2 WORLD CONVENTIONAL AND HEAVY OIL

2.1 Sources of Hydrocarbons

World conventional oil (“light oil”, >20°API) production from natural sources must eventually peak and enter into decline because of increasing world demand, inexorable reservoir production rate decline, a fixed resource base, and the indisputable fact that few new sedimentary basins remain to be exploited. Many believe this will occur in the period 2005-2010.[viii] Current consumption is approximately 77 MBOD (Oil and Gas Journal), Canada produces about 2.2 MBOD. This is about 3.3% of the world total, but a disproportionate amount of this figure comes from <20°API heavy oil, more than of 45% of Canadian oil production, or about 1.5% of the world’s total oil production. Of world production, about 7-8 % of the total comes from heavy oil.

After the peak in world conventional oil production rate is passed, perhaps about 5 years from now, light oil production will gradually decline at a rate that will be somewhat tempered, but not reversed (Fig. 2.1), by the gradual introduction of, among others, the new Canadian-developed technologies such as gravity drainage and pressure pulsing. The advent of superior 3-D seismic methods and geochemistry analysis in the last 20 years, combined with the knowledge generated from the huge database that is now extant for hundreds of basins world-wide, mean that when a new basin is explored, the potential resource capacity of the basin can be well-bounded, even if only a few exploratory wells have been drilled. Essentially, all land-based basins have been so explored, and few remote basins remain totally unevaluated. For example, the large Falkland Islands (Malvina Islands) Basin offshore Argentina has been explored in the last few years, and it is one of the few remaining large basins that remained untouched. Incidentally, it has turned out to be disappointing, based on preliminary exploratory drilling by Phillips and Shell in the period 1997-2000.

Simply put, the world is running out of conventional oil because the world is running out of new basins to explore and exploit. Furthermore, the remaining basins are remote, and remote resources are quantity and cost-limited: exploitation costs are high in deep and remote basins (deep offshore, Canadian Pacific Coast, Antarctic fringe, Arctic basins…), therefore only larger finds will be developed, and recovery ratios will be less than for “easy” basins. It is unlikely that these basins will provide any more than another 10-15% of the conventional oil already known to be in place in explored basins.

Nevertheless, the world will never run out of oil, for several reasons. First, conventional oil comprises a small fraction of hydrocarbons in sedimentary basins (Table 1). As price pressure increases in the future, and as now extraction methods and processing technologies are developed and perfected (such as coal conversion and shale oil extraction), these resources will become available. The time frame for these, including the methane hydrate resource in the deep ocean, is probably several generations.

Table 1: Relative Hydrocarbon Resource Size

HC Resource Type	Estimated % of total HC in sedimentary basins
Conventional oil (>20°API)	2-3%
Heavy oil (<20°API gravity)	5-7% (mostly in UCSS)
Natural gas	4-6%
Gas hydrates (mainly sub-ocean floor)	10-30% (extremely uncertain because of poor and spotty data)
Kerogen and oil in shales	30-50%
Coal and lignite seams	20-30%

Second, as technology evolves, other energy sources (hydrogen cycle?) will displace oil just as oil displaced coal. Even now, natural gas is displacing oil in fleet vehicles in many cities (Toronto, Los Angeles, Beijing), and this trend will continue. However, natural gas is a valuable resource, and it too is limited. Alberta's production rate of natural gas is expected to peak in the next two years, and for the entire world, the peak should arrive in about 15-18 years.

Third, there are new technologies emerging for greater energy efficiency and energy recycling. For example, in 2002, the City of Los Angeles will likely start disposing of municipal biosolids through deep injection. At the high temperatures at depth (50-80°C), anaerobic methanogenic bacteria can degrade all the free hydrogen in the carbohydrate-rich organic wastes into CH_4, within several years, and if the wastes are placed into a suitable geological formation, the evolved gas can be collected and re-used. This emerging technology is suitable not only for municipal biosolids, but can be used for any organic material (animal wastes from feed lots, sawdust, etc.). Not only will this technology generate CH_4, it seems to be environmentally benign and cost competitive with current waste treatment methods, even without factoring in the value of the gas that is generated. (Visit www.terralog.com for more information.)

Fourth, even if in some distant future all the organic carbon (oil, gas, coal, kerogen) in basins is consumed, oil can be manufactured from wood or assembled from elements (H from electrolysis of water, C from plants), given sufficient commodity price. One seemingly rational replacement is ethanol (C_2H_5OH) production from plant carbohydrates; large-scale fermentation facilities with low capital costs, using genetically engineered crops that have enhanced starch contents and high production rates, is an entirely realistic alternative to oil. Alternatively, genetically optimized methanol (CH_3OH) producing bacteria can supply from plant carbohydrates the feedstock for fuel cell engines that burn H_2 directly (although these devices still produce CO_2 during hydrogen reforming from methanol).[9] Given a sustained high price for oil in a limited supply market, these technologies will undoubtedly be implemented in the future.

Thus, it appears that, in economic terms, oil is an infinite resource, not a fixed resource. Furthermore, it appears that if the commodity price for oil is forced too high by supply control, genuinely effective OPEC production limits for example, several emerging technologies can be activated to address the demand. This is important in the context of world prices. If huge capital investments in heavy oil extraction and upgrading plants are made, if coal-to-oil facilities are constructed, and if large shale oil exploitation operations are funded, these will not be "shut down" if the oil price later drops. National and corporate interests in countries that may invest in such facilities will act to keep them operating for reasons of oil supply security and other economic factors. For example, at a commodity price >US$20.00, Canadian and Venezuelan heavy oil production and oil sands mines are economical, and are being rapidly developed. Approximately 1,000,000 b/d additional oil production from Canada, and a similar amount from

[9] It is not widely appreciated that fuel cells based on H_2 use a liquid feedstock, CH_3OH, to generate the hydrogen, and CO_2 is emitted as a by-product. Furthermore, the current source for the methanol is exclusively production from natural gas (CH_4), a valuable and clean fuel in its own right.

Venezuela, exclusively from <20°API resources, will gradually enter the world market in the next 7-8 years. If the price drops to the point where these are no longer profitable, it is unlikely that they will be closed because of the huge capital investment involved (moderately negative cash flow is better than no cash flow).

2.2 How Much Heavy Oil is There?

2.2.1 World and Canadian Heavy Oil Resources

Figure 2.2 is a chart that has been widely published.[10] The world resource is about 12×10^{12} bbl, or about 2000 cubic kilometres of volume, a cube with sides 12.6 km long. Apparently, there is more than twice as much resource available in <20°API oil as in conventional oil >20°API. Furthermore, it is widely believed that the heavy oil resource is somewhat underestimated in comparison to the conventional oil resource because of poorer-quality data. Note that this amount of heavy oil does not include shale oil, a resource that is vaster, but much less concentrated in terms of unit volume, and also much less accessible because of inherent low permeability.[11]

Heavy oil resources are found throughout the world, but Canada and Venezuela are singularly endowed. The two countries appear to share 35-40% of the world resources of <20°API heavy oil, approximately 2.5×10^{12} bbl in the Canadian HOB and Oil Sands regions, and 1.5×10^{12} bbl in the Venezuelan Faja del Orinoco tar sands belt (based on recently published estimates in the 2001 Margarita Conference).[ix] The specific amount, particularly in Venezuela, is to a degree conjectural: it depends on the definition of what is an oil stratum in terms of thickness and oil saturation level. Nevertheless, given that similar uncertainties exist for such estimates around the world (the oil industry in many regions is only beginning to take an interest in heavy oil), the actual amounts quoted here are reasonable estimates. Other countries with appreciable heavy oil resources include Russia, Nigeria, Indonesia and China, as well as several of the Middle East

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[10] Oil estimates are courtesy of Dr George Stosur, USDOE (retired), and are widely available in the literature, particularly in the various UNITAR conferences on Heavy Oil and Tar Sands

[11] Shale oil is usually in the form of kerogen, a semi-solid organic material that may be considered as immature oil and gas, not having been exposed to an adequate catagenic environment as to generate the more fluid HC components.

nations (well-endowed with conventional) where more shallow heavy oil has been ignored because of the large production capacity of their conventional oil reservoirs.

To put the available heavy oil resource into an understandable context, its size in Canada alone is so large (~$350\text{-}400\times10^9$ m^3, more than 20% of the World total) that, at a stable combined US and Canadian consumption rate of ~1.2×10^9 m^3/yr, there is enough heavy oil in Canada to meet 100% of this demand for over 100 years if the overall extraction efficiency is ~30%. In the best strata, the new extraction technologies in Canada are already approaching, and in some cases exceeding, this recovery ratio of 30%. Oil sands mines approach 85% extraction. Imperial Oil Limited at Cold Lake is approaching 25% extraction. The four new SAGD projects initiated in Canada in 2001 (Foster Creek – AEC; MacKay River – Petro-Canada; Surmont – Gulf Canada, now Conoco;Primrose – CNRL) expect to achieve >50% extraction. In good reservoirs, CHOPS can exceed 20% recovery.

An informal poll of Canadian petroleum engineers and scientists involved in new production technologies in 2001 yielded the following estimates of ultimate recovery of Canadian heavy oil (including present, emerging, and yet-to-be developed technologies):

- 20% extraction with 95% certainty
- 35% extraction with 50% certainty
- 50% extraction with 5% certainty

Evidently, even given the persistent optimism of engineers, the expectations for reasonable recovery ratios are clear: a large percent of the heavy oil is currently economically and technologically available, and more will become so. Using a factor of 35%, and assuming (optimistically) that the recovery ratio from conventional oil will eventually reach 60%, there is still more heavy oil available as a future resource than all the conventional oil that has been or will be produced.

2.2.2 Canadian Heavy Oil Belt Resources

The recent NEB report on Conventional Heavy Oil resources of the Western Canada Sedimentary Basin (2001, see footnote 1) has identified 50×10^9 m^3 (~350×10^9 bbl) of heavy oil in place in the HOB. This is about 15% of the total <20°API resource in Alberta, exclusive of the ill-defined Carbonate Triangle. They estimate that 21% of this, $\sim 74\times10^9$ bbl, can be recovered with current technology. This is 1000 days of supply for the entire world at current consumption rates. Given Canada's light population, it is of huge economic importance, with a current commodity value somewhat below CAN$\$3\times10^{12}$ at a world price of US$25.00. Given the technological progress that is ongoing, referring to the 50% probability estimate of Canadian industry engineers, the NEB estimate of technologically accessible reserves in the HOB is conservative, perhaps by a factor of two. The writer believes that a reasonable estimate of the recovery from the HOB in Canada is on the order of 150×10^9 bbl.

Importantly, based on interaction with many producers, the NEB published estimates of the amount of economically produceable oil. If operators can accept total costs of ~CAN$13.00/bbl, ~80% of the HOB resource is economically accessible. This can be compared to the average price of about CAN$18.00 – 25.00 that producers received in the period Jan-Sept 2001 (bitumen at Cold Lake from $9.62 to $28.80/bbl in this period, and Lloyd blend at Hardisty from $22.00 to 34.00/bbl). Apparently, primary heavy oil production through CHOPS methods is currently quite profitable, despite the historically high differential price between conventional feedstock and heavy oil.

2.3 World Issues

The apparent richness of the World resource base presented here is a radically different picture from the narrow view of resource limits proselytized several decades ago with great publicity in the Western press. (Doomsayers always seem to get better press coverage than rationalists, and one may coin an appropriate adage: "Bad news makes good news".)

In fact, those who claim that the world is greedily and detrimentally consuming irreplaceable resources and shortchanging future generations consistently ignore technical progress, market pressures, and the historical record.[x] Commodities have never been cheaper, efficiency and productivity are increasing, and new ideas such as deep biosolids injection may generate new sources of energy, even energy recycling.[xi] It is interesting to read the predictions of doomsayers[xii] in the context of continued technological advances. For example, the "Club of Rome" in 1972, using exponential growth assumptions and specious extrapolations under static technology, ignoring new ideas and even ignoring basic economic principles, predicted serious commodity shortages before the year 2000, including massive oil shortages and famine.[xiii] The world has not seen these events: there is a smaller percentage of the world population that suffers food deprivation than in the past; metal recycling and replacement has reduced the need for new mines; as countries develop, greater efficiencies and better technologies have resulted in environmental improvements; and world population is no longer predicted to exceed 10 billion. Also, oil supplies continue to be generated, and will so continue.

This is not to say that there will not be fluctuations in price as supply and demand disparities arise and as political problems evolve. Large capital investments and lead times are required for massive increases in heavy oil production; for example, in Canada, an investment of about CAN$12,000,000,000 will be made in the period 1998 –2006 to achieve an additional 800,000 – 900,000 b/d production.[12] The four large Venezuelan Faja del Orinoco projects (Cerro Negro, Exxon-Mobil and PDVSA[13]; Hamaca, Chevron-Texaco, Phillips and BP; Petrozuata, Conoco and PDVSA; and SINCOR, TotalFinaElf, PDVSA and Statoil) will require a similar aggregate CAPEX to achieve a similar production rate (about 750,000 b/d) by the year 2005, having started as early as 1998. The scale of such investments suggests that if depressed oil prices arise again in the future for a prolonged period, retarded development should later lead to supply shortfalls and price increases, a cycle not unlike the Canadian heavy oil price cycle discussed in Section 1.4.3.

Price fluctuations may also arise because of political instability. The large Middle East oil reserves are found in countries that have only vestigial democratic institutions and economies based almost exclusively on oil exports. These countries, along with several other OPEC countries that are politically unstable, such as Nigeria and Venezuela, will be providing over 50% of world supply by the year 2010 (Fig. 2.3). There are substantial risks for oil supply interruptions for the major importers: Europe, Japan and the United States. For example, the Gulf War of 1991 caused a sharp spike in prices, even though there were few interruptions in supply as the Persian Gulf States agreed to ramp up production to meet losses from Iraq and

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[12] It is interesting to note that a production rate in an oil sands surface mining operation is a long-term sustainable rate, rather than a depleting rate, as in conventional reservoir exploitation. Thus, a new barrel of oil production from a surface mine can be counted on for at least 35 years, perhaps longer, whereas most reservoirs have ceased production, or are severely depleted, within a similar time frame.

[13] Petroleos de Venezuela s.a. (PDVSA) is the state-owned oil company in Venezuela and is a partner in all the large projects. In addition, affiliate companies of PDVSA (BITOR, s.a.) have several much smaller projects in the same region.

Kuwait. It appears that a concerted effort by the Western democracies to encourage a peaceful shift to democracy and an integration into the World trade system can only be of long-term benefit to all the importing and exporting countries alike. A policy or propping up non-democratic regimes for short-term oil supply integrity is not likely to be beneficial over a period of decades.

What does all this have to do with heavy oil and CHOPS technology? First, the new production technologies are proof that science and knowledge continue to advance; we can look forward to further advances. Second, oil prices will not skyrocket and remain high indefinitely: there are alternative technologies such as synthetic oil from coal waiting in the wings. Third, the new technologies have been forced by circumstances to become quite efficient and profitable, even with unfavorable refining penalties. Fourth, exploration costs for new conventional oil production capacity will continue to rise unceasingly in all mature basins, whereas technologies such as CHOPS actually can lower the costs of "technology-based" oil. Fifth, there is technological feed-back from the heavy oil production technologies that is improving conventional oil recovery ratios. Sixth, the amount of resources as heavy oils in UCSS is vast, and this may come to dominate the resources picture in the next generation. .

Thus, though it is obvious that there is a limit to the amount of conventional (light) oil in sedimentary basins, and this is relevant to the oil industry in the short term (2000-2030), it is likely to be inconsequential to the energy industry in the long term (50-200 years). It appears that the World is entering a phase of large-scale development of heavy oil. Canada, by virtue of its vast resource and by virtue of a consistent investment in new production technologies over the last 40 years (starting with the Clark Hot Water Extraction Process and Cyclic Steam Stimulation, both commercialized 30-40 years ago), appears to be in a uniquely favorable position to benefit from this development.

One factor may seriously affect the development of heavy oil. Concerns over permanent atmospheric warming (polar ice cap melting, altered climate…) from CO_2 generation have given rise to an increasingly strident demand for massive reductions in oil consumption, imposition of carbon taxes, and other "solutions". Even given the uncertainties involved in this concern (ocean CO_2 uptake may increase, the effects may be less than the modelers predict…), based on the history of the world, technological developments are as likely to solve this potential problem as is abandonment of the HC economy. Biosolids injection results in about 40% of the dry mass of the organic matter remaining in place as elemental carbon, permanently sequestered, and this is a cumulative effect. Other technologies involving sequestration of CO_2 are being investigated.[xiv] Nevertheless, the heavy oil resources are carbon-rich, and there will be increased pressures in the next 30 years to address this issue. One possible partial solution is to increase the coking percentage (carbon rejection ratio) in heavy oil processing, and to dispose of the coke through deep well injection. There are other possibilities: for example, H_2 from CH_4 is currently also used to increase the H:C ratio, but other sources of cheap H_2 may evolve. These may eventually displace liquid HC consumption in vehicles.

Arguments can be made that, environmental issues aside, Canadian heavy oil resources should be developed only slowly, "preserving" the resource for generations far into the future. For example, if Canada stopped exports and only met its own needs from the heavy oil base, using current consumption values, there is no doubt that there is enough oil for 1000 years.

This argument is deeply flawed. Given the known resource base, within a century new technologies will be implemented that will displace oil as a primary energy source. The history of new technology development is clear: as a new technology is perfected, it inevitably drives out the old technology. Coal development in 1750-1900 drove out wood as the primary energy source; oil displaced coal in the last century; natural gas exploitation is substantially reducing the need for new oil production; the new energy system of the future, whatever it is based on, will drive out oil and natural gas as the primary energy sources. If we attempt to guard the heavy oil resources by production limits, some time in the future, likely about 100 years from now, the resource will be abandoned in favor of the new energy system, and Canada will follow the rest of the world in the gradual conversion.

Should the oil be preserved as a petro-chemical feedstock for plastics and other products? The amount of oil so consumed is a small percentage of world consumption, and various replacements will arise with time. Preservation arguments for feedstock supplies are also flawed.

It appears that if Canada does not aggressively develop its heavy oil resource base, it will be left in the ground. Nevertheless, there are forces demanding this action, based largely on concerns over global warming. These issues have to be studied and addressed.

Figure 2.1: Conventional Oil Production Will Peak in the Next Decade; ∆Demand Will be Met by Heavy Oil, Gas, & Other Sources

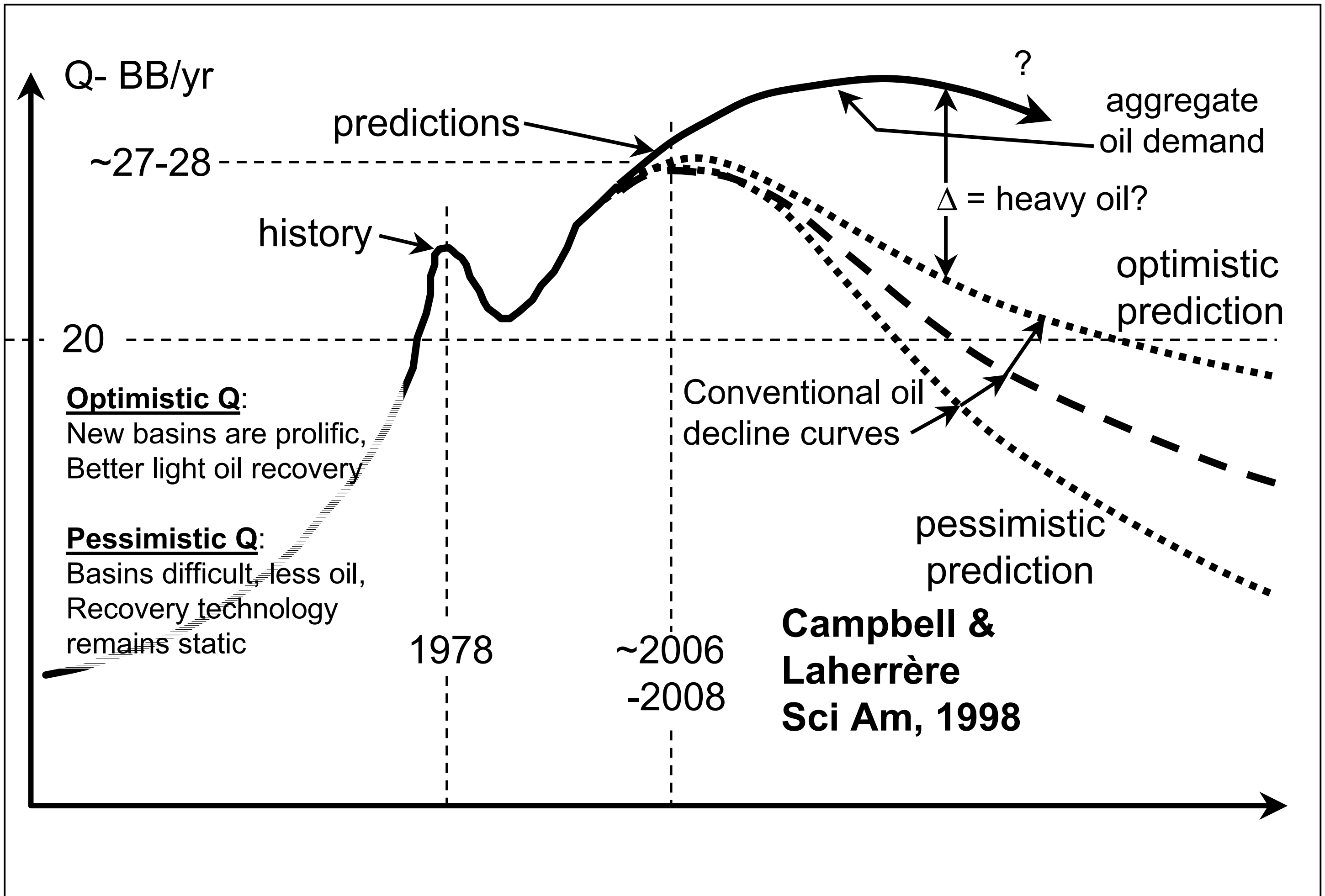

Figure 2.2: The Size of the World Heavy Oil (<20°API) Resource (not necessarily recoverable reserves)

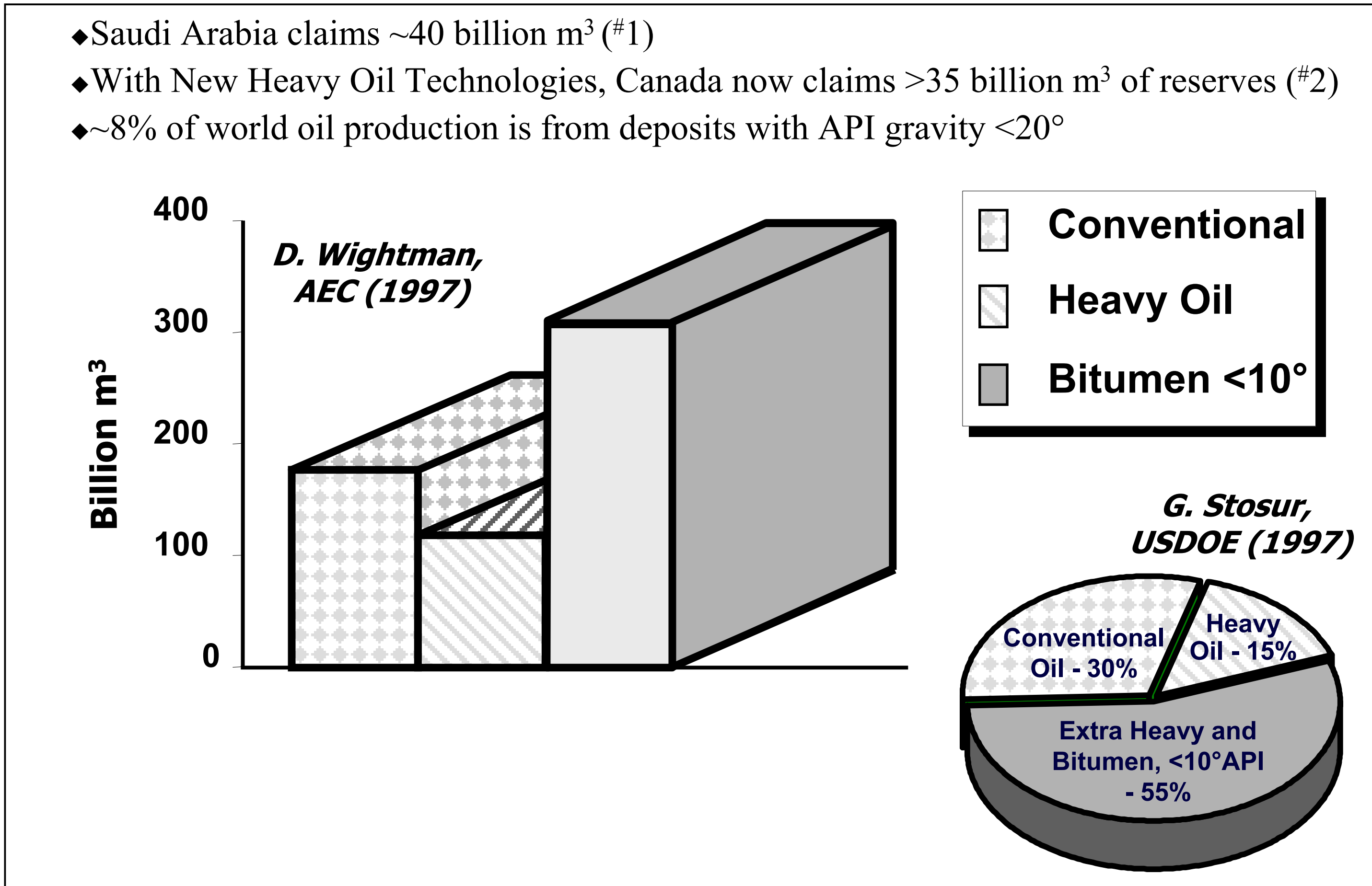

Figure 2.3: OPEC Production Compared to Others