resources Conservation Board (ERCB) (http://www.ercb.ca/portal/server.pt ). Estimated in-place resources for the Alberta oil sands are 1804 BB (286.6 billion cubic meters (BCM)) (ERCB, 2010, p. 3). Estimated remaining reserves of in situ and mineable crude bitumen is 168.6 BB (26.8 BCM); only 4.6% of the initial established crude bitumen has been produced since commercial production began in 1967 (ERCB, 2012). Most of the in-place bitumen is within unlithified sands of the Cretaceous McMurray Formation of the Mannville Group. An estimated 64.5 BCM is located within carbonates of the Devonian Grosmont Formation, located mainly within the western Athabasca field (ERCB, 2010). Alberta's 2007 crude bitumen production totaled 482.5 MB (76.7 million cubic-meters (MCM)), which was equivalent to 1.32 MB per day (210 thousand cubic-meters per day); of this total bitumen production, 59% (284.7 MB) was from surface mining and 41% (197.8 MB) from *in-situ* production (ERCB, 2008). The bitumen that was produced by surface mining was upgraded to SCO; *in-situ* bitumen production was marketed as non-upgraded

crude bitumen (ERCB, 2008). Cumulative bitumen production for Alberta in 2009 was 302 MB mined and 245 MB *in-situ* recovery (48 MCM mined and 39 MCM, respectively) (ERCB, 2010).

Alberta bitumen production has more than doubled in the last decade, and is expected to increase to greater than 3 MB per day (> 0.48 MCM) over the next decade. Over the last 10 years, the contribution of bitumen to Alberta's total crude oil, raw bitumen, and SCO production has increased steadily. Alberta bitumen and SCO contribution was 62% in 2006, 69% in 2009, and is estimated to reach 86% of cumulative petroleum by 2016, and 89 % by 2019 (ERCB, 2008, 2010). Figure 1 shows the increasing contribution of bitumen and SCO to Alberta's petroleum supply. This production through time is associated in Figure 2 with SCO price.

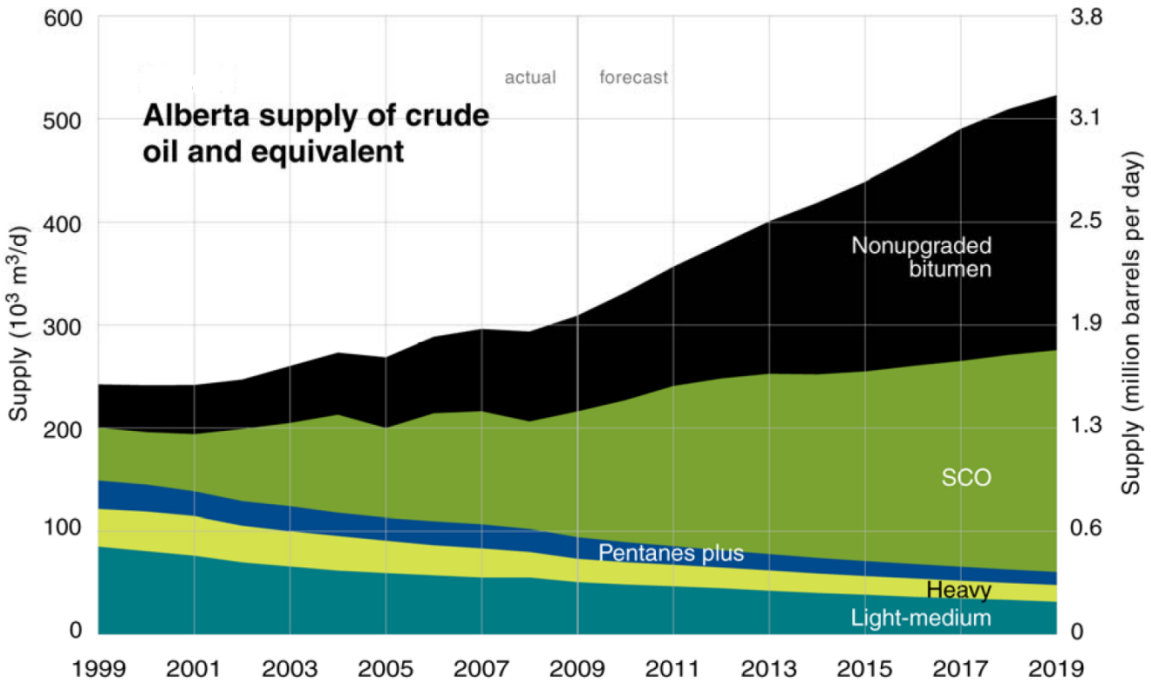

Figure 1. Alberta supply of crude oil and equivalents (ERCB, 2010, Figure 3). SCO refers to synthetic crude oil produced from bitumen.

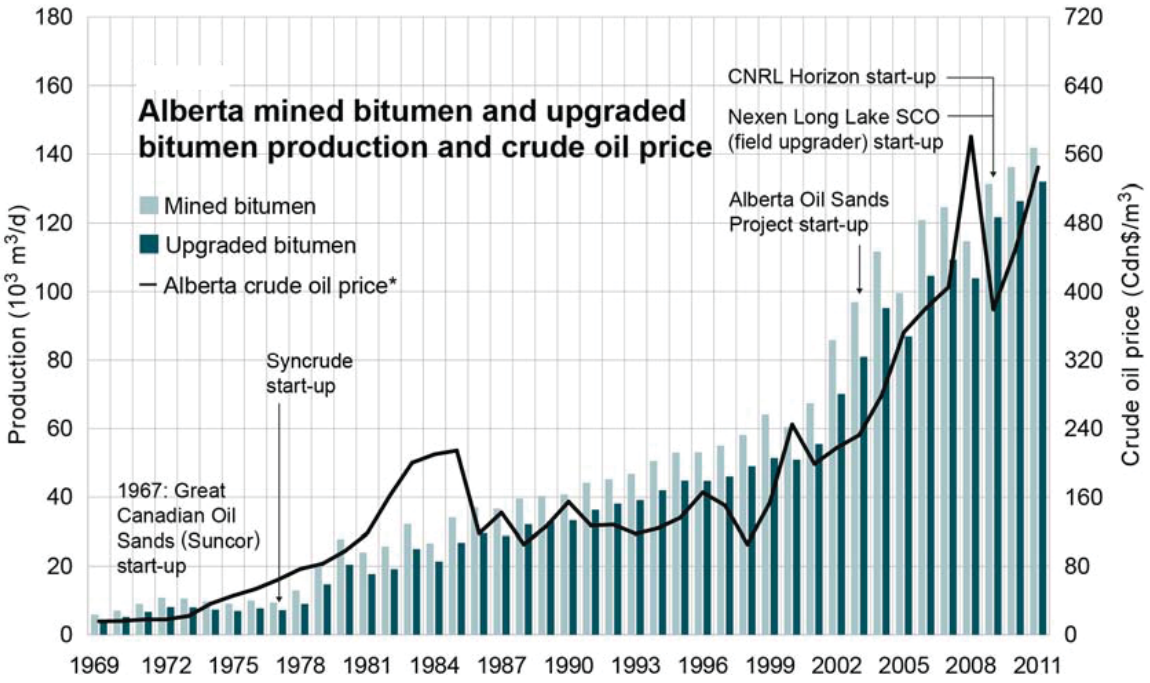


Figure 2. Alberta mined and upgraded bitumen production, and average wellhead crude oil price through time (ERCB, 2012, Figure 6). Start-up times refer to onset of production from various companies and processes.

## Resource Technology

As of December 2008, Alberta bitumen reserves under active development (mainly by surface mining) accounted for only 15% of the remaining established reserves of 21 BB (3.3 BCM). Unlocking the huge potential of the remaining bitumen resources will require enhancing other *in-situ* technologies. The most commonly used *in-situ* technologies are Steam Assisted Gravity Drainage (SAGD) and Cyclic Steam Stimulation

(CSS). SAGD and CSS utilize considerable energy and water to produce steam; also required are good permeability (both vertical and horizontal), relatively thick pay zones (> 10 m), and an absence of barriers (cemented zones, thick laterally-continuous shales) and the lack of significant top/gas, top/lean or bottom water thief zones. Generally the cross-bedded sands of lower point bar depositional environments are characterized by vertical permeability ranging from 2 to 6 Darcie (D). Associated inclined heterolithic stratification (IHS) from upper point bar deposits exhibit a 2 to 3 order of magnitude decrease in permeability, and siltstone in abandoned channel and point bar strata exhibit a 2 to 3 order-of-magnitude decrease in permeability (Strobl et al., 1977; Strobl, 2007, Strobl, in press). Depositional heterogeneities at vertical and lateral scales influence bitumen recovery from in-situ processes. A comprehensive, two-volume edition book entitled: "Handbook on theory and practice of bitumen recovery from Athabasca oil sands" (Masliyah et al., 2011) focuses on the extraction of bitumen from oil sands mainly using surface mining methods, and also includes a chapter on *in-situ* processes. Volume I covers the basic scientific principles of bitumen recovery, froth treatment, diluents recovery, and tailings disposal; Volume II is devoted to industrial practices (editor, Jan Czarnecki, at jc7@ualberta.ca). Some of the focus of recent *in-situ* technology and advances includes:

- Integration of future oil sands technology with that of emerging oil shale co-production in the western United States
- New developments concerning *in-situ* recovery and underground refining technologies for oil sands in western Canada include underground combustion and refining

- Use of Cold Heavy Oil Production with Sand (CHOPS) as a specialized primary type of production where progressive cavity pumps assist in lifting bitumen and sand to the surface, and utilize this sand production to create wormholes in the strata to increase permeability in the reservoir.
- Search for alternative sources of energy for steam production, including the use of nuclear energy in conjunction with *in-situ* oil sands production plants (Peace River, Alberta).
- Further development and integration of technologies that include solvent co-injection, electro-magnetic heating, wedge (in-fill) wells, in-situ combustion, hot-solvent gravity drainage, Supercritical Partial Oxidation (SUPOX), and various hybrid developments, including $CO_2$ flooding (Rudy Strobl, Nov. 14, written communication).

Critical technology needs include enhancing current methods and developing new more-environmentally-friendly methods of extraction, production, and upgrading of oil sands. Emphasis of surface mining operations is on reclamation of tailings and consolidated tailings, and on re-vegetation of open-pit mine sites. In early February 2009, the Energy Resources Conservation Board (ERCB) issued Directive 074 that outlines new cleanup rules and harsh penalties for non-compliance regarding tailings ponds regulations for the oil sands areas. This directive resulted from the ERCB acknowledgment that, although operators invested heavily in improved tailings reduction strategies, targets set out in the original development applications have not been met.

Firm performance criteria are defined for reclaiming the tailings ponds, with performance inspections, and subsequent penalties due to neglect, omission, or commission.

Most of the bitumen resources are extracted by *in-situ* technologies (mainly thermal, such as Steam Assisted Gravity Drainage and Cyclic Steam Stimulation). Because there is significant co-production of greenhouse gases with bitumen production and upgrading, critical technology needs involve research into: 1) alternative sources of heat for generation of steam (e.g., geothermal, nuclear, burning of slag); 2) methods to reduce the viscosity of the bitumen so it will flow to the well bore or through pipelines more easily (such as use of diluents, catalysts, microbial and nanotechnology); 3) underground *in-situ* extraction, refining, and upgrading; and 4) co-sequestration of greenhouse gases by injection into abandoned reservoirs or other deep geologic sites. There was in the past an excess supply of produced sulfur, above what was used in agricultural and other markets. Excess sulfur is stockpiled from bitumen and sour gas production and refining. Produced and stored sulfur is sold to various markets, the largest being China, mainly converted to sulfuric acid for use in manufacturing phosphate fertilizer (ERCB, 2012).

## Environmental Issues

The primary environmental issues relate to the balance among greenhouse gas emissions and water/energy usage and the recovery, production and upgrading of bitumen. Specifically, the critical environmental focus is how to cleanly, efficiently, and safely extract, produce, and upgrade the bitumen. Goals include reducing (1) energy

required to heat the water to steam and (2) $CO_2$ emissions. Current greenhouse gas emissions are decreasing and remaining emissions are compensated for by carbon trading and (or) $CO_2$ sequestration; and (3) improving the economics and processes of extraction, production and upgrading of the bitumen. Some of the areas of focus include

- Land reclamation in surface mining
- Tailings and consolidated tailings disposal and reclamation
- Bitumen upgrading and co-production of other products from tailings (such as vanadium, nickel, and sulfur)
- *In-situ* recovery
- Underground refining.

Oil sand developers in Canada are focused on reducing $CO_2$ emissions by 45% per barrel by 2010, as compared to 1990 levels. Also in Canada, developers are legislated to restore oil sand mining sites to at least the equivalent of their previous biological productivity. For example, at development sites near Fort McMurray, Alberta, the First Nation aboriginal community, as part of the Athabasca Tribal Council, and industry have worked together to reclaim disturbed land (Boucher, 2012) and industry has reclaimed much of the previous tailings pond areas into grasslands that are now supporting a modest bison herd (~ 500 – 700 head).

## EMD Oil (Tar) Sands Technical Sessions, Publications, and other Products

AAPG Studies in Geology 64 entitled "Heavy-oil and oil-sand petroleum systems in Alberta and beyond" is in the final stage of production. This oil sands and heavy oils research includes presentations from the 2007 Hedberg conference in Banff, Canada titled "Heavy oil and bitumen in foreland basins – From processes to products." Publication editors are Frances Hein, Dale Leckie, Steve Larter, and John Suter. Contained are 28 chapters (Appendix A) that encompass depositional settings of oil sands and heavy oil accumulations, reservoir characterizations, geochemical characteristics of bitumen and of oil biodegradation, geologic and petroleum system modeling, petroleum reserves and resources, surface mining and in-situ production processes, such as SAGD, for accumulations in Canada, Russia, the United States, and Venezuela, and oil sands tailings and water use management

The April, 2012 AAPG National Convention in Long Beach, California included an EMD-sponsored poster session titled "Heavy oil and oil shale." This thermal-maturation cradle-to-grave theme included petrographic and stratigraphic features of oil shale and heavy oil sources and hosts, and production techniques for and fracture characteristics of heavy oil reservoirs. The Higley and Hein (2011) AAPG Natural Resources Research paper contained resource information on oil sands. On Sept. 20$^{th}$, 2011, an email blast to AAPG members was written by Debra Higley; the provided information included resources located on the AAPG/EMD Oil (Tar) Sands site and works in progress. Frances Hein, previous Chair of the EMD Oil (Tar) Sands Committee, was the AAPG EMD co-chair for the AAPG International Conference & Exhibition (ICE), held in Calgary in September, 2010. EMD-sponsored sessions included a full day on unconventional resources, which included morning and afternoon

sessions on Heavy Oil/Bitumen and the Bakken, and a plenary talk by Dr. Dale Leckie on Nexen's Long Lake SAGD project in northern Alberta. At the 2009 AAPG Annual Meeting in Denver the Energy Minerals Division (EMD) of AAPG poster session on oil (tar) sands was part of the unconventional resources sessions; a similar EMD session was included in the 2010 AAPG Annual Meeting in New Orleans.

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## Appendices

**Appendix A: Chapter List – Frances J. Hein, Dale Leckie, Steve Larter, and John R. Suter, eds., in press, Heavy-Oil and Oil-Sand Petroleum Systems in Alberta and Beyond: AAPG Studies in Geology 64.**

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**Appendix B: Web Links for Oil Sands/Heavy Oil Organizations and Publications**

The following provides updates to the Members-Only Webpage located at http://emd.aapg.org/members_only/oil_sands/index.cfm .

Alabama Geological Survey website: http://www.gsa.state.al.us

Alaska Division of Geological and Geophysical Surveys: http://www.dggs.dnr.state.ak.us

Alberta Energy Resources Conservation Board (ERCB): www.ercb.ca

Alberta Chamber of Resources: www.abchamber.ca

Alberta Department of Energy: www.energy.gov.ab.ca

Alberta Department of Sustainable Resource Development: www.srd.alberta.ca

Alberta Innovates – Energy and Environmental Solutions:

www.albertainnovates.ca/energy/

Alberta Environment Information Centre: www.environment.gov.ab.ca

Alberta Geological Survey: www.ags.gov.ab.ca

Alberta Government: www.alberta.ca

Alberta's Industrial Heartland Association: www.industrialheartland.com

Alberta Ingenuity Centre for In Situ Energy: www.aicise.ca

Alberta Innovation & Science: www.aet.alberta.ca

Alberta Research Council: www.arc.ab.ca

Alberta Sulphur Research Ltd.: www.chem.ucalgary.ca/asr

Athabasca Regional Issues Working Group: www.oilsands.cc

Bureau of Land Management – Details on the Oil Shale and Tar Sands PEIS:

http://www.blm.gov/wo/st/en/prog/energy/oilshale_2/PEIS_details.html

Canadian Association of Petroleum Producers: www.capp.ca

Canadian Energy Research Institute: www.ceri.ca

Canadian Geoscience Council: www.geoscience.ca

Canadian Heavy Oil Association: www.choa.ab.ca

Canadian Institute of Mining, Metallurgy & Petroleum: www.cim.org

Canadian Petroleum Institute: www.cppi.ca

Canadian Society of Petroleum Geologists: www.cspg.org

Canadian Well Logging Society: www.cwls.org

CanMet Mining and Mineral Sciences Laboratories: www.nrcan.gc.ca

Careers: The Next Generation: www.nextgen.org

Climate Change Central: www.climatechangecentral.com

EnergyInet: www.energyinet.com

Environment Canada: www.ec.gc.ca

Fort McMurray Chamber of Commerce: www.fortmcmurraychamber.ca

Freehold Owners Association: www.fhoa.ca

Geological Survey of Canada: http://gsc.nrcan.gc.ca/

Institute for Sustainable Energy, Environment and Economy: www.iseee.ca

International Energy Foundation: www.ief-energy.org

National Energy Board: www.neb-one.gc.ca

National Research Council's Industrial Research Assistance Program: www.irap-pari.nrc-cnrc.gc.ca

Natural Resources Canada: www.nrcan-rncan.gc.ca

New Mexico Bureau of Geology and Mineral Resources: http://geoinfo.nmt.edu/index.html

Oklahoma Geological Survey http://www.ogs.ou.edu/homepage.php

Oil Sands Discovery Centre: www.oilsandsdiscovery.com

Petroleum Society of Canada: www.petsoc.org , www.spe.org/canada

Petroleum Technology Alliance Canada: www.ptac.org

Petroleum Technology Research Centre: www.ptrc.ca

Saskatchewan Industry and Resources: www.ir.gov.sk.ca

Saskatchewan Government: www.ir.gov.sk.ca

Saskatchewan Research Council: www.src.sk.ca

Seeds Foundation: www.seedsfoundation.ca

Small Explorers and Producers Association of Canada: www.sepac.ca

Society of Petroleum Engineers: www.speca.ca

The Canadian Society of Exploration Geophysicists: www.cseg.ca

The Environmental Association of Alberta: www.esaa.org

U.S. Energy Information Administration: www.eia.doe.gov , http://search.usa.gov/search?affiliate=eia.doe.gov&v%3Aproject=firstgov&query=oil+sands

U.S. Geological Survey: http://www.usgs.gov, http://energy.cr.usgs.gov

U.S. Bureau of Land Management: www.blm.gov

Utah Heavy Oil: http://www.heavyoil.utah.edu/outreach.html; http:/map.heavyoil.utah.edu/

Utah Geological Survey: Tar Sands Information.

http://geology.utah.gov/emp/tarsand/index.htm