# NCEP Staff Background Paper - Unconventional Oil

## Introduction

This paper explores the potential contribution of unconventional oil to future world oil supplies, discusses current production of unconventional oil in Venezuela and Canada, and reviews some of the cost, energy, and environmental challenges currently associated with the extraction and refining of unconventional oil resources.

## Unconventional Oil Resources

Unconventional oil is an umbrella term for oil resources that are typically more challenging to extract than conventional oil. While many unconventional oil resources cannot be economically produced at the present time, two exceptions are extra-heavy oil from Venezuela's Orinoco oil belt region and bitumen — a tar-like hydrocarbon that is abundant in Canada's tar sands.[1] These resources are already being economically produced and are likely, in coming years, to become increasingly important to global oil supplies generally, and to U.S. oil security in particular, given their close proximity to U.S. markets. Canada's tar sands are especially valuable from an energy security perspective since they are not controlled by governments that are politically unstable or aligned with the Organization of Petroleum Exporting Countries (OPEC).

Both of these Canadian and Venezuelan unconventional oils are characterized by the fact that they are nearly as dense as, or denser than, water.[2] Venezuelan extra-heavy crude is significantly more viscous than conventional crude,[3] while Canadian bitumen is even more so.[4] The high densities and viscosities of these hydrocarbons pose significant challenges for extraction and transport (e.g., standard pipelines generally cannot ship raw, extra-heavy oil or bitumen[5]), while their high levels of sulfur and other characteristics can make them challenging and energy-intensive to refine.

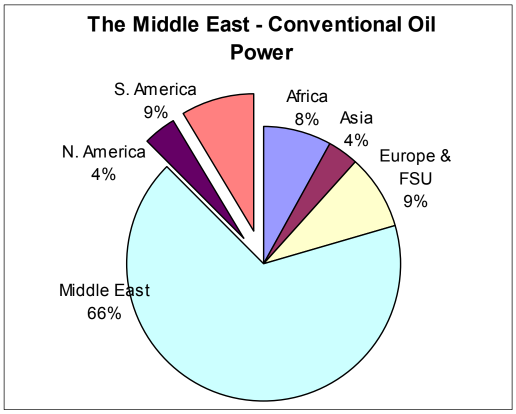
Today, Canada and Venezuela both produce approximately 3 million barrels per day (MBD) of oil.[6] As of 2000, they produced approximately 0.6 MBD and 0.3 MBD,[7] respectively, of this total from unconventional oil in raw form (typically mixed with a diluent to allow pipeline transport) or as a syncrude (generally a light, sweet petroleum created through one or several basic refining procedures). By 2015, government forecasts project that Canada and Venezuela combined will produce nearly 3.5 MBD of extra-heavy oil or diluted bitumen and syncrude[8].

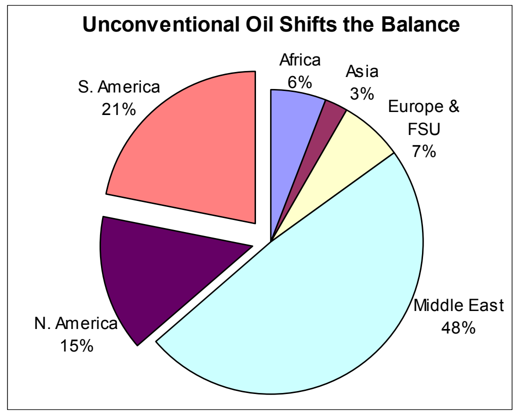
## Are Unconventional Oil Resources Economically Recoverable?

As has already been noted, most unconventional oil resources, like oil shales, are not currently economically recoverable. The exceptions, as indicated above and described in more detail below, are Canadian tar sands and Venezuelan extra-heavy oil.

If these unconventional oil resources are recognized as established reserves at some point in the future, overall estimates of globally recoverable oil would increase substantially. In 2002, the *Oil & Gas Journal* accepted Canada's classification of 174 billion barrels of oil sands as established reserves and Canada became the second largest oil reserve-holding nation in the world after Saudi Arabia.[9] If the 235 billion barrels of extra-heavy oil that Venezuela considers recoverable, but that are not currently acknowledged as established or proven, are re-classified in the same way as Canada's oil sands, Venezuela would be credited with the largest oil reserves in the world. This change in classification would help to tilt the balance of global oil reserves away from the Middle East, though neither of these unconventional oil-producing regions is likely to displace the Middle East as the lowest-cost or highest volume supplier of oil to world markets anytime soon.

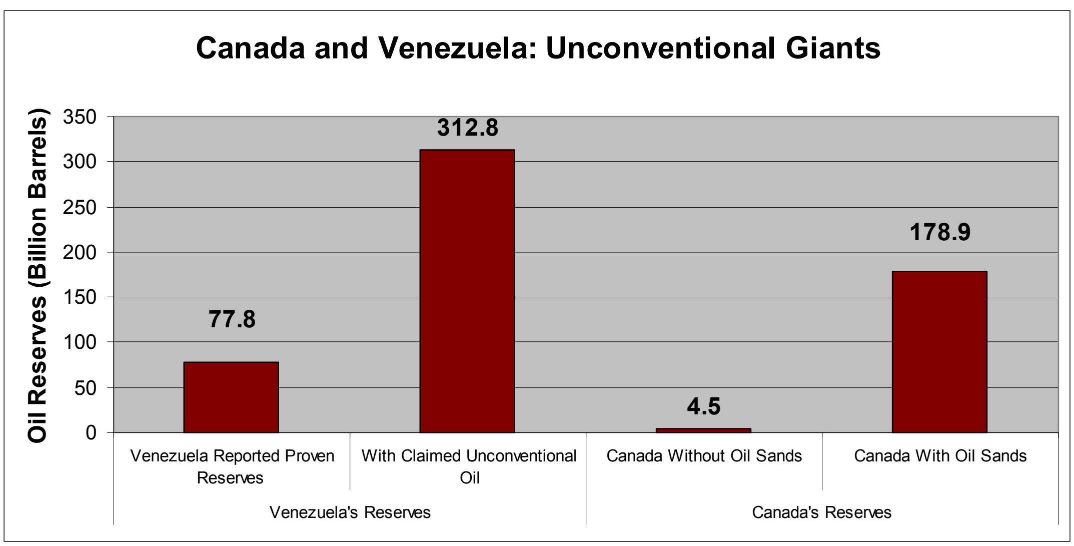
**Figure 1: Effect of Canadian and Venezuelan Unconventional Oil on World Oil Reserve Balance**




Data Source: EIA International Energy Outlook 2004[10], Oil and Gas Journal[11]

**Figure 2: Unconventional Potential**




Data Source: Oil and Gas Journal[12]

**Canadian Potential**

It has been estimated that Canada will likely supply as much as 1.2 MBD of diluted bitumen and syncrude by 2010.[13] Unlike Venezuela's extra-heavy oil deposits, which tend to contain oil in liquid form, Canada's oil is locked in sticky sedimentary layers called tar sands. These deposits tend to be approximately 10–12 percent bitumen by volume and pose some unique challenges in terms of resource extraction. Presently, most tar sands are harvested either by strip mining, or by heating or solvating underground deposits and pumping out the resulting oil (in-situ production). Though strip mining is still the most common means of commercially extracting tar sands, in-situ production will likely overtake strip mining operations as technology advances — simply because the majority of bitumen resources are not surface accessible[14].

Canada's tar sands deposits, though, are vast. Up to 2.5 trillion barrels exist in Alberta alone.[15] Of this amount, Canada's National Energy Board estimates that up to 315 billion barrels may ultimately be recoverable.[16] As has already been noted, the prospects for tar sands have improved sufficiently to warrant classification of 174 billion barrels as proven reserves in the *Oil and Gas Journal.*[17]

While labor-intensive, a comfortable profit margin exists for these projects with oil prices at $24 a barrel or more.[18] Given current oil prices, tar sands are attractive investments. As always, however, uncertainty about future prices and price volatility poses challenges for unconventional oil producers. An additional challenge facing Canadian producers is the potential lack of available U.S. refining capacity that can handle diluted or upgraded bitumen.[19]

**Venezuelan Potential**

Venezuela has traditionally been recognized as a country with substantial reserves of conventional oil and is the only country in the Western Hemisphere to belong to OPEC. Its currently proven oil reserves total 77.8 billion barrels, approximately 35 billion barrels of which are extra-heavy oil.[20] Though this is a considerable amount of oil, it is dwarfed by the potential of extra-heavy oil reserves that are not yet considered proven. Up to 1.2 (and perhaps even 1.7) trillion barrels may exist in Venezuela's Orinoco Belt[21] (a band of oil deposited roughly beneath the Orinoco River). The Venezuelan government considers nearly 235 billion barrels of this total as established reserves;[22] since the country's OPEC production quotas are partially based on its reserves, recognition of these resources by other OPEC members would likely allow Venezuela's production quota to increase.[23]

It has been estimated that Venezuela could provide as much as 1.4 MBD of extra-heavy oil to the marketplace by 2010, whether as syncrude or in a non-upgraded form[24].

In Venezuela, the difficulty of extracting heavy, viscous oil from deep underground (Venezuela's deposits are much deeper than Canada's oil sands) makes the recovery of unconventional oil more difficult and capital-intensive than in Canada.[25]

**Energy and Environmental Considerations**

The energy required and the environmental impacts incurred in extracting and utilizing unconventional, extra-heavy and bitumen-based oils are generally greater than in the case of conventional oil. Tar sands require substantial amounts of energy for mining and separating (in the case of strip mining operations) or for heating underground reservoirs (in the case of in-situ production). Similarly, extra-heavy oil requires significant effort to bring to the surface and transport for processing. Upgrading extra-heavy oil or bitumen to syncrude also requires significant quantities of energy. In many cases, natural gas is used to generate electricity to power equipment and physical plants, as well as to produce hydrogen or power cokers for the upgrading process. In Canada, rising rates of natural gas consumption are already creating stresses in natural gas markets and may prove unsustainable in the long run. Substitute fuels for powering unconventional oil production are under consideration, including coke combustion or gasification (consuming a process byproduct), or even nuclear power.[26]

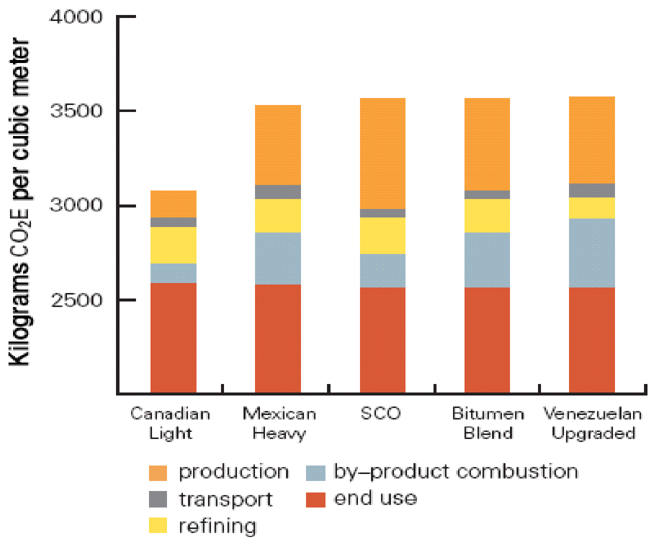
Besides their greater upstream energy requirements, producing extra-heavy oil and bitumen entails greater environmental impacts than conventional oil production. In the case of Canadian tar sands production, large amounts of water are necessary to separate bitumen from the sand and other solids, or to produce steam, depending on which oil-recovery method is being used. As many as four barrels of water may be used to produce a barrel of bitumen, though most can be reclaimed. For in-situ production, however, which commonly uses steam to heat deposits, as much as one barrel of this water may be unrecoverably trapped underground for each barrel of extra-heavy oil produced. [27] Used process water that is not recycled is released into tailings ponds, some of which have remained in use for a decade or more, and which can pose leaching threats to surface and groundwater. In surface mining, large areas of overlying forest and muskeg (a wet, swampy vegetation) must be removed before mining can begin. Like in-situ production, surface mining relies on large amounts of water, with resultant tailing ponds, though the water is mostly necessary to separate bitumen from other solids.[28]

The release of by-products, including air pollutants, is also more significant in producing bitumen than is the case for conventional oil production. Pollutants like sulfur dioxide, nitrogen oxides, hydrogen sulfide, volatile organic compounds, ozone, polycyclic aromatic hydrocarbons, particulate matter, and reduced sulfur compounds are commonly released during bitumen production.[29]

Additionally, at least two times (and as much as six times) more carbon dioxide is emitted in producing and upgrading extra heavy oil and bitumen as compared to conventional oil. Canada's ratification of the Kyoto Protocol may expose tar sands production to additional costs, though the Canadian government has worked to address uncertainty about this issue and Suncor, a major tar sands producer, expects the Kyoto requirements to add only 20 to 27 cents (Canadian) per barrel of oil produced.[30] Other environmental concerns associated with unconventional oil production include the disposition of byproducts as larger amounts of materials like coke and sulfur are produced in upgrading and refining bitumen and extra-heavy oil than in conventional oil production.

The production of extra-heavy oil in Venezuela, where there is less environmental regulation than in Canada, also appears to be more environmentally damaging than conventional oil production, though definitive data on this question are difficult to locate. The extra-heavy oil produced in Venezuela is typically high in sulfur, as well as in metals like nickel and vanadium.[31] The production of extra-heavy oil clearly requires greater energy inputs, so it is likely that associated environmental impacts are also more significant than in the case of conventional oil production.

**Figure 3: Lifecycle $CO_2$ Equivalent Emissions**




Source: Alberta Chamber of Resources; Data source: T.J. McCann and Associates[32]

## Conclusion

Given these challenges there is significant commercial pressure to develop more efficient and lower-cost means of producing unconventional oils. Considerable progress has already occurred. Costs for Canadian syncrude production have declined by more than 50 percent since the early 1990s,[33] while carbon dioxide emissions for a given volume of oil sands production have decreased approximately 35 percent in the same timeframe.[34] The efficiency of extra-heavy oil production in Venezuela has also improved significantly as a result of better pumping technologies and with the integration of production and upgrading operations so as to supply a higher-value export product.[35]

Globally, significant unconventional oil resources are not limited to Canada and Venezuela. Russia, for example, is estimated to have similarly large reserves of extra-heavy oil (though they are unlikely to be tapped in the near future), while numerous other countries also have relatively large unconventional resources (the potential U.S. resource base, for instance, is estimated at 40 billion barrels).[36] With further technology development and depending on the price of conventional oil in the future, some of these additional unconventional resources may eventually become economical.

[1] Bob Williams, "Heavy Hydrocarbons Playing Key Role in Peak-Oil Debate, Future Energy Supply," *Oil & Gas Journal* 101, no. 29 (2003). In some cases, bitumen and extra-heavy oil are used interchangeably; for the purposes of this memo, and in light of the substantially higher viscosities of oil from Canada's tar sands, Venezuela's resources will be referred to as extra-heavy oil and Canada's resources will be referred to as bitumen.
[2] Ibid., also National Energy Board (Canada), *Canada's Oil Sands: Opportunities and Challenges to 2015* (Calgary, AB: National Energy Board, 2004).
[3] Guntis Moritis, "New Techniques Improve Heavy Oil Production Feasibility," *Oil & Gas Journal* 96, No. 42 (1998). Viscosities in several Orinoco Belt extra-heavy projects range from 2,000 to 5,000 centipoise at reservoir temperatures.
[4] National Energy Board, *Opportunities and Challenges*. Viscosity at room temperature (often warmer than reservoir temperatures) is typically greater than 50,000 centipoise.
[5] Alberta Chamber of Resources, *Oil Sands Technology Roadmap: Unlocking the Potential* (Edmonton, AB: Alberta Chamber of Resources, 2004).
[6] BP, *Energy in Focus: BP Statistical Review of World Energy* (London: BP, 2004)
[7] Williams, "Heavy Hydrocarbons."
[8] United States Department of Energy, Energy Information Administration, *International Energy Outlook 2004 With Projection to 2025* (Washington, DC: Energy Information Administration, 2004): 44; and Canada National Energy Board, *Opportunities and Challenges,* 61-73.
[9] Radler, "Worldwide Reserves." Not all groups accept Canada's classification of tar sands as proven reserves. BP, for example, only credits those fields currently being developed, in keeping with its classification of other nations' reserves.
[10] Energy Information Administration. *International Energy Outlook 2004.* Washington: April 2004.
[11] Radler, "Worldwide Reserves."
[12] *Ibid.*
[13] Williams, "Heavy Hydrocarbons."
[14] National Energy Board, *Opportunities and Challenges*.
[15] Williams, "Heavy Hydrocarbons."
[16] National Energy Board (Canada), *Canada's Oil Sands: A Supply and Market Outlook to 2015* ( Calgary, AB: October 2000).
[17] Radler, "Worldwide Reserves."
[18] Tar sands producers, for example, maintain a comfortable profit margin when oil prices exceed $24 per barrel. National Energy Board, *Opportunities and Challenges*. The last time prices dipped below that level was a several-day span in 2003. WTRG Economics. "Crude Oil Spot and Natural Gas Spot Prices". *Energy Economics Newsletter*, http://www.wtrg.com/daily/oilandgasspot.html, June 9, 2004.
[19] National Energy Board, *Opportunities and Challenges*; Martin Meyers and Robert Esser, *Western Canada's Oil Sands: An Investment Boom Increases the Marketing Challenge* (Cambridge, MA: Cambridge Energy Research Associates, 2002).
[20] Marilyn Radler, "Worldwide Reserves."
[21] See *Petroleum Economist*, "Analysis: Nonconventional Hydrocarbons – Scratching the Surface," March 31, 2002; United States Department of Energy, Energy Information Administration, "Country Analysis Briefs: Venezuela," June 2004, http://www.eia.doe.gov/emeu/cabs/venez.html; Williams, "Heavy Hydrocarbons;" Radler, "Worldwide Reserves"
[22] Several sources offering different analyses of Venezuela's current accounting of conventional and unconventional resources. Marilyn Radner, in *Oil & Gas Journal* notes that PDVSA (Petroleos de Venezuela S.A. – the state oil company) report 312 billion barrels as total reserves, and 235 billion as the technically recoverable total from the Orinoco Belt. Of the 77.8 billion barrels listed as proven reserves, 35 billion is attributed to unconventional heavy and extra heavy crude in the Orinoco region ("Worldwide Reserves"). The United States Department of Energy, Energy Information Administration notes "Venezuela is home to the Western Hemisphere's largest proven oil reserves at 77.8 billion barrels, as of January 2003. Substantial extra-heavy oil and bitumen deposits are not included in this total," and goes on to comment that estimates of "extra-heavy oil and bitumen deposits" range from 100 – 270 billion barrels of recoverable reserves, while also noting that several projects are already tapping into Venezuela's unconventional crude in "Country Analysis Briefs: Venezuela," June 2004, http://www.eia.doe.gov/emeu/cabs/venez.html. Typically, reserves currently being developed are considered

proven, lending credence to *Oil & Gas Journal*'s assertion that part of the claimed 270 billion barrel Orinoco belt is already included in Venezuela's proven reserves total.

[23] Steve Ixer and Margaret McQuaile, "Venezuela Wants OPEC to Make Room for its Extra Heavy Oil," *Platt's Oilgram News* 81, no. 194 (2003).

[24] Williams, "Heavy Hydrocarbons."

[25] *Petroleum Economist*, "Analysis: Nonconventional Hydrocarbons."

[26] National Energy Board, *Opportunities and Challenges*; Alberta Chamber of Resources, *Oil Sands Technology Roadmap*.

[27] National Energy Board, *Opportunities and Challenges*.

[28] Ibid.

[29] Ibid.

[30] Suncor Energy, "Climate Change: Kyoto," http://www.suncor.com/default.aspx?ID=1467. Suncor's cost estimate is for 2010.

[31] *Petroleum Economist*, "Analysis: Nonconventional Hydrocarbons," Williams, "Heavy Hydrocarbons;" Guntis Moritis, "New Techniques Improve Heavy Oil Production Feasibility," *Oil & Gas Journal* 96, No. 42 (1998).

[32] Alberta Chamber of Resources, *Oil Sands Technology Roadmap*.

[33] Williams, "Heavy Hydrocarbons."

[34] National Energy Board, *Opportunities and Challenges*

[35] Moritis, "New Techniques."

[36] Williams, "Heavy Hydrocarbons."